ICAR-NRCP

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2018-19

वार्षिक प्रतिवेदन

Annual Report

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

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भाकृअनुप
ICAR

वार्षिक रिपोर्ट

ANNUAL REPORT

2018–19

भा.कृ.अनु.प. - राष्ट्रीय अनार अनुसंधान केंद्र
ICAR-National Research Centre on Pomegranate
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Preface

It is my pleasure to bring before you the Annual Report 2018–19 of the ICAR-National Research Centre on Pomegranate, Solapur, which completed 13 years of journey on September 25, 2018. The Centre has made several remarkable accomplishments during this short span and feels proud to be a part of growing pomegranate sector in India. Constant increase in pomegranate area, production and productivity has been observed in India since last 7 years. Record pomegranate area of 2.46 lakh ha and production of 28.65 Lakh MT have been projected as first estimates for 2018–19 on Ministry of Agriculture and Farmers Welfare, GoI, website, though 2018–19 was a drought year.

Pomegranate export of 67.89 thousand MT (Value Rs. 6885 million) is also a record figure till date showing 43.41% increase over previous year. It is visible that the Centre has played important role in improving pomegranate scenario in India by combating important diseases improving fruit yield and quality, providing quality planting material, identifying suitable pomegranate growing areas in India, developing sound package of practices, acting as reservoir of germplasm for breeding, giving value addition technologies, dissemination, commercialization and transfer of technologies and imparting on-site and in-house trainings to stakeholders. The Centre has introduced pomegranate cultivation in different states through Tribal Sub Plan, (TSP), Mera Gaon Mera Gaurav (MGMG) and Scheduled Cast Sub Plan (SCSP) by demonstrations, inputs, Soil Health Cards and technical guidance. The promising pomegranate scenario and the positive feedback of review committees and farmers give us confidence to move forward with higher commitment.

It is also observed that some of the states like Haryana and Uttar Pradesh which are highly or moderately suitable for pomegranate, are not growing pomegranate, hence, introducing pomegranate in these areas may prove promising in improving economic status of the poor farmers in these states. It is a point of concern, that though India is the largest producer of pomegranate, yet its export share in world trade of pomegranate is just 14% in comparison to China (34%) and Iran (29%) with respectively 50% and 33% less area than India. Demand for big size fruit and very few (only 9) chemicals with label claims appear to be major concerns for export from India. The Centre is making efforts to overcome these constraints, so as to increase export that will in turn improve market rates for the benefit of farmers. The Centre has a challenging task ahead to improve export through breeding large size variety and pesticide residue free production; work on these aspects is in progress. I am sure ICAR-NRCP will continue to move forward with confidence to achieve new milestones and to fulfill the vision of our Hon'ble Prime Minster of Doubling Farmers' Income by 2022. It is a matter of great privilege to serve the institute that is working for the benefit of pomegranate growers all over India.

I wish to place on record my sincere gratitude to Dr. T. Mohapatra, Secretary, DARE and Director General, ICAR for his constant guidance and encouragement to face the challenges and move ahead. I am obliged to Dr. A.K. Singh, DDG (HS) for his support and guidance, which encourages us to move forward with confidence. Kind cooperation and support rendered by all the staff members of SMD (HS) to this Centre is thankfully acknowledged. I place on record my sincere gratitude to Hon'ble members of RAC for guidance and keen interest in improving the research activities of the institute.

The Centre could not have achieved its targets without constant support and cooperation of all scientific, administrative, technical and supporting staff as well as senior research fellows, young professionals in various research projects. I am indebted to one and all for their unflinching support and place on record my sincere thanks to them with the hope for their constant co-operation in future for the betterment of this young dynamic Centre.

Jyotsana Sharma
Director (Acting)

Introduction

Pomegranate (*Punica granatum* L.) fruit can be considered as old as human life. The fruit of paradise in the hands of first human on the earth-Adam and Eve is believed by many to be pomegranate and not apple, because the Garden of Eden was located somewhere in area today known as Middle East known for pomegranate since old ages. Pomegranate, native to Iran and the Himalayas, is the most historic fruit tree domesticated for its innumerable health benefits. Folk medicines have been using this tree for a long time and its use in modern-day medicine continues. All parts of this miracle tree-roots, stems, leaves, bark, flowers, fruits, seeds, rind, etc. are being exploited in pharmacy, the leather or dye industry or for decorative value. The nutraceutical, pharmaceutical, and cosmetic industries are having proliferating business with pomegranate especially in the European, American and some Asian markets including India. About two decades back consumer awareness towards its innumerable health benefits increased market demand, resulting in alluring monetary returns from this horticulture crop especially in India, resulting in constant increase in area and production of this crop.

The history of commercial cultivation of pomegranate in India starts in 1936 with identification of GBG-1 by Dr. GS Cheema- the father of Indian Horticulture- which was later named 'Ganesh' in 1970. This was the first popular commercial cultivar of pomegranate for extensive cultivation in Maharashtra. The release of cultivar 'Ganesh' revolutionized pomegranate cultivation and export in India. In 1986, Mahatma Phule Krishi Vidyapeeth, Rahuri released G-137 prolific bearer but fruits were superior. All these varieties were soft seeded, high yielders but lacked red colour. Quest for red varieties of pomegranate was fulfilled by release of cultivars like Mridula, Phule Arakta and Bhagawa. Among these Bhagawa, a soft seeded variety with bright red attractive rind and aril colour-released in 2003–04, became highly popular due to its demand in export and local markets. With the release of variety Bhagawa having high market and export

potential more than 80% area in India has come under this variety. The popularity of this variety can be witnessed through increase in pomegranate area (108.93%), production (268.53%), productivity (76.23%) and export (56.96%) during last 7 years. As per recent estimate, currently more than 2.5 lakh families are earning livelihood from this crop in India and maximum growers fall under marginal or below marginal land holding category.

Due to rapid increase in pomegranate area with monoculture of variety Bhagawa, the emerging pomegranate industry started facing hurdles due to diseases and insect pests, non-availability of disease free planting material, disease resistant varieties and lack of processing technologies. Envisaging the economic importance of pomegranate and the significant role of this crop in shaping the economy of the growers in arid and semi-arid regions, the ICAR-National Research Centre on Pomegranate, Solapur addressed these hurdles on priority and gave solutions to major challenges. Noteworthy technologies for promotion of pomegranate include:

1. A well established, 'Field Gene bank' with 362 germplasm lines including indigenous and exotic lines established at ICAR-NRCP, Solapur which serves collection of genes for diverse characters.
2. Promising, cost effective, eco-friendly integrated disease & insect pest management schedule with the use of bio-formulations and preventive strategies during rest period, for effective management of major diseases and insect pests and bringing down the losses due to biotic and abiotic stresses.
3. Tissue culture cum biohardening technology for propagation of disease free planting material and technology for biohardened hardwood cutting propagating material.
4. A 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%.
5. Technologies for total utilization of pomegranate for product diversification and higher returns. These include 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) and Ganesh (26.43% w/w); hi-fibre cookies from de-oiled seed cake of pomegranate; sparkling pomegranate wine from pomegranate juice.
6. Apart from this a promising bio-fortified variety of pomegranate, 'Solapur Lal' has been developed through breeding at this Centre. It matures in 160–165 days. The new variety has more iron, zinc, ascorbic acid and anthocyanin contents over the ruling variety Bhagawa. It has about 25–35% higher yield over Bhagawa. This bio-fortified variety is a boon to combat nutritional deficiencies in human beings.

Further analysis of Benefit:Cost ratio of different field, vegetable and fruit crops in Maharashtra revealed, maximum benefit:cost ratio of 2.5 for pomegranate cultivation. Hence, this ancient fruit with available technologies can be considered an ideal crop for climate resilience and rural economy with the technologies available, cluster approach and government intervention.

However, there are some policy issues that require intervention of policy Makers. These include lack of regulations for (i) sale of unregistered chemicals/bioformulations, (ii) unregistered consultants/Agridoctors and (iii) strict nursery certification (iv) Government support for encouraging community farming and putting up processing units for value addition of unmarketable produce during natural calamities and poor market value (v) label claim for more chemicals is of prime importance for improving export, which is less than 2% of the total production. Pomegranate as on day has label claim for just 9 agro-chemicals.

Analysis of pomegranate statistics for last 6–7 years shows that, average increase per year; in area was 14.7%, production 29.7%, productivity 13.2% and export 16.3%. 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 crop can become one of the most important horticultural crops of India.

Keeping in mind, the important role that this ancient fruit crop can play in modern horticulture, not only as a 'super health fruit', but also in doubling farmers' income in rural areas of arid and semi-arid regions that face challenges of natural calamities and unpredicted weather conditions, ICAR-NRCP continues to move forward confidently to fulfill its mandate, mission and vision.

MANDATE

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

MISSION

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

VISION

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

कार्यकारी सारांश

कृषि एवं किसान कल्याण मंत्रालय, भारत सरकार द्वारा 2018–19 मे जारी प्रथम अनुमानानुसार अनार के क्षेत्रफल को 2.46 लाख हैक्टेयर तथा उत्पादन को 28.65 लाख मेट्रिक टन दर्शाया गया है। भारत से अनार का निर्यात 67.86 हज़ार टन रहा (Rs.6885 million) जो अपने आप में एक रेकॉर्ड है और पिछले वर्ष कि तुलना में 43.41% ज्यादा है। अत: अनार को अनियमित वर्षा वाले शुष्क तथा अर्ध शुष्क क्षेत्रों में किसानों कि आर्थिक स्तिथि को सुधारने हेतु सबसे महत्वपूर्ण फसल माना जा सकता है। यह केंद्र अनार संबन्धित सभी चुनौतियों से निबटने के लिए विभिन्न विषयों पर सफलतापूर्वक अनुसंधान करने में कारगर पाया गया है। वर्ष 2018–19 के दौरान भा.कृ.अनु.प. - राष्ट्रीय अनार अनुसंधान केंद्र ने 9 संस्थान परियोजनाएं, 14 बाह्य वित्त पोषित परियोजनाएं, 4 सहयोगात्मक परियोजनाएं, 1 अनुसूचित जाति उप योजना (SCSP) एवं 1 अनुसूचित जनजातीय उप योजना (TSP) को संचालित किया है। इनमें से 3 बाह्य वित्त पोषित तथा 1 सहयोगात्मक परियोजना को सफलतापूर्वक पूर्ण किया गया है। इस केंद्र कि मुख्य उपलब्धियों का सारांश नीचे दिया गया है।

आनुवांशिक संसाधन: वर्ष 2018–19 के दौरान 13 एग्जोटिक संग्रहण (12 एग्जोटिक संग्रहण फ्रांस से तथा 2 संयुक्त राज्य अमरीका से) एवं 1 देशज संग्रहण (भगवा का संगोला क्लोने, संगोला से) का समायोजन प्रक्षेत्र जीन कोष में किया गया है जिसके फलस्वरूप भा.कृ.अनु.प. - राष्ट्रीय अनार अनुसंधान केंद्र के प्रक्षेत्र जीन कोष में जननद्रव्यों कि कुल संख्या 362 हो गई है (140 देशज एवं 222 एग्जोटिक)। 18 जंगली जननद्रव्यों का द उ स दिशानिर्देशों के अनुसार चरित्र चित्रण किया गया है। सोलापुर लाल और सोलापुर अनारदाना का द्वितीय वर्ष के लिए ऑन साइट DUS परीक्षण DUS दिशानिर्देशों के अनुसार पूर्ण किया गया है और इन क़िस्मों के रजिस्ट्रेशन के लिए निर्णायक अर्जी पौध किस्म और कृषक अधिकार संरक्षण प्राधिकरण, नई दिल्ली को भेज दी गई है।

फसल सुधार: सोलापुर लाल का भगवा किस्म के तुलनात्मक मूल्यांकन में सोलापुर लाल को 18 दिन अगेती, 36% अधिक उत्पादन वाला तथा फल गुणवत्ता मे बेहतर पाया गया। रोपण के चौथे वर्ष में मृग बहार कि फसल में सोलापुर अनारदाना मे 4.8% अम्लता एवं 465 मिलीग्राम/100 ग्राम अंथोसायनिन पाया गया।

भगवा किस्म का उच्च गुणवत्ता वाला कुल जीनोम अनुक्रमण (346 Mb) चतुर्थ श्रेणी अनुक्रमणीय तकनीकों द्वारा किया गया (पैकबायो सीक्वेल, 10 X क्रोमियम, बायोनैनो सफायर)। अनुमानित जीनोम (356 Mb) का लगभग 96.92% कवरेज को 342 स्केफोल्ड्स मे N 50 मूल्यांक 16.1 Mb के साथ किया गया है। यह अब तक का अनार का सर्वश्रेष्ठ असेंबलड जीनोम है तथा पूर्व में प्रकाशित दाबेंजी एवं ताइशीनहाँग के जीनोम अनुक्रमण से काफी बेहतर है।

अनार किस्म दाबेंज़ी के ड्राफ्ट जीनोम अनुक्रमण की व्यापक मायनिंग करके हायपर-वैरियेबल SSR चिंहकों का विकास किया गया।

पौध प्रवर्धन: वूडी प्लांट मीडियम पर पैराफिन मोम से ढके हुए (केवल कटे हुए निचले हिस्से) नोडल खंडो और शूट प्ररोहों या फिर मीडियम पॉली विनयल प्यर्रोलिडोन मिलाने से सार्थक रूप से मीडिया में फेनोल निष्कर्षण कम पाया गया तथा पॉली विनयल प्यर्रोलिडोन के समायोजन से कल्चर

स्थापन मे भी कोई कमी नहीं पाई गई (78.053%)। मोडीफाइएड मुरशीग स्कूग मीडियम में एडनिन सल्फ़ेट (60 मिली ग्राम/लीटर), आर्जिनिन (60 मिली ग्राम/लीटर), काएनेटिन (1.0 मिली ग्राम/ लीटर), थाइडियाजुरोन (0.1 मिली ग्राम/लीटर) एवं नप्थलीन एसटीक एसिड (0.2 मिली ग्राम/लीटर) के समायोजन वाले माध्यम में सबसे ज्यादा शूट गूड्न (3.8 शूट्स/ माइक्रोशूट्स) पाया गया। सूछम प्रविर्धित पौधों के जैवकठोरीकरण के लिए अस्पेर्जिलस *नाइजर* एएन 27, पेनिसिलियम *पीनोफिलम*, सेडोमोनास *फ्लोरसेन्स*, मयकोरायझा (ग्लोमस इंट्रारडिसस/ राइजोफेगस *इर्रेगुलेरिस*) की पहचान कि गई। अस्पेर्जिलस नाइजर एएन 27 + पेनिसिलियम पीनोफिलम इनोकुलटेड पौधों में सार्थक रूप से ज्यादा पौध लंबाई, पौध छत्र तथा रेडूसिंग शुगर पाया गया।

फसल उत्पादन: अनार के विभिन्न फल विकास के चरणों में पोषक तत्व प्रबंधन के लिए तीन नए अमीनो एसिड आधारित सूक्ष्म पोषक फ़ार्मूलेसन तत्व विकसित किए गए थे। अमीनो एसिड आधारित सूत्रीकरण I और II के पर्ण छिड़काव के परिणामस्वरूप पोषक तत्वों में सुधार के अलावा निर्यात योग्य ग्रेड फलों (फलों का वजन> 250 ग्राम) के उच्चतम प्रतिशत (46.57%) के साथ फलों की पैदावार में 41.23% की वृद्धि हुई। ज़ीटाल सेलेक्ट WSF ग्रेड II RDF के 75% प्लस प्रोराइज पैकेज पर फलों की गुणवत्ता के अलावा फलों के उत्पादन में 50% की वृद्धि हुई है। उपसतह ड्रिप सिंचाई प्रणाली (एस डी आई) जिसमे लैटरल को पौधों से 30 से.मी. की दूरी पर बिछाया गया और इनलाइन ड्रिपर 30 x 30 से.मी. की दूरी पर थे उसमें उच्चतम जल उपयोग क्षमता (WUE) पायी गई।

अनार में फसल नियमन के लिए एथेफॉन 0.2 मिली/ ली का पर्ण छिड़काव एवं उसके बाद इथेफॉन 0.4 मि.ली./ ली के पर्ण छिड़काव के एक सप्ताह बाद सबसे ज्यादा विपर्णन (90% - पर्ण छिड़काव) दर्ज किया गया। मृग बहार के दौरान भागवा में जिब्ब्रेलिक अम्ल @ 50 मिलीग्राम/ लीटर का फोलियर स्प्रे औसत फल वजन (266.2 ग्राम/ फल) और उपज (24.57 किग्रा/ वृक्ष) के सुधार करने में फायदेमंद था।

फसल सुरक्षा: कॉम्बिफ़ार्मूलेसन क्लोरेंट्रानिलिप्रोएल 8.80% + थियामेथोक्साम 17.5% @ 0.75 मिली/ ली, थ्रिप्स (फूल कीड़े) का सबसे अच्छा प्रबंधन किया तथा थ्रिप्स प्रभावित फलों में 76.50% की कमी दर्ज़ की गई। फल भेदक (फ्रूट बोरर) और अनार के चूसने वाले कीटों के खिलाफ सरसों आधारित योगों की जैव-प्रभावकारिता भा.कृ.अनु.प. - केन्द्रीय कटाई उपरान्त अभियांत्रिकी एवं प्रौद्योगिकी संस्थान, लुधियाना (अकेले और अन्य जैविक उत्पादों के साथ संयोजन में) प्रभावी पाई गई। कंट्रोल (75%) की तुलना में थ्रिप्स से क्षति सबसे कम (4%) सरसों फ़ार्मूलेसन (1 ग्राम/ लीटर) + नीम तेल (3 मिली लीटर/ लीटर) + सरसों का तेल (3 मिली लीटर/ लीटर) तथा कंट्रोल की तुलना में (11.32%) फल भेदक की क्षति सबसे कम (1.98%) सरसों फ़ार्मूलेसन (1 ग्राम/ लीटर) + नीम का तेल (3 मिली लीटर/ लीटर) में पायी गई। फ्रूट पियर्सिंग मोथ (ई. मैटरना), फेरोमोन मिश्रण बी, क्यू और एन जिसमें निश्चित अनुपात में फेरोमोन और पौधे के वाष्पशील थे, नर कीटों को आकर्षित करने और फंसाने में अधिक प्रभावी थे। अनार में रूट-नॉट निमेटोड (सूत्रक्रीमी) (एम. *इनकोगनिटा*) के प्रबंधन में फ्लुन्सफ्लोन 2% जीआर @ 40 ग्राम /पौध का उपयोग प्रभावी था।

आणविक लक्षण वर्णन और एक्सएपी की जनसंख्या संरचना को समझने के लिए, एक्सएपी विशिष्ट 419 जीनोम व्यापक एसएसआर प्राइमरों की पहचान और डिज़ाइन किया गया है। आर जीन (R genes) की भिन्न संख्या और जानकारी अतिसंवेदनशील और मध्यम प्रतिरोधी अनार जननद्रव्यों के ट्रांसस्क्रिप्टोमिक डेटा से निकाली गई है। BLASTP होमोलोजी खोज नमूनों के सभी संयोजनों के

अपरेगुलेटेड वंशाणुओं के बीच स्थानीय डेटाबेस के उपयोग से R जीन प्रोटीन के पहचान लिए किया गया था। 16 नमूना संयोजनों में से, FS_2 बनाम FT_1 संयोजन की अपरेगुलेटेड जीन की सूची में सबसे अधिक R जीन्स (140) पायी गई।

औषधीय पौधों से 28 एंडोफाइट्स (बासिल -10; पुदीना -8; तुलसी -5; लेमॉनग्रास -3; अमला -2) का निष्कर्षण करके जिवाणु झुलसा (बेक्टेरियल ब्लाइट, टेलिया) के खिलाफ इनकी प्रभावकारिता का आंकलन किया गया था। 19 बैक्टीरियल, 4 एक्टिनोबैक्टीरियल और 5 फंगल एंडोफाइट की जांच की गई और एक्सएपी के खिलाफ इन विट्रो स्तिथि में, 3 एक्टिनोबैक्टीरिया एंडोफाइट्स, क्रमशः 68.12% (एई -3), 69.85% (एई -4) और 77.10% (एई -5) के एक्सएपी निषेध के साथ सबसे प्रभावी थे। बैक्टीरियल ब्लाइट प्रभावित अनार के बागों की फाइटोस्फीयर और मिट्टी से अलग किए गए बैक्टीरियोफाज को जैन्थोमोनस *एक्सोनोपोडिस* पीवी *प्यूनकी* के इन विट्रो विगलन में प्रभावी पाया गया। ये अनार के जैविक उत्पादन में संभावित पौध संरक्षक के रूप में काम आ सकते हैं। संशोधित एकीकृत रोग एवं कीट पीड़क प्रबंधन अनुसूची का दूसरे वर्ष के दौरान राष्ट्रीय अनार अनुसंधान केन्द्र में परीक्षण किया गया था, अनुसूची के अनुसरण से 11.45 किलोग्राम/ पौध और 100% तेलिया मुक्त उपज प्राप्त हुई, फंफूंद धब्बे एवं सड़न की घटना 2% से कम थी। फसल के आराम की अवधि के दौरान छह आसान कदम, जिसमें पोषण, तनाव और बोर्डो मिश्रण स्प्रे शामिल हैं, ने बरसात के मौसम की फसल में तेलिया रोग का पूर्ण नियंत्रण किया। अनार में बैक्टीरियल ब्लाइट को मिटाने के लिए अब इसे बढ़ावा दिया जा रहा है।

सीरटोसिस्टीस फिंब्रीयाता के निवारक उपचार के लिए अस्पेर्जिलस नाइजर एएन 27, राइजोफेगस *इर्रेगुलेरिस*, ट्राइकोडर्मा *हार्जियनम* और एक नया फंफूंद एंडोफाइट FE-8 युक्त बायोफोर्मूलेसन थे, जिनका 1 महीने के अंतराल पर दो बार उपयोग किया जाता है। 100% मर रोग (विल्ट) को नियंत्रण देने वाले तीन उपयोगी निदानक उपचारों की पहचान की गई, जिसमें रासायनिक ड्रेंचिंग के बाद एस्परगिलस नाइगर एएन 27, राइजोफेगस इर्रेगुलेरिस शामिल हैं। प्रभावी रसायन प्रोपिकोनाज़ोल और टेबुकोनाज़ोल थे। रूट नॉट नेमेटोड इन्फेक्शन को कम करने में बायोफ़ॉर्मुलेशन अस्पेर्जिलस नाइजर एएन 27 (67.74% की कमी), मायोक्रिरिज़ल कवक राइजोफेगस *इर्रेगुलेरिस*, (65.61%) अकेले और संयोजन में (64.23%) प्रभावी पाया गया, थियोकार्बोनीक एसिड के उपयोग ने 2 मिली लीटर/ लीटर कि दर से अनुपचारित नियंत्रण (59.23 गांठ/ग्रा जड़) कि तुलना में रूट नॉट नेमेटोड इन्फेक्शन में अधिकतम कमी (81.24%) को दर्शाया।

खाद्य प्रसंस्करण: स्प्रे ड्रायिंग का उपयोग करके अनार के बीज के तेल के माइक्रोएन्कैप्सुलेशन (एमई) की प्रक्रिया को मानकीकृत किया गया। चावल स्टार्च और मक्का प्रोटीन आयसोलट संयोजन (1:3), 23.73% तेल लोडिंग और 161 डिग्री सेल्सियस सुखाने का तापमान माइक्रोएन्कैप्सुलेशन उपज (84.10%) और माइक्रोएन्कैप्सुलेशन दक्षता (93.90%) के साथ अनुकूलित प्रक्रिया स्थिति पायी गई। मोसम्बी किस्म न्यूसेलर तथा अनार किस्म भगवा के रस के मिश्रण की उपयुक्तता का खमीर (सेक्रोमायसीस *सीरीवाइजी*, NCIM 3218) के उपयोग से गुणवत्ता वाली मदिरा के उत्पादन पर अध्ययन किया गया था। मिश्रित शराब स्वाद, सुगंध और समग्र स्वीकार्यता के मामले में अत्यधिक स्वीकार्य पायी गई।

अन्य संस्थागत गतिविधियां: केंद्र ने महाराष्ट्र, मध्य प्रदेश, पश्चिम बंगाल और छत्तीसगढ़ के राज्यों में SCSP, TSP और मेरा गाँव मेरा गौरव (MGMG) के माध्यम से प्रदर्शन, कृषि आदानों, मृदा स्वास्थ्य

कार्ड, प्रशिक्षण कार्यक्रमों और तकनीकी मार्गदर्शन द्वारा लगभग 600 किसानों को लाभान्वित किया है। । भा.कृ.अनु.प. - राष्ट्रीय अनार अनुसंधान केंद्र की प्रौद्योगिकियों को सात उद्यमियों ने व्यवसायिकरण करने के लिए लिया और इन प्रौद्योगिकियों को 13 प्रदर्शनियों में प्रदर्शित किया गया था, किसानों और हितधारकों सहित 1000 से अधिक आगंतुकों ने सूचना के लिए केंद्र का दौरा किया। इसके अतिरिक्त, मानव संसाधन विकास के तहत कुल नौ स्टाफ ने प्रशिक्षण लिया और क्षमता निर्माण गतिविधियों के तहत 20 सम्मेलनों और 8 कार्यशालाओं में राष्ट्रीय अनार अनुसंधान केंद्र के कर्मचारियों ने भाग लिया।

भा.कृ.अनु.प. - राष्ट्रीय अनार अनुसंधान केंद्र के सभी कर्मचारीयों ने सक्रिय रूप से हिंदी पखवाड़ा, स्वच्छ भारत अभियान, सतर्कता जागरूकता सप्ताह, सांप्रदायिक सद्भाव अभियान सप्ताह, आदि के तहत संस्थान गतिविधियों में भाग लिया। केंद्र ने (स्वतंत्र या सहयोग से) तीन कार्यशालाओं, एक किसान मेला सह कार्यशाला, 4 किसानों के लिए प्रशिक्षण, कॉलेज के छात्रों के लिए 7 और 4 सार्वजनिक और निजी संस्थाओं के लिए प्रशिक्षण का आयोजन किया। इसके अलावा, भा.कृ.अनु.प. - राष्ट्रीय अनार अनुसंधान केंद्र प्रौद्योगिकियों को अलग-अलग हितधारकों तक पहुंचाने के लिए विभिन्न संगठनों के सहयोग से विभिन्न इंटरैक्टिव बैठकें आयोजित की गईं।

केंद्र ने 17 शोध पत्र पीयर समीक्षा वाली शोध पत्रिकाओं प्रकाशित किए, जिनमें से 2 NAAS रेटिंग 9 से अधिक शोध पत्रिकाओं में और 10 NAAS रेटिंग 6 या उस से अधिक वाली शोध पत्रिकाओं में प्रकाशित हुए, इसके अलावा, 2 किताबें, 12 पुस्तक अध्याय, 18 लोकप्रिय लेख और 4 एक्सटेंशन बुलेटिन/ फ़ोल्डर्स भी प्रकाशित किए गए थे। वैज्ञानिकों को पेशेवर सोसायटी द्वारा मौखिक प्रस्तुति और सर्वश्रेष्ठ पोस्टर पुरस्कारों से भी सम्मानित किया गया।

Executive Summary

The Ministry of Agriculture and Farmers Welfare, GoI, in its first estimates for horticultural crops for the year 2018–19 has projected record pomegranate area of 2.46 lakh ha and production of 28.65 Lakh MT, though 2018–19 was a drought year. Pomegranate export of 67.89 thousand MT (Value Rs 6885 million) is also a record figure till date showing 43.41% increase over previous year. Hence it can be considered as one of the most important crops for improving economic status of the farmers in arid and semi-arid regions with erratic rainfall. The Centre is instrumental in taking research on various aspects to meet the challenges of this popular crop. During the year under report, ICAR-NRCP handled 9 institute projects, 14 externally funded projects, 4 collaborative projects, 1 Scheduled Castes Sub Plan (SCSP) and 1 Tribal Sub-Plan (TSP)scheme. Out of these 3 externally funded projects and 1 collaborative project have been successfully completed. The major achievements are summarized here.

Genetic Resources: During 2018–19, 14 accessions including 13 EC (12 EC from France; 1 EC from USA) and one IC (superior clone of Bhagawa from Sangola) were collected. Thus, FGB's of ICAR-NRCP has 362 collections (140 IC+222 EC). Eighteen pomegranate wild accessions were characterized as per DUS criteria. Second year on-site DUS testing of new hybrids 'Solapur Lal' and 'Solapur Anardana' was completed as per DUS characterization of PPV& FRA and final application for registration of these varieties submitted.

Crop Improvement: Comparative evaluation of pomegranate variety Solapur Lal during fourth year in *mrig bahar* recorded 18 days early maturity and 36% higher yield over Bhagawa besides better fruit quality. Solapur Anardana during the fourth year of planting in *mrig bahar* recorded 4.8% titrable acidity and 465.0 mg/100g anthocyanin.

Genome sequencing of cv. Bhagawa was done with high quality genome (346Mb) using the sequencing technologies (PacBio Sequel, 10X Chromium Genomics and BioNano Direct Labeling on Saphyr). It has 96.92% of estimated genome size (356.98Mb) with 342 scaffolds having average N50 value of 16.1Mb. This is the first report of maximum recovered genome sequence size in pomegranate cv. Bhagawa in comparison to other reported genome sequences of cv. Taishanhong and cv. Dabenzi.

Genome wide mining and development of hypervariable SSR markers from the draft pomegranate genome sequence of cv. Dabenzi was carried out.

Plant Propagation: Nodal segments and shoot tip explants inoculated on WPM media with PVP under dark condition or paraffin wax sealed explants (cut ends only) on WPM medium in dark (for one week) exhibited significantly lower phenol exudation and addition of PVP into the medium didn't negatively impact the culture establishment (78.05%). Higher proliferation rate of micropropagated plants (3.8 shoots per micro-shoots) was recorded on modified MS medium supplemented with Adenine Sulphate (60mg/l), L-Arginine (60mg/l), 1.0 mg/l Kinetin, 0.1mg/l TDZ and 0.2mg/l NAA. Potential biopriming agents - *Aspergillus niger* strain AN27, *Penicillium pinophilum, Pseudomonas fluorescens,* AMF *(Glomus intraradices* syn. *Rhizophagus irregularis)* – were identified for bio-hardening of *in vitro* raised plants of pomegranate. Biopriming agents

A. niger strain AN27 + *P. pinophilum* resulted in significantly higher plant height, canopy and reducing sugar content.

Crop Production: Three new amino acid based micronutrient formulations were developed for nutrient management in different fruit development stages of the pomegranate. The foliar application of amino acid based formulation I & II resulted in 41.23% increase in fruit yield with highest per cent (46.57%) of exportable grade fruits (>250g/fruit) besides improvement in nutrients. Application of zetol select WSF grade II at 75% of RDF plus ProRise package increased fruit yield by 50% with significantly higher quantity of fruits weighing >300 g besides fruit quality. The subsurface drip irrigation system (SDI) laterals placed at 30 cm away from plants and inline dripper spacing of 30 x 30 cm had the highest WUE.

Foliar spray of Ethephon@200ppm followed by Ethephon@400ppm at 1week after first spray recorded highest defoliation (90% - 9DAFS) for crop regulation in pomegranate. Foliar spray of GA_3@50ppm was beneficial for improving fruit size with average fruit weight (266.2 g/fruit) and yield (24.57 kg/tree) in Bhagawa during *mrig bahar*.

Crop protection: Combi-formulation, Chlorantraniliprole 8.80% + Thiamethoxam 17.5% @ 0.75ml/l, provided best protection against thrips, with 76.50% reduction in thrips affected fruits.

Bio-efficacy of the mustard based formulations from ICAR-CIPHET, Ludhiana (alone and in combination with other organic products) was found effective against fruit borer and sucking pests of pomegranate. Thrips damage was lowest (4%) in mustard formulation (1g/l) + Neem oil (3ml/l) + Mustard oil (3ml/l) compared to control (75%) and Fruit borer damage was lowest (1.98%) in mustard formulation (1g/l) + Neem oil (3ml/l) compared to control (11.32%). Fruit piercing moth (*E. materna*), Pheromone blends B, Q and N that contained pheromone and plant volatiles in definite proportions were more effective in attracting and trapping male moths. Use of Fluensulfone 2% GR@ 40 g/ plant was effective in management of root-knot nematode (*M. incognita*) in pomegranate.

In order to carry out molecular characterization and understand the population structure of *Xap* isolates, identified and designed 419 genome wide SSR primers specific to *Xap*. Varying number of R genes from the transcriptomic data were found for prediction of R genes among blight susceptible and moderately resistant pomegranate genotypes. BLASTP homology search was performed between the upregulated genes of all combinations of sample to the local database of R gene proteins. Out of 16 sample combinations, FS_2 vs. FT_1 combination revealed highest number of R genes (140) in the list of upregulated genes.

Efficacy of endophytes from medicinal plants was assessed for bacterial blight management by isolating 28 endophytes (Basil-10; Pudina-8; tulsi-5; lemongrass-3; Amla-2). Among 19 bacterial, 4 Actinobacterial and 5 fungal endophytes screened *in vitro* against *Xap*, 3 actinobacteria endophytes were most effective with *Xap* inhibition of 68.12% (AE-3), 69.85% (AE-4) and 77.10% (AE-5) respectively. Bacteriophages isolated from the phyllosphere and soil of bacterial blight affected pomegranate orchards gave effective *in vitro* lysis of *Xanthomonas axonopodis* pv. *punicae.* These can be potential plant protectants in organic production of pomegranate.The modified IDM schedule at ICAR-NRCP, was tested during second

year. The schedule gave 100% blight free yield of 11.45 kg/plant. The incidence of fungal spots/ rots was below 2%. Six easy steps during rest period of the crop including nutrition, stress and Bordeaux mixture spray gave complete control of bacterial blight in following rainy season crop. This is being promoted now to eradicate bacterial blight in pomegranate.

Promising preventive treatments for *Ceratocystis fimbriata* were fungal bioformulations containing *Aspergillus niger* AN27, *Rhizophagus irregularis*, *Trichoderma harzianum* and one new fungal endophyte FE-8, applied twice at 1 month interval. For curative 3 promising treatments giving 100% wilt control were identified, which include chemical drenching followed by *Aspergillus niger* AN27, *Rhizophagus irregularis* formulations. The promising chemicals were propiconazole and tebuconazole. Root knot nematode infestation was best reduced using bioformulations having *A.niger* AN27 (67.74% reduction), Mychorrizal fungi *R. irregularis* (65.61%) alone and in combination (64.43%), with maximum reduction (81.24%) with thiocarbonic acid @ 2ml/l against untreated control having 59.23 knots/g roots.

Post-Harvest Technology: The process of microencapsulation (ME) of pomegranate seed oil using spray drying was standardized. The rice starch and whey protein isolate combination (1:3), 23.73% oil loading and 161°C drying temperature were the optimized process conditions with ME yield (84.10%) and ME efficiency (93.90%). The suitability of juice of sweet orange var. Nucellar for blending with pomegranate var. Bhagawa juice and fermentation was studied for production of quality wine using yeast *Saccharomyces cerevisiae* (NCIM 3218). The blended wine was found to be highly acceptable in terms of taste, flavour, aroma, and overall acceptability.

Other Activities: The Centre has taken up pomegranate cultivation in the states of Maharashtra, Madhya Pradesh, West Bengal and Chhattisgarh through SCSP, TSP and Mera Gaon Mera Gaurav (MGMG) through demonstrations, inputs, Soil Health Cards, trainings and technical guidance benefiting around 600 farmers. ICAR-NRCP technologies were commercialized to seven entrepreneurs and displayed in 13 exhibitions and more than 1000 visitors including farmers and stakeholders visited the centre for information. In addition to this, a total nine staff underwent trainings under HRD and attended 20 conferences and 8 workshops under capacity building activities.

All the Staff of ICAR-NRCP actively participated in activities under Hindi Pakhwada, Swachch Bharat Abhiyan, Vigilance Awareness Week, Communal Harmony Campaign Week, *etc*. The Centre also organized (independently or in collaboration) three workshops, one farmer fair cum workshop, 4 trainings for farmers, 7 for college students and 4 for public and private agencies. Apart from this, various interactive meetings were organized in collaboration with different organizations to disseminate the ICAR-NRCP technologies to different stake holders.

The Centre published 17 research papers in peer reviewed journals, out of which 2 were in journals with NAAS rating ≥ 9 and 10 were in NAAS rating ≥ 6. In addition, 2 books, 12 book chapters, 18 popular articles and 4 extension bulletins/folders were also published. The scientists also got recognitions from professional Societies besides oral presentation and best poster awards.

Research Programmes & Projects

INSTITUTE RESEARCH PROJECTS

S.No.	Project Title	PI	Co-PIs	Status
1	Draft Genome Sequencing and *De novo* Assembly of Pomegranate (*Punica granatum* L.) (01.02.2017-30.11.2022)	Ms. Roopa Sowjanya P.	Dr. Shilpa P. Dr. N.V. Singh Dr. Prakash G. Patil	Ongoing
2	Genetic Mapping of Bacterial Blight and Fruit Quality Traits in Pomegranate (01.01.2018-31.12.2022)	Dr. Prakash G. Patil	Dr. Jyotsana Sharma Dr. Shilpa P. Dr. N.V. Singh Dr. K.D. Babu	Ongoing
3	Propagation, Bio-hardening and Mass Multiplication of Elite Planting Material in Pomegranate (01.10.2014-30.09.2019)	Dr. N.V. Singh	Dr. K.D. Babu, Dr. J. Sharma Dr. Shilpa P. Ms. Roopa Sowjanya P.	Ongoing
4	Crop Regulation Practices for Improving Productivity of Pomegranate (01.04.2018-31.03.2023)	Dr. K. Dhinesh Babu	Dr. N.V. Singh Dr. A. Maity Dr. Jyotsana Sharma	Ongoing
5	Package of Practices for Organic Cultivation of Pomegranate (01.08.2018-31.07.2023)	Dr. Ashis Maity	Dr. Jyotsana Sharma Mr. Mallikarjun M.H. Dr. N.N. Gaikwad	Ongoing
6	Post-harvest Management, Value Addition and Improving Knowledge of Stakeholders for Increasing Production and Marketing of Pomegranate (01.07.2014-30.06.2019)	Dr. Gaikwad Nilesh. N.	Dr. K. Dhinesh Babu	Ongoing
7	Development and Refinement of Integrated Crop Protection Technologies for Improved Productivity of Pomegranate (01.04.2013-31.03.2020)	Mr. Mallikarjun	Dr. Jyotsana Sharma Dr. U.R. Sangle	Ongoing
8	Flagship Project on Integrated Approach to Eradicate Bacterial Blight (01.03.2013-31.03.2020)	Dr. Jyotsana Sharma	Dr. A.Maity, Dr. NV. Singh. Dr. Shilpa, P, Dr. K.D. Babu, Dr. Prakash G. Patil; Dr. A. Kumar, ICAR-IARI, New Delhi; Dr. Manjunath, Dr. R.K. Mestha, UHS, Bagalkot	Ongoing
9	Biological Control of Wilt Complex Problem in Pomegranate (01.12.2016-30.11.2021)	Dr. U.R. Sangle	-	Ongoing

EXTERNALLY FUNDED PROJECTS

S.No.	Funding Agency	Project	PI	Co-PIs	Status
1	RKVY, DAC, GoI	Horticulture Crop Pest Surveillance and Advisory Project for Mango, Pomegranate & Banana	Dr. Jyotsana Sharma	Mr. Mallikarjun	Ongoing
2	PPV&FRA, New Delhi, GoI	Establishment of DUS Centre at ICAR-NRCP, Solapur	Dr. Shilpa P.	Ms. Roopa Sowjanya P.	Ongoing
3	NHB, Gurugram, GoI	Standardization and Demonstration of Propagation and Production Technologies for Protected Cultivation of Pomegranate (*Punica granatum* L.)	Dr. N.V. Singh	Mr. Mallikarjun Dr. N. Gaikwad Dr. D.T. Meshram	Ongoing
4	NMPB, Min, of Ayush GoI.	Utilization of Pomegranate for Development of Functional Medicinal Ingredients	Dr. Nilesh N. Gaikwad	Dr. Debi Sharma ICAR-IIHR, Bangalore Dr. Krishna Das Saha CSIR-IICB, Kolkata	Ongoing
5	ICAR-IPTM	Intellectual Property Management and Transfer/ Commercialization of Agriculture Technology Scheme	Dr. Jyotsana Sharma, Director, ICAR-NRCP	Dr. Nilesh N. Gaikwad	Ongoing
6	ICAR-AICRP	All India Coordinated Research Project on Arid Zone Fruits	Dr. K. Dhinesh Babu	Dr. N.V. Singh Mr. Mallikarjun	Ongoing
7	ICAR-Consortia Research Platform on Water	Response of Pomegranate to Deficit Irrigation and Partial Root Zone Drying	Dr. A.K. Nair ICAR-IIHR, Bangalore	Dr. D.T. Meshram	Ongoing
8	Indofil Industries Ltd.	Evaluation of Bioefficacy and Phytotoxicity of IFFC 016, IFFC 017 and IFFC 018 Against Fungal Leaf and Fruit Disease Complex in Pomegranate	Dr. Jyotsana Sharma	Dr. K.D. Babu Mr. Vijay S. Lokhande	Ongoing
9	BVG Life Sciences Ltd.	Effect of BVG Products on Growth, Pest and Diseases Incidence and Yield of Pomegranate	Dr. N.V. Singh	Dr. Jyotsana Sharma Mr. Mallikarjun Dr. Ashis Maity	Ongoing
10	MOSCOS Food Processing Pvt. Ltd, Nashik	Technical Consultancy for Establishment of Minimal Processing and Packaging Unit for Pomegranates	Dr. Nilesh N. Gaikwad	-	Ongoing
11	Nagarjuna Fertilizer &Chemicals Ltd.	Effect of Zetol Select Water Soluble Fertilizer Grades and ProRise Solutions of Nagarjuna Fertilizers and Chemicals Ltd on Pomegranate Yield and Quality	Dr. Ashis Maity	Dr. Jyotsana Sharma	Ongoing
12	ADAMA India Pvt. Ltd.	Evaluation of MCW-2 (2% GR) against Root Knot Nematode (*Meloidogyne incognita*) in Pomegranate	Mr. Mallikarjun	Dr. Jyotsana Sharma Dr. Mallesh S.B.	Completed
13	Dow Agro Science India Pvt. Ltd.	Field Evaluation of the bioefficacy of Spinetoram 12% SC against Thrips and Fruit Borer in Pomegranate (PI).	Mr. Mallikarjun	-	Completed
14	Bayer Crop Science Ltd, Mumbai	Contract Research Project on Performance Evaluation of Fosetyle Al-80WP (Aliette) and other Protection Range Chemicals on Pomegranate Health and Productivity	Dr. Jyotsana Sharma	Mr. Mallikarjun	Completed

TRIBAL SUB-PLAN

S. No.	Project Title	PI	Co-PIs	Status
1	Introduction of Pomegranate Cultivation to Tribal Farmers of Gadchiroli Dt., Maharashtra, Bankura & Purulia Dt. of West Bengal, Anuppur Dt., Madhya Pradesh and Koriya Dt. of Chhattisgarh	Dr. D.T. Meshram	Dr. A. Maity Dr. N.V. Singh	Ongoing

SCHEDULED CASTES SUB-PLAN

S. No.	Project Title	PI	Co-PIs	Status
1	Promotion of Pomegranate Among Scheduled Caste Farmers	Dr. N.V. Singh	Dr. Shilpa P. Mr. Yuvraj Shinde Mr. Mahadev S. Gogaon	Ongoing

INTER-INSTITUTIONAL COLLABORATIVE PROJECTS

S. No	Project Title	Collaborative Institutes	PI	Co-PI	Status
1	Delineation of Potential Areas for Pomegranate Cultivation in India using Remote Sensing and GIS Techniques	ICAR-NRCP, Solapur ICAR-NBSSLUP, Nagpur	Dr. D.T. Meshram	Dr. A. Maity	Ongoing
2	Unraveling the Mechanism and Developing Mitigation Strategies for Aril Browning and Fruit Cracking in Pomegranate	ICAR-NRCP, Solapur ICAR-NIASM, Baramati	Dr. N.V. Singh	Dr. Shilpa, P Dr. A.Maity Dr. K.D. Babu Dr. D.T. Meshram	Ongoing
3	Development of a Smart Sprayer for Young Pomegranate Orchard	ICAR-NRCP, Solapur ICAR-CIAE, Bhopal	Er. C.P. Sawant ICAR-CIAE, Bhopal	Dr. Nilesh N. Gaikwad	Ongoing
4.	Development and Evaluation of Eco-friendly Mustard based Antimicrobial Formulations using other Botanicals for the Control of Bacterial Blight and Insect Pests of Pomegranate	ICAR-NRCP, Solapur ICAR-CIPHET, Ludhiana	Dr. S.K. Tyagi ICAR-CIPHET, Ludhiana	Dr. Jyotsana Sharma Mr. Mallikarjun Dr. K.D. Babu	Completed

Genetic Resources

CHAPTER 1

1.1 PROJECT: CONSERVATION, CHARACTERIZATION AND SUSTAINABLE USE OF DIVERSITY IN POMEGRANATE

1.1.1 Germplasm Collection and Conservation

Out of 47 accessions of pomegranate including 45 collections of France and 2 collections of USDA, California introduced through ICAR-NBPGR, New Delhi, survival was limited to only 13 EC. This includes, 12 from France (EC-937310; EC-937303; EC-937342; EC-937305; EC-937315; EC-937322; EC-937340; EC-937343; EC-937311; EC-937317; EC-937304; EC-937321) and one from USA (EC-947180), being maintained under polyhouse condition. Besides, one clone of Bhagawa (claimed to have less incidence of bacterial blight, superior to Bhagawa for fruit size and colour), collected from farmer field of Sangola, Solapur, Maharashtra was maintained under polyhouse. Apart from these, 348 germplasm accessions including 139 IC and 209 EC were maintained at Field Gene Banks of ICAR-NRCP, Solapur. In total, ICAR-NRCP with 362 pomegranate accessions is the largest collection in the country.

(a) (b) (c)

Fig. 1.1 : New Pomegranate Germplasm Accessions Collected during 2018–19 from (a) France (b) USA (c) Sangola, Maharashtra

1.1.2 Germplasm Characterization

1.1.2.1 *In silico* Discovery, Validation and Characterization of Novel Genomic Simple Sequence Repeats (SSRs) Markers in Pomegranate (*Punica granatum* L.)

Fifty scaffolds (MTJX0100001-MTJX01000050) of pomegranate cv. Taishanhong were downloaded from NCBI (http://www.ncbi.nlm.nih.gov/) to identify SSR repeats and primers were designed

for respective SSR repeat using GMATA software. 1064827 SSR repeats of 1–6 motif length were identified. It was observed that mononucleotide (94.96%) repeats were found to be most frequent followed by di (4.16%) and tri (0.67%) nucleotide types.

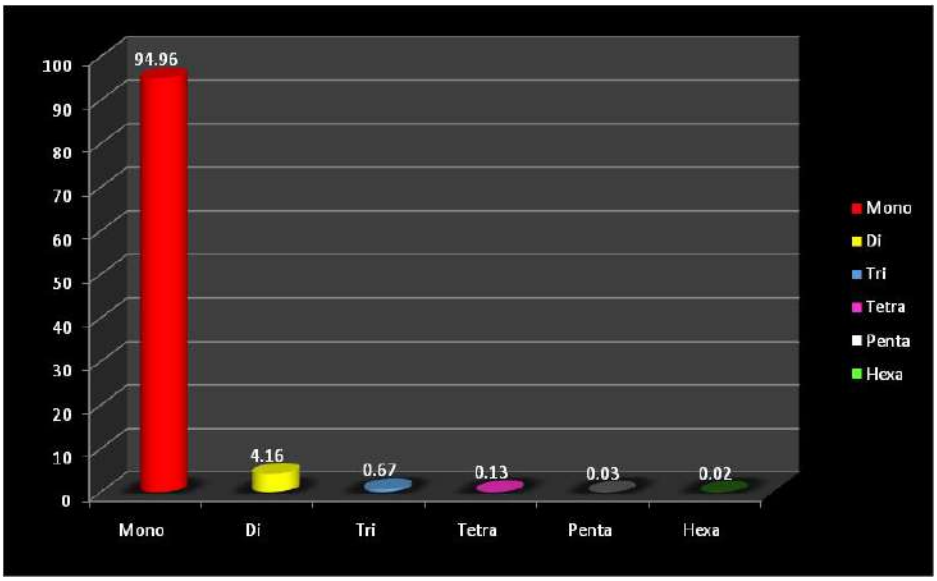


Fig. 1.2 : Frequency Distribution of Genomic SSRs Identified in the Study

From 1064827 SSR repeats identified SSR primers were designed for 437952 repeats. Among the designed SSR primers, highest primers were designed for scaffold MTJX0100014 (5.72%) i.e. 25069 and lowest for MTJX01000050 (0.80%) i.e. 3490. Randomly selected 219 SSR primers were further analyzed for secondary structure formation using Oligo-analyzer tool. Of which 24 genomic SSR primers with no or minimum secondary structures were selected and validated among 24 diverse pomegranate genotypes. 16 primers which showed good amplification were selected for molecular characterization of selected genotypes. Out of 16, 12 SSR primers (85.71%) were found to be polymorphic. These primers produced in total 35 alleles, ranging from 1 to 4 with an average of 1.4 alleles per locus. The heterozygosity value ranged from 0.15 to 0.64 and PIC values ranged from 0.14 to 0.57. PgDSSR 28, PgDSSR 37, PgDSSR 48 genomic SSR primers were found to be the most informative primers with higher number of alleles (4), heterozygosity (0.64, 0.58, 0.44) and PIC (0.57, 0.54, 0.41) values. These polymorphic markers could be very useful to analyze genetic diversity and degree of polymorphism in pomegranate genotypes.

1.1.2.2 Germplasm Characterization for Important Horticultural Traits

Evaluation of 44 pomegranate accessions for 28 morphological and physico-chemical traits of quantitative nature was done during *mrig* bahar of 2018–19. The data were analysed for descriptive statistics, Analysis of Variance (ANOVA), Pearson correlation between the selected characters and diversity analysis. Mean, range (Minimum, Maximum) and coefficient of variation (CV%) for different traits under study were tabulated. In ANOVA, a significant difference between the genotypes was observed at both 5% and 1% level of significance for all traits. This indicated the presence of adequate variability among the genotypes for the different characters.

Table 1.1: Descriptive Statistical Analysis of Quantitative Traits in 44 Pomegranate Genotypes

S. No.	Characters	Mean	Min.	Max.	CV%	F cal
1	Tree height (m)	3.26	1.93	4.58	7.65	22.89**
2	Tree Spread (m)	3.50	1.74	4.45	9.57	10.85**
3	No. of thorns/m shoot	8.43 (2.88)	4.67 (2.16)	12.44 (3.53)	8.77 (4.24)	27.19 ** (31.03)
4	Leaf blade length (mm)	50.98	39.55	59.80	5.36	10.35**
5	Leaf blade width (mm)	15.46	11.07	18.36	4.98	13.65**
6	Petiole length (mm)	4.55	3.51	5.59	8.06	4.92**
7	Petiole width (mm)	0.98	0.78	1.13	5.30	5.34**
8	Calyx length (mm)	36.09	30.14	44.32	4.141	11.01**
9	Calyx width (mm)	12.70	9.20	16.04	5.33	19.90**
10	Petal length (mm)	22.21	17.51	29.37	4.93	11.45**
11	Petal width (mm)	17.48	12.68	22.71	5.93	7.59**
12	Fruit weight (g)	216.10	57.94	373.07	10.80	56.32**
13	Fruit Length (cm)	6.77	4.42	8.73	3.93	64.14**
14	Fruit Diameter (cm)	7.10	4.56	8.89	3.86	69.58**
15	Crown length (mm)	15.07	10.95	19.42	5.57	17.25**
16	No. of arils/ fruit	465.54 (2.64)	171.85 (2.23)	691.13 (2.84)	11.82 (1.98)	23.39** (32.5)
17	Aril per cent (%)	59.95	39.23	70.26	3.48	38.10**
18	100 arils weight (g)	27.15	14.40	39.93	6.41	45.88**
19	100 arils dry weight (g)	6.21	3.84	8.32	5.59	24.83**
20	Rind Thickness (mm)	3.19	1.70	4.68	6.39	38.50**
21	TSS (^{0}Brix)	16.68	14.06	19.38	2.51	18.37**
22	Acidity (%)	1.76 (1.15)	0.21 (0.46)	8.07 (2.84)	5.88 (2.78)	938.21** (1331.97)
23	Aril length (mm)	9.86	7.44	11.50	2.76	39.44**
24	Aril width (mm)	6.07	4.82	7.48	3.49	33.48**
25	Juice % (w/w)	34.62	22.69	54.11	4.98	64.99**
26	100 Seed weight (g)	1.92	1.10	3.34	6.14	47.80**
27	Seed length (mm)	6.49	5.43	7.68	4.04	9.46**
28	Seed width (mm)	2.69	2.28	3.46	5.251	6.13**

** Significant both at 1% & 5% level of significance;
Note: Values within the brackets are the transformed data

Correlation study showed that fruit weight was significantly and positively correlated with fruit length (0.76), number of arils per fruit (0.94), aril % (0.76), 100 aril weight (0.94), aril length (0.89), fruit juiciness (0.73), seed length (0.83). TSS and Acidity are negatively correlated with significance of 0.92. On the basis of estimation of Squared Euclidean Distance between 44 genotypes for the 28 quantitative characters, they were grouped into four clusters. 27 genotypes of cultivated varieties with medium to large fruit size, bold, juicy, sweet arils of commercial value were grouped in Cluster-I (17) and II (10), except IC-318790 and IC-318790 which were grouped in cluster-II due to more number of arils per fruit. Clusters-III (7) and IV (10) were found to have vigorous tall plant growth habit, with small to medium size fruits, highly acidic arils, suitable for anardana purpose. However, "Amlidana" a hybrid variety was included in cluster-IV along with wild genotypes due to high acidic arils.

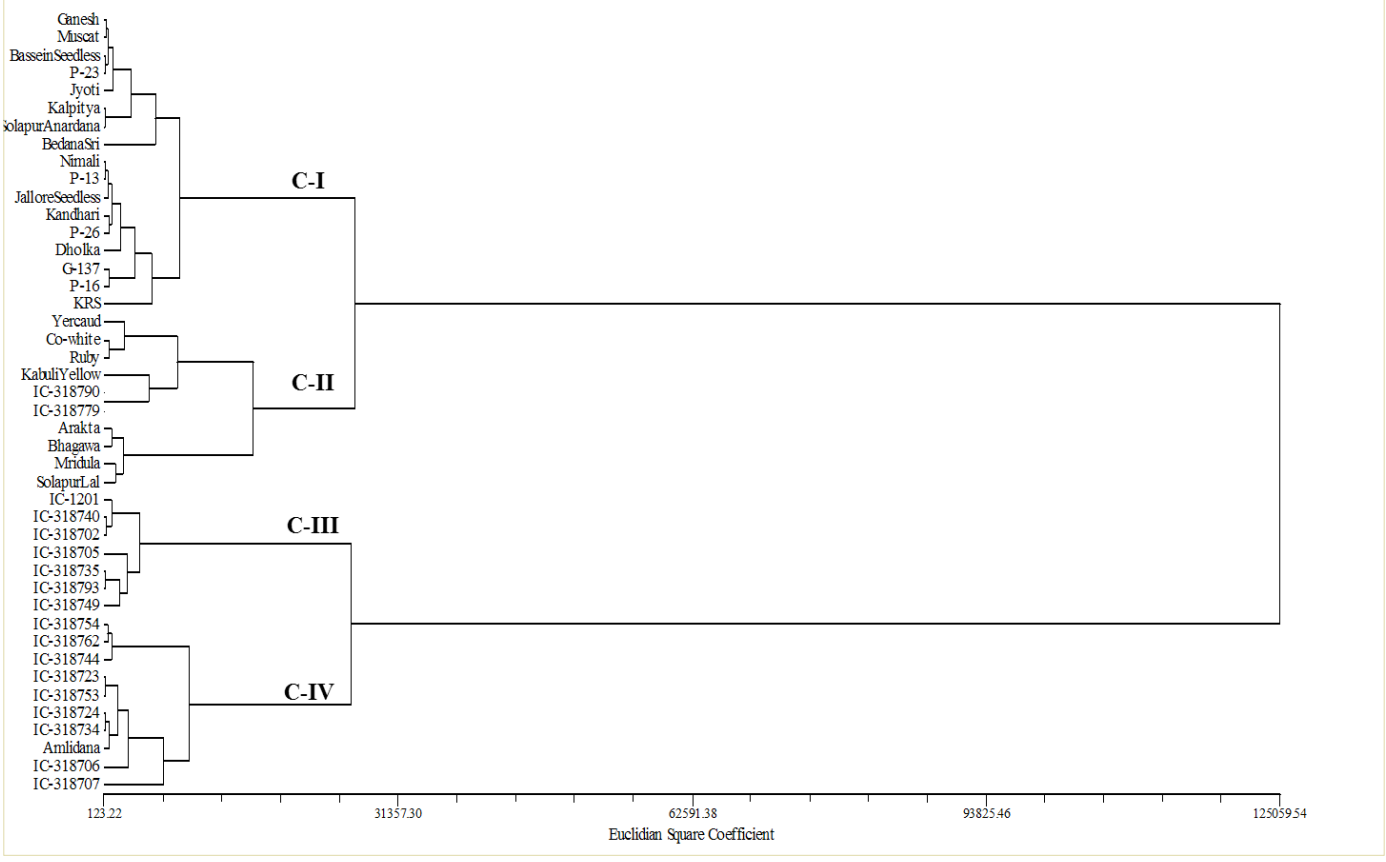


Fig. 1.3 : UPGMA Dendrogram of Squared Euclidean Distance Illustrating the Genetic Relationship among 44 Pomegranate Genotypes

1.1.2.3 Screening of Germplasm Against Thrips and Fruit Borer

Among 49 pomegranate germplasm screened against thrips and fruit borer, none of them were found resistant or tolerant to thrips or fruit borer. Infestation varied between 15–78% for thrips and 13–19% for fruit borer respectively.

Crop Improvement

2

CHAPTER

2.1 PROJECT: GENETIC IMPROVEMENT OF POMEGRANATE

2.1.1 Evaluation of Varieties/ Hybrids from ICAR-NRCP

2.1.1.1 Comparative Evaluation of Solapur Lal

Evaluation of pomegranate variety Solapur Lal in comparison to the ruling variety, Bhagawa during the fourth year of planting in mrig bahar recorded 18 days early maturity, 36% higher yield over Bhagawa besides better fruit quality.

Table 2.1: Comparative Evaluation of Solapur Lal with Bhagawa

Characters	Solapur Lal	Bhagawa
Plant height (m)	1.75	1.60
Maturity (days)	162	180
Fruit weight (g)	245.2	254.0
No. of fruits /tree	102.0	72.0
Yield (kg/plant)	25.01	18.28
Yield (t/ha)	18.49	13.58
Aril colour	Deep red	Red
Fruit colour	Red	Red
Rind thickness (mm)	Medium	Medium
Juice (%)	44.0	44.5
TSS (^{o}B)	17.6	15.9
Titrable acidity (%)	0.40	0.45
Ascorbic acid(mg/100g)	19.0	14.8
Anthocyanin (mg/100g)	395	360
Iron (mg/100g)	1.50	0.90
Zinc (mg/100g)	0.50	0.40

Solapur Lal

Bhagawa

Fig. 2.1 : Comparative Evaluation of Solapur Lal *vs*. Bhagawa during Fourth Year

2.1.1.2 Comparative Evaluation of Solapur Anardana

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

Table 2.2: Comparative Evaluation of Solapur Anardana with Amlidana

Characters	Solapur Anardana	Amlidana
Plant height (m)	1.80	1.40
Maturity (days)	148	150
Fruit weight (g)	252.0	225.0
No. of fruits /tree	85.0	60.0
Yield (kg/plant)	21.42	13.50
Yield (t/ha)	15.85	9.99
Aril colour	Red	Light pink
Fruit colour	Red	Yellow
Seed texture	Medium	Medium
Juice (%)	43.1	41.3
TSS (°B)	16.6	15.6
Ascorbic acid (mg/100g)	18.0	14.2
Anthocyanin (mg/100g)	465.0	60.5
Titrable acidity (%)	4.80	4.20

Solapur Anardana

Amlidana

Fig. 2.2 : Comparative Evaluation of Solapur Anardana *vs.* Amlidana during Fourth Year

2.1.1.3 Evaluation of Hybrids Developed from ICAR-NRCP

Eight hybrids developed at ICAR-NRCP, Solapur were evaluated for yield and quality during third year. The yield ranged from 5.25–9.97 kg/ tree.

Table 2.3: Evaluation of Hybrids Developed from ICAR-NRCP

Hybrid	Fruit Weight(g)	No. of Fruits/Tree	Yield (kg/Tree)	TSS (°B)	Titrable Acidity (%)
Bhagawa	250.4	42	10.50	15.8	0.45
Bhagawa x Patna-5	285.2	35	9.97	16.7	0.38
Bhagawa x Nana	165.4	40	6.60	12.4	4.86
Bhagawa x Daru	233.0	40	9.32	15.2	3.84
Bhagawa x Kalpitiya	272.4	48	13.05	16.6	0.51
Bhagawa x Nayana	165.0	50	8.25	14.4	0.54
Bhagawa x IC-318712	175.5	42	7.35	14.1	5.12
Ganesh x Kalpitiya	218.4	48	10.48	14.4	0.54
Ganesh x Nayana	255.0	46	11.73	16.8	0.45

2.1.1.4 Evaluation of Pomegranate Selections

Evaluation of pomegranate selections developed at ICAR-NRCP during fourth year of planting was carried out for different physico-chemical traits. The results revealed that yield ranged from 7.56 to 18.28 kg/tree.

Table 2.4: Evaluation of Pomegranate Selections of Pomegranate

Genotype	Fruit Weight(g)	No. of Fruits/Tree	Yield (kg/ Tree)	TSS (°B)	Acidity (%)	Fruit Color	Aril Color
Bhagawa	254.0	72.0	18.28	15.9	0.45	Red	Red
Selection 391-7	258	55	13.64	15.1	0.38	Yellowish pink	Light pink
Selection 391-8	252	30	7.56	15.2	0.42	Yellowish pink	Light pink
Selection 375-13	250	35	8.75	17.2	0.38	Yellowish pink	Light pink
Selection 375-15	275	55	15.1	16.9	0.38	Yellowish pink	Light pink
Selection 388-20	255	51	13.0	16.4	0.42	Yellowish pink	Light pink
Selection 388-21	249	57	14.19	16.7	0.38	Yellowish pink	Light pink
Selection 317-22	260	45	11.70	16.5	0.42	Yellowish pink	Light pink
Selection 216-26	251	42	10.54	16.2	0.42	Yellowish pink	Light pink
Selection 216-27	257	56	14.39	15.8	0.42	Yellowish pink	Light pink

Fig. 2.3 : Evaluation of Pomegranate Hybrids/ Selections of Pomegranate

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

2.2.1 *In silico* Analysis and Development of Informative Markers

In silico analysis was performed by retrieving draft pomegranate genome sequence of cv. Dabenzi (296.38 Mb), with objective to explore pomegranate genome and transcriptome sequence information for large scale development of informative hypervariable SSRs (HvSSRs) markers, to construct SSR based saturated linkage map and to identify QTLs for BLB resistance and fruit quality traits in pomegranate.

2.2.1.1 Genome Wide Survey for SSR Motifs in the Pomegranate Genome

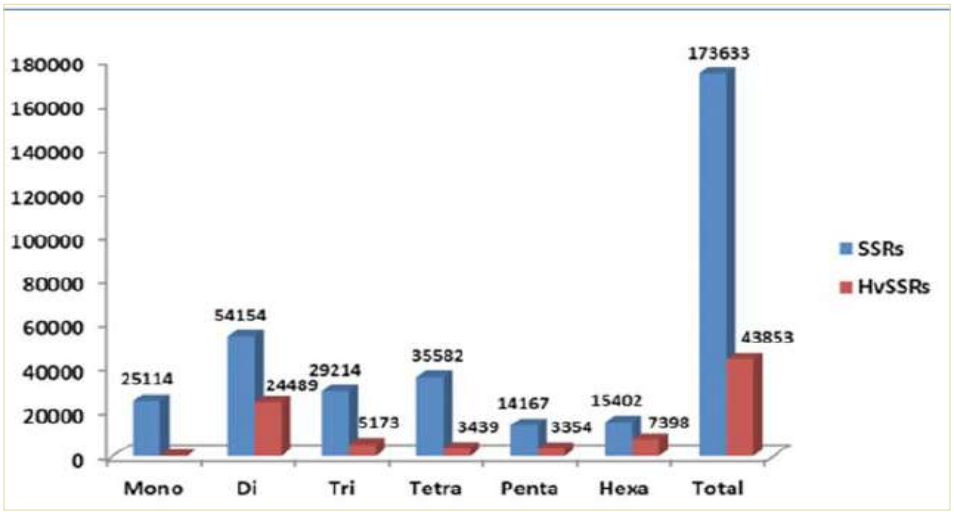
A total of 17,405 pomegranate contigs representing draft pomegranate genome sequence of *cv,* Dabenzi were retrieved form NCBI and surveyed for SSR motifs through MISA tool. However, in the previous year only 530 contigs were analysed and this year entire genome was surveyed. A total of 1,73,633 SSR motifs were identified, with an overall density of 527.97 SSRs/Mb. Concerning the frequency of repeat types, dinucleotide repeats were found to most abundant (31.19%), followed by tetra- (20.5%), tri- (16.8%) and mono- (14.46%) nucleotides. Among di-nucleotides, the SSR motif AT/AT (64.90%), followed by AG/CT (28.51%) were more abundant among all identified SSR motifs. Similarly, the motifs AAT/ATT (34.66%) and AAG/CTT (28.91%) were most pronounced for tri-nucleotide repeats, With regard to the hypervariable nature (≥20bp), total 43,853 (29.53%) hyper motifs identified and 2,856 HvSSR primer pairs were designed.

Table 2.5: MISA Statistics

SSR Mining	Total
Examined sequences size (bp)	281,320,358
Total number of SSRs	1,73,633
Number of contigs with SSRs	5,524
Number of cintigs with more than 1 SSRs	2,377
Relative abundance of SSRs (per Mb)	527.97
Number of compound SSRs	15,483

Table 2.6: Characterization of Microsatellite Motifs in the Pomegranate Genome

Motif	SSRs	Class I HvSSRs (>20bp)
Di	54,154 (31.19%)	24,489 (55.84%)
Tri	29,214 (16.83%)	5,173 (11.80%)
Tetra	35,582 (20.50%)	3,439 (7.84%)
Penta	14,167 (8.16%)	3,354 (7.65%)
Hexa	15,402 (8.87%)	7,398 (16.87%)
Total	1,48,519 (85.53%)	43,853 (29.53%)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120000
100000
80000
60000
40000
20000
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24489
29214
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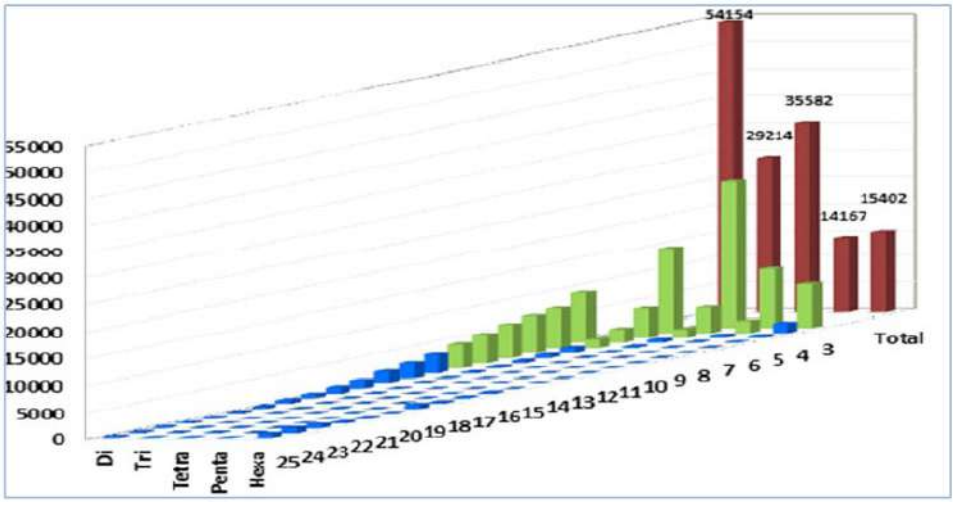
Mono
Di
Tri
Tetra
Penta
Hexa
Total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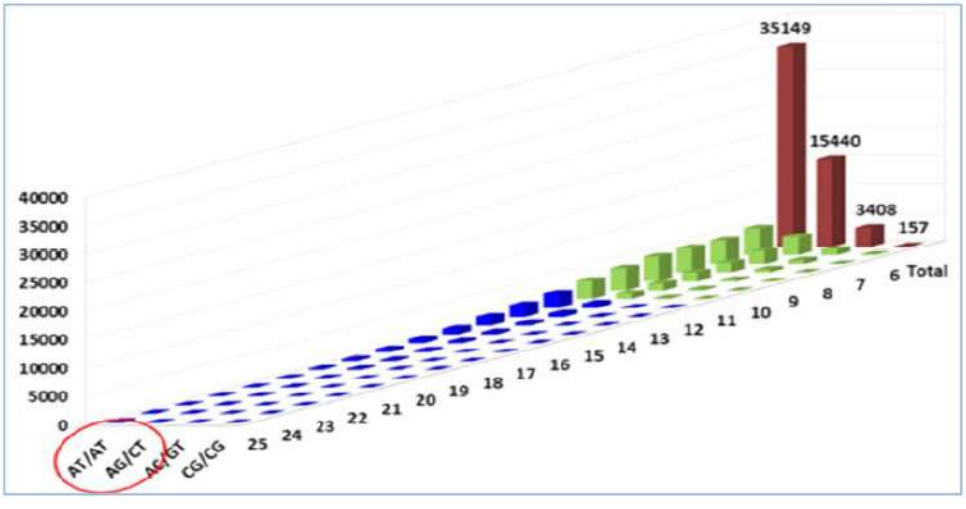
Total
Di
Tri
Tetra
Penta
Hexa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15440
3408
157
Total
AT/AT
AG/CT
AC/GT
CG/CG

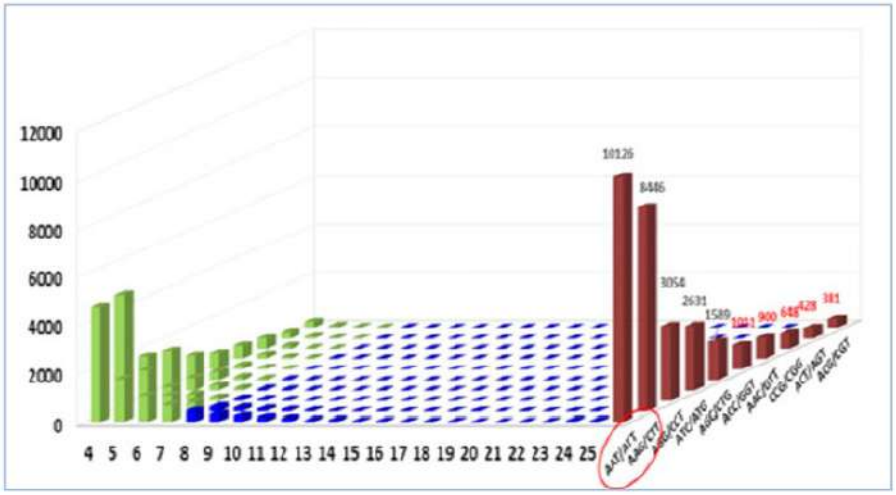


Fig. 2.4 : Frequency Distribution of Different SSR Repeats Types and Numbers in Pomegranate Genome based on MISA Statistics

2.2.1.2 Validation of HvSSR Markers for Polymorphism and Diversity Analysis

For validation of markers of markers, a of Total 280 HvSSR primers were got synthesized. Of which 110 primers were screened on a set of eight pomegranate genotypes which showed consistent amplification.

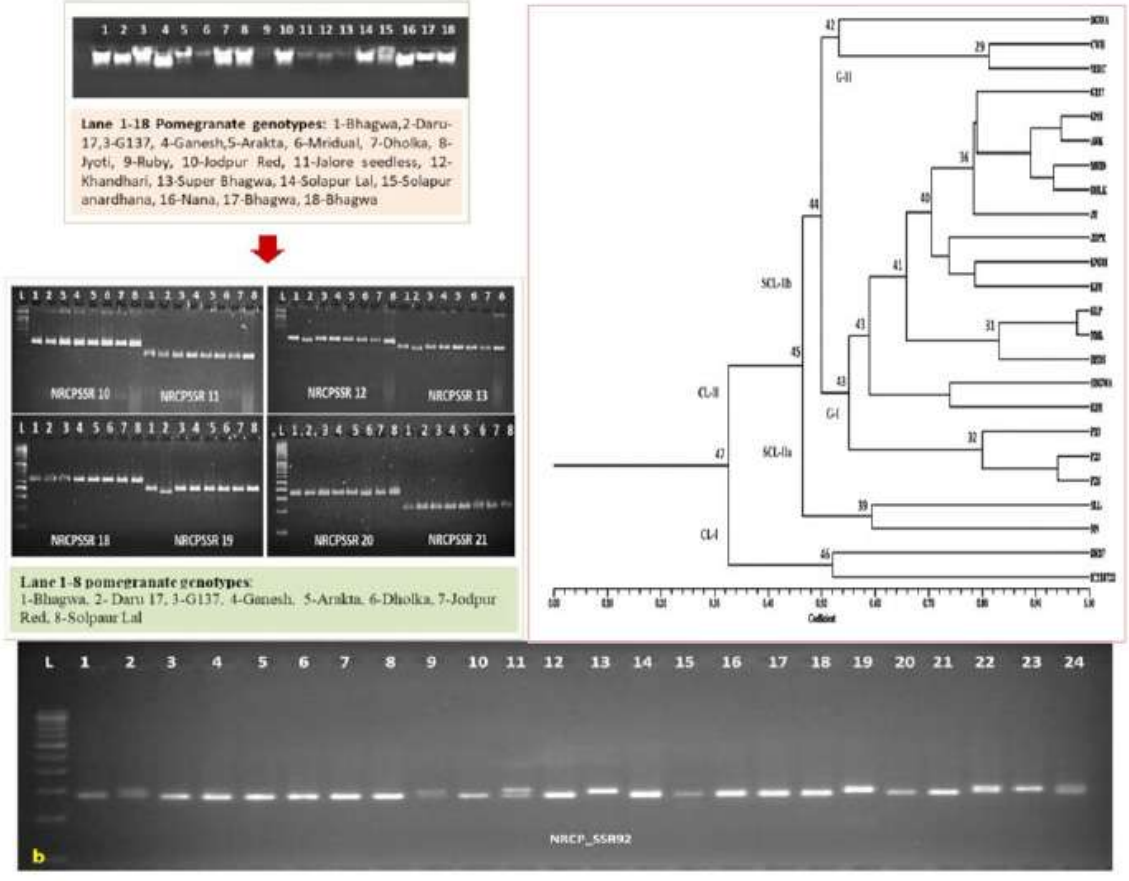


Fig. 2.5 : Assaying of HvSSR Markers on Eight Pomegranate Genotypes Followed by Assaying on 24 Pomegranate Genotypes for Diversity Study

Eighty-one (76.42%) of these HvSSRs showed conspicuous allelic polymorphism on simple 3% agarose gel. The utility of these newly developed HvSSRs was further demonstrated through examination of genetic variation among 24 diverse pomegranate genotypes by screening 44 HvSSRs. The SSR-based analysis exhibited high genetic diversity (68%) among the genotypes. To the best of our knowledge, this is the first report on development and validation of HvSSRs in pomegranate at genome wide scale. The DNA markers developed here will have a variety of genotyping and breeding applications in pomegranate.

In-order to identify genes/QTLs through association mapping approach 166 pomegranate breeding lines were propagated succefully through hard wood cuttings. These lines are being phenotyped for bacterial blight resistance in the green house.

2.3 PROJECT: DRAFT GENOME SEQUENCING OF POMEGRANATE cv. BHAGAWA

2.3.1 Genome Sequencing

The concurrent efforts towards finished genome assembly of Indian promising pomegranate cultivar "BHAGAWA" has lead to final assembly of high quality genome that invoving multiple technologies i.e. PacBio Sequel, 10X Chromium Genomics and BioNano Direct Labeling on Saphyr. The technologies adopted and their detailed methodologies with results as obtained were as follows.

2.3.1.1 PacBio-Falcon Diploid Assembly

PacBio long reads have random sequencing errors and thus needs to undergo error correction step before assembly step. Falcon assembler has been used in the recent time for large genome assembly along with generation of diploid contigs. It perfoms error correction and genome assembly using Overlap Layout Consensus (OLC) algorithm. Falcon is a diploid aware assembler and it handles diploid heterozygous nature of genome to generate long contiguous high quality assembly. To choose an appropriate read length cutoff and coverage threshold for error correction step DAZZLER suite was used, run by Falcon which performs an all-against-all comparison to find overlaps between raw reads, and outputs a set of error-corrected reads.

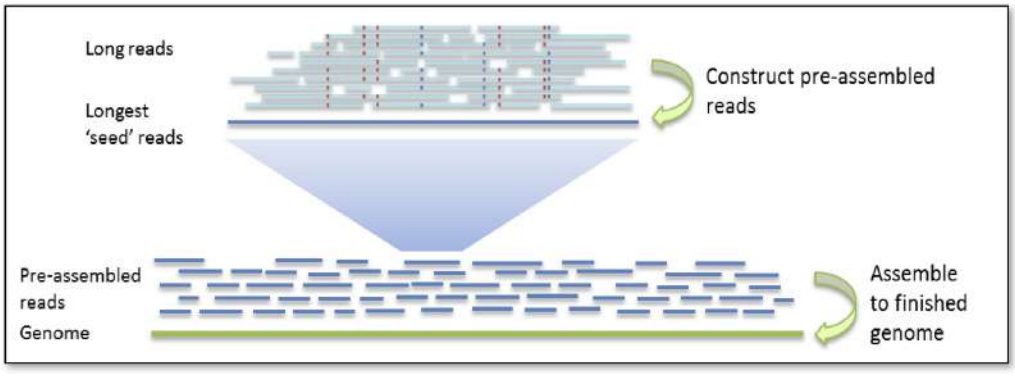


Fig. 2.6 : Long Read Assembly Algorithm for Falcon Diploid Assembler

After masking of repeats and low-complexity regions assemblies were done at multiple parameters in order to obtain the best assembly. Then the falcon assemblies are performed, Unzip is run, wherein it takes the contigs from FALCON and phases the reads based on heterozygous SNPs identified in the

initial assembly. It then produced a set of partially-phased primary contigs and fully-phased haplotigs which represent divergent haplotypes.

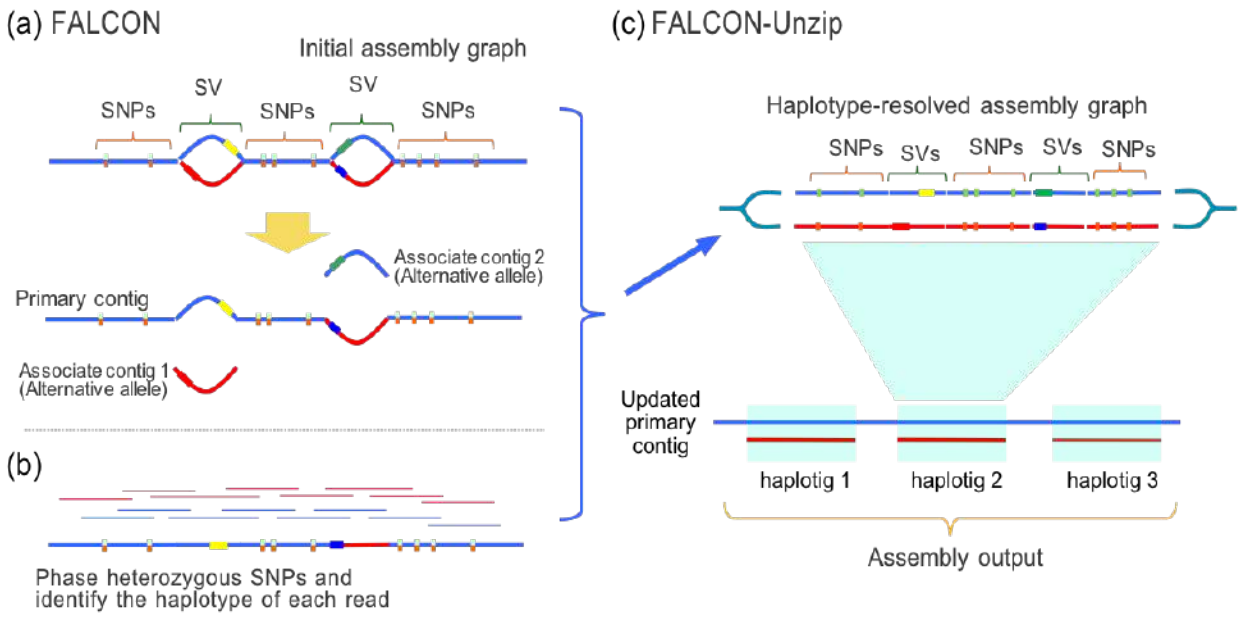


Fig. 2.7 : Unzipping the Falcon Diploid Assembly

Table 2.7: Assembly Stats from the Falcon-Unzip Pipeline

Parameters	Primary Contig	Associated All Contig	Associated Haplotig	Unzipped Primary Contig	Unzipped Associated Contig	Polished Primary Contig	Polished Associated Contig
Num_seqs	589	2612	377	479	1062	446	663
Sum_length	343273303	156856531	30532871	338771522	108051319	337712522	97589147
Min_length	3111	3482	3482	20075	155	20171	157
Avg_length	582807	60052.3	80989	707247.4	101743.2	757203	147193.3
Max_length	18862644	383020	304063	18872772	1688540	18895324	1691411
Q1	28117	40479	48950	36333	23873	38042	47409
Q2	58075	51932	69728	70752	48837	77275	82380
Q3	153686	69334	100493	237613	108988	292395	179856
N50	6851224	63848	94695	6792422	228225	6803435	270452

The terms Q1, Q2, Q3 are the interquartile lengths of the genome assembly.

2.3.1.2 10X Chromium Based Scaffolding

The assembled contigs for each parental haplotype were taken for scaffolding using the Illumina generated datasets using Scaff10x. The algorithm for scaffolding involves extraction of barcoded tags

from 10X raw sequencing reads and mapping of reads to the draft assembly using BWA mem module. Barcodes are retrieved, and then sorted together with contigs as well as mapping coordinates. A relation matrix is built to record the shared barcodes among the contigs, which may be linked. Then order and orientation of linked contigs are finally determined after nearest neighbours are found.

Table 2.8: Scaffolding Stats from the Polished Consensus Primary Contigs

Parameters	10X Scaffolded Sequences
Num_seqs	432
Sum_length	337725096
Min_length	20173
Avg_length	781771.1
Max_length	18895332
Q1	37539
Q2	73468
Q3	275742
N50	9886763

2.3.1.3 Hybrid Assembly Scaffolding using the BioNano Optical Map

The iterative-Scaffolds for each parental haplotype were hybrid scaffolded using DeNovo Optical Map generated by BioNano Access. The enzyme used in the case of Scaffolding was DLE-1 and we used a One-enzyme workflow under BioNano Access.

Table 2.9: Scaffolding Stats from the Optical Mapping Workflow

Parameters	Optical Mapping
Num_seqs	373
Sum_length	343274854
Min_length	4899
Avg_length	920307.9
Max_length	22450822
Q1	32076
Q2	54363
Q3	131777
Sum_gap	5551218
N50	16118620

2.3.1.4 Gap-filling using Iterative PBJelly and Polishing using Pilon

Finally on the Optical Map assisted Scaffold orientation and Scaffolding of the 10X based scaffolds we have finally gap filled the genome using multiple iterations of PBJelly2 and later *via* Pilon Polishing the genome.

Table 2.10: Gap-Filling and Polishing Stats on BNG Scaffolded Genome

Parameters	PBJelly 2 Iterations Gap-Fill	Pilon Gap-Filling and Polishing
Num_seqs	342	342
Sum_ length	346205259	346084043
Min_ length	4899	4899
Avg_ length	1012296.1	1011941.6
Max_ length	22450822	22449918
Q1	40304	40303
Q2	65895	65895
Q3	156155	156153
Sum_gap	4948198	4944921
N50	16123190	16121951

3

CHAPTER

Plant Propogation

3.1 PROJECT: PROPAGATION, BIO-HARDENING AND MASS MULTIPLICATION OF ELITE PLANTING MATERIAL IN POMEGRANATE (*Punica granatum* L.)

3.1.1 Strategies to Manage Phenolic Browning of the Medium

An *In vitro* experiment was set up to evaluate various innovative strategies to tackle media browning or phenol exudation from explant. Nodal segments inoculated on WPM media with PVP under dark condition exhibited lowest phenol exudation (106.154 µg/ml/). However, at par results were exhibited by nodal segments on WPM media with PVP in light (109.744 µg/ml), MS media with PVP under dark (110.256 µg/ml) and wax sealed nodal segments on WPM media under light as well as dark (142.051, 108.205 µg/ml). All these treatments performed significantly better than other treatments and control. Independent of experimental conditions Nodal segments inoculated on WPM media performed better than MS media as far as phenol exudation or media browning is concerned. Exclusion of light during initial period (one week) of culture establishment was found better than continuous light condition for reducing media browning. Irrespective of media and experimental conditions, addition of PVP in the media and wax sealing of nodal segment performed significantly better than all other treatments. The culture establishment was significantly higher in all the treatments as compared to control (19.254%). Media composition and experimental condition did not have any significant impact on culture establishment. Shoot tips on WPM medium, kept in dark and received the treatment of sealing of cut ends with sterile paraffin wax (109.487 µg/ml) or addition of PVP into the medium (120.000 µg/ml) and shoot tip inoculated on MS medium having PVP and kept in dark (136.410 µg/ml) along with cut ends sealed explants under dark condition on MS medium (129.744 µg/ml) registered significantly lesser phenol exudation than other treatments and control. Among experimental conditions explants kept in dark (one week) produced significantly lesser phenol (250.460 µg/ml) as compared to light condition (305.836) and shoot tip explants on low salt WPM medium resulted into lesser phenol exudation than explants on high salt MS medium. Though, there is reduction in culture establishment of explants with wax sealing treatment but addition of PVP into the medium didn't negatively impact the culture establishment (78.052%) and produced at par results with the best treatment (T3) (83.882%).

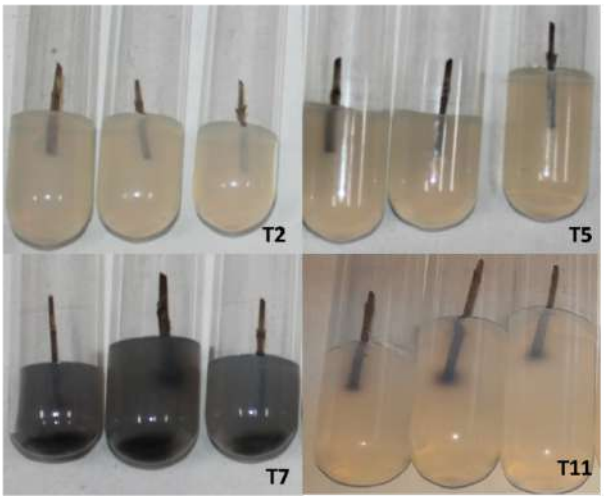


Fig. 3.1 : Effect of Phenol Management Strategies on Media Browning

Table 3.1: Treatments for Managing Phenolic Browning

Sr. No.	Treatment Name	Composition
1	Treatment 1	Agitation of explant with 0.1% cold solution of citric acid and ascorbic acid.
2	Treatment 2	Sealing of cut end of explant with sterile paraffin wax.
3	Treatment 3	Addition of 100µl of autoclaved distilled water at the time of inoculation of explant.
4	Treatment 4	Position shifting of explant after 3 days of inoculation in same media.
5	Treatment 5	Addition of 1g/l of PVP in media.
6	Treatment 6	Addition of 100mg/l of citric acid and 100 mg/l ascorbic acid in media.
7	Treatment 7	Addition of 200mg/l of activated charcoal in media.
8	Treatment 8	Addition of 400mg/l of activated charcoal in media.
9	Treatment 9	Agitation of explant with 0.1% cold solution of citric acid and ascorbic acid + Addition of 200mg/l activated charcoal and 100mg/l of citric acid and ascorbic acid in media.
10	Treatment 10	Addition of 200mg/l of activated charcoal in media + Position shifting of explant after 3 days of inoculation in same media.
11	Treatment 11 (Control)	No treatment to explant and medium without activated charcoal and PVP

Table 3.2: Effect of Media Composition, Experimental Condition and Phenol Management Strategies on Media Browning (µg Phenol/ml Medium) with Nodal Segment Explants

Treatment Name	MS Media		Average	WPM Media		Average	Grand Average
	Light	Dark		Light	Dark		
T2	186.923	194.026	190.475	142.051	108.205	125.128	157.801
T5	186.667	110.256	148.462	109.744	106.154	107.949	128.205
T8	264.359	214.872	239.615	149.231	161.538	155.385	197.500
T11	544.077	504.144	524.110	478.879	444.838	461.859	492.984
Average	315.662	263.987	289.825	233.907	213.843	238.915	264.37

Table 3.2 (Contd.)...

...Table 3.2 (Contd.)

Critical Difference Values		
-	CD 5%	CD 1%
Media (M)	11.286	14.954
Experimental condition (EC)	11.286	14.954
Treatments (T)	26.468	35.069
M x EC	15.961	21.148
M x T	37.432	49.596
B x C	37.432	49.596
M x EC x T	52.937	70.139

Experimental Conditions	
Name	**Average**
Light	274.785
Dark	238.915

Media	
Name	**Average**
MS media	289.825
WPM media	238.915

Table 3.3: Effect of Media Composition, Experimental Condition and Phenol Management Strategies on Per cent Culture Establishment of Nodal Segment Explants

Treatment	MS Media		Average	WPM Media		Average	Grand Average
	Light	Dark		Light	Dark		
T1	78.052	89.712	83.882	78.052	89.712	83.882	83.882
T2	78.052	89.712	83.882	89.712	71.562	80.637	82.260
T3	71.562	89.712	80.637	89.712	89.712	89.712	85.175
T5	78.052	89.712	83.882	89.712	78.052	83.882	83.882
T8	78.052	78.052	78.052	89.712	89.712	89.712	83.882
T10	89.712	89.712	89.712	89.712	89.712	89.712	89.712
T11	11.754	29.998	20.876	23.508	11.754	17.631	19.254
Average	71.435	71.443	71.439	76.145	73.555	74.849	73.144

Critical Difference Values		
-	CD 5%	CD 1%
Media (M)	6.174	8.181
Experimental condition (EC)	6.174	8.181
Treatments (T)	14.480	19.186
M x EC	8.732	11.569
M x T	20.478	27.133
B x C	20.478	27.133
M x EC x T	28.961	38.371

Experimental Conditions	
Name	**Average**
Light	73.79
Dark	72.499

Media	
Name	**Average**
MS media	71.439
WPM media	74.850

Table 3.4: Effect of Media Composition, Experimental Condition and Phenol Management Strategies on Media Browning (µg Phenol/ml Medium) with Shoot Tip Explants

Treatment	MS Media		Average	WPM Media		Average	Grand Average
	Light	Dark		Light	Dark		
T2	188.718	129.744	159.231	178.718	109.487	144.103	151.667
T3	282.051	242.051	262.051	202.051	233.590	217.821	239.936
T5	186.923	136.410	161.667	186.923	120.000	153.462	157.564
T7	306.410	258.974	282.692	199.744	190.000	194.872	238.782
T8	267.949	192.231	230.090	211.282	156.154	183.718	206.904
T11	603.876	557.906	580.891	590.975	506.645	548.810	564.851
Average	332.772	271.761	302.267	278.900	229.159	254.029	278.148

Critical Difference Values		
-	CD 5%	CD 1%
Media (M)	10.781	14.284
Experimental condition (EC)	10.781	14.284
Treatments (T)	25.283	33.498
M x EC	15.246	20.200
M x T	35.755	47.374
B x C	35.755	47.374
M x EC x T	50.565	66.996

Experimental Conditions	
Name	Average
Light	305.836
Dark	250.460

Media	
Name	Average
MS media	302.267
WPM media	254.029

Table 3.5: Effect of Media Composition, Experimental Condition and Phenol Management Strategies on *In Vitro* Shoot Tip Explant Culture Establishment

Treatment Name	MS media		Average	WPM media		Average	Grand Average
	Light	Dark		Light	**Dark**		
T2	59.902	48.242	54.072	54.732	71.562	63.147	58.609
T3	78.052	78.052	78.052	89.712	89.712	89.712	83.882
T5	66.392	78.052	72.222	89.712	78.052	83.882	78.052
T8	78.052	71.562	74.807	89.712	59.902	74.807	74.807
T11	11.754	11.754	11.754	29.998	29.998	29.998	20.876
Average	56.235	64.365	60.300	76.273	67.203	71.738	66.019

Critical Difference Values		
-	CD 5%	CD 1%
Media (M)	6.721	8.905
Experimental condition (EC)	6.721	8.905
Treatments (T)	15.763	20.885
M x EC	9.505	12.594
M x T	22.292	29.536
B x C	22.292	29.536
M x EC x T	31.525	41.770

Experimental Conditions	
Name	Average
Light	66.254
Dark	65.784

Media	
Name	Average
MS media	60.300
WPM media	71.738

3.1.2 New Growth Regulators and Media Combinations for *In Vitro* Proliferation and Rooting

Higher proliferation rate (3.8 shoots per micro-shoots) was recorded on Modified MS medium supplemented with Adenine Sulphate (60mg/l), L-Arginine (60mg/l), 1.0 mg/l Kinetin, 0.1mg/l TDZ and 0.2mg/l NAA [T(M)6], however, this treatment was at par with the performance with T(M)5, T(M)7, T(M)8, and T(M)9. This combination was significantly superior over remaining treatments. However, micro shoots on modified MS medium with 60mg/l Adenine Sulphate, 60mg/l L-Arginine, 1mg/l BAP, 0.1 mg/l TDZ and 0.2mg/l NAA (8.18 cm) and Modified MS + Adenine Sulphate (60mg/l) + L-Arginine (60mg/l) + 1mg/l BAP + 0.1mg/l Zeatin Riboside + 0.1mg/l NAA (7.66cm) registered at par results for the tallest shoot length and these two treatments were significantly superior to other treatments. T(M)7 (Modified MS + Adenine Sulphate (60mg/l) + L-Arginine (60mg/l) + 1mg/l BAP + 0.1mg/l TDZ + 0.1mg/l NAA + Undisclosed media supplements) resulted into highest average shoot length (3.78 cm).

Table 3.6: Effect of Basal Medium and Growth Regulators on *In Vitro* Shoot Proliferation

Treatment	Proliferation Rate per Microshoot per Cycle *	Tallest Shoot Length (cm) at 30 DAI	Avg. Shoot Length (cm) at 30 DAI
T(M)1	2.00	4.26	2.46
T(M)2	2.40	4.82	3.08
T(M)3	3.40	5.96	3.56
T(M)4	2.40	5.26	3.18
T(M)5	3.60	4.90	3.58
T(M)6	3.80	5.40	3.56
T(M)7	3.60	5.58	3.78
T(M)8	3.60	8.18	3.64
T(M)9	3.40	7.66	3.68
CD (p=0.05)	0.715	0.879	0.409

*side shoots and vertical splitting

Fig. 3.2 : *In Vitro* Shoot Proliferation on T8 Medium

In vitro rooting of micro shoots on WPM medium, irrespective of growth regulation concentration and type, took lesser number of days (15.200) for root initiation as compared to half strength MS medium. As depicted in table, number of major roots per shoot (5.000) and the rooting per cent (76.00%) was found significantly more in WPM medium supplemented with 1.0 mg/l (NAA).

Table 3.7: Effect of Basal Medium and Growth Regulators on *In Vitro* Rooting

Treatment	Days to Root Initiation	No. of Major Roots	Rooting (%)
T(R)1	18.400	2.000	52.000
T(R)2	17.600	2.000	64.000
T(R)3	19.400	3.200	48.000
T(R)4	18.200	3.200	56.000
T(R)5	15.600	2.400	72.000
T(R)6	15.200	2.600	72.000
T(R)7	17.200	4.400	64.000
T(R)8	17.400	5.000	76.000
CD (p=0.05)	2.067	0.827	12.883

Fig. 3.3 : *In Vitro* Rooting on T6 Medium

3.1.3 Exploiting Plant Beneficial Microbes as Bio-hardening Agents

A pot culture experiment comprising of 15 treatments involving five beneficial microbes (*Aspergillus niger* AN 27, AMF, *Penecillium pinophilum, Trichoderma viridae* and *harzianum* and *P. fluorescens*) either alone or in combination was carried out using one year old *in-vitro* raised pomegranate plants of cv. Bhagawa for further utilization of these microbes as potential bio-hardening agents. The growth, physiological and biochemical parameters of the inoculated and control plants were recorded at 90 days after inoculation. Microbial treatments were found effective in improving most of the above given attributes. Plants inoculated with *Aspergillus niger* strain AN27 + *Penicillium pinophilum* resulted into significantly better plant height (225.00 cm), plant spread E-W (198.33 cm) and amount of reducing sugar (0.95%) as compared to control. *Aspergillus niger (Asp) + Pseudomonas fluorescens* (T7) inoculated plants performed significantly better with respect to total chlorophyll (1.84 mg/g FW), SPAD value (41.23) and total phenol content (0.81 mg/g FW) as compared to non-inoculated plants. Plants inoculated with AMF (*Glomus intraradices*) was at par with *Aspergillus niger + P. fluorescens (T8)* in total chlorophyll content (1.71mg/g FW), AMF alone (T2) was at par with with *Asp+ P. fluorescens (T8)* in SPAD value (34.97). AMF+ *P. pinophilum* (0.80 mg/g FW) (T10) and AMF+ *P. fluorescens* (T11) (0.80 mg/g FW) inoculated plants were at par with *Aspergillus niger + P. fluorescens* (T8) inoculated plants in total phenols content. Microbes and microbial formulations were evaluated for their utilization hardening of *in-vitro* raised pomegranate plants as bio-priming agents.

Fig. 3.4 : *In Vitro* Cultures and Broth of Plant Beneficial Microbes

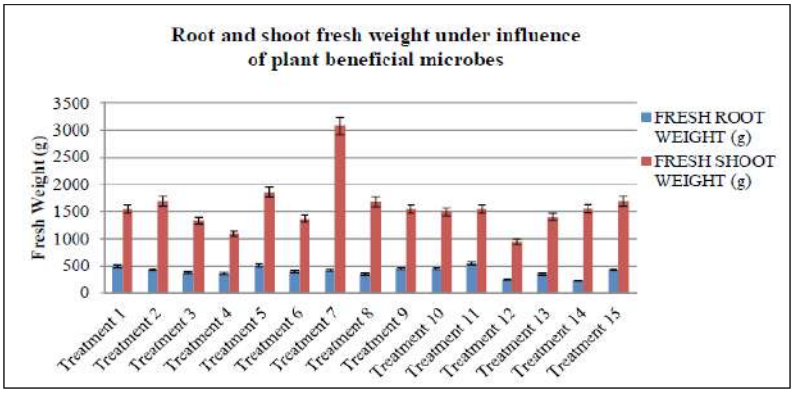


Fig. 3.5: Root & Shoot Fresh Weight

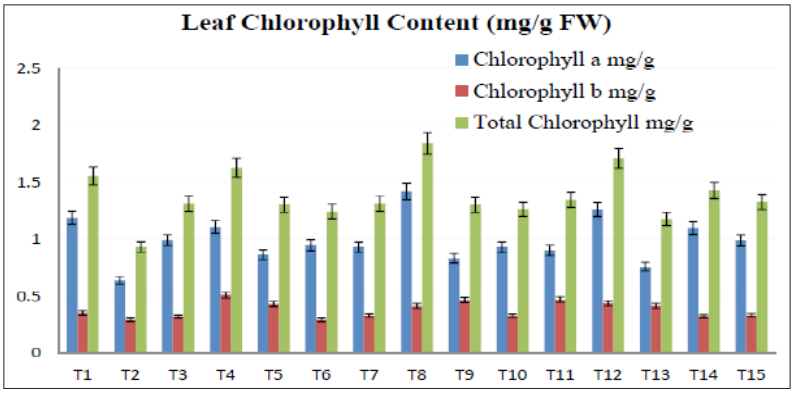


Fig. 3.6 : Leaf Chlorophyll Content

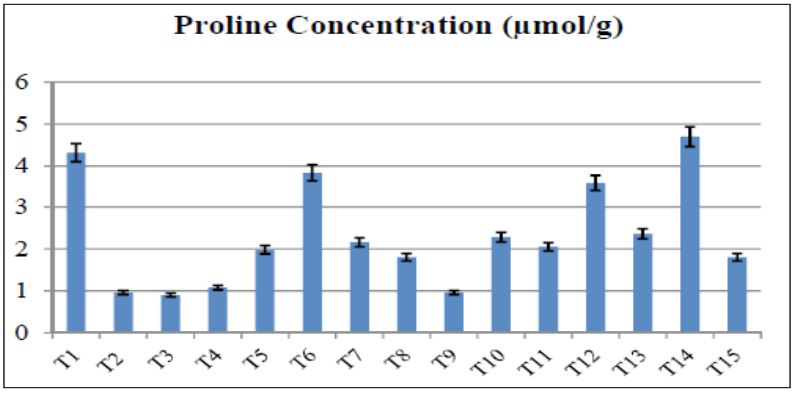


Fig. 3.7: Proline Concentration

Table 3.8: Effect of Plant Beneficial Microbes on Morphological, Physiological and Biochemical Attributes of Host Plant

Treatment	Plant Ht. (cm)	Plant Spread E-W (cm)	Plant Spread N-S (cm)	Stem Dia. (mm)	RLWC (%)	SPAD value	Reducing Sugars (%)	Total phenols (mg/g FW)
T4	183.33	113.33	101.67	21.50	82.51	33.40	0.67	0.77
T5	195.00	156.67	131.67	24.61	85.34	26.03	0.52	0.76
T7	225.00	198.33	175.00	27.80	85.09	26.77	0.95	0.76
T8	186.67	175.00	135.00	27.20	88.42	41.23	0.87	0.81
T12	171.67	115.00	106.67	20.13	88.63	36.10	1.14	0.79
T13	190.00	135.00	141.67	23.42	86.60	24.67	1.17	0.79
T14	183.33	141.67	126.67	26.27	89.10	30.63	1.09	0.78
T15 (Control)	131.67	93.33	96.67	19.71	83.75	24.53	0.55	0.75
CD (p=0.05)	39.18	49.01	NS	NS	NS	7.77	0.41	0.03

4

CHAPTER

Crop Production

4.1 PROJECT: DEVELOPMENT AND REFINEMENT OF INTEGRATED CROP PRODUCTION TECHNOLOGIES FOR IMPROVED PRODUCTIVITY

4.1.1 Nutrient Management

4.1.1.1 New Amino Acid Based Micronutrient Formulations for Pomegranate

Keeping in mind the differential requirement of pomegranate plants at different growth stages, three amino acid based micronutrient formulations (Formulation I, Formulation II and Formulation III) were developed in the laboratory.

Fig. 4.1 : Growth Stage Specific Three Amino Acid based Micronutrient Formulations for Pomegranate

Formulation I was for flowering and other two for fruit enlargement and development. These three formulations were evaluated in different combinations on 4-years old pomegranate orchard at Hiraj Research Farm, ICAR-National Research Centre on Pomegranate, Solapur. Formulation I was sprayed at the time of initiation of flower bud and Formulation II and III were sprayed two times 60 days after application of Formulation I at one month interval. There were five treatments: T1- Control; T2- Three times foliar applications of chelated micronutrients (X-Fert mix) @ 0.25%; T3- Three times foliar applications of EDTA chelated micronutrients (Rexolin) @ 0.1%; T4- Foliar application of Formulation I followed by two sprays of Formulation II @ 10 ml/l; T5- Foliar application of Formulation I followed by two sprays of Formulation III @ 10 ml/l.

The results showed that micronutrient application significantly increased total number of hermaphrodite flowers/tree and per cent hermaphrodite flowers. Highest number of hermaphrodite flowers was recorded in T5 treatment. Highest number of fruit set was also recorded in T5 followed by T4 and T3. There was significant increase in marketable fruit yield upon application of various micronutrient formulations and the highest increase (by 41.23-48.35%) in fruit yield was recorded in T4 and T5 treatments which were at per with each other. Further plants in T4 treatment recorded highest per cent (46.57%) of exportable grade fruits (fruits weighing > 250 g) compared to other treatments (25.96 – 31.74%).

T1-Control

T3- EDTA chelated micronutrients

T4-FormulationI followed by Formulation II

T5-FormulationI followed by Formulation III

Fig. 4.2 : Fruit Bearing in Pomegranate Due to Different Micronutrient Formulations

Application of micronutrients significantly increased average fruit weight and juice acidity. Highest juice acidity was recorded in T4, T5 and T2 treatments (0.38-0.41%).The fruit obtained from T4 treatments also had highest ascorbic acid concentration (19.06 mg/100 ml juice), total phenol (1591.00 mg GAE l^{-1}), anthocyanin (41.47 mg l^{-1}) and non-reducing sugar (2.12%). Significant improvement in fruit micronutrients (Fe, Mn, Zn, Cu and B) content was observed upon application of micronutrient formulations. The fruits obtained from T4 and T2 treatment recorded highest amount of Fe, Mn, Zn and Cu content. The arils of T5 treatment recorded the highest content of micronutrients. Significant improvement in rind micronutrient content was observed upon

application of micronutrient formulations. The rind of fruits obtained from T4 treatment also recorded highest content of micronutrients (Fe, Mn, Zn, Cu and B). The foliar analysis after harvest revealed that plants in T4 treatment had significantly higher concentration of micronutrients particularly Fe, Mn, Cu and B than other treatments even after harvest of crop.

Study of leaf micronutrient status on temporal scale revealed that foliar application of Formulation I followed by Formulation II or Formulation III i.e. T4 and T5 maintained significantly higher Fe concentration in leaves throughout the fruit growth and development period. The plants under T4 treatment also maintained significantly higher Cu concentration in leaves during later fruit growth period (i.e. 120-220 days after defoliation). Unlike Cu, the plants in T4 treatment maintained significantly higher B concentration in leaves during flowering and early fruit growth stage (i.e. 30-90 days after defoliation) and also at harvest.

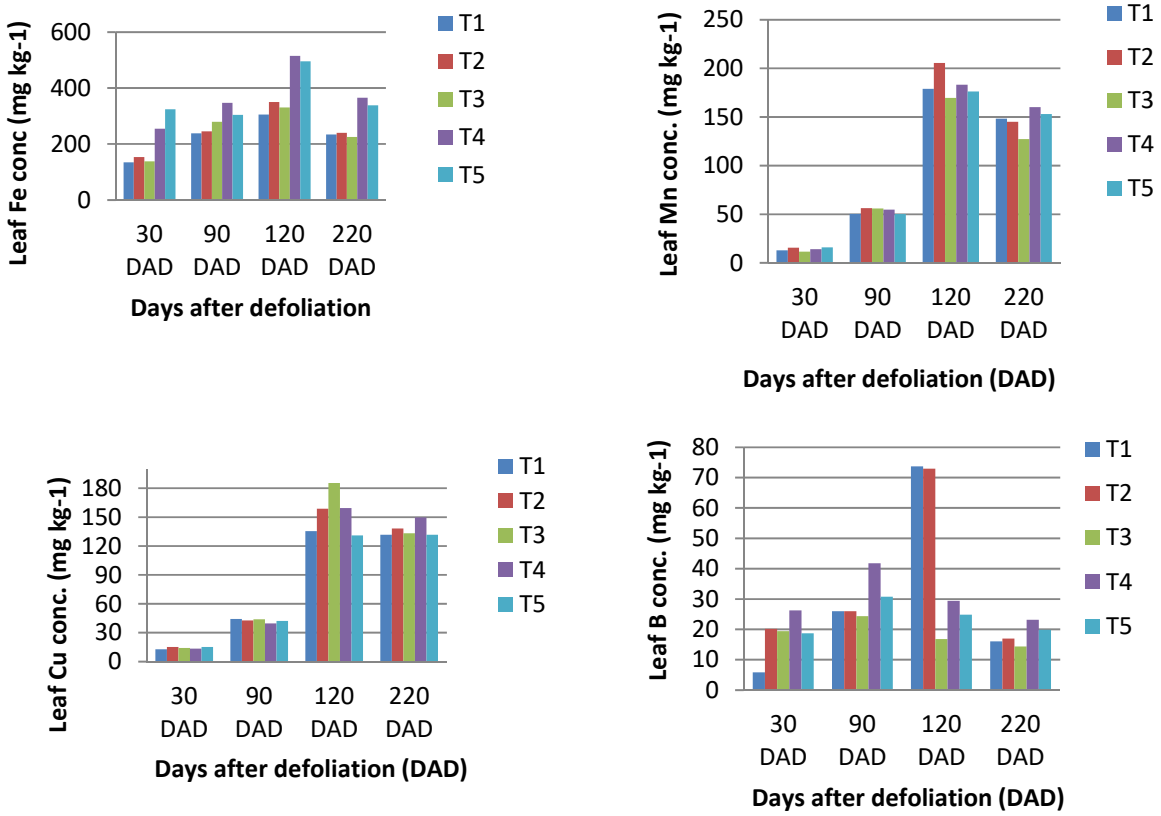


Fig. 4.3 : Changes in Micronutrient Status on Temporal Scale in Different Micronutrient Formulation Treatments

4.2 WATER MANAGEMENT

4.2.1 Comparison of Various Irrigation Methods with Sub-surface Drip Irrigation System for Pomegranate (*Punica granatum* L.) Production

The experiment was conducted on comparative performance evaluation of micro-irrigation methods to find out the effect of growth performance of 5th year pomegranate orchard. Six treatments were replicated four times in RBD during 2018-2019.

4.2.1.1 Growth Performance (GP)

Various micro-irrigation treatments encouraged plant growth, reduced moisture evaporation and also regulated soil temperature. Maximum plant height, flowers, branches, stem diameter was recorded in SDI with double laterals (30*30 cm) followed SDI with double laterals (40*40 cm), SDI with double laterals (50*50 cm), DI with double laterals (4D), SDI with single laterals (30 cm) and DI with single lateral (2D). Soil moisture withholding was also higher in the SDI with double laterals (30*30 cm).

4.2.1.2 Water Use Efficiency (WUE)

The subsurface drip irrigation system buried at 30 cm and inline dripper spacing of 30 x 30 cm had the higher WUE**.** WUE had its highest value in the T_2 (4.01 kgm^{-3}) compared to T_4, T_3, T_1, T_5 and T_6 (3.74, 3.48, 3.05, 1.98 and 1.49 kgm^{-3}, respectively). The potential yield of pomegranate was reduced by soil moisture stress and consequently had impact on the yield and WUE of pomegranate. In addition, sub-surface drip irrigation allows uniform delivery of water directly to the plant root zone. This can increase water use efficiency over other irrigation methods.

4.2.1.3 Root Distribution Pattern (RDP)

The rooting pattern plays a major role in the water uptake process and in allocating fertilizers. Two uniform trees were selected for excavation at each treatment and prepared by cutting. The 1.80 meter circle was divided into 0–60 cm, 60–120 cm and 120–180 cm portions. Each portion was excavated for three depths viz. 0–30 cm, 30–60 cm and 60–90 cm. The data on distribution pattern of roots in right hand side(RHS) and left hand side(LHS) lying on SDI and DI were studied. In table also shown that, the root pattern plays a major role in the water uptake process under SDI and DI. The maximum rooting depth is around 1.8 m and most of the roots are observed in the first 30 to 50 cm whatever the case. In the asymmetric case, roots densities is much higher under SDI by 30 x 30 cm, followed by 40 x 40 cm, 50 x 50 cm and two laterals with 4 drippers. The RHS and LHS roots indicate that the roots are present in the whole of the domain even far from the buried pipe. It can be concluded that inline subsurface drip irrigation system has a noticeable effect on the root development when the distance drip is short.

Table 4.1: Cumulative Growth Performance in Various Micro-irrigation Treatments

Treatments	Plant Height (cm)	Plant Spread (cm)		Stem Diameter (cm)	Stem Girth (cm)	Thorn Length (cm)	Flowers (Nos.)
		EW	SE				
T_1	130	119	110	2.5	2.7	2.5	120
T_2	135	125	130	2.6	2.9	2.9	105
T_3	138	138	131	3.8	3.0	3.7	145
T_4	134	125	122	2.9	2.8	3.5	125
T_5	126	112	110	2.4	2.4	2.6	120
T_6	132	130	125	2.5	2.7	2.7	130

Table 4.2: Effect Micro-irrigation Treatments on Yield, Water use Efficiency and Root Geometry of Pomegranate

Treatments	Nos. of fruit per tr. (Nos.)	Av. Fruit Weight (gms)	Yield ($kgtree^{-1}$)	WU (m^3)	WUE (Kgm^{-3})	RDP (LHS in gm)	RDP (RHS in gm)
T_1	30.25	265.25	7.7	2.5	3.05	463.53	82.11
T_2	62.0	323.75	20.8	5.0	4.01	508.85	469.72
T_3	52.20	269.50	14.3	4.2	3.48	484.78	440.40
T_4	47.25	294.25	13.0	3.3	3.74	444.05	381.25
T_5	28.25	270.50	7.5	4.9	1.49	384.71	85.21
T_6	52.00	291.25	14.8	8.3	1.98	337.54	342.88

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

SDI at 30 cm x 30 cm Double Inline Laterals

SDI at 30 cm Single Inline Lateral

SDI at 30 cm x 30 cm Double Inline Lateral Root Distribution Pattern

SDI at 30 cm Single Inline Lateral Root Distribution Pattern

Fig. 4.4 : Root Distribution of Pomegranate

In lateral geometry experiment, 3 main treatments and 6 sub-treatments in split plot design were conducted to find out the effect of 5th year old age pomegranate orchard during 2018–2019. Laying out the single lateral with two drippers, two laterals with four drippers and ring type laterals with six drippers in lateral geometry.

4.2.1.4 Growth Performance

The 0.60*ET_r is the best treatment having double laterals with 4 drippers followed by ring type and single lateral (2D) and maximum plant height, flowers, branches and stem diameter was recorded in 0.60* ET_r with T2 treatments. Monthly shaded area (m^2), wetted area (%), total area leaves (m^2) and leaf area index at solar noon hours is mentioned.

4.2.1.5 Water use Efficiency (WUE)

In *Hasta bahar*, the values of water requirement to be applied to pomegranate tree ranged from 3870.00 to 5850.00 litres/ year/ tree for 5th year pomegranate tree. The higher WUE in the T_2 (3.00 kgm^{-3}) compared to T3 and T_1 (2.39 and 2.03 kgm^{-3}, respectively). The potential yield of pomegranate was reduced by soil moisture stress and consequently had impact on the yield and WUE of pomegranate. In addition, two laterals with four drippers drip irrigation allow uniform delivery of water to the plant root zone. This can increase water use efficiency with less water over other irrigation methods. The data on distribution pattern of roots in right hand side(RHS) and left hand side(LHS) lying on T1, T2 and T3 were studied. In table also shown that, the root pattern plays a major role in the water uptake process under 3 treatments. In the asymmetric case, roots densities is much higher under T3 (Ring type with 6D), followed by T2 (two laterals with 4D) and T1 (single lateral with 2D). The RHS and LHS roots indicate that the roots are present in the whole of the domain in T3 and T2, however, in T1 treatments LHS root densities is more comparing to RHS due to water delivering only left hand side. It can be concluded that ring type with six drippers system has a noticeable effect on the root development when the numbers of dripper is more.

Table 4.3: Cumulative Growth Performance in Lateral Geometry Experiment

Treatments (0.40 to 0.80 * ETr)	Plant Height (cm)	Plant Spread (cm)		Stem Dia. (cm)	Stem Girth (cm)	Thorn Length (cm)	Flowers/ Tree (No.)	SA (m2)	WA (%)	TA (m2)	LAI_{SN}
		EW	SE								
T_1	135	122	115	2.8	2.7	2.7	115	2.10	28.35	5.60	2.66
T_2	139	138	134	3.9	3.0	3.8	145	2.35	30.25	6.85	2.91
T_3	130	120	112	2.7	2.8	3.0	110	1.98	27.25	7.53	3.80

(**Note:** T_1- single lateral(2D), T_2 - double laterals (4D), T_3-Ring type (6Di)), SA - Shaded area (m^2), WA-Wetted area(%), TA-Total area of leaves (m^2) and LAI_{SA}- Leaf area index at Solar noon hour (m^2/m^2)), **(Spacing-4.5 x 2 m)**

Table 4.4: Effect Lateral Geometry Treatments on Yield, Water use Efficiency and Root Geometry of Pomegranate

Treat-ments	Fruits/ Tree (No.)	Avg. Fruit wt (g)	Yield ($kgtree^{-1}$)	WU (m^3)	WUE (Kgm^{-3})	RDP at LHS (g)	RDP at RHS (g)
T_1	30.25	260.24	7.87	3.87	2.03	410.25	102.52
T_2	50.85	295.45	15.03	5.08	3.00	425.56	390.85
T_3	48.20	290.50	14.00	5.85	2.39	474.64	450.40

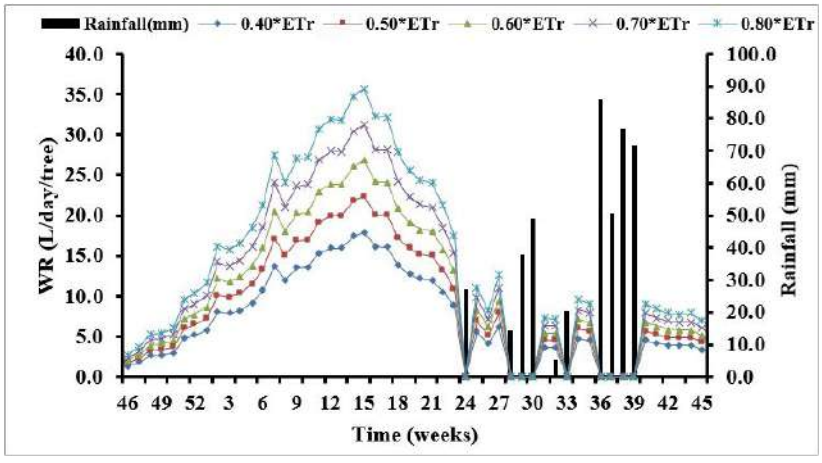


Fig. 4.5 : Pomegranate Evapotranspiration, ET_p (Litres/ Day/ Tree)

Double Lateral with Four Drippers

Ring Type DI with Six Drippers

Signal Lateral with Two Drippers

Fig. 4.6 : Effect of Lateral Geometry on Pomegranate

4.2.2 Effect of Mulches and Irrigation Level on Yield, Quality and WUE of Pomegranate (*Punica granatum* L.)

4.2.2.1 Climatic Parameters at Experimental site

The daily climatic parameters which is required for the estimation of ET_r, was recorded.

4.2.2.2 Estimation of Reference Crop Evapotranspiration (ET_r, mm)

Reference crop evapotranspiration (ET_r, mm) is the major component of pomegranate water requirement. It is the quantity of water transpired by plants during their growth or retained in the plant tissue and the moisture evaporated from the surface of soil and vegetation. It is used to describe the atmospheric "demand" for water. The major factors affecting reference crop evapotranspiration are climatic parameters. Consequently, reference crop evapotranspiration is a climatic parameter and can be computed from weather data. Reference crop evapotranspiration expresses the evaporative power of the atmosphere at a specific location and time of the year and does not consider the crop characteristics and soil factors. Hence, the daily climatic data for the period of April, 2018 to March, 2019 were used to determine daily, weekly and monthly reference crop evapotranspiration (ET_r) by using Penman-Monteith Method. The monthly ET_r values are presented, which also shows that the trend of variation of average ET_r values over the year. The yearly reference crop evapotranspiration (ET_r) obtained are 1731.32 mm. The ET_r was maximum in May (19–21 SMW) and minimum in September (35–39 SMW). The weekly minimum and maximum ET_r ranged from 21.83 to 55.21 mm.

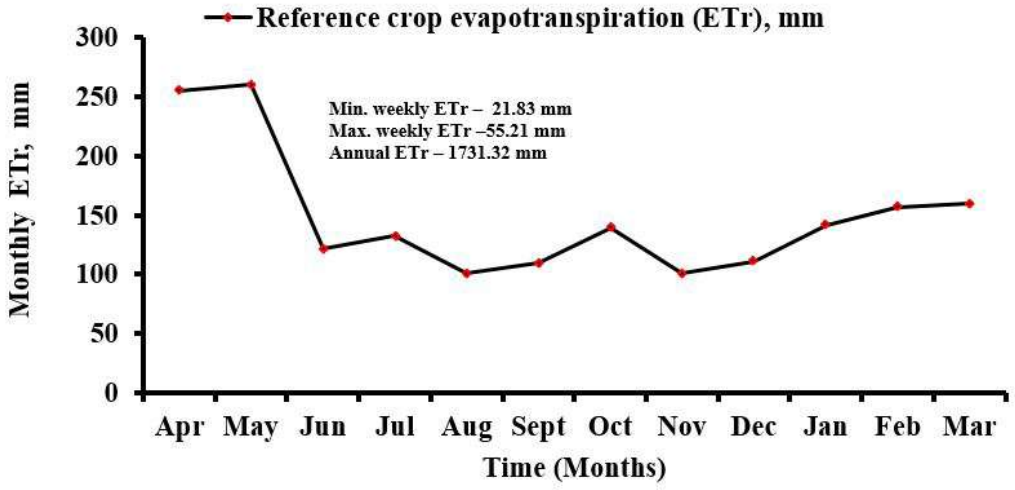


Fig. 4.7 : Monthly ET_r (mm) Values from April, 2018 to March, 2019 at Experimental Site

4.2.2.3 Development of Crop Coefficient (K_c) Values

Crop coefficients are needed to estimate pomegranate evapotranspiration (ET_p) with reference crop evapotranspiration (ET_r). These coefficients are dimensionless numbers that are multiplied by the ET_r values to know pomegranate evapotranspiration in mm. It varies with crops, age, phenological stages, location, by time of the years and specific cultural or management practices. Therefore, the weekly crop coefficient values were computed by using equation and converted in monthly basis. The monthly crop coefficient curve for pomegranate tree in 7th year is presented in the figure, indicates that the values of crop coefficient increased from 0.20 to 1.00 due to the development, maturation of the leaf surface, increased number of leaves, foliage, water sprout, flowers and fruits of the tree during 7th year. The K_c values increased linearly from October to December months due to increase in number of leaves, water sprout, flowers, fruits and shaded area as observed from the representative trees and decreased from January to February months due to removing of water sprout and leaf drop. The crop coefficient (0.80-1.00) increased in the month of October to November due to increases excess water sprout, foliage and management practices.

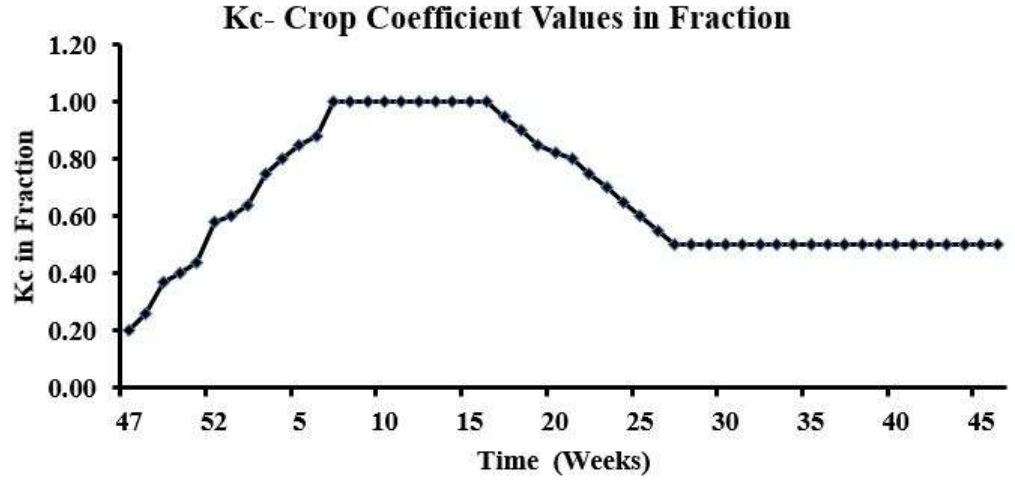


Fig. 4.8 : Crop Coefficient Curve for 7th Year Pomegranate Tree

4.2.2.4 Estimation of Pomegranate Evapotranspiration (ETp, Litres/Day/Tree)

The daily water to be applied through drip irrigation system at 90% efficiency from December, 2017 to June, 2018 ranged from 5–43 litres/day/tree for 7th old age of pomegranate tree at 0.70*ETr is the best. It gradually increases or decreases during different development stages of pomegranate tree due to the variation of reference crop evapotranspiration, pan coefficient, wetted area and crop coefficient values. Lower Kc values represent slower plant growth and lower plant canopy cover, indicating lower ETp. The four months pomegranate evapotranspiration are 4387.00 liters/tree and water to be applied to pomegranate tree ranged from 731 to 1462 liters/month/tree based on different irrigation levels from 0.40 to 0.80. The critical stages wise water requirement in $Lstage^{-1}t^{-1}$ including number of days for pomegranate Bhagawa cv. (*i.e.* new leaf initiation, crop development and maturity) were identified and tabulated.

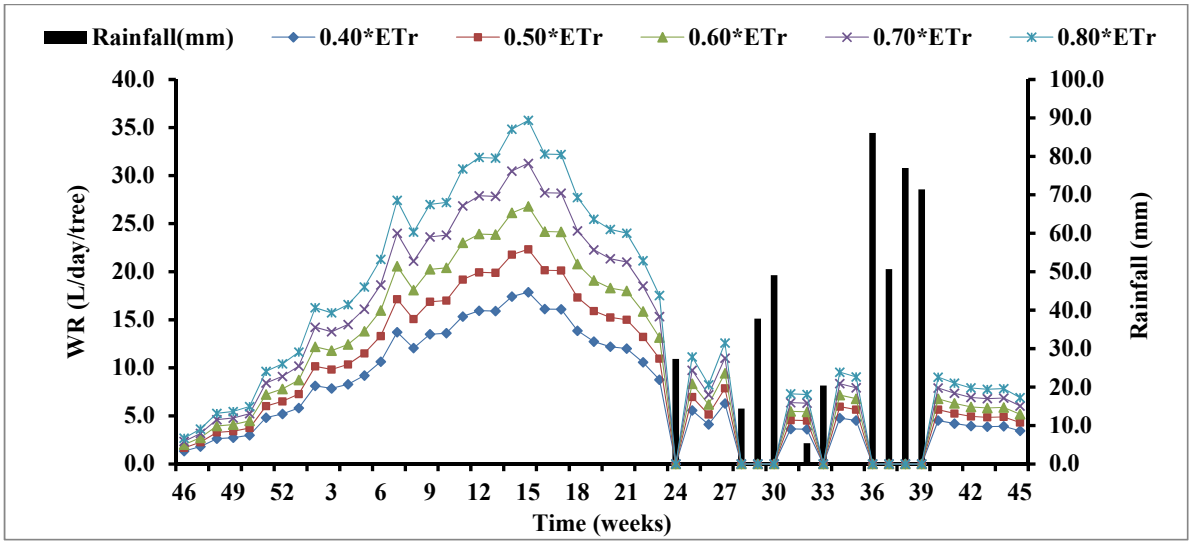


Fig. 4.9 : Daily Pomegranate Evapotranspiration (Liters/Day/Tree) of 7th Year Tree

Table 4.5: Critical Pomegranate Plant Stages for Irrigation in *Hasta* Bahar

Sr. No.	Critical Stages for Irrigation	Nos. of Days	WR ($LStage^{-1}t^{-1}$)
1.	New leaf initiation	22–25	84–175
2.	Crop development (Flowering to fruitset)	70–80	1449–2905
3.	Mid (Fruit development)	60–70	1386–2772
4.	Maturity	60–70	2250–3856
5.	Harvesting	50–60	1520–2450

4.2.2.5 Pomegranate Evapotranspiration for Inorganic and Organic Mulches (ETp, Litres/Day/Tree)

An experiment on different organic (*i.e.* Wheat, Safflower and Sugarcane baggas) and inorganic mulches (*i.e.* Black and White, Black and Pervious) was conducted to find out the effect of mulches on soil properties and growth of pomegranate. Eight treatments including control were replicated four times in split plot design. Various-mulching treatments encouraged plant growth, reduced moisture evaporation and also regulated soil temperature. Depletion of soil moisture was very high in untreated plants. Maximum number of fruits was recorded in sugarcane baggas and pervious mulches with 0.70*ETr, followed by wheat, safflower and black and white and black. Soil moisture retention was also higher in the black mulch treated plants.

4.2.2.6 Growth Parameters

Bhagawa cv. of pomegranate was evaluated for their growth parameters in organic and inorganic. Plant height, plant spread (EW & NS), stem diameter, stem girth, thorn length and flowers ranged from 115 to 165 cm, 127 to 148 cm, 115 to 139 cm, 3.0 to 4.7 cm, 2.6 to 2.9 cm, 2.7 to 3.9 cm and 90 to 250.

Organic Mulch

Inorganic Mulch

Organic Mulch & its Root Geometry Pattern

Inorganic Mulch & its Root Geometry Pattern

Fig. 4.10: Effect of Mulching on Pomegranate

Table 4.6: Growth Performance of Organic and Inorganic Experimental Plots

Mulch	Plant Height (cm)	Plant Spread (cm)		Stem Diameter (cm)	Stem Girth (cm)	Thorn Length (cm)	Flowers/ Tree (No.)
		EW	NS				
Organic mulch (0.50 to 0.90*ETr)							
T1	115	127	118	3.5	2.9	2.9	145
T2	140	130	141	3.9	3.2	3.7	176
T3	165	148	138	4.8	3.0	3.9	212
T4	137	130	132	4.5	2.8	3.8	90
Inorganic mulch (0.50 to 0.90*ETr)							
T1	130	155	135	3.8	2.9	2.8	195
T2	150	165	142	3.9	3.0	3.2	158
T3	171	172	140	4.5	2.8	3.8	250
T4	142	148	138	4.2	2.7	4.10	156

(**Organic**- T_1-Wheat, T_2-Safflower, T_3-Sugarcane baggas, T_4-Control and Inorganic-T_1-Black & White, T_2-Black, T_3-Pervious,T_4-Control; Irrigational level: I_1-0.50 , I_2-0.60, I_3-0.70, I_4-0.80 & I_5-0.90)

Water Use Efficiency: The data revealed that pomegranate fruit yield responded differently to different quantities of water applied through drip irrigation system with two laterals with four drippers **.** The influence of mulches (i.e. organic & inorganic mulches) with irrigation on fruit yield and quantity of irrigation applied is envisaged form the fact that, yield increment of pomegranate to the tune of 25–45 per cent was recorded in double lateral with four drippers and organic and inorganic mulches with 60 per cent saving irrigation water applied and highest water use efficiency (2.8 & 2.6) in sugarcane baggas and pervious mulches. It is evident from the data presented in the table**,** that mulch and irrigation levels had significant effect on the yield attributes. Sugarcane baggas & pervious (T_3) and irrigation level (I_3) recorded the maximum number of fruits (62 & 58 nos.), average fruit weight (325 & 320 g), yield (11.18 &10.46 kgplant^{1}) and this level was at par with T_3*I_3. Similarly, in irrigation levels of drip irrigation at different irrigation had significant effect on the yield attributes (number of fruits, av. Fruit weight) and water use efficiency. The data on distribution pattern of roots in right hand side(RHS) and left hand side(LHS) lying on organic and inorganic mulches were studied. A mean value of the index was calculated for each depth and on the north side and south side of the profile to examine the possible effect of drip line and its wet bulb on root repartition. In the asymmetric case, roots densities are much higher under sugarcane baggas and pervious mulches, followed by wheat and black & white and safflower & black mulches. The RHS and LHS roots indicate that the roots are present in the whole of the domain. It can be concluded that sugarcane baggas & pervious mulches has a noticeable effect on the root development.

Table 4.7: Effect of Organic and Inorganic Mulches and Irrigation Levels on Yield Attributes and Water Use Efficiency of Pomegranate

Mulch	No. of Fruits/ Tree	Avg. Fruit Weight (g)	Yield (Kgha^{-1})	WR (Lb^{-1}t^{-1})	WUE (kgha^{-1}m^{-3})	RDP (LHS in gm)	RDP (RHS in gm)
Organic (0.50 to 0.90*ETr)							
T_1	47	255	6.65	2401	2.6	408.00	381.18
T_2	48	265	7.09	3601	2.1	550.85	485.25
T_3	62	325	11.18	3952	2.8	475.42	430.25
T_4	42	250	5.82	6002	0.96	420.15	308.24
Inorganic (0.50 to 0.90*ETr)							
T_1	40	250	6.5	2401	2.2	402.15	308.15
T_2	53	264	7.6	3601	2.1	435.65	430.25
T_3	58	320	10.46	3952	2.6	412.25	350.21
T_4	42	286	6.60	6002	1.2	308.25	315.22

(**Organic**- T_1-Wheat, T_2-Safflower, T_3-Sugarcane baggas, T_4-Control and **Inorganic**-T_1-Black & White, T_2-Black, T_3-Pervious, T_4-Control; **Irrigational level**: I_1-0.50 , I_2-0.60, **I_3-0.70,** I_4-0.80 & I_5-0.90)

4.3 CROP MANAGEMENT

4.3.1 Standardization Ethephon Concentration for Crop Regulation in Pomegranate

As pomegranate is basically deciduous in nature, defoliation through foliar spray of chemicals is useful for crop regulation. The growth regulator Ethephon was applied through foliar spray

to pomegranate variety Bhagawa in mrig bahar. Ethephon was applied in single spray or double sprays at one week interval along with a control. Preliminary observations revealed that T3 (Ethephon@200ppm followed by Ethephon@400ppm at 1 week after spray) recorded the highest defoliation on 9 DAFS (90%) and 12 DAFS (95%).

Table 4.8: Defoliation of Pomegranate Variety Bhagawa due to Ethephon Application

Treatment	Foliar spray (26.06.18)	Second spray (1week after first spray)	Defoliation (%)				
			Days after First Spray (DAFS)				
			3 Days	6 Days	9 Days	12 Days	15 Days
T1	Ethephon@1000ppm	-	55	70	85	85	85
T2	Ethephon@200ppm	Ethephon@200ppm	25	50	60	65	65
T3	Ethephon@200ppm	Ethephon@400ppm	25	50	90	95	95
T4	Ethephon@200ppm	Ethephon@600ppm	25	50	90	90	90
T5	Ethephon@200ppm	Ethephon@800ppm	25	50	65	70	70
T6	Ethephon@200ppm	Thiourea@0.3%	45	60	70	75	75
T7	Thiourea@0.3%	-	30	45	55	60	60
T8		-	10	15	20	25	25

4.3.2 Effect of Growth Regulators on Enhancement of Fruit Size

An experiment was conducted to enhance the fruit size of pomegranate cultivar Bhagawa during tenth year of planting in mrig bahar. The growth regulator, Gibberellic acid was foliar sprayed at 7 different concentrations (10,20,30,40,50,60,70 ppm) along with control (water spray). The highest mean fruit weight (266.2g) was recorded from GA3@50ppm. The fruit weight was lowest in control (215.6g). Similarly, highest yield (24.57kg/tree) was recorded from GA3@50ppm whereas control registered the lowest yield (17.07kg/ha).

Table 4.9: Effect of Gibberellic Acid on Pomegranate Fruit Size

Treatment	Fruit Weight (g/Fruit)	Fruit Length (cm)	Fruit Diameter (cm)	No. of Fruits/ Tree	Yield (kg/Tree)
Treatment	230.4	7.40	7.22	82.2	18.93
GA_3@10ppm	235.5	7.50	7.36	85.0	20.01
GA_3@20ppm	242.0	7.60	7.48	87.5	21.17
GA_3@30ppm	253.8	7.72	7.60	89.2	22.63
GA_3@40ppm	266.2	7.80	7.68	92.3	24.57
GA_3@50ppm	260.5	7.76	7.64	91.0	23.70
GA_3@60ppm	245.2	7.62	7.50	90.3	22.14
GA_3@70ppm	215.6	6.90	6.76	79.2	17.07
Control					


GA_3@10ppm


GA_3@20ppm


GA_3@30ppm


GA_3@40ppm


GA_3@50ppm


GA_3@60ppm


GA_3@70ppm


Control

Fig. 4.11: Effect of Gibberellic Acid on Fruit Size and Yield

Crop Protection

5

CHAPTER

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

5.1.1 Insect Pests

5.1.1.1 Promising Insecticides for Borer and Sucking Pests of Pomegranate

Among 6 combi-products tested for the second season against sucking pests in pomegranate, chlorantraniliprole 8.80% + thiamethoxam 17.5%, followed by chlorpyriphos 50% + alphacypermethrin 5% EC, profenophos 40% + cypermethrin 4% EC and Chlorpyriphos 16% + Alphacypermethrin 1% EC 71.52% were found promising with more than 0–76% reduction in thrip damage on fruits.

5.1.1.2 Pheromone Compounds of Fruit Piercing Moth with Special Reference to *Eudocima materna* (Lepidoptera: Erebidae)

Experiments were conducted at Bio-control Research Laboratories (BCRL), Indian Council of Agricultural Research-National Bureau of Agricultural Insect Resources (ICAR-NBAIR) Bengaluru, and ICAR-NRC on Pomegranate Solapur during 2018–19. Efforts were made to combine the pheromones with fruit extracts so that the trapping of *E.materna* moths could be enhanced. Three effective blends (B, Q and N) were formulated and used for field evaluation using Fero-T traps.

5.1.1.2.1 Comparative Field Trial for Lure Optimization

Field experiments were conducted at Kegaon, Solapur during 2018 where doses of superior pheromone blends were evaluated. Bhagawa and Ganesh cultivars of pomegranate were selected for this study. The experiments were conducted in 1.2 acres of pomegranate-cultivated field. There were statistically no differences in attracting and trapping female *E. materna* moths. Statistical significant differences were found among the blends and doses ($F_{4,15}$= 6.423; P= 0.004) in attracting male moths as found in earlier experiments, blends at 20µl trapped significantly higher number of moths compared to control.

Different pheromone blends at varying doses were also evaluated at NRCP farm at Hiraj, Solapur. All the doses of different blends were significantly superior when compared to control in attracting

male moths ($F_{4, 15}$=4.284; P=0.025). Female moths were also found trapped but their numbers were negligible compared to trap in control. Pheromone blend B at 20µl was found superior compared to other treatments in trapping male *E. materna* moths. (31 moths; mean 9.25 ± 2.36 moths/trap).

The reasons for low number of moth catches per trap may be attributed wide fluctuations in the infestation levels of the fruit piercing moths and pheromone lures were not highly stable under field conditions. No antioxidant was used while formulating the pheromone blends which could have stabilized the pheromone lures for a longer period of time. The occurrence of a negligible number of female moths in traps was quite intriguing. However, further investigations are required for conclusive results.

Table 5.1: Comparative Evaluation of Blends B, Q and N at Kegaon and Hiraj, Solapur

Blend (Dose-µl)	*Number of Male Moths Caught (Mean ± SE)		Number of Female Moths Caught (Mean ± SE)	
	Kegaon	Hiraj	Kegaon	Hiraj
Blend-B (20 µl)	9.50±0.94[a]	9.25±2.36[a]	2.50±0.51	0.75±0.28
Blend-B(40 µl)	8.25±1.61[a]	8.25±2.61[ab]	1.75±0.44	1.25±0.25
Blend-Q (20µl)	7.50±1.69[a]	8.50±0.85[ab]	1.25±0.28	0.50±0.25
Blend-N (20 µl)	6.25±1.01[ab]	5.25±0.85[ab]	1.0±0.32	0.75±0.28
Control	0.50±0.20[b]	0.50±0.15[b]	0.22±0.16	0.25±0.12
Df	4, 15	4, 15	4, 15	4, 15
F	6.423	4.284	1.354	0.746
P	0.004	0.025	0.613	0.748

Means followed by different letters in a column are significantly different by Tukey's Post-hoc tests (P<0.05);
* Mean of four replicate

5.1.1.3 Population Dynamics of Borer and Sap-Sucking Pests of Pomegranate in Relation to Weather Parameters

Fruit borer incidence showed a highly significant positive correlation with mean maximum and minimum temperatures, rainfall and negative correlation with relative humidity on both Ganesh and Bhagawa varieties. Thrips showed negative correlation with rainfall and positive correlation with RH and temperature on both the varieties. Mealy bug showed a positive correlation with temperature and relative humidity and negative with rainfall on Bhagawa variety.

Table 5.2: Correlation of Weather Parameter with Incidence of Thrips, Fruit Borer, Mealy Bugs

Pest and Variety	Correlation Coefficient with Different Weather					
	Mean Min. & Max. Temp.		Mean Min. & Max. R.H.		Rainfall	
	Ganesh	Bhagawa	Ganesh	Bhagawa	Ganesh	Bhagawa
Fruit borer (G)	0.78	0.86	-0.63	-0.51	0.85	0.89
Thrips	0.24	0.46	0.42	0.33	-0.28	-0.44
Mealy bug	-	0.80	-	0.72	-	-0.61

5.1.1.4 Population Dynamics of Fruit Sucking Moths of Pomegranate

The population of fruit sucking moth was monitored from August to October, 2018. Three different species of fruit sucking moth were recorded during the season with the dominance of *E. materna*. Among the collected adults, the male moth was predominant in all the species. The peak activity of the moth was from 7.30 pm to till 11.30 pm and from the first week of August to September, though reduced activity was observed upto 2.00 am and till November end.

The emergence pattern of male and female moth was recorded from field-collected population reared under laboratory conditions during 2018-19. During 2018-19 (August to November), 747 moths (males=474; females=273) were recorded. The average sex ratio of reared adult *E. materna* female to male was 1.74.

Table 5.3: The Ratio of *E. materna* Female to Male Moths from Field-Collected Population

Period (Year 2018)	Number of Moths Emerged		Total No. of Moths Emerged	Sex Ratio (♂/♀)
	Female	Male		
Aug 5 to Aug 20	38	63	101	1.66
21 Aug 21 to Sep 5	48	84	132	1.75
Sep 6. to Sep 20	52	95	147	1.83
Sep 21 to Oct 5	55	105	160	1.91
Oct 6 to Oct 20	54	92	146	1.70
Oct 21 to Nov 5	15	22	37	1.47
Nov 6 to Nov 21	11	13	24	1.18
Total	273	474	747	1.74

5.1.2 Fungal Diseases and Disorders

5.1.2.1 Effective Wilt Management Strategy

Evaluation of 10 promising biological and chemical treatments was done in severely wilt (due to *Ceratocystis fimbriata*) affected orchard. Promising preventive treatments were fungal bioformulations containing *Aspergillus niger* AN27, Mychorrizal fungi *Rhizophagus irregularis* (Syn. *Glomus intraradices*), *Trichoderma harzianum* and one new fungal endophyte FE-8, applied twice at 1 month interval. For curative (once wilt is observed) as well as preventive 3 promising treatments giving100% wilt control were identified (i) First drenching with propiconazole 25%@2ml/l +Chlorpyriphos @ 20ml/plant in 10 litre solution after 30 days of first application 2nd drenching with *Aspergillus niger* AN27@5g/plant with 2Kg FYM/plant after 30 days of 2nd application - *Rhizophagus irregularis* @25g/plant with 2kg FYM/plant) l (ii) Drenching with Fosetyl Al@6g/plant 80% WP and Tebuconazole 25.9% w/w EC 3ml/plant in alteration2 drenching of each (iii) three drenching with propiconazole 25%@2ml/l+Chlorpyriphos @ 2ml/l at 20 days interval.

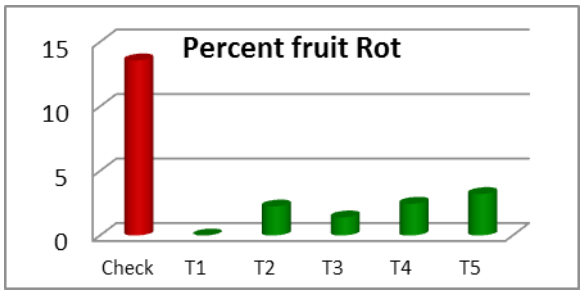
5.1.2.2 Root Knot Nematode Management

Root knot nematode infestation was best reduced using bioformulations having *A. niger* AN27 (67.74% reduction), mychorrizal fungi *R. irregularis* (65.61%) alone and in combination (64.43%),

with maximum reduction (81.24%) with thiocarboni acid@2ml/l against untreated control having more than 50 knots per gram root.

5.1.2.3 Fungal Spots and Rots

In a field trial 18 different fungicides and their combinations were evaluated for various fungal spots and rots. Incidence of fungal spots was too low and not uniformly distributed in the plot hence conclusive inferences could not be derived. Fungal rots showing maximum average incidence up to 13.65% in the plot was 100% controlled with T1 (2 sprays of mandipropamid @ 1ml/l at 15 days interval, first at flowering and second at fruit enlargement). Other treatments that recorded significantly low incidence (≤ 3.25%) than control were T2 (propiconazole @ 1ml/l + azoxystrobin@1ml/l, 2 sprays of each in alteration at 15 days interval); T3 (aoxystrobin 20% +difenoconazole 12.5% SC @ 2ml/l 2 sprays at 15 days interval, first at flowering and second at fruit enlargement) and T4 (chlorothalonil 50% +metalazxyl M 3.75% @2ml/l (2 sprays first at flowering and second t fruit setting) and T5 (Bordeaux mixture @ 0.5% 15days interval). One important inference was that preventive sprays at flowering and fruit set were more effective than after disease appearance.



T1: Mandipropamid @ 1ml/l

T2: Propiconazole@1ml/l+azoxystrobin@1ml/l

T3:Azaoxystrobin 20% +difenoconazole12.5% SC

T4: Chlorothalonil 50% +metalazxyl M 3.75%

T5: Bordeaux mixture @ 0.5%

Check: No spray

Fig. 5.1 : Effect of Fungicides on Incidence of *Colletotrichum* Fruit Rot Incidence

5.1.2.4 Disorders

5.1.2.4.1 Chemical Toxicity

During the year under report symptoms of chemical toxicty (confused with bacterial blight or fungal spots) were reported from Maharashtra, Karnataka, Madhya Pradesh, Gujarat and Rajasthan. Surveys were done in selected affected orchards in Sangli, Solapur and samples collected. Samples were also received from farmers in other states. The incidence varied from 5–15 per cent. Isolations failed to give association of any biotic cause and major reasons that could be interpretted based on and preliminary pilot trial taken at the Centre and information of sprays taken during the season were analysed and short listed. The major reason was low pH (below 6.5) of spray solutions due to use of excess ferrous sulphate or copper sprays at pH below 7, certain brands of micronutrient mixture sprays or blind use of citric acid or lemon juice to spray solutions without checking pH of sollutions. Planned trials would be taken up during the season.

Fig. 5.2 : Symptoms of Chemical Toxicity on Fruits in Various Farmers' Fields

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

5.2.1 Efficacy of Endophytes from Medicinal Plants in Bacterial Blight Management

The endophytes were isolated from medicinal plants such as Tulsi, Basil, Pudina, Lemon grass and Amla. Total 28 endophytes were isolated from medicinal plants. Basil showed maximum population of the endophytes as compared to other. Ten endophytes were isolated from Basil. Five endophytes were isolated from Tulsi, 8 from Pudina, 3 from Lemmon grass, 2 from Amla.

Table 5.4: Medicinal Plants Used for Isolation of Endophytes

Sr. No.	Medicinal Plant	Number of Endophytes Collected			
		Bacterial	Fungal	Actinobacterial	Total
1.	Tulsi (*Ocimum tenuiflorum)*	3	1	1	5
2.	Basil (*Ocimum basilicum)*	8	0	2	10
3.	Pudina (*Mentha spicata)*	3	3	2	8
4.	Amla (*Phyllanthus emblica)*	2	0	0	2
5.	Lemongrass(*Cymbopogon schoenanthus)*	3	0	0	3
	Total	19	4	5	28

Medicinal plant at S. No, 1-3 belong to family Lamiaceae, 4 to Phyllanthaceae and 5 to Poaceae

5.2.2 *In vitro* Evaluation

These isolated endophytes were screened against bacterial blight (BB) pathogen *Xanthomonas axonopodis* pv *punicae* (*Xap*) by using dual culture technique in which endophyte and pathogen *Xap* were inoculated on same plate. Among 19 bacterial, 4 Actinobacterial and 5 fungal endophytes screened *in vitro* against *Xap*, all endophytes significantly inhibited growth of *Xap*. However, 3 actinobacteria endophytes were most effective with *Xap* inhibition of 68.12% (AE-3), 69.85% (AE-4) and 77.10% (AE-5) respectively. Among bacterial endophytes BE-4, BE-10, BE-5 and BE-2 were most promising with 67.72% 63.97%, 59.09% and 58.22% inhibition of *Xap* growth respectively and 2 fungal endophytes FE2 and FE3 with 59.71% inhibition of *Xap*.

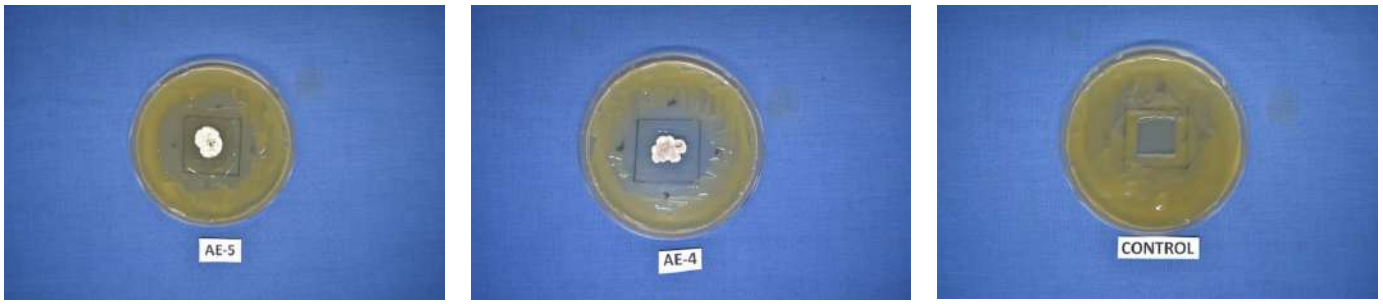


Fig. 5.3 : Actinobacter Endophytes from Basil Stem (AE-5) and Pudina Root (AE-4) Inhibiting BB Pathogen *Xap*

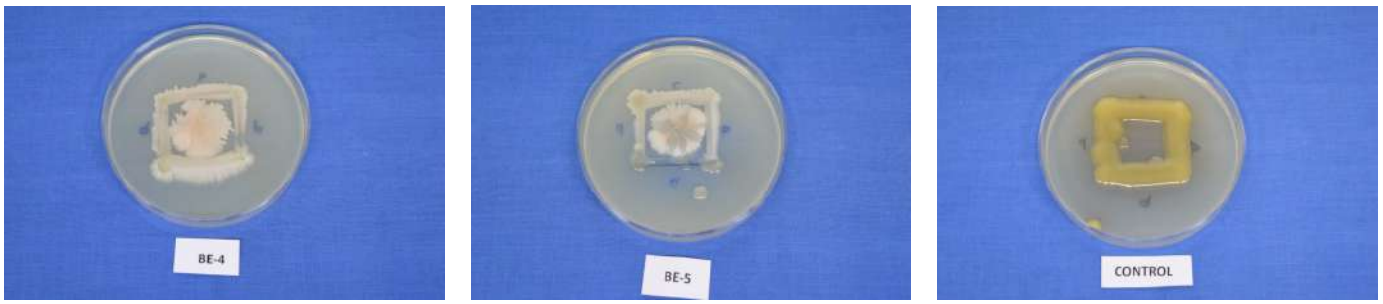


Fig. 5.4 : Bacterial Endophytes from Basil Leaf (BE-4) and Tulsi Stem (BE-10) Inhibiting BB Pathogen *Xap*

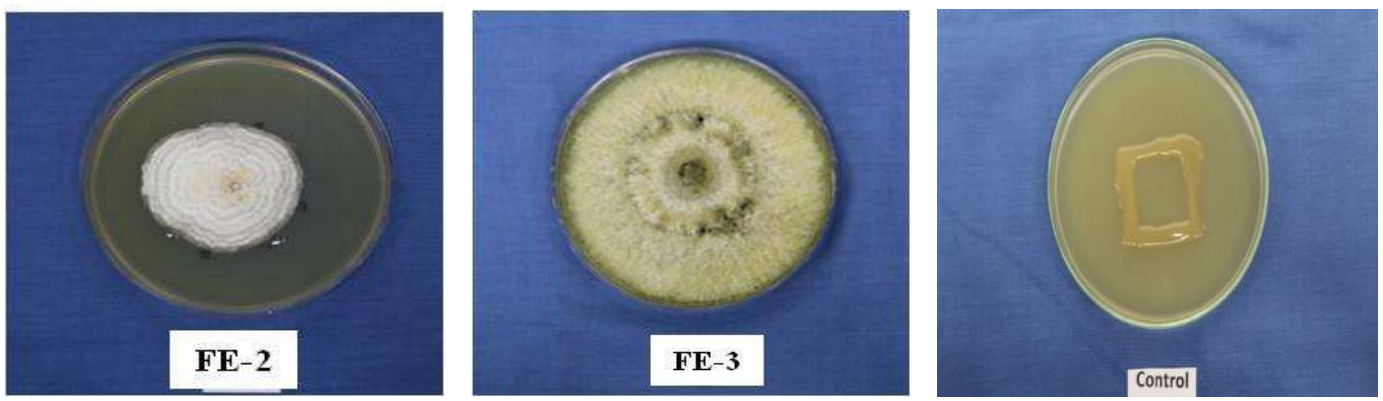


Fig. 5.5 : Fungal Endophytes from Pudina Stem (FE-2 and FE-3) Inhibiting BB Pathogen *Xap*

Promising Endophytes from Medicinal Plants against Bacterial Blight (BB) Pathogen *Xap*

5.2.3 Polyhouse Evaluation

In a polyhouse trial 2 actinobacteria endophyte isolates AE-4 and AE-5 reduced BB above 40% with 3 theraputic sprays at 15 days interval, whereas in preventive sprays (3 sprays) 2 bacterial endophytes BE 2 (*Bacillus subtilis*) and BE-4 (*Bacillus subtilis*) and 1 actinomycete isolate AE-5 and 1 fungal endophyte FE-8 (*Trichoderma asperellum*) reduced BB by 40–68% up to 30 days and 32–51% up to 40 days after *Xap* sprays. As the efficacy was reduced after 30 days, hence sprays need to be repeated after 15–20 days for effective control.

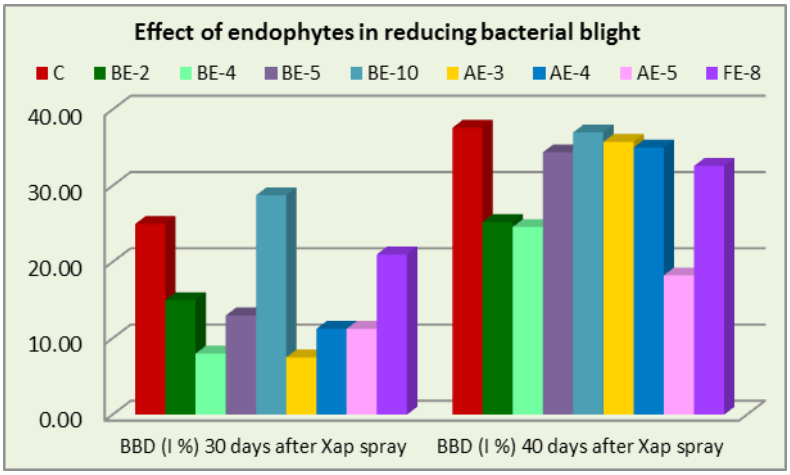


Fig. 5.6 : Efficiency of Endophytes from Medicinal Plants in Reducing Bacterial Blight in Polyhouse Trials

5.2.4 Field evaluation

In a field trial among 19 endophytes, phyllosphere microflora and bioagents tested during rainy season crop, only 2 endophytes from pomegranate (TC-310 and TC-137) both *Bacillus* spp. gave 50.59 and 63.78 per cent control. In all other treatments bacterial blight was more or recorded non-significant reduction.

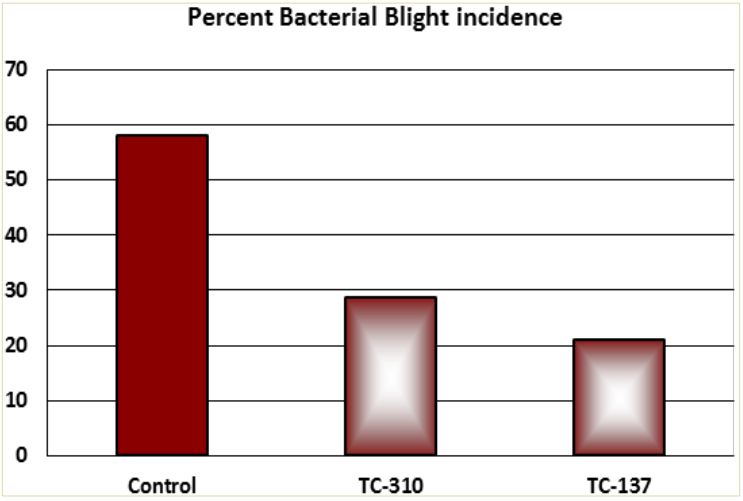


Fig. 5.7 : Effect of Endophytes on Bacterial Blight Incidence on Fruits

5.2.5 Efficacy of Copper Nano Particles

Copper nano particles (CNP) at 0.004% spray tested in polyhouse was less effective than streptocycline (SC) (0.005%) in checking BB, however CNP (at 0.004%) recorded 56% less BB than control whereas streptocycline recorded 90% less BB than untreated check with 62% incidence and 50% severity on infected leaves.

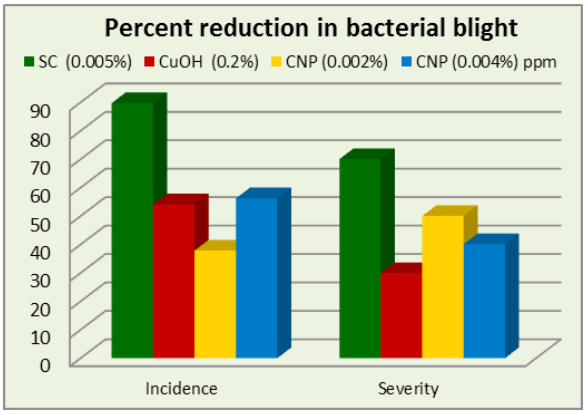


Fig. 5.8 : Efficacy of Copper Nano Particles on Bacterial Blight

5.2.6 Identification of Defense Inducers Against Bacterial Blight of Pomegranate

In our efforts to identify the resistance inducers, phenylpropanoid pathway defense inducers were evaluated against *Xap* in pomegranate under polyhouse conditions at UHS, Bagalkot. PPP is the gateway metabolism of plant defense, and its activation is known for significant improvement of the defense against plant pathogens. A total of 6 new inducers; β-amino butyric acid (BABA), γ-amino butyric acid (GABA), Eicosapentaenoic acid (EPA), proline, arachidonic acid (AA) and chiotosan were evaluated for their efficacy in inducing the resistance and compared with *Pseudomonas putida* and *Bacillus subtilis*. Out of inducers, β-amino butyric acid (BABA) and γ-amino butyric acid (GABA) are the new promising agents which are at par with *Pseudomonas putida*. BABA (600ppm), *P. putida* (10ml/litre) and GABA (600ppm) had shown 81.17, 75.01 and 72.35% resistance respectively over controls. Testing of promising inducers under field conditions is in progress at UHS Bagalkot.

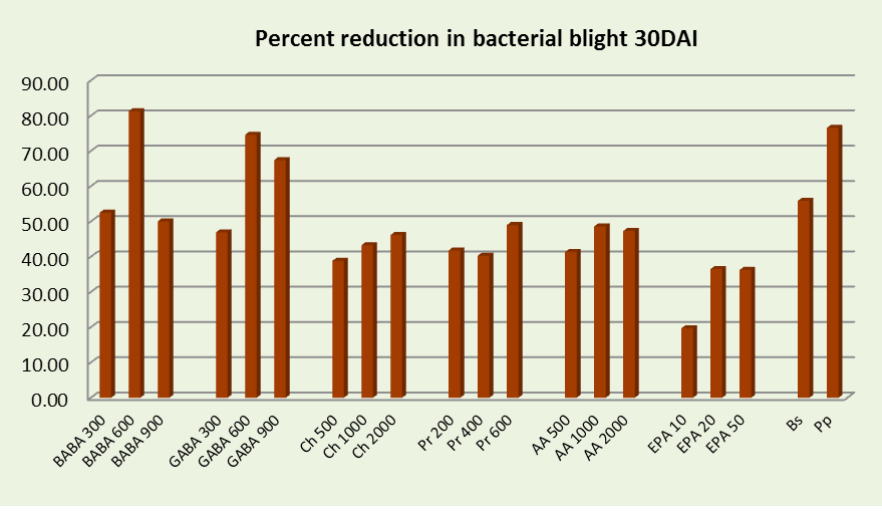


Fig. 5.9 : Efficacy of Phenylpropanoid Pathway Defense Inducers at 3 Concentrations (ppm) in Reducing Bacterial Blight under Greenhouse Conditions

β-amino butyric acid (BABA), γ-amino butyric acid (GABA), Chitosan (Ch), proline (Pr), arachidonic acid (AA), Eicosapentaenoic acid (EPA), *Bacillus subtilis* (Bs) and *Pseduomonas putida* (Pp)

5.2.6.1 Identification of Plant Defense Related Phenylpropanoid Compounds as Potential Formulations in Management of Bacterial Blight in Pomegranate

Application of plant defense activators such as chitosans, bronopol and nitrous oxide has lead to activation of phenylpropanoid pathway in pomegranate. Such phenylpropanoids could be exploited as spray formulations for management of bacterial blight in pomegranate. To test the hypothesis, this study has been designed at UHS, Bagalkot. One of the 'Daru' derivative 'UHSP1" has exhibited high tolerance with disease severity score of 1.91 significantly (P<0.01) differing from the highly susceptible variety 'Bhagawa' with disease severity score of (55.06). Leaf samples were collected from both pathogens inoculated and control plants at 0, 6, 12, 24, 48, 72 hours of post inoculation (hpi) at 3 days interval upto 15 days. Secondary metabolites have been extracted from the collected samples in 60% aqueous methanol and metabolite analysis using LC/MS in both positive and negative mode is under progress with National Centre of Biological Science (NCBS), Bengaluru

5.2.6.2 Pomegranate Phyllosphere Bacteria Producing Volatile Organic Compounds

Highly antagonistic pomegranate phyllosphere bacteria against *Xap* as well as *Ceratocystis fimbriata* have been found to produce promising volatile compounds. Identification of these Volatile Organic Compounds (VOCs) is under process at IARI, New Delhi. The bacteria were being subjected to head space GC-MS analysis using SPME (Solid Phase Micro-Extraction) technique

Table 5.5: Pomegranate Phyllosphere Bacteria Producing Volatile Compounds

S. No.	Isolate Code	Species Identity
1.	Pg_3	*Acinetobacter lwoffii*
2.	Pg_4	*Bacillus megaterium*
3.	Pg_5	*Phyllobacterium* sp.
4.	Pg_6	*Microbacterium arborescens*
5.	Pg_8	*Sphingomonas yunnanensis*
6.	Pg_9	*Aureimonas phyllosphaerae*
7.	Pg_10	*Massilia varians*
8.	Pg_11	*Bacillus cereus*
9.	Pg_12	*Staphylococcus hominis*
10.	C4_1	*Sporosarcina aquimarina*

5.2.6.3 Correlation of BB Susceptibility with Morphological, Biochemical and Nutritional Fruit Parameters

Fruit quantitative characters including morphological, biochemical and nutritional parameters were recorded in 24 pomegranate genotypes which recorded BB disease reaction from moderately resistance to highly susceptible. Statistically significant differences were found between the genotypes for the traits under study except for non-reducing sugar (%). Correlation (R) between BB incidence and severity with the various fruit morphological, biochemical and nutritional traits was

highly significant. Both BB incidence and severity were found positively correlated with fruit weight (0.76**, 0.77**), fruit length (0.77**, 0.81**), fruit diameter (0.76**, 0.77**), 100 aril weight (0.50*, 0.53**), aril length (0.53**, 0.59**), aril width (0.56**, 0.59**), antioxidant capacity (0.42*, 0.43*) and pH (0.60**, 0.67**) traits. While a significant negative correlation was found with total phenol (-0.45*, -0.51*) and reducing sugar (-0.40*, -0.41*) content. Genotypes studied revealed statistically significant correlation of BB incidence and severity with nutritional content in fruits. Both BB incidence and severity were found to have positive correlation with Fruit P content (0.50*, 0.55*) and Fruit K content (0.55**, 0.59**). Fruit N content (0.44*) showed the positive correlation with BB severity only. It is also noted that both BB incidence and severity are positively (0.96**) correlated. While a significant negative correlation was found with the TSS (-0.73**, -0.78**), acidity (-0.88**, -0.91**) and seed texture (-0.73**, -0.76**). Correlation (R) values given in parenthesis, values with single star (*) significant at 5% and with double star (**) significant at 1%.

5.2.6.4 Molecular Characterization of *Xap* Isolates

For molecular characterization and understanding the population structure of *Xap* isolates, which are distributed across India, whole genome sequence of *Xap* strain LMG 859 was retrieved from EMBL database (217 contigs). *In silico* analysis and mining of simple sequence repeats (SSRs) motifs in the whole genome of *Xanthomonas* resulted in identification and designing of 419 SSR primers. The classification of SSRs based on motif types revealed that Tri-nucleotide repeats were most frequent (47.2%) followed by Tetra (20.8%), Hexa (15.3%), Di (11.7%) and Penta (5.01). Further, 100 SSR primers were got synthesized from Di and Tri motifs types which are distributed across the entire genome. Now these primers are being validating on a set of *Xap* isolates collected from diverse pomegranate growing areas. The work is in progress at ICAR-NRCP, Solapur.

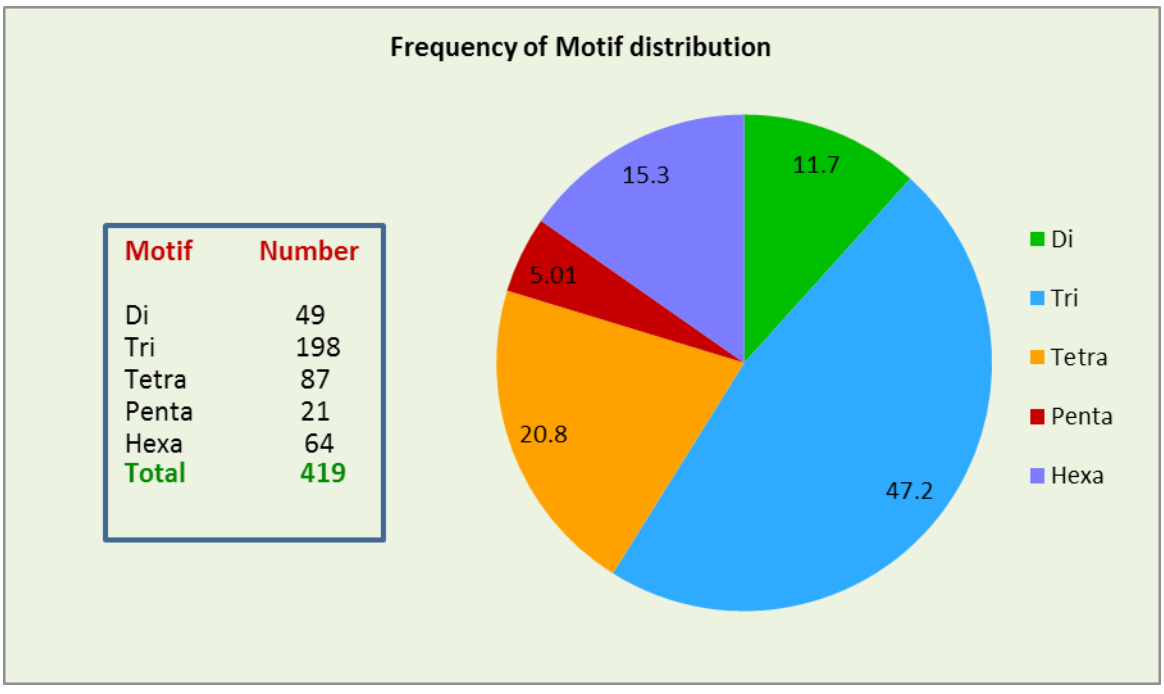


Fig. 5.10: Distribution of SSR Motif Types in the Whole Genome Sequence of *Xanthomonas axonopodis* pv. *punicae* Strain LMG 859

5.2.6.5 Validation of Housekeeping Genes for Expression Analysis

Primers for 11 housekeeping gene in pomegranate have been worked out and standardized at UHS Bagalkot. These housekeeping genes can be used for normalization during various stress response. The primers identified are 18s rRNA, 16s rRNA, Alpha-Tubuline, Beta-Tubuline, GAPDH, Cycloprotine, Elongation-FII, Elongation-FI, Ubiquitin gene, Aspertate and Actine. The work is in progress to ascertain the stress specific genes including diseases.

5.2.6.6 Prediction of R Genes among the up Regulated Genes of Different Challenge Inoculated Transcriptome Samples of Blight Susceptible and Moderately Resistant Pomegranate Genotypes

5.2.6.6.1 Isolation of Good Quality Total RNA

Good quality total RNA extraction holds the key for quality cDNA synthesis to initiate transcriptome related studies. Presence of several secondary metabolites in pomegranate tissues poses challenge in extraction of quality RNA. An experiment was therefore initiated to evaluate efficiency of different RNA extraction protocols using seven different tissues of pomegranate. Among seven protocols evaluated Phenol Chloroform method was found to be the best with good quality total RNA from all 7 types of tissues used at least cost and shortest duration.

5.2.6.6.2 : cDNA Quantification

Table 5.6: Comparative Evaluation of Time and Cost Involved in Different Protocols

Sr. No.	Method Name	Total Duration	Cost (7 Samples/Reaction)
A.	Phenol Chloroform method	50 min	208.26.00
B.	Plant RNA purification reagent	50 min	900.87.00
C.	Plant RNA isolation kit (GeNei™)	48 hrs	3990.00
D.	Modified CTAB LiCl method	72 hrs	267.78.00
E.	Banana peel RNA extraction method	48 hrs	841.42.00
F.	TRIzol reagent method	2 hrs	817.00.00
G.	RNeasy plant mini kit (QIAGEN)	35 min	3850.87.00

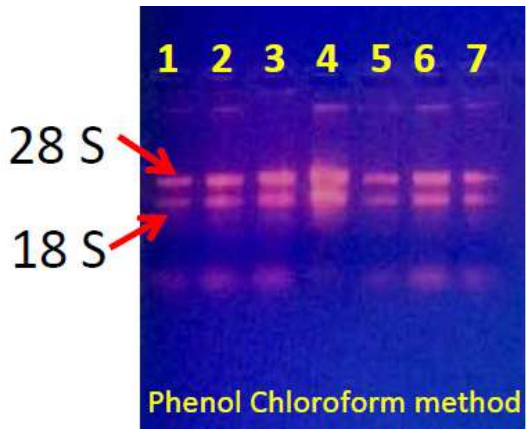


Fig. 5.11: 28s and 18s Bands of rRNA from Pomegranate Tissues

5.2.6.6.3 Prediction of R Genes among Blight Affected Transcriptome Samples

Prediction of R genes among blight susceptible and moderately resistant pomegranate genotypes revealed varying number of R genes from the transcriptomic data. BLASTP homology search was performed between the up regulated genes of all combinations of sample to the local database of R gene proteins. Out of 16 sample combinations, FS_2 vs. FT_1 combination revealed highest number of R genes (140) in the list of up regulated genes.

Table 5.7: Predicted Upregulated R Genes in Each Combination

Sample Combination	Number of Upregulated Gene Matching with R Genes	Sample Combination	Number of Upregulated Gene Matching with R Genes
FS_1 vs. FS_C	72	LS_1 vs. LS_C	54
FS_1 vs. FT_1	115	LS_1 vs. LT_1	93
FS_2 vs. FS_C	70	LS_2 vs. LS_C	114
FS_2 vs. FT_1	140	LS_2 vs. LT_1	76
FS_3 vs. FS_C	72	LS_3 vs. LS_C	75
FS_3 vs. FT_1	126	LS_3 vs. LT_1	110
FS_C vs. FT_C	175	LS_C vs. LT_C	73
FT_1 vs. FT_C	83	LT_1 vs. LT_C	49

Samples:
LS_1 to LS_3 (susceptible genotype with blight infection stage I and III on leaf)
LS_C control (susceptible genotype non-inoculated leaf)
FS_1 FS_3 (susceptible genotype with blight infection stage I to III on fruit)
LT_1 and LF_1 (moderately resistant genotype with blight infection stage I on leaf and fruit).

5.2.6.6.4 Validation of Differential Expressed Genes through RT-PCR

To validate the results of RNA-Seq data analysed for differential expression of genes, we used RT-PCR to validate the expression of three genes coding for xyloglucan endo transglycosylase, superoxide dismutase and alcohol dehydrogenase expressed differentially in *Xap* inoculated tissues and control of Bhagwa and IC 524207 tissues. We selected these genes randomly from the data generated from DEGseq analysis. We designed the forward and reverse primers for the genes and amplified the genes in all 12 samples. The gene that codes for xyloglucan endo transglycosylase was slightly over-expressed in infected leaf samples of Bhagwa at stage 1 and 3 of infection as compared with the control. Similarly, the gene that codes for xyloglucan endo transglycosylase was under-expressed in infected leaf samples of IC 524207 at stage 1 of infection versus the control. Xyloglucan endo transglycosylase showed higher expression in infected fruit samples of Bhagwa at stage 2 of infection versus the control. We did not obtain any data for infected fruit samples of Bhagwa at stage 1 and stage 3 or IC 524207 at stage 2.

For the gene coding for alcohol dehydrogenase, the control sample of infected leaf of Bhagwa had higher expression than at any of the stages. We did not obtain any data for the control infected leaf samples of IC 524207. Similarly, we did not obtain any data from infected fruit samples of Bhagwa at stage 1 and 2, but the expression of alcohol dehydrogenase was similar at stage 3 of Bhagwa and its control in infected fruit samples.

For the gene coding for superoxide dismutase, we did not obtain any data for infected fruit samples of Bhagwa at stages 1 and 3, but we found over-expression of the gene in infected fruit samples of Bhagwa at stage 2 versus the control. However, we did not obtain any data for IC 524207 at stage 1 of fruit infection.

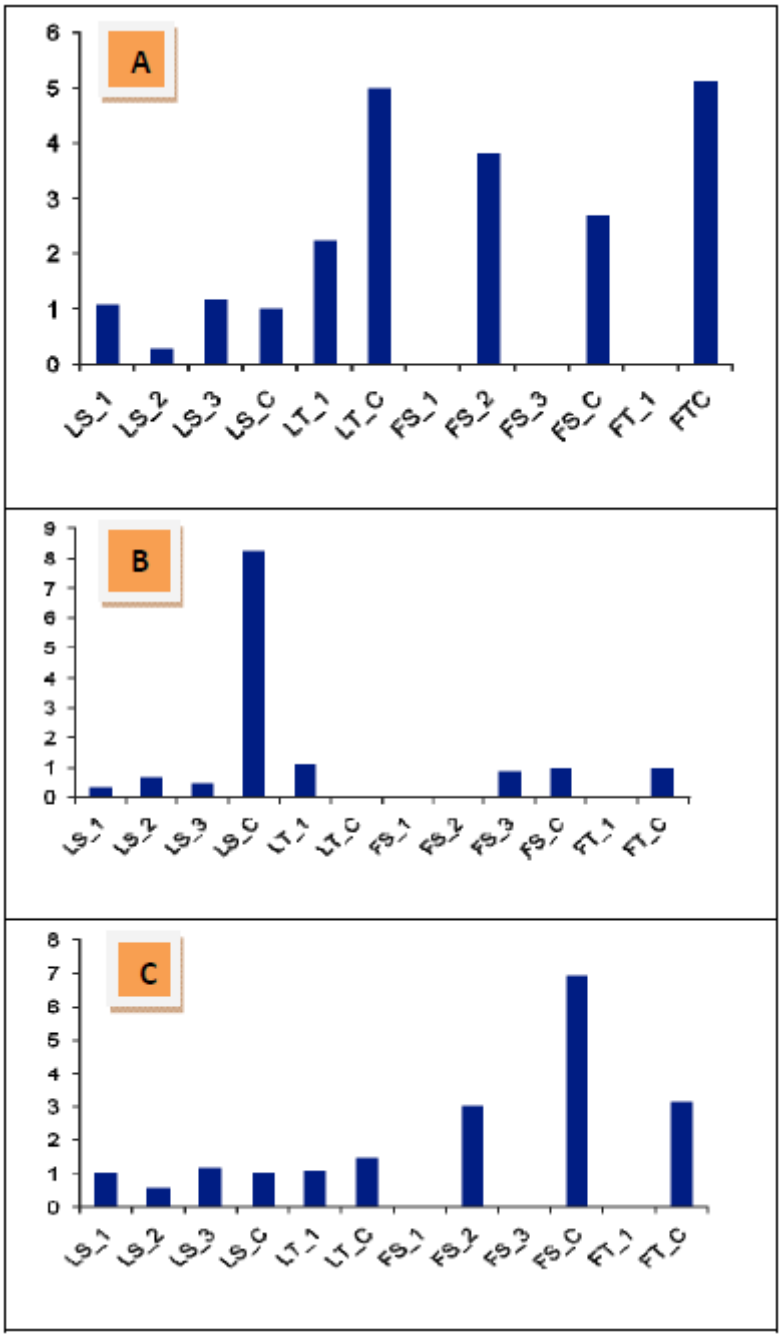


Fig. 5.12: A). Bar Graph Representing Relative Quantification of Xyloglucan Endo Transglycosylase B). Bar Graph Representing the Relative Quantification of Superoxide Dismutase and C). Represents the Relative Quantification of Alcohol Dehydrogenase

For all the figures on X-axis name of the sample is given and on Y-axis the sample's relative quantification is denoted. RT PCR does not show any amplification in the samples with missing bars.

5.2.6.7 Modified IDM Schedule

The modified IDM schedule at NRCP was tested in second year. The schedule gave 100% blight free yield of 11.45 kg/plant. The incidence of fungal spots/ rots was below 2%. No bactericides have been sprayed in the plot for last 24 months? ?. The use of bio-formulations including *Aspergillus niger* AN27 *and Rhizophagus irregularis etc.* were also found to check wilt in 4 year old plantation completely. In the treated plot no wilt incidence was recorded during last 3 years after initial wilt of 4 plants due to *Ceratocystis fimbriata* within 6 months of planting.

Modified IDM Schedule

- Adding Humic acid and Sulphur 80% @ 10g/plant for reducing soil pH and adding along FYM @ 40Kg/plant and vermicompost, poultry manure, neem cake
- Soil application of bioformulations (Aspergillus niger AN27 @1kg/acre and Mycorrhiza (*Rhizophagus irregularis* Syn. *Glomus intraradices*) @ 5 kg/acre) twice a year
- Giving severe stress to plants during hottest months for natural defoliation and leaving defoliated stems exposed to sun for 20-25 days before crop initiation
- Reduced and split doses of N after lemon size fruit stage along with potash and phosphorous
- Four Micronutrient and 4 salicylic acid 300 ppm sprays at 1 month interval starting at pre-flowering stage
- IDIPM sprays of fungicides and insecticides at 7–10 days interval as per requirement

Fig. 5.13: Plot with Modified Schedule in Flowering (Front) in Comparison to Plot without Modified Components (Rear)

Fig. 5.14: Produce with Modified IDM Schedule at Harvest

5.2.6.8 Front Line Demonstrations on Blight Management

Seven (7) FLDs in Bagalkot and Belgaum districts of Karnataka were conducted under Flagship project on bacterial blight for demonstration of NRCP-Integrated disease management schedule + UHS Bagalkot bioformulations (a. Consortia of *Trichoderma harzianum + Pseudomonas putida+Paecilomyces lilacinus+*nitrogen fixing bacteria+ chitosan and b.Chitosan + *P. putida*) under supervision of UHS Bagalkot. Bacterial blight reduction ranged between 72.84 to 89.38%, marketable yield varied from 9.5 to 16 t/acre and benefit :cost ratio in adopted orchards ranged from 1.27 to 1.51. Field days were conducted in some of these plots.

Table 5.8: Demonstrations of IDM Developed by NRCP Integrating Bioformulations Developed by UHS, Bagalkot Against Bacterial Blight of Pomegranate

S. No.	Name of the Farmer	Location	No. of Plants	Year and Season	Total Yield in MT/Acre	Per cent BBD Reduction	C:B Ratio
1	Mr. Manjunath Naik	Thulsigeri, Bagalkot, Karnataka	1400	Hasth bahar 2018	12.5	84.21	1:3.2
2	Mr. Maruthi M. Adiveppa	Govinakoppa, Bagalkot, Karnataka	950	Hasth bahar 2018	9.5	81.89	1:4.7
3	Mr. Appanagoud Patil Jinoour	Junnur Lokapura, Mudhol taluk, Belgaum, Karnataka	2100	Hasth bahar 2018	14.0	72.84	1:4.5
4	Mr. Krishna Salapur	Chikkasamshi, Bagalkot, Karnataka	1600	Mrig bahar 2018	16.0	77.62	1:4.1

Table 5.8 (Contd.)...

...Table 5.8 (Contd.)

S. No.	Name of the Farmer	Location	No. of Plants	Year and Season	Total Yield in MT/Acre	Per cent BBD Reduction	C:B Ratio
5	Mr. Manjunatha Biradar Patil	Thulsigeri, Bagalkot, Karnataka	700	Mrig bahar 2018	15.2	89.38	1:5.1
6	Mr. Desai	Honnakatti, Bagalkot, Karnataka	1400	Hasth bahar 2018	14.0	81.38	1:2.7
7	Mr. Rafiq Banglewale	Tulsigeri, , Bagalkot, Karnataka	1100	Mrig bahar 2018	9.8	79.64	1:5.1

Fig. 5.15: Front Line Demonstration on Bacterial Blight Management (UHS Bagalkot + ICAR-NRCP, Solapur) and Field Day at Bagalkot on Sep 29, 2018

Post-Harvest Management and Value Addition

6

CHAPTER

6.1 PROJECT: POST-HARVEST MANAGEMENT, VALUE ADDITION AND IMPROVING KNOWLEDGE OF STAKEHOLDERS FOR INCREASING PRODUCTION AND MARKETING OF POMEGRANATE

6.1.1 Fermentation Studies on Pomegranate and Sweet Orange Blended Juice

The suitability of sweet orange (*Sweet orange sinensis* L.) var. nucellar juice for blending with pomegranate (*Punica granatum* L.) var. Bhagawa juice and fermentation was studied for the production of quality wine using yeast *Saccharomyces Cerevisiae* (NCIM 3218). The juices were extracted using hydraulic press and analyzed for the physicochemical properties. The TSS of pomegranate, sweet orange and blended juice (pomegranate: sweet orange 70:30) was adjusted to 23° brix. The inoculum was added in pasteurized juices and blend which was fermented at 25°C for three weeks. The juices and fermentation products were analyzed for TSS, acidity, ascorbic acid, sugar content, total phenolic content, antioxidant capacity, total anthocyanin. The alcohol profile, minerals and vitamin composition of fermented product was studied. The blend wine was found to be rich in nutritional profile with total phenolic content of 1673.7 mg/L GAE, antioxidant capacity 29.01 mg/L of AAE and 62.92% inhibition by FRAP and DPPH method respectively. The anthocyanin content was found to be 17.39 mg/L of cyanidine. Mineral profile shows Potassium 214.5 mg/L, Sodium 33.94 mg/L, Calcium 2.70mg/L, Iron 4.12mg/L in blended wine sample. The vitamin B spectrum reveals 67mg/100g of Y vitamin B2 (riboflavin), and 13.3mg/100g of Vitamin B3 (nisin) and 1.04 mg/100g vitamin B5 (pentothenic acid) in blended wine sample. The blended wine was found to be highly acceptable in terms of taste, flavour, aroma, and overall acceptability.

6.1.1.1 Biochemical Parameters for Juice, Juice Blend and Wines

Biochemical analysis of juices, blend and their fermented products were depicted in table. The pomegranate juice has shown significantly higher TSS and total sugars as compared to sweet orange juice which has high acidity (35.13%) and ascorbic acid content (235.45%) as compared to pomegranate juice.

Table 6.1: Physicochemical Composition of Juice and Wine

Samples /Parameters	TSS (° B)	Acidity (%)	Ascorbic acid (mg/100 ml)	Total sugar (%)	Reducing Sugar (%)
Pomegranate Juice	14.1[a]	0.37[d]	14.16[d]	13.83[a]	12.8a
Sweet orange juice	10.4[e]	0.50[c]	47.5[a]	10.13[d]	9.2[c]
Juice blend	11.8[d]	0.39 [d]	23.76[c]	12.5[c]	11.2[b]
Pomegranate wine	12.4[c]	0.68[b]	12.5[d]	13.83[a]	12.8[a]
Sweet orange wine	7.6[f]	0.75[a]	37.5[b]	8.1[e]	6.7[d]
Blend wine	13.3[b]	0.67[b]	22.5[c]	13.8[a]	12.5[a]

At the end of fermentation process TSS was found to be reduced up to 12.4, 7.6 and 13.3 °brix respectively in pomegranate, sweet orange and blend wine showing higher conversion of sugars into alcohol in case of sweet orange wine.

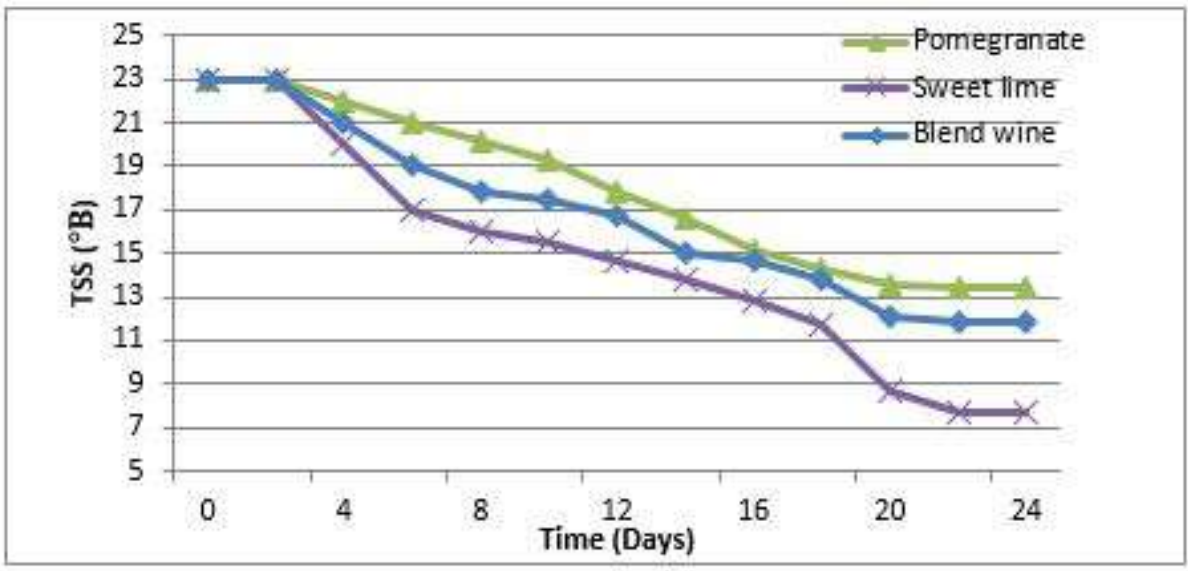


Fig. 6.1 : TSS Reduction During Fermentation Process

During fermentation TSS of blend, pomegranate and sweet orange wine decreased from 23 °B to 13.4, 11.9 and 7.7 °B respectively. The fermentation process was completed at the end of 20th day for pomegranate and blend wine while it took 22 days in case of sweet orange wine. This signifies the utilization of sugar by yeast cells for the alcohol production with consequent reduction in TSS. This also signifies yeast cells are supporting the sweet orange juice fermentation more effectively as compared to pomegranate juice. The blending of sweet orange juice with pomegranate enhances the rate of fermentation.

6.1.1.2 Bioactive Compounds in Juice, Juice Blend and Wine

The bioactive compounds such as total phenol content, antioxidant activity by FRAP and DPPH method, and anthocyanin content for pomegranate juice, sweet orange juice, blended juice P: S (70:30), pomegranate wine, sweet orange wine, blend wine were determined and depicted in table and figure. In table also shown nutritional superiority of pomegranate juice and wine over sweet orange juice and wine. the blended wine was found to be rich in total phenols, antioxidant activity and anthocyanin conent.

Table 6.2: Assessment of Bioactive Components

	Total Phenolic Content (mg/LGAE)	Antioxidant Activity FRAP Method (mg/L of AAE)	Antioxidant Activity DPPH Method (% Inhibition)	Anthocyanin Content (mg/L of Cynidine)
Pomegranate Juice	2546.66[a]	31.79[a]	73.44[b]	26.23[a]
Sweet orange juice	749.33[d]	19.24[e]	79.26[a]	14.71[e]
Blend Juice	2127.0[b]	28.7[f]	73.85[b]	22.67[b]
Pomegranate Wine	1982.3[bc]	29.74[b]	60.08[d]	20.76[c]
Sweet orange wine	568[d]	19.240[e]	77.51[a]	10.86[f]
Blend wine	1673.7[c]	29.01[c]	62.92[c]	17.39[d]

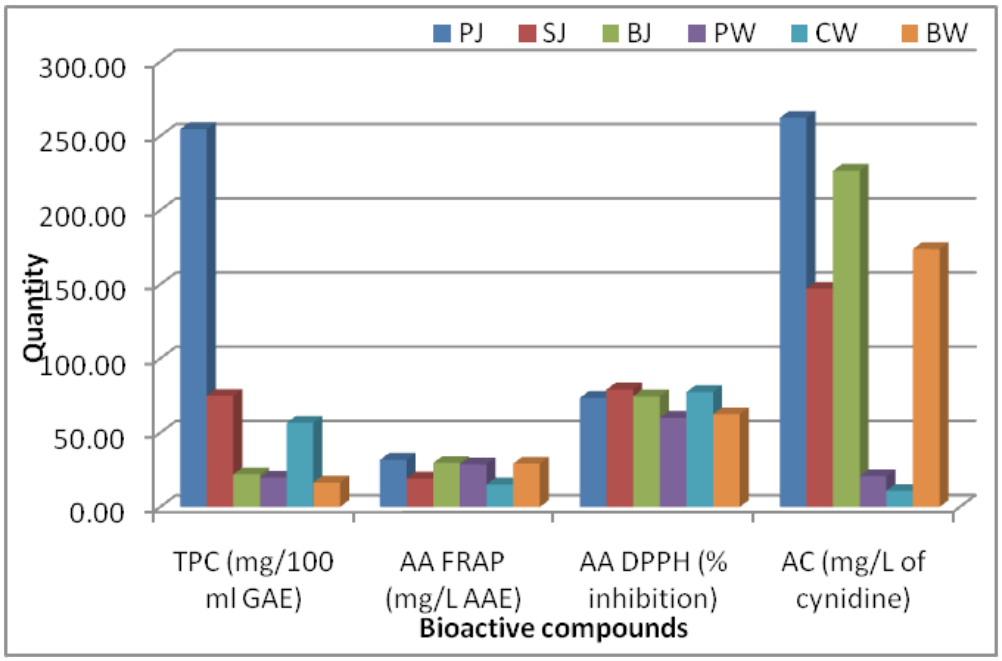


Fig. 6.2 : Bioactive Compounds in Pomegranate, Sweet Orange, Blended Juice and Fermented Products There of

(PJ: Pomegranate juice, SJ: Sweet orange juice, BJ: blended juice(70:30), PW: Pomegranate wine, CW: Sweet orange wine, BW: Blend wine, TPC: Total phenol content, AA: Antioxidant Activity, AC: Anthocyanin content)

6.1.1.3 Vitamin and Mineral Composition

The results of the vitamins and mineral composition suggests that vitamin B3, B6 which were absent in pomegranate wine were observed in blended wine as contribution from the sweet orange juice. The absence of vitamins B3 and B6 in pomegranate wine might be due stages of clarification and pasteurization in wine processing.

Table 6.3: Vitamin and Mineral Profile of Wines

Wine Sample	Minerals (mg/L)				Vitamins (mg/100 ml)			
	Potassium	Iron	Calcium	Sodium	B2 (Riboflavin)	B3 (Nisin)	B5 (Pantothenic acid)	B6 (Pyridoxine)
Blend wine	214.5	4.12	2.70	33.94	ND	0.067	1.3	0.1
Pomegranate wine	230.0	6.05	0.02	38.25	1.617	ND	0.6	ND
Sweet orange wine	166.68	1.65	9.41	8.46	0.17	0.04	ND	ND

6.1.1.4 Sensory Quality

The developed wines were analyzed for sensory score on nine point hedonic scale. The use of sweet orange in blending with pomegranate enhances the flavor, and aroma of blended wine significantly ($P<0.001$.) Flavor is one of the most important sensory parameters to determine the character and quality of wine. The pomegranate as such does not have any characteristics flavor or aroma however the sweet orange owing to presence of Limonene, β-myrcene, linalool, hexanal, ethyl butanoate does have its own characterstic aroma and flavor which is contributed in enhancement of flavor and aroma of blended wine over pomegranate wine. However, there is no significant difference in terms of taste, colour, mouthfeel, after taste parameters than pomegranate wine. Sensory evaluation studies on blend wine shows higher sensory acceptability especially in terms of flavour, aroma & taste than pomegranate and sweet orange wine.

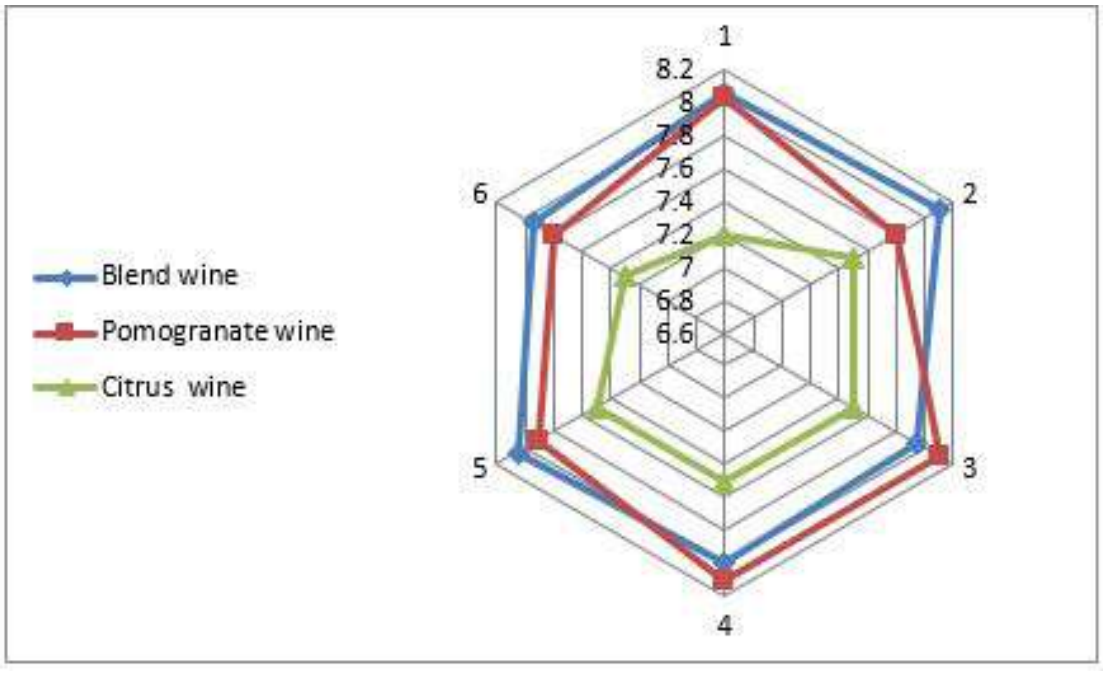


Fig. 6.3 : (1-Taste, 2-Flavor, 3-Color , 4-Mouth Feel, 5-Aroma & 6-after Taste) Radar Plot for Sensory Analysis of Developed Wines

6.1.2 Determination of Maturity Indices for Pomegranate Variety Solapur Lal

To determine the maturity indices for harvesting of pomegranate var. Solapur Lal, the flowers were tagged on the day of anthesis. The fruit samples were collected after fruitset an an interval of 15 days. Once maturity is approached, the samples were collected at 5 days interval to fix up the appropriate maturity indices for harvesting. Solapur Lal attained maturity at 160 days after anthesis.

Table 6.4: Maturity Indices for Pomegranate Variety Solapur Lal

Stage of Fruit Development (Days after Anthesis)	Fruit Weight (g)	TSS (°B)	Titrable Acidity (%)	TSS/Acid Ratio
90 days	175.2	13.0	0.58	22.4
105 days	201.6	14.2	0.51	27.8
120 days	226.4	15.3	0.48	31.9
135 days	249.2	16.2	0.45	36.0
150 days	268.6	17.0	0.42	40.5
160 days	275.0	17.6`	0.40	44.0
165 days	275.4	17.6	0.40	44.0

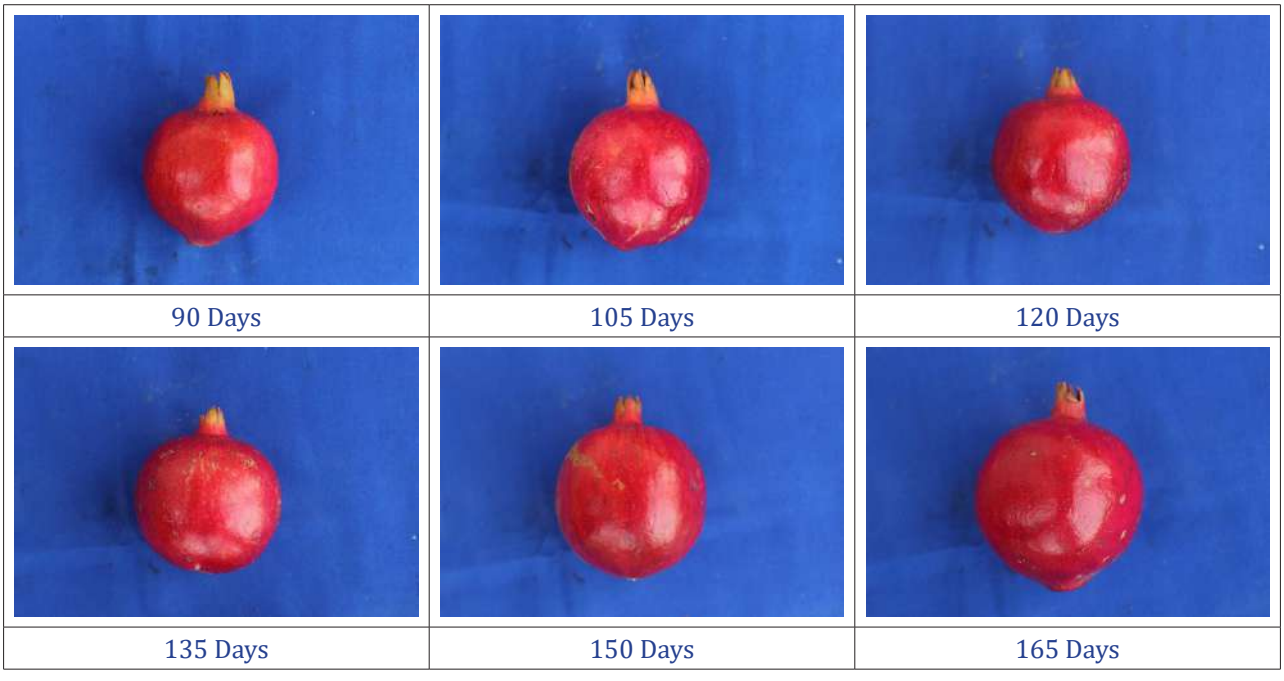


Fig. 6.4 : Maturity Indices for Pomegranate Variety Solapur Lal

6.1.3 Determination of Anardana Recovery

Anardana is the dried form of arils obtained by drying the arils of pomegranate in the hot air oven with air circulation facility. It is useful as souring agent. Preliminary results revealed that Anardana

recovery from 14 sour type pomegranate hybrids ranged from16.5–22.0%. Anardana recovery was highest in Solapur Anardana (21.8%) whereas it was lowest ub Amlidana (16.5%).

Table 6.5: Anardana Recovery from Pomegranate Hybrids

Sl. No.	Verities/ Weight	Anardana Recovery (%)
1	NRCP H-1	18.5
2	NRCP H-2	20.2
3	NRCP H-3	18.0
4	NRCP H-4	20.6
5	NRCP H-11	20.4
6	NRCP H-12 (Solapur Anardana)	21.8
7	NRCP H-15	20.5
8	NRCP H-21	21.2
9	NRCP H-23	21.0
10	NRCP H-25	21.6
11	6/4	19.2
12	6/5	18.2
13	HA	20.5
14	Amlidana	16.5

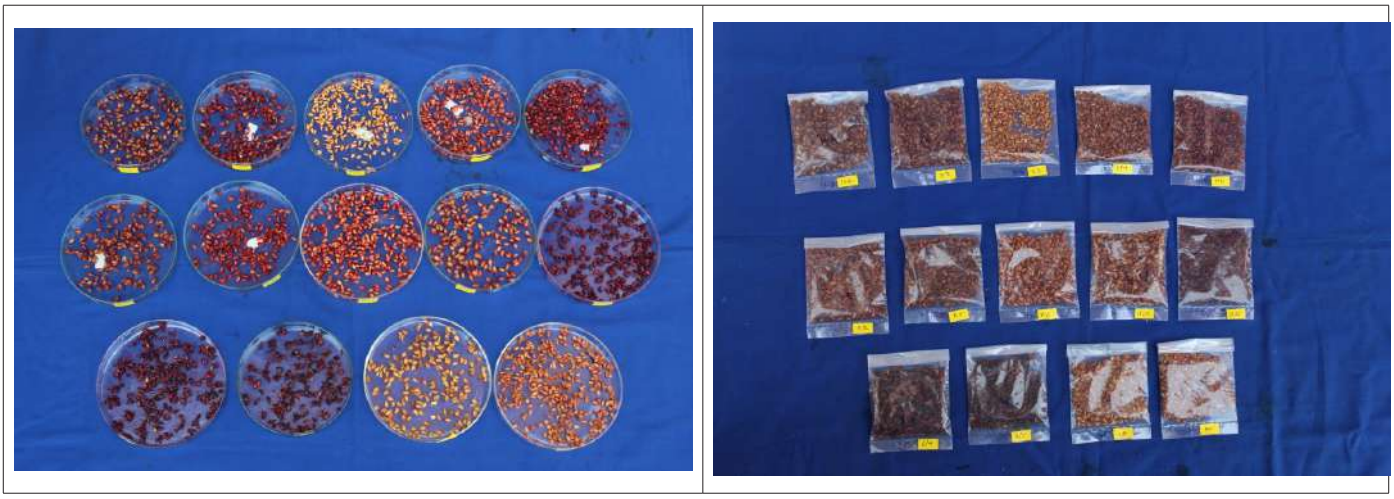


Fig. 6.5 : Top Row: H-1, H2, H3, H4, H11; Midrow: H12, H15, H21, H23, H25; Bottom Row: 6/4, 6/5, HA, Amlidana (From Left to Right) Anardana Prepared from Sour Type Pomegranate

7 CHAPTER

Externally Funded/ Collaborative Projects

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

During *mrig* bahar (2018-19), 18 pomegranate wild accessions characterized for 36 DUS characters as per PV&FRA guidelines. For the important selected traits the data showed that all the genotypes have tall growth with spreading habit. Shoot thorniness was found low in IC-318706, IC-318702 and IC-318707. Tree foliage density was sparse in 1201. Longer leaf blade was found in IC-318762. Narrower leaf blade was recorded in 1201, IC-318723, IC-318764, IC-318735, IC-318740, IC-318702, IC-318793 and IC-318749. All genotypes were found to have lanceolate leaves with obtuse apex shape. Medium anthocyanin coloration in petiole of IC-318705 was noted. Calyx length was medium in all accessions. Narrower calyx width was measured in IC-318744, IC-318740, IC-318702, IC-318793 and IC-318749. Orange coloured calyx and corolla was observed in all genotypes. All the accessions possessed short fruit length while IC-318707 had medium length. Smaller fruit diameter was found in IC-318705, IC-318735, IC-318740, IC-318702 and IC-318793. IC-318735 had oval shaped fruits while ovate in all other accessions. Thin rind was measured in IC-318754, IC-318723, IC-318790, IC-318753, IC-318779, IC-318705, IC-318762, IC-318724, IC-318706 and IC-318734. Pink colored arils were found in 1201, IC-318706, IC-318740, IC-318793, IC-318707. Aril length was short in all accessions. Aril width was narrow in IC-318754 and 318793. All the genotypes seeds were found to be hard. Short seed length was found in IC-318705, 318735, 318740, 318702 and 318749. Narrow seed width was observed in IC-318705. 17 genotypes (1201, IC-318723, IC-318790, IC 318779, IC-318705, IC-318762, IC-318764, IC-318706, IC-318735, IC-318740, IC-318712, IC-318793, IC-318707, IC-318749) were found have high TSS (^{0}Brix) content in juice. Higher juice acidity (%) was found in all accessions except IC-318740 showed medium acidity. IC-318705 showed medium fruit juiciness.

Fig. 7.1: Distinguishing Morphological DUS Characters in Pomegranate

7.2 PROJECT: UTILIZATION OF POMEGRANATE FOR DEVELOPMENT OF FUNCTIONAL MEDICINAL INGREDIENTS MICROENCAPSULATION OF POMEGRANATE SEED OIL BY USING SPRAY DRYING

The response surface methodology (RSM) is used for optimization of multi-factor process conditions, for determining the effects of each factor and its interactions. RSM was used for optimization of process variables (rice starch: whey protein isolate, inlet air temperature and oil load). From preliminary experimental results solid content (wall material content) was fixed at 30% in emulsion and process variables selected were as follows.

Table 7.1: The Experimental Conditions Used for Spray Drying Experiment

Wall Material Rice Starch: Whey Protein Isolate (RS:JSS)	Inlet Air Temperature (°C)	Oil Load (%)
1:3, 3:1 and 5:1	160, 170 and 180	20, 25 and 30

Pomegranate seed oil extracted from cold press at temperature of 60°C and pressure of over 550 Mpa for 2 hours. The native rice starch and whey protein isolate were used as encapsulating materials. The experimental Box Behnken design (Design expert software, 9.0, trail version) was used for microencapsulation of pomegranate seed oil by using different combinations of Starch (RS): Whey Protein Isolate (WPI) as wall material. The independent variables selected for the design were RS: WPI combinations, inlet air temperature and oil load with three levels of each factor.

The 30% solid content (wall material) was fixed in emulsion based on preliminary experiments for all sets of experiments. The different oil loads 20, 25 and 30% with respect to wall material added gradually with continuous stirring and then the mixture was homogenised with hand held homogenizer at 12000 rpm for 10 min. Spray drying process was carried out using the laboratory spray dryer (Make: Labultima; Model: LU-222 advanced). The evaporation rate of 1000 $mL.h^{-1}$ was used for this study. The spray dryer operating conditions feed flow rate (1.875 ml min^{-1}), aspiration rate (50 Nm^3h^{-1}), atomization flow (1 kg cm^{-2}), inlet high temperature (195°C), outlet high temperature (160°C), cool temperature (90°C) and log interval (200 min) for encapsulation were finalized after preliminary experiments. The spray dried microencapsulated pomegranate seed oil powder was collected immediately after each set of experiment and stored in airtight amber colour pouches for further analysis. The response variables encapsulation yield, encapsulation efficiency, moisture content, bulk density, tapped density, Carr's index and Hausner's ratio were analyzed in triplicate for all 17 set of experiments. Particle size analysis and surface morphology analysis for spray dried powder at optimum conditions were carried out using zetasizer and scanning electron microscope.

RSM was employed to optimize microencapsulation of pomegranate seed oil using a three-factor, three levels Box-Behnken design (BBD). The design setup consists of 17 experimental runs, including 5 centre point runs. The process conditions examined includes independent variables X_1= Rice starch and whey protein isolate combinations, X_2=Inlet air temperature (°C) and X_3 = Oil loading (%). The optimum conditions of process variables were derived using desirability function. Design Expert Statistical Software package 7.0.0 trial version (Stat-Ease Inc., Statistics Made Easy, Minneapolis, MN, USA) was used to perform statistical analysis. Analysis of Variance (ANOVA) was carried out to check significance of model and process variables.

The experimental design and responses namely microencapsulation yield, encapsulation efficiency, moisture content, bulk density, tapped density, Carr's index and Hausner's ratio determined under different experimental runs are depicted in table.

7.2.1 Effect of Process Variables on Yield

Yield of microencapsulated pomegranate seed oil powder varied from 82.56 to 89.00% under different experimental runs. The result of study showed that the increase in yield positively correlated with the increasing rice starch amount in wall material and inlet air temperature. Howerever, the microencapsulation yield increased initially and later decreased with increasing oil load. This phenomenon of reduced yield at the higher oil load can be explained with increase in viscosity with increased oil load which might have resulted in to bad atomization of the emulsion. The increase in yield with increase in rice starch might have been observed due low viscosity of rice starch. This might have lead to faster drying of microparticle solution and collection of dried powder without getting stuck in drying chamber. Increase in inlet air temperature led to increase yield which might be attributed to faster drying, no leaching of oil from capsules and thus reduced sticking of microparticles in drying chamber.

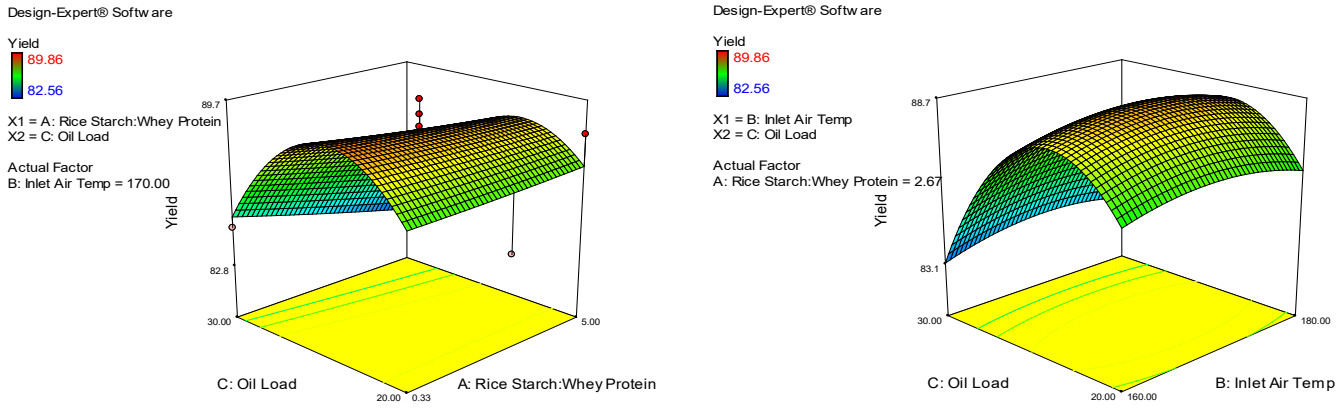


Fig. 7.2: Effect of Rice Starch and whey Protein Isolate Combination, Oil Load and Inlet Air Temperature on Microencapsulation Yield

Table 7.2: Experimental Design and Observed Responses of Encapsulated Pomegranate Seed Oil Powder with RS: WPI Coating Combinations

Run	Rice Starch	Inlet Air Temperature (°C)	Oil Load (%)	Yield (%)	Efficiency (%)	Moisture Content (%)	Bulk Density (g/cc)	Tapped Density (g/cc)	Carr's Index	Hausnerr's Ratio
1	1 (-1)	180	25	86.05	87.42	3.70	0.33	0.39	14.49	1.17
2	3	160	20	86.64	72.45	3.99	0.45	0.51	11.09	1.12
3	1	160	25	88.00	97.32	3.95	0.34	0.44	23.32	1.30
4	3	180	30	83.59	62.41	3.76	0.40	0.50	10.18	1.11
5	5	170	20	88.33	86.57	4.60	0.45	0.53	15.14	1.18
6	3	170	25	89.62	89.79	4.12	0.40	0.50	20.01	1.25
7	1	170	20	84.40	73.49	3.50	0.31	0.42	26.84	1.37
8	5	180	25	89.86	73.75	3.60	0.45	0.54	15.93	1.19
9	3	160	30	82.56	70.92	3.82	0.46	0.51	9.09	1.10
10	5	170	30	83.59	69.14	3.65	0.35	0.53	10.87	1.12

Table 7.2 (Contd.)...

...Table 7.2 (Contd.)

Run	Rice Starch	Inlet Air Temperature (°C)	Oil Load (%)	Yield (%)	Efficiency (%)	Moisture Content (%)	Bulk Density (g/cc)	Tapped Density (g/cc)	Carr's Index	Hausnerr's Ratio
11	3	170	25	87.50	85.00	4.00	0.37	0.47	22.00	1.28
12	3	170	25	89.00	89.00	4.15	0.36	0.41	19.61	1.24
13	3	170	25	88.50	86.00	4.25	0.37	0.49	18.50	1.23
14	5	160	25	83.20	77.59	4.14	0.45	0.51	11.09	1.12
15	3	180	20	87.22	67.14	4.01	0.37	0.50	26.02	1.35
16	3	170	25	88.25	88.70	3.99	0.41	0.46	17.88	1.22
17	1	170	30	84.43	91.57	3.93	0.31	0.46	11.54	1.13

7.2.2 Effect of Process Variables on Microencapsulation Efficiency

The encapsulation efficiency is an important indicator for microencapsulated particles and refers to the potential of the wall materials to encapsulate or hold the core material inside the microcapsule. Results revealed that the measured encapsulation efficiency varied from 62.41 to 97.32%. It was observed that increase in oil loading resulted increasing encapsulation efficiency initially and later on it was decreased. The reduced microencapsulation efficiency might be on account of insufficient coating material for encapsulation of the oil and this would have been resulted in more surface oil. Increase in inlet air temperature resulted in increased encapsulation efficiency. This could be due to sudden formation of semi-permeable membrane on the droplet surface at higher inlet air temperature which stops further leaching of oils to particle surface. Further increase in inlet air temperature resulted in to decrease in encapsulation efficiency this might be due to formation of cracks and fissures on the surface of the particles leading to coming out of oil to surface. At low oil load, increase in WPI increases encapsulation efficiency slightly. However, at higher oil load, as WPI increases the encapsulation efficiency increases significantly. Higher amount of whey protein isolate demonstrated higher microencapsulation efficiency.

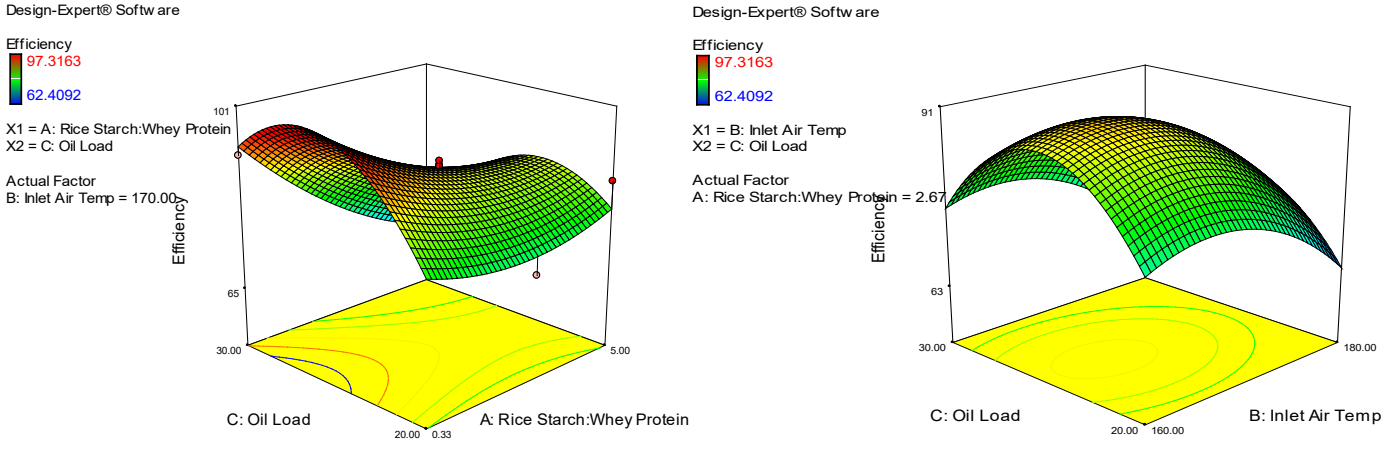


Fig. 7.3: Effect of Oil Load, Inlet Air Temperature and Rice Starch and whey Protein Isolate Combination, on Microencapsulation Efficiency

7.2.3 Effect of Process Variables on Moisture Content

Moisture content of microencapsulated pomegranate seed oil powder varied from 3.50 to 4.60% (w.b) under different experimental runs. The drying temperature is directly proportional to the evaporation rate and inversely proportional to the final water content of the dried microparticles.

At high drying temperatures, there is a higher evaporation rate of water on the droplet surface which leads to the rapid formation of a semipermeable membrane, resulting in the protection of the release of the bioactive compounds during the drying process and, consequently, in a higher bioactive retention. The higher air inlet temperature results decrease in moisture content of microencapsulated pomegranate seed oil powder. This might be due to decrease in relative humidity air with increased inlet air temperature which could have driven up more moisture from the microcapsules. Although the increase in oil loading at low rice starch contents shows the increase in moisture content, the increase in oil loading at high rice starch shows decreased moisture content.

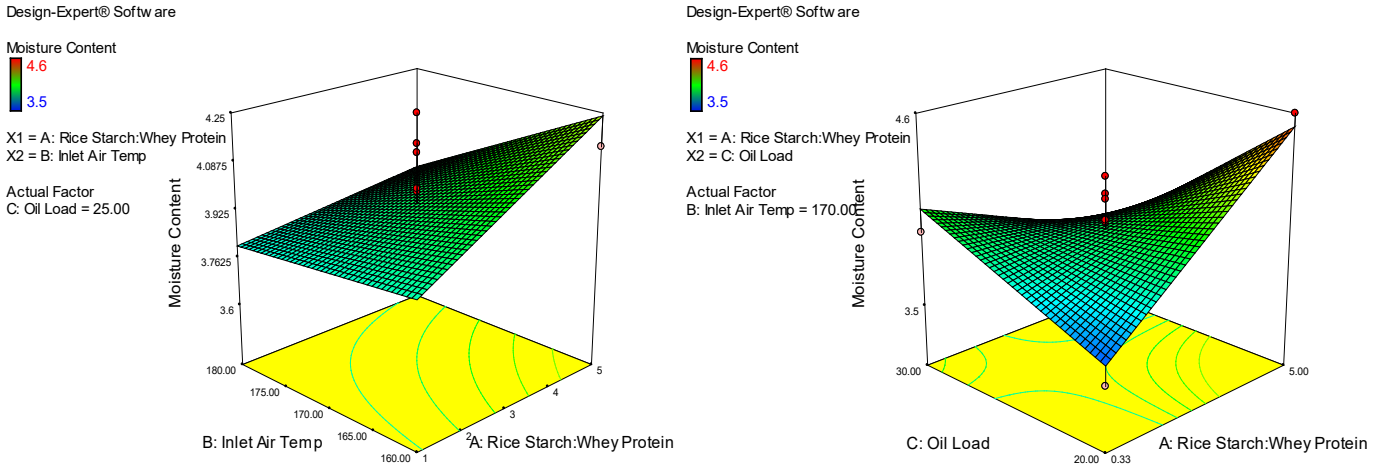


Fig. 7.4: Effect of Oil Load, Inlet Air Temperature and Rice Starch and whey Protein Isolate Combination, on Moisture Content of Microencapsulated Powder

7.2.3.1 Determination of Optimum Conditions

The Derringer's desirability function was employed for optimization purpose. Rice starch and whey protein isolate combination (1:3, 3:1 and 5:1), oil load (20, 25 and 30%) and drying inlet air temperature (160, 170 and 180°C) were set within range. The responses microencapsulation yield and microencapsulation efficiency was set for maximization and moisture content for minimization function. Based on the maximum desirability value (0 to 1), optimum conditions were selected

The predicted optimized process conditions using rice starch and whey protein isolate combinations as wall material were 23.73% oil loading, 1:3 rice starch and whey protein isolate combination and 161°C drying temperature with desirability of 0.83. The predicted values of microencapsulation yield, microencapsulation efficiency and moisture content after numerical optimization were 87.70%, 97.32% and 3.71% (wb) respectively. The observed responses of microencapsulation yield, microencapsulation efficiency and moisture were 84.10%, 93.90% and 3.90% (wb) respectively. Models were validated by comparing the predicted and observed responses of confirmation experiment.

7.2.4 Morphology of Microencapsulated Pomegranate Seed Oil Powder

Surface morphology of encapsulated microcapsules of pomegranate seed oil obtained at optimized conditions was studied and depicted in figure. Most of the particles are smooth spheres with little appendages and no fissures or cracks in the wall system. This smooth surface may be due to faster film formation, which also explains the better encapsulation efficiency and lower lipid oxidation observed in these powders.

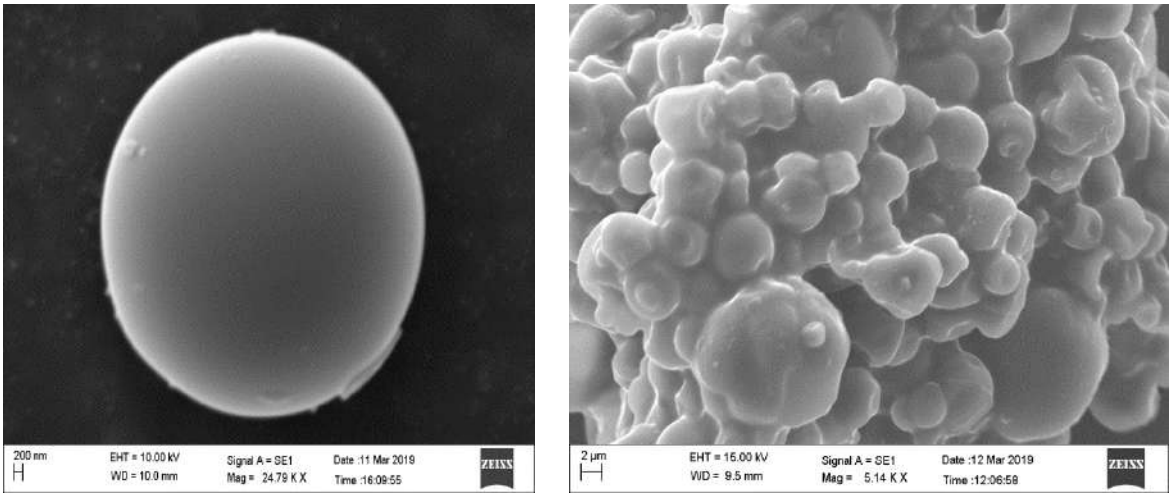
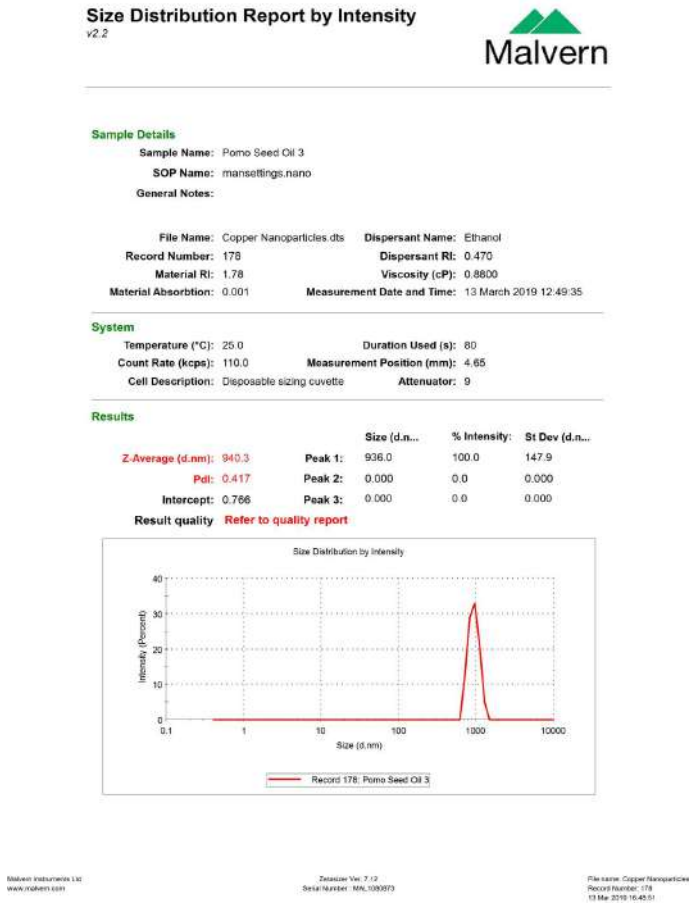


Fig. 7.5: Surface Morphology of Microencapsulated Pomegranate Seed Oil Powder Produced at Optimized Conditions

7.2.5 Particle Size Analysis of Microencapsulated Pomegranate Seed Oil Powder

The result of particle size analyzer (Zetasizer) revealed that pareticle size is 0.94 µm (940.3 nm). The single peak implies that particles are more homogeneous in nature.



Size Distribution Report by Intensity
v2.2

Malvern

Sample Details

Sample Name:	Pomo Seed Oil 3		
SOP Name:	mansettings.nano		
General Notes:			
File Name:	Copper Nanoparticles.dts	Dispersant Name:	Ethanol
Record Number:	178	Dispersant RI:	0.470
Material RI:	1.78	Viscosity (cP):	0.8800
Material Absorbtion:	0.001	Measurement Date and Time:	13 March 2019 12:49:35

System

Temperature (°C):	25.0	Duration Used (s):	80
Count Rate (kcps):	110.0	Measurement Position (mm):	4.65
Cell Description:	Disposable sizing cuvette	Attenuator:	9

Results

			Size (d.n...	% Intensity:	St Dev (d.n...
Z-Average (d.nm):	940.3	Peak 1:	936.0	100.0	147.9
PdI:	0.417	Peak 2:	0.000	0.0	0.000
Intercept:	0.766	Peak 3:	0.000	0.0	0.000
Result quality	Refer to quality report				

Fig. 7.6: Particle Size Distribution for Microencapsulated Pomegranate Seed Oil Powder Produced at Optimized Conditions

7.3 PROJECT: RESPONSE OF POMEGRANATE TO DEFICIT IRRIGATION AND PARTIAL ROOT ZONE DRYING

Field experiment was conducted during 2018-19 on light texture soil at National Research Center on Pomegranate, Solapur (latitude 17^{0}10$^{''}$, longitude 74^{0}42$^{''}$and 483.5 m msl) in the Western Part of Maharashtra to assess the deficit and partial root zone drying irrigation system at different phenological stages (*i.e.* new leaf initiation period, development, maturity, harvesting and rest period) of Pomegranate. The soil of the experimental site is tight texture soil throughout the soil profile. Layout of experiments at 4.5 X 2.0 m; 4.5 X 3.0 m and 4.5 X 4.0 m was given in figures.

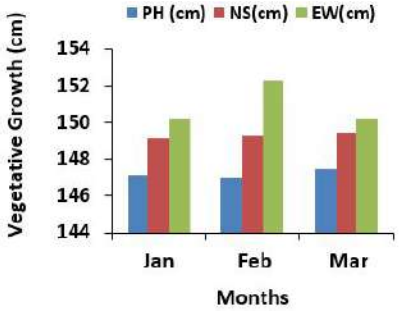
Spacing 4.5 x 2.0 m

Spacing at 4.5 x 3.0 m

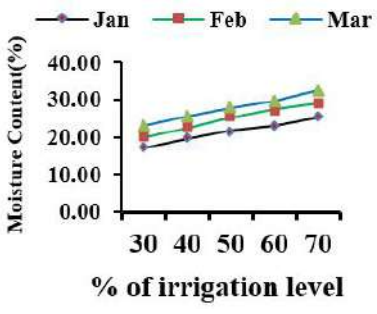
Spacing at 4.5 x 4.0

Fig. 7.7: Effect of DI on Vegetative Growth Performance, Soil Moisture, RLWC and Root Geometry

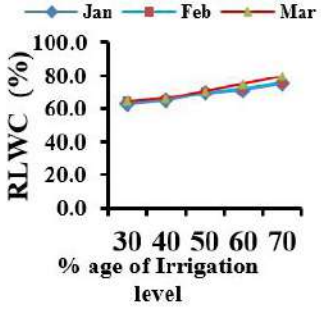
The result showed that, the performance evaluation of DI systems at different plant spacing and wetted soil volume at 40, 50, and 60% for 3rd, 4th and 5th year's old pomegranate orchards was the best. DI reduced moisture content and maximum plant height, branches and flowers is recorded in having WSV at 40, 50 & 60% and is given in figure**.** Soil moisture content and relative leaf water content under deficit irrigation is presented in figures. The moisture content and relative leaf water content in % age varies between 17.29 to 32.59 and 62.9 to 79.3% respectively.



Vegetative Growth in cm



Soil Moisture in % Age



RLWC in % Age

Fig. 7.8: Effect of PRZDI on Vegetative Growth Performance, Soil Moisture, RLWC and Root Geometry

The performance evaluation of PRZDI systems at 40% *ET$_c$, 60% *ET$_c$, 80% *ET$_c$ and 100% *ET$_c$ (control) having 20, 40, and 60% ASWD at drying side showed that less water produce good performance of vegetative growth, no water shoot and luxury. PRZDI reduced moisture content and maximum plant height, branches and flowers is recorded in having WSV at 100% * ET$_c$ with 20% ASWD and is given in figures. The moisture content and relative leaf water content varies between 23.5 to 31.8 and 62.9 to 79.3 per cent, respectively. The moisture content and relative leaf water content varies between 17.29 to 32.59 and 60.3 to 80.5 per cent, respectively.


40% with 20% ASWD


60% with 20% ASWD


80% with 20% ASWD


100% with 20% ASWD

Fig. 7.9

7.3.5.1 Vegetative Growth

The data pertaining to vegetative growth of plant presented in table indicate that these parameters significantly influenced by the various irrigation levels over control. Irrigation levels at 80 per cent by shifting irrigation of 20 per cent available soil water deficit (ASWD) showed higher plant height, plant spread and leaf area index (*i.e.* 2.70, 2.77, 2.78 per cent, respectively) in I_1*T_1, I_2*T_1 and I_3*T_1. It might be due to the application of needful irrigation with proper phenological stages to the better nutritional environment in the root zone as well as in plant system. The increase in plant height, spread and leaf area index was recorded highest at 80 per cent with 20 per cent shifting of irrigation at drying side for 5 year old pomegranate tree.

Table 7.3: Effect of Partial Root Zone Drying on Growths Characteristics for 5th Year Pomegranate Tree

Treatments	Plant Height(cm)	LAI (%)	Plant Spread (m)	
			E-W	N-S
Irrigation Levels				
I_1*40%	162.3	2.66	1.75	1.65
I_2*60%	165.6	2.71	1.45	1.62
I_3*80%	170.5	2.75	2.26	2.42
I_4*100%	172.6	2.77	1.87	1.75
Shifting of Irrigation at Drying Side				
T_1- 20% ASWD	174.2	2.78	1.80	1.96
T_2-40% ASWD	166.5	2.78	1.85	1.75
T_3-60% ASWD	165.2	2.89	1.85	1.65

7.3.5.2 Water Use Efficiency

The results revealed that pomegranate yield responded differently to different quantities of water applied through drip irrigation and it's presented in table. The influence of PRDZI with the quantity of irrigation water applied and is envisaged form the fact that, yield increment of pomegranate was recorded and irrigation water saved up to 20 per cent for 5th year pomegranate tree. The PRZDI water significantly influenced the mean yield which is evident from the fact that, the mean yield in absolute

quantities was considerably reduced in comparison to other irrigation level. Drip irrigation at 60 and 80 per cent level recorded better quantity parameters because drip irrigation and needful irrigation provided a consistent moisture regime in the soil due to which root remains active throughout the phase resulting in optimum availability of moisture and proper translocation of food materials which accelerated the fruit growth and development of quality characters in the fruits. The table clearly indicates that different irrigation level with sifting of available soil water deficit had a significant effect on water use efficiency of pomegranate. As regards different irrigation level with shifting of different available soil water deficit ASWD, maximum water use efficiency was 2.55 kg m^{-3} at 80 per cent with 20 per cent ASWD for 5th year pomegranate tree in *hasth bahar*.

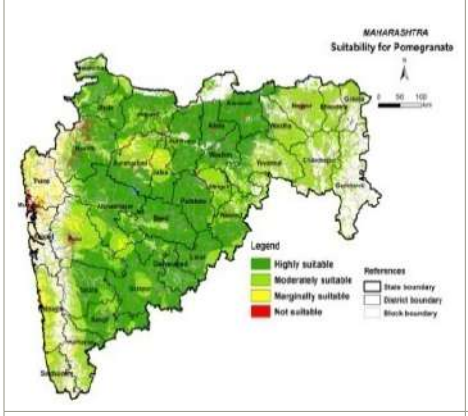
Table 7.4: Effect of Partial Root Zone Drying and Best Shifting of Irrigation on Yield Attributes and Water use Efficiency for 5th Year Pomegranate Tree

Best Treatments	No. of Fruits/ Tree (Nos.)	Av. Fruit Weight (gms)	Yield ($kgtree^{-1}$)	WU (m^3)	WUE (Kgm^{-3})
40%*20%ASWD	35	298	10.4	6	1.74
60%*20%ASWD	60	250	15.0	8	1.88
80%*20%ASWD	80	350	28.0	11	2.55
100%*20%ASWD	50	330	16.5	14	1.18

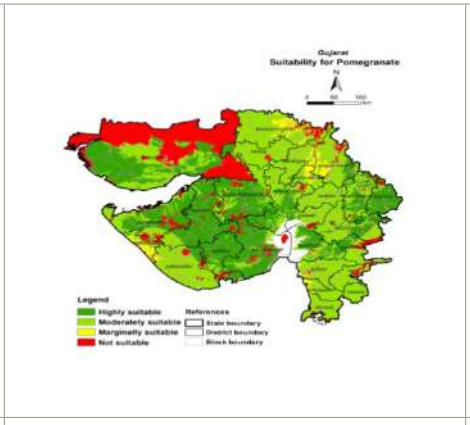
(**Note:** I_1-40% Irrigation, I_2 – 60% Irrigation, I_3-80% Irrigation, I_4-100% Irrigation, T_1- 20% ASWD, T_2- 40% ASWD and T_3- 60% ASWD **(Plant Spacing-4.5 x 2.0 m)**

7.4 PROJECT: DELINEATION OF POTENTIAL AREAS FOR POMEGRANATE CULTIVATION IN INDIA USING REMOTE SENSING AND GIS TECHNIQUES

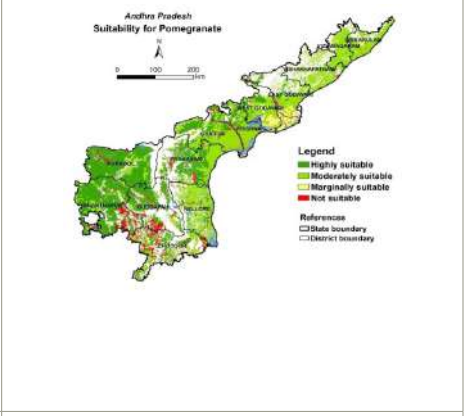
Pomegranate potential areas were identified in respect of highly suitable, moderately suitable, marginally suitable and not suitable based on rainfall, slope, soil depth, surface texture, drainage, soil reaction (pH), climatic parameters and 4-5 places surveyed actual ground tooth of the cultivated pomegranate area for verification. The developed GIS and remote sensing maps for 15 states of India is used for planning of pomegranate cultivation in non-traditional area. This suitability maps is developed through GIS and Remote Sensing techniques at NBSS & LUP, Nagpur.



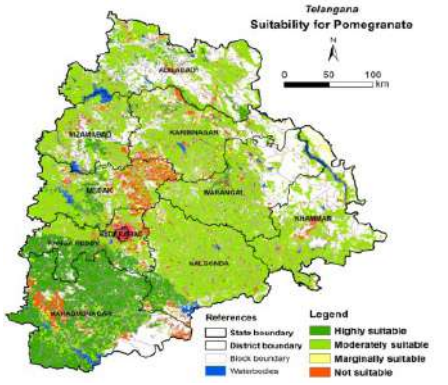
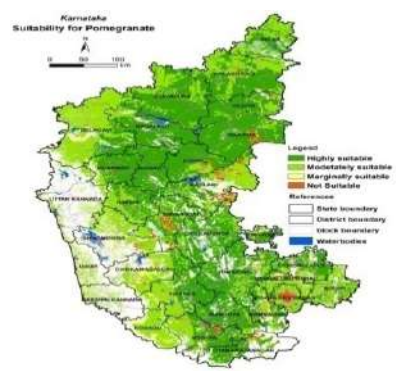
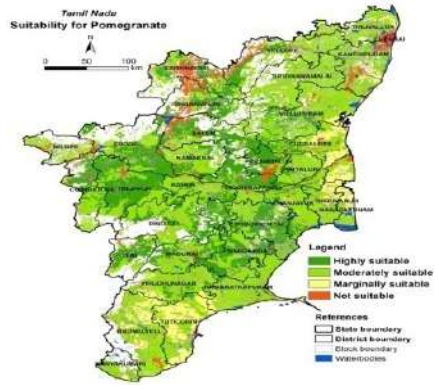
Maharashtra State



Gujarat State



Andra Pradesh State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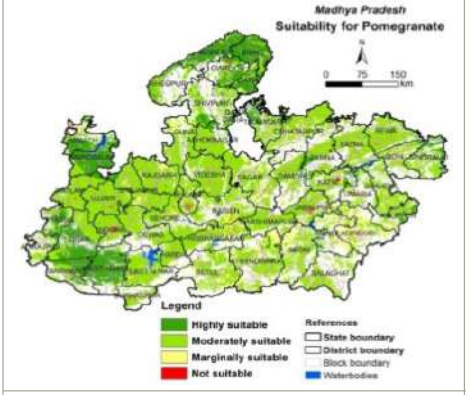
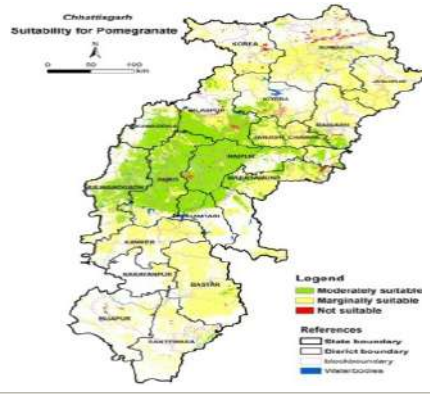
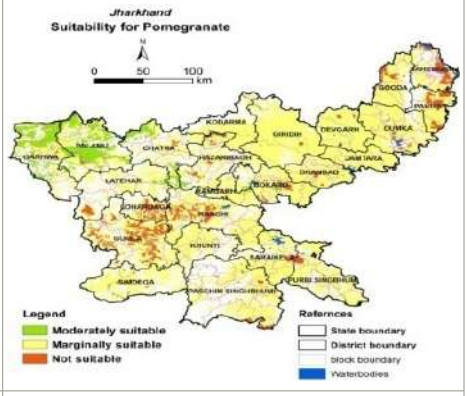
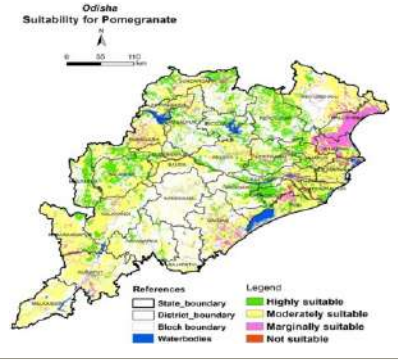
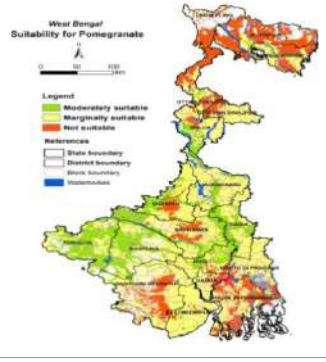
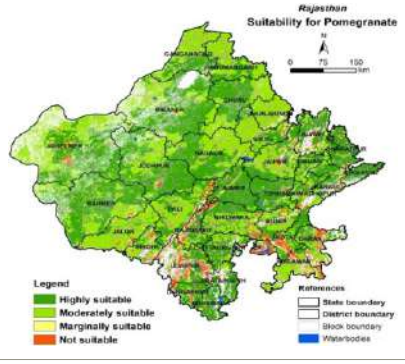
		
Madya Pradesh State	Chattishgard State	Jarkhand State
		
Odisha State	West Bengal State	Rajasthan State

7.5 PROJECT: STANDARDIZATION AND DEMONSTRATION OF PROPAGATION AND PRODUCTION TECHNOLOGY FOR PROTECTED CULTIVATION OF POMEGRANATE (*Punica granatum* L.)

An Field experiment was conducted during 2018–2019 on light texture soil at ICAR-NRCP, Solapur in the Western Part of Maharashtra to assess the performance of growth and climatic parameters under 35%, 50% shade net and control (open field) with RBD. The size of the each shade net house was 40 m x 20 m and size of the each open field plot was 6 m x 16 m. The plant to plant and row to row

spacing is 3.0 x 2.0 m. Fertigation and crop protection measures were adopted as per the package of cultivation practices. The varieties of pomegranate (*i.e.* Ganesh, Arakta, Mridula for 35% shade net, Super Bhagawa, Bhagawa, Solapur Lal for 50% shade net) and Bhagawa, Ganesh, Solapur Lal and Super Bhagawa was cultivated under shade net and open field of an experimental has been given in figures.

General View of the Shade Net House with 35 & 50% Shade

Internal View of the Shade Net House with 35 & 50% Shade

View of Open Field Plantations

7.5.1 Water Requirement under Shade Net House and Open Field

The daily water to be applied through drip irrigation system from July, 2018 to April, 2019 ranged from 2–19 $Ld^{-1}t^{-1}$ for 1st year old age of pomegranate tree at $0.30*ET_r$. It gradually increases or

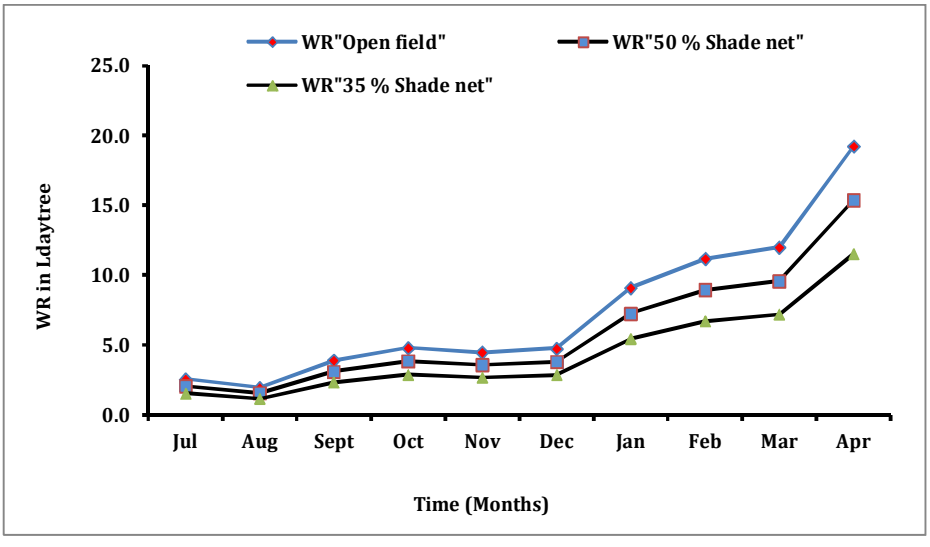


Fig. 7.10: Water Requirement of Plants in Open Field and Shade Net House (*i.e.* 35% & 50%) in $Lday^{-1}Tree^{-1}$

decreases during different development stages of pomegranate tree due to the variation of reference crop evapotranspiration, pan coefficient, wetted area and crop coefficient values. Lower Kc values represent slower plant growth and lower plant canopy cover, indicating lower ET_p. The ten months pomegranate evapotranspiration for shade net and open field water to be applied to pomegranate tree ranged from 1834 to 2293 Lt^{-1}. The water requirement in $Lday^{-1}t^{-1}$ including number of days for pomegranate Bhagawa cv. for open field and shade net (*i.e.* 35% & 50%) and in mentioned**.**

7.5.2 Growth Parameters

Bhagawa cv. of pomegranate was evaluated for their growth parameters in 50%, 35% shade net and open field. Plant height, plant spread (EW & SE), stem diameter, stem girth, thorn length and flowers ranged from 113 to 147 cm, 63 to 116 cm, 56 to 119 cm, 1.8 to 2.8 cm, 1.0 to 1.9 cm ,1.5 to 1.9 cm, 95 to 120 nos. and 90 to 110 cm,74 to 94 cm, 75 to 104 cm, 1.45 to 2.10 cm, 1.2 to 1.85 cm, 1.65 to 1.85 cm and 79 to 105 Nos.

Table 7.5: Growth Performance under 35%, 50% Shade Net House and Open Field Experimental Plots

1st Year Days	Plant Height (cm)	Plant Spread (cm)		Stem Diameter (cm)	Stem Girth (cm)	Thorn Length (cm)	Flowers
		EW	SE				
50% Shade net							
T1	130	98	92	2.5	1.9	1.9	105
T2	123	87	76	1.9	1.2	1.7	110
T3	114	63	56	1.8	1.0	1.9	90
35% Shade net							
T1	147	116	119	2.5	1.8	1.5	105
T2	113	98	91	1.9	1.5	1.6	120
T3	132	101	103	2.8	1.0	1.7	95
Open field							
T1	98.75	73.75	75.00	1.85	1.7	1.7	90
T2	90.00	78.75	86.25	1.50	1.6	1.65	85
T3	97.50	86.25	90.00	1.45	1.2	1.77	79
T4	110.00	93.75	103.75	2.10	1.85	1.85	105

(35% **shade net**- T_1- Ganesh, T_2-Arakata, T_3-Mrudula; 50% **Shade net**-T_1-Super Bhagawa, T_2-Bhagawa, T_3-Solapur Lal and T_4-Control (**Open field-**T_1-Ganesh, T_2- Bhagawa, T_3-Super Bhagawa & T_4-Solapur Lal))

7.6 PROJECT: EFFECT OF ZETOL SELECT WATER SOLUBLE FERTILIZER GRADES AND PRORISE SOLUTIONS OF NAGARJUNA FERTILIZERS AND CHEMICALS LIMITED ON POMEGRANATE YIELD AND QUALITY

A field trial was conducted with Zetol select water soluble fertilizer grades I (comprising of 6-45-6, 8-21-21 and 8-6-38), grade II (comprising of 6-40-10, 9-17-21 and 5-10-35) and ProRise package consisting of Actin, Durmalin and Multi-C of NFCL to evaluate their effect on pomegranate fruit yield

and quality applied in the fertigation programme. The results of first season trial are summarized below.

- The use of zetol select WSF grades (both normal and low pH) lowered soil pH and electrical conductivity significantly.
- Fertigation of plants with zetol select WSF grade II at 75% of RFD plus application of ProRise package maintained stable organic carbon level in soil contrary to the farmer's practice where it declined.
- Soil fertilized with zetol select WSF grade II & I maintained higher available N, P, K, S and DTPA extractable Fe and Cu content in soil during initial fruit growth period where they are mostly required.
- Fertigation with zetol select WSF grade II plus use of ProRise package maintained significantly higher K, Mg and Mn concentration in leaves at flowering and also continued to maintained higher N, P, K, Ca, Mg and Fe concentration in foliage at fruit maturity.
- Application of zetol select WSF grade II at 75% of RFD plus ProRise package increased fruit yield by 50% with significantly higher per cent fruits weighing >300 g.
- The use of zetol select WSF grade II with ProRise package also improved perceptibly various fruit quality attributes viz. aril per cent, ascorbic acid, anthocyanin and non-reducing sugar content in fruit. However, the said practice significantly lowered the phenol content in fruit.
- Fertigation of plant with zetol select WSF grade II plus application of ProRise package improved concentration of K, Mg and Fe in the fruit.
- Plant fertilized with zetol select WSF grade I at 75% of RFD plus application of ProRise package recorded least Cercospora fungal spot incidence on fruits.

T3: Zetol Select WSF Grade II at 75% of RFD Plus ProRise Package

T4: Zetol Select WSF Grade II of Low pH at 75% of RFD Plus ProRise Package

T7: Farmers' Practice

Fig. 7.11: Photos Showing the Response of Pomegranate Plant to Fertigation with Zetol Select WSF Grade II at 75% of RFD Plus Application of ProRise Package in Terms of Fruit Yield and Size

7.7 PROJECT: EVALUATION OF MCW-2 (2% GR) AGAINST ROOT KNOT NEMATODE (*Meloidogyne incognita*) IN POMEGRANATE

MCW-2 (Fluensulfone 2% GR) @ 40 gram per plant (i.e. 10 gram per dripper) and 50 gram per plant (i.e. 12.5 gram per dripper) as soil application below every dripper in different interval showed

effective control of root-knot nematode population with 200.3 and 179.85 gall/ 10g root and compare to Carbofuran @ 40/plant 424.44 galls./10 root and MCW-2 (Fluensulfone 2% GR) @ 30 gram per plant 403.63 gall/10 root wt. and in control 532.55 gall/ 10 of the root was found.

MCW-2 (Fluensulfone 2% GR) @ 40 gram per plant (i.e. 10 gram per dripper) and 50 gram per plant (i.e. 12.5 gram per dripper) as soil application below every dripper showed effective control of root-knot nematode population and was found on par with each other and superior over standard check treatments and untreated control.

MCW-2 (Fluensulfone 2% GR) @ 40 gram per plant (i.e. 10 gram per dripper) and 50 gram per plant (i.e. 12.5 gram per dripper) recorded significantly more marketable yield in comparison to standard check treatments and untreated control.

MCW-2 (Fluensulfone 2% GR) @ 40 gram per plant (i.e. 10 gram per dripper) and 80 gram per plant (i.e. 20 gram per dripper) did not show any phytotoxicity symptoms on pomegranate crop and found safe to use.

Application of MCW-2 (Fluensulfone 2% GR) did not cause any ill effect to soil-dwelling earthworm populations as well as there was no any harmful effect was noticed in per cent egg parasitization caused by a nematophagous fungus *(Paecilomyces lilacinus).*

Therefore, use of MCW-2 (Fluensulfone 2% GR) @ 40 gram per plant (i.e. 10 gram per dripper) can be suggested for effective management of root-knot nematode *(M. incognita)* in pomegranate.

7.8 PROJECT: FIELD EVALUATION OF THE BIO-EFFICACY OF SPINETORAM 12% SC AGAINST THRIPS AND FRUIT BORER OF POMEGRANATE

Among the five different concentration of Spinetoram 12% SC and standard evaluated against the borer and sucking pests of pomegranate the Treatment T3 @ 1.0 ml/l provide the better reduction of thrips with 90.32% followed by T2 (87.88) and least reduction was observed in T4 (80.22) and T5 (82.73). The incidence of the fruit borer and other sucking pest of pomegranate observed was low during the experimental period at 10 days interval with the least effect on the non-targeted insects in both control and treatments. Evaluation @ 1.0 and 2.0 ml/l water no phytotoxicity symptoms were observed with least effect on non-targeted insects.

Table 7.6: Different Doses of Spinetoram 12% SC w/v Evalauted Against Thrips and Fruit Borer in Pomegranate

Tr. No.	Name of the Insecticides	Dose ml/l with 0.25ml Sticker
T_1	Spinetoram 12% SC w/v	0.50
T_2	Spinetoram 12% SC w/v	0.75
T_3	Spinetoram 12% SC w/v	1.00
T_4	Spinetoram 12% SC w/v	2.00
T_5	Cyantroniliprole 10.26 OD	0.75
T_6	Untreated control	Water spray

7.9 PROJECT: DEVELOPMENT AND EVALUATION OF MUSTERED BASED ANTIMICROBIAL FORMULATIONS USING OTHER BOTANICALS FOR THE MANAGEMENT OF BACTERIAL BLIGHT AND INSECT PEST OF POMEGRANATE

In vitro evaluation of new mustered formulation against aphids, mealybug and scale insect mustered @ 1.0 g/l water gave 40% reduction of aphids over the control 24 hr. after treatment and 5g/l water against mealybug and scale insect gave 100% mortality after 24 hours of treatment. Bio-efficacy of the mustard based formulations were evaluated against fruit borer and sucking pests of pomegranate in organic block. Mustard formulation was sprayed in different doses however, 3.0 g/l dose alone or 1g/l dose in combination with other organic formulations were found effective It was found that thrips damage was lowest (4%) in treatment combination mustard formulation (1g/l) +Neem oil (3ml/l)+ Mustard oil (3ml/l) in comparison to control with 75% damage; Fruit borer damage was lowest (1.98%) in combination treatment of mustard formulation (1g/l) + Neem oil (3ml/l) where as in control damage was 11.32% and highest damage was in combinations where along with mustard formulation pongamia, mustard or castor oil was also used. Highest percentage (74%) of healthy fruits was in treatment combination with mustard formulation (1g/l) +Neem oil (3ml/l) + Mustard oil (3ml/l) in comparison to control having only 13.20% healthy fruits.

The bio-efficacy of new or modified mustard based formulation evaluated alone in five different doses/ against thrips. Among the different treatments T4 with dose @ 15g/litre water gave the better control of thrips 74.01% followed by T3 67.5% control, T2 and T1 (63.15 and 63.08) @ 5 and 3g/l water respectively in comparison to control and lowest reduction 24.5% was observed in control.

7.10 PROJECT: ICAR-AICRP ON ARID ZONE FRUITS, ICAR-CIAH, BIKANER

For MLT on Solapur Lal, it was planted along with Bhagwa, Phule Bhagwa Super and Ganesh; For MLT on Solapur Anardana, it was planted along with Amlidana and 1181. The plants are in establishment stage. Seven different propagules were also planted and established for comparative evaluation for resistance to biotic/abiotic stress.

Evalauted two doses of Cyantroniliprole 10.26% OD and Lambda cyhalothrin 5% EC and single dose of Fipronil 5% SC and Spinosad 45% SC was evaluated against borer and sucking pests of pomegranate. The treatment T2 provide the best control of thrips with 62.35% over the control followed by T4 (59.23%) and least reduction over the control was observed in T6 (52.48) and T5 (51.53). The incidence of the fruit borer and other sucking pest of pomegranate observed was too low during the experimental period for satisfactory evaluation.

Evaluated two doses of Cyantroniliprole 10.26% OD and Lambda cyhalothrin 5% EC and single dose of Fipronil 5% SC and Spinosad 45% SC was evaluated against borer and sucking pests of pomegranate. The treatment T2 provided the best management of thrips with 62.35% over the control followed by T4 (59.23%) and least reduction over the control was observed in T6 (52.48) and T5 (51.53). The incidence of the fruit borer and other sucking pest of pomegranate observed was too low during the experimental period for satisfactory evaluation.

Table 7.7: Bio Efficacy of New Insecticide Molecule Cyantroniliprole10.26% OD Against Pest Complex on Pomegranate

Formulations Tested Against Thrips and Fruit Borer			% Reduction of Thrips Over Control
T. No.	Treatments Details	Dose (ml/l) + 0.25 ml Sticker	
T_1	Cyantroniliprole 10.26% OD	0.20	55.45
T_2	Cyantroniliprole 10.26% OD	0.30	62.35
T_3	Lambda cyhalothrin5% EC	0.50	54.86
T_4	Lambda cyhalothrin 5% EC	1.00	59.23
T_5	Fipronil 5% SC	1.00	51.53
T_6	Spinosad 45% SC	0.25	52.48
T_7	Control	Water	-

7.11 PROJECT: HORTICULTURE CROP PEST AND DISEASE MONITORING PROJECT—HORTSAP

7.11.1 Horticultural Crop Pest and Disease Monitoring Project—HORTSAP

Survey of insect pests of pomegranate conducted in different parts of Maharashtra and Karnataka covering an area of 95 acre and 40 pomegranate orchards. The levele of infestation of thrips varied from to 4.0–72.5%, aphids 3–12%, whiteflies and mealy bugs 2–8%, fruit borer incidence varied from 7–18% and shot hole borer and stem borer incidence varied from 30–60%.

Activities under Tribal Sub-Plan

Table 1: Tribal Farmers Adopted by ICAR-NRCP, Solapur

State	District	Sub-District	Village	ST Population Benefited (Nos.)	Year of Adoption	Status as on 31.03.2019
Maharashtra	Gadchiroli	Sironcha	Bamani, Ranggapalli, Gumalkonda, Pochanpalli, Mukalliguta and Venkatpura	65	2014–15	Orchard Established and six orchards are in fruiting stage.
Chhattis garh	Koriya	Manendragarh	Gudru Bharatpur	15	2017–18	One orchard is in bearing and two new orchards established.
Madhya Pradesh	Anuppur	Kotma	Manmari Reusa Reula Chaka Baskhala Dhurvasin Chouhari Chapani Kadmaha Jaminiya Thoudha Baskhali Pathrodi Behratola	100	2017–18	Three new orchards established and fourteen are in bearing stage.
West Bengal	Bankura	Onda Ranibandh Bankura I Simlapal	Ratanpur Haludkanali Andharthola Mandalgram	290	2015–16	Orchards are in bearing stage.
West Bengal	Bankura	Sonamukhi Indpur Chhatna	Panchal Raghunathpur Chhatna 2 Ghosergram	250	2016–17	Orchards established first crop to be regulated
West Bengal	Purulia	Puncha Kashipur Balarampur	Bahadurpur Tilabani Tilai Dandudi Jasudi	150	2016–17	Orchards are in bearing stage, production was taken from early mrig bahar flowering.

Fig. 1: Pomegranate Orchard at Bankura and Purulia Districts of West Bengal in Flowering Stage

Fig. 2: Technical Inputs Provided to Tribal Farmers and Pomegranate Orchards at Gadchiroli, MS

Fig. 3: ICAR-NRCP's FLD Orchards under TSP at Kotma, M.P. and Koriya, Chhattisgarh

Table 2: Training Programmes/ Workshop Organized for Tribal Farmers

Sl. No.	Name of the Training Programme	Place	Date	ST Farmers Benefitted (Nos.)
1	Optimum pomegranate production in Hasta Bahar for tribal farmer's of Tikkamgad & Bundhelkhand regions, Madya Pradesh	ICAR-NRCP, Solapur	09.10.18-12.10.18	30
2	Two days farmers' fair for enhancing the stakeholders participation from the government department-cum-workshop on Pomegranate cultivation under Tribal sub-plan programme, jointly organized by ICAR-NRCP and SRIJAN	Kotna, Anuppur, M.P.	31.10-18 - 01.11.18	200
3	Skill development on nutrient and water management in pomegranate for tribal farmers of Gadchiroli district, Maharashtra	Vill.-Bamani, Tal-Sironcha, Dist-Gadchiroli	04.01.19	210
4	Training of pomegranate farmers and SRIJAN staff Tikkamgarh, Anuppur and Koriya	Kotma and Tikkamgarh, M.P. and Koriya, Chhattisgarh	19.02.19-23.02.19	60
5	Training of tribal farmers of Kotma district on ideal pomegranate practices	Thodha village, Kotma, Anuppur, M.P.	17.06.19	50

Fig. 4: Glimpses of Training Programmes and Workshop Organized by ICAR-NRCP under TSP

Outreach Activities

TRAININGS/ WORKSHOPS/ FARMERS FAIR/ FIELD DAY

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

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

S. No.	Title of Training/ Workshop/ Farmers Fair/ Field Day/ FLD	Venue	Date	Participants (No.)
1	International Conference at KVK, Baramati	KVK, Baramati, Pune	11.04.18	100
2	Technical program of the Annual Zonal Workshop of KVKs under the jurisdiction of ICAR –ATARI, Zone VIII, Pune	MPKV, Rahuri	05.05.18	50
3.	Farmers' fair on Pomegranate Production technology for Doubling Farmers Income	Bhavaninagar, Indapur Tk., Pune.	19.05.18	500
4.	Pomegranate field day on Arka Microbial consortium	Gonihalli, Hulikunte Hobli, Shira Tk., Tumkur,	02.06.18	250
5.	Training programme cum awareness programme to pomegranate growers of Arasikere	Shashival Village Arasikere Hobli, Hassan..	18.06.18.	300
6.	QRT meeting of ICAR-NIASM, Baramati	ICAR-NIASM, Baramati	08.07.18	25
7.	Management of Bacterial blight and value addition opportunities in Pomegranate crop	Paithan, Aurangabad	08.08.18	78
8.	Field day (three days) organized by UHS Bagalkot	HRS, Thidagundi Bijapur; FPO, Kaladagi and Ankasamudra, Bellary	08.08.18-10.08.18	100
9.	Inauguration of Microbiology Club Programmes	DBF Dayanand College of Arts and Science, Solapur	13.08.18	50
10.	Seminar cum Training programme on Exportable quality pomegranate production and marketing	Gobichettipalayam, Erode.	06.09.18-08.09.18	300
11.	Field Day on Application of biologicals in integrated crop management'	Chikkasamshi, Bagalkot	29.09.18	100
12.	Seminar cum Training program on Exportable quality pomegranate production and marketing	SAU, Jodhpur	03.10.18-04.10.18	75

Table 1 (Contd.)...

...Table 1 (Contd.)

S. No.	Title of Training/ Workshop/ Farmers Fair/ Field Day/ FLD	Venue	Date	Participants (No.)
13.	Exibition-2018 by Sakal Agrowon	Achievers Multipurpose hall, Solapur	04.10.18-06.10.18	780
14.	Agriculture Technology Week- KVK, Bableshwar.	Bableshwar, Ahmednagar	06.10.18-08.10.18	650
15.	Plant diagnostic camp on pomegranate	Karkhamb, Pandharpur	30.10.18	60
16.	One-day training programme on Insect pest and disease of pomegranate and their management	KVK Mohol	15.11.18	200
17.	One-day training programme on Insect pest and disease of pomegranate and their management	KVK Mohol	30.11.18	250
18.	World Soil Day 2018	KVK Mohol, Solapur	05.12.18	50
19.	Skill development on nutrient and water management in Pomegranate for tribal farmers Maharashtra under CRP on Water project.	Mukaligutta, Sironcha, Gadchiroli	04.01.19	210
20.	Front Line Demonstration (FLD-10 nos) at tribal farmers field, Sironcha Taluk,Gadchiroli.	Bamani, Ranggapalli, Gumalkonda, Pochanpalli, Mukalliguta and Venkatpura; Sironcha, Gadchiroli.	04.01.19	100
21.	District level Mahila Mela, Solapur	KVK, Solapur	18.01.19	50
22.	National Conference on Contemporary Research in Life Sciences and Cancer Biology	DBT, V.G. Shivdare College of Arts, Commerce and Science, Solapur	19.01.19	100
23.	Field day on the Effect of fertigation with Zetol select water soluble fertilizers grades and ProRise package of NFCL on pomegranate fruit yield and quality.	Kegaon village, Solapur	24.01.19	50
24.	Agriculture Technology Week of KVK	KVK Mohol, Solapur	29.01.19	75
25.	One day workshop by Directorate of Horticulture Krushi Bhavan, Gandhinagar	Dhrangadhra, Surendranagar	13.02.19	100
26.	Field Day for farmers	Paniv, Malshirus, Solapur	16.02.19	100
27.	Cluster Seminar on Pomegranate at the Centre of Excellence for Pomegranate (Indo –Israel Action plan)	Dhindhol -Bassi, Jaipur	01.03.19-02.03.19	75

SCIENTIFIC AGRO ADVISORIES

In response to quires of farmers, information on pomegrante was provided to the farmers through e-mail and mobile phone. Scientific agro-advisories were sent to more than **2934** pomegranate growers through the "m-Kisan portal" during the period under report.

Lokmat Agrotsav–2019 at Market Yard, Pandharpur, Dist. Solapur Feb 13–16, 2019

Global Farmers Fair at KVK Narayangaon, Jan 3–6 2019

Krishidham Expo 2019 at ICAR-CPRI Meerut U.P., Feb 15–17, 2019

KISAN Agriculture Trade Fair at Pimpri-Chinchwad, Maharashtra, Dec 12–16, 2018

Fig. 1: Participation of ICAR-NRCP in Different Exhibitions All Over India

Transfer of Technology and Entrepreneurship Development

ICAR-NRCP, Solapur organized the following trainings, workshops/ field day/ FLD, Technology transfer agreement for entrepreneurs/ 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

S. No.	Name of Training Programme	Participants (Nos.)	Date
	Duration: 3 Days or More Duration		
1	Three Days Training Programme on Skill Development in Pomegranate Production and Value Addition in Pomegranate for The Farmers of Dhule, Maharashtra	22	28.05.18–30.05.18.
2	Four Days Exposure Visit-Cum-Training on Pomegranate to Second Year B.Sc (Ag.) Students, Institute of Agrl. Sciences, BHU, Varanasi, U.P.	18	21.06.18–24.06.18
3	Three Days Training Programme on Model Production and Protection Practices in Pomegranate for Staff of EPC Industries Ltd, (Mahindra Group of Company) Nasik, Maharashtra	26	10.07.18–12.07.18
4	Four Days Training Programme on Propagation, Model Production Practices and Value Addition in Pomegranate for Pomegranate Growers And Officers of Madhya Pradesh, India	20	21.08.18–24.08-18
5	Training on Optimum Pomegranate Production During Hasth Bahar in Tikamgarh & Bundelkhand Regions of M.P.	30	09.10.18–12.10.18
	Duration: Below 3 Days		
1	Training on Pomegranate Cultivation Marketing and Utilization for the Farmers of Anantpur, Andhra Pradesh	25	13.04.18
2	Training on Skill Development in Pomegranate Production for the Staff of Bayer Crop-Science Ltd.	40	13.06.18–14.06.18
3	Training on Ideal Pomegranate Practices for Tribal Farmers of Thodha Village, Kotma District, Madhya Pradesh	50	17.06.18
4	Training to students of Rajarshi Chhatrapati Shahu Maharaj College of Agri-business Management, Sangli	16	19.03.19
5	Training to Students of College of Agriculture, Osmanabad	57	25.03.19

Field Day on the Effect of Fertigation with Zetol Select Water Soluble Fertilizers Grades and ProRise Package of NFCL on Pomegranate Fruit Yield and Quality.-24.01.19, Kegaon, Solapur

Training to Students of Inst. of Agrl. Sciences, BHU, Varanasi

Workshop on Quality Production and Processing in Pomegranate: Issues & Strategies, ICAR-NRCP, 09.07.18

Dr. R.K. Pal, Ex-Director, ICAR-NRCP Addressing the Audience

Training of Tribal Farmers on Ideal Pomegranate Cultivation

Training of Tribal Farmers of Kotma, Anuppur

Workshop on Management of Bacterial Blight and Value Addition Opportunities in Pomegranate at Paithan, Aurangabad, 08.08.18

Visit of Ramnagara Farmers, Karnataka, 15.12.18

Fig. 1: Training Programmes by ICAR-NRCP, Solapur

CAFT Trainees from UHS Bagalkot, 22.01.19

College of Agriculture, Osmanabad, 25.03.19

Awareness to Trainee Participants about the Different Insects Pests and their Symptoms of Damage on Different Parts of Pomegranate

Training to Staff of EPC Industries Nasik (A Mahindra Group Company) Pvt. Ltd., 10.07.18–12.07.18

Fig. 2: Training Programmes by ICAR-NRCP, Solapur

Table 2: Workshop/ Field Day/ FLD Conducted

S. No.	Name of Training Programme	Participants (Nos.)	Date
1.	One day Workshop on Quality Production and Processing in Pomegranate: Issues & Strategies, for farmers of Maharashtra, Karnataka and Telangana.	225	09.07.18
2.	Foundation day and workshop on Addressing farmers' issues in pomegranate production, protection and marketing	220	25.09.18
3.	Mahila Kisan Goshti at Pimpri, Tk Barshi, Solapur	100	15.10.18
4.	Two days farmers' fair - cum- workshop on "Pomegranate cultivation under Tribal sub-plan programme" for enhancing the stakeholders participation from the Government, jointly organized by ICAR-NRCP and SRIJAN	200	31.10.18–01.11.18
5.	Workshop on Eradicate Corruption: Build a New India under Vigilance Awareness Week organized at ICAR-NRCP, Solapur -	18	01.11.18

TECHNOLOGY TRANSFER AGREEMENT

For Entrepreneurs

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

Table 3: MoU with Entrepreneurs

S. No.	Technology Transferred	Address of Beneficiary	Date of MoU	Revenue received (Rs)
1.	A novel bio-formulation for potassium fertilizer supplement and process of preparation thereof.	M/s. Natura Crop Care #4, DITP, Textile Park, Doddaballapur, Bengalaru-561 203	15.05.18	250000/-+ GST Total= 2,75000/-
2.	Propagation of planting material of pomegranate var. Solapur Lal through micropropagation	M/s. HU Gugle Agro Biotech Company Survey No. 562, Karmala Road, Jamkhed, Dist. Ahmednagar, MS	17.08.18	1,00,000/- +GST @ 18% Total= 1,18,000/-
3.	Propagation of planting material through air layers/ hard wood cutting of pomegranate var. Solapur Lal	M/s Mohite Farm A/P Kati, Tal. Indapur, Dist. Pune, Maharashtra, India 413 120	31.08.18	90000+18%GST Total= 1,06,200/-
4.	Development of pomegranate juice and RTS beverage	Mr. Bhushan Anant Pukale Khardi, Tal- Pandharpur, Dist- Solapur. 413 317	23.10.18	75,000/-+ GST@18% Total=
5.	Propagation of planting material of pomegranate var. Solapur Lal through air layering/ hard wood cutting	Agricultural Development Trust's Krishi Vigyan Kendra, Baramati, At post Malegaon Khurd Tal. Baramati Dist. Pune, Maharashtra- 413 115	16.11.18	90000/-+GST @18% Total= 1,06,200/-
6.	Process of minimal processing and shelf life extension of minimally processed arils.	Ramagiri Food and Technology (P) Ltd.,39, Ramagiri, 7th Cross, Sharadhamba Temple Road, Jalahalli Village, Bengaluru 560 013	18.02.19	100000/-+GST @18% Total= 1,18,000/-
7.	DPR for minimal processing and packaging of arils	M/S Karvi Agro processing Producer co Ltd.	31.12.18	94,100/-

For Students

Table 4: MoU with Academic Institutes

S. No.	Programme	Beneficiary & Address	Date	Revenue Generated (Rs.)
1.	Students of UG and PG research	DBF Dayanand College of Arts & Science, Dayanand Nagar, Solapur	21.08.18	Nil
2.	Students of UG research	K.K. Wagh College of Agricultural Biotechnology, Nashik	26.12.18	10,000/-
3.	Student for UG, PG and Ph.D. research	Tulajaram Chaturchand College, Baramati, Pune	22.02.18	30,000/-
4.	Students of UG and PG research	Agriculture and Allied Colleges, Loni-Pravara, Pravara Rural Education Society, Pravaranagar, Ahmadnagar	04.01.19	Nil
5.	Students of UG and PG	Shivdare College of Arts, Science and Commerce, Solapur	01.07.18	70000/-
6.	Students of UG	Walchand College of Arts and Science, Solapur	01.07.18	20000/-

Table 5: Exhibitions

S. No.	Name of the Exhibition	Organizer	Venue	Participants (No.)	Date
1.	Exhibition-Workshop on Quality Production and processing in Pomegranate: Issues & Strategies	ICAR-NRCP, Solapur	ICAR-NRCP, Solapur	78	09.07.18
2.	Exhibition-14th Foundation Day of ICAR-NRCP, Solapur	ICAR-NRCP, Solapur	ICAR-NRCP, Solapur	180	25.09.18
3.	Agrowon Exhibition	Agrowon Sakal	Achievers multipurpose hall, Solapur	770	04.10.18-06.10.18
4.	Exhibition-Technology week of KVK, Bableshwar	KVK, Bableshwar	Bableshwar, Ahmednagar	650	06.10.18-08.10.18
5.	Exhibition, Solapur Social Foundation	Solapur Social Foundation	Pune	930	16.11.18-18.11.18
6.	Krishithon-2018, Nashik	CRM Media exhibitors	Nashik	800	25.11.18
7.	Exhibition on occasion of World Soil Day	KVK -Mohol	KVK, Mohol, Solapur	42	05.12.18
8.	KISAN Agriculture Trade Fair	KISAN	Sector No. 5, Moshi, Pimpri-Chinchwad	8200	12.12.18–16.12.18
9.	Global Farmers Fair	KVK, Narayangaon	KVK, Narayangaon	470	03.01.19–06.01.19
10.	Exhibition–QRT meeting of ICAR-IIMR, Hyderabad	ICAR-IIMR, Solapur	ICAR-NRCP, Solapur	57	21.01.19
11.	National Horticulture Fair-2019	ICAR-IIHR Bangalore	ICAR-IIHR Bangalore	1690	23.01.19–25.01.19
12.	Krishi Dham Expo-2019	ICAR-CPRI, Meerut	ICAR-CPRI, Meerut	1400	15.02.19–17.02.19
13.	Lokmat Agrotsav-2019	Lokmat News	Market yard, Pandharpur,	950	13.02.19–16.02.19

POMEGRANATE GROWERS/ VISITORS TO ICAR-NRCP, SOLAPUR

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

Table 6: Visitors to ICAR-NRCP

S. No.	Date	Organization/ Place of Beneficiaries	Category	No. of Beneficiaries
1.	13.04.18	Anantpur District, A.P.	Farmers	35
2.	24.04.18	Baramati, Pune, M.S.	Farmers	19
3.	20.08.18	Kachchh, Gujarat	Farmers	40
4.	29.08.18	Karnool, Telangana	Farmers	35
5.	21.12.18	KVK, Mohol	Farmers	25
6.	21.12.18	Kachchh, Gujarat	Farmers	52
7.	22.01.19	Mehakar area, Buldhana, MS	Farmers	14
8.	23.01.19	Mehakar area, Buldhana, MS	Farmers	14
9.	20.01.19	Lonar area, Buldhana, MS	Farmers	24
10.	28.02.19	Tuljapur, Osmanabad, MS	Farmers	15
11.	30.01.19	Morbi area, Gujarat	Farmers	45

Institutional Activities

COMMITTEE MEETINGS: RAC, IRC, IMC, IJSC

The meeting of the 12th Research Advisory Committee (RAC) of ICAR- National Research Centre on Pomegranate was held on September 05, 2018 at ICAR-NRCP, Kegaon, Solapur under the Chairmanship of Dr. RB Deshmukh, Former Vice Chancellor, MPKV Rahuri. The committee visited experimental site at NRCP farm and also in polyhouse. They interacted with concerned scientists and gave valuable suggestions to improve the experimental output. They also visited the block at Hiraj to see newly released variety, 'Solapur Lal'. The RAC members were briefed on the developments at the Centre during 2012 to 2018 by Dr. (Mrs.) Jyotsana Sharma, Director. The committee appreciated the infrastructure developments and research efforts made by the Centre under the dynamic leadership of Dr. R.K. Pal, Director during 2012–2017 and Dr. (Mrs.) Jyotsana Sharma wef. 01.01.2018.

Table 1: Research Advisory Committee of ICAR-NRCP

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

*Not attended the meeting

After detailed deliberations, on the progress made by the Centre during 2017–18, several valuable suggestions and 5 recommendations were given by the XIIth RAC.

Recommendations of 12th RAC, -5th Sept, 2018

- Organic farming practices for cultivation of pomegranate should be standardized
- In pomegranate breeding emphasis should be on development of bacterial blight, disease and wilt resistant varieties with average fruit weight about 300g, attractive rind and aril colour and softness of arils.
- Large scale screening of pomegranate genotypes/ segregation populations should be undertaken against bacterial blight disease and wilt, etc.
- *Actinomycetes* consortia developed by ICAR-IIHR, mustard cake, etc. should be evaluated for control of wilt disease of pomegranate.
- Promote the entrepreneurship through commercialization of technologies for value addition in pomegranate.

IRC Meeting

The meeting of the 13th Institute Research Council (IRC) of ICAR- National Research Centre on Pomegranate was held on April 11, 2018 at ICAR-NRCP, Kegaon, Solapur under the chairmanship of Dr. (Mrs.) Jyotsana Sharma, Director (Acting), ICAR-NRCP, Solapur. All the Scientists of the Centre attended the meeting. The RAC suggestions and recommendations were also included in respective projects for timely action.

Table 2: Institute Research Council of ICAR-NRCP

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

12th RAC Meeting, Sept 05, 2018

13th IRC Meeting, April 11, 2018

15th IMC Meeting, October 23, 2018

Fig. 1: RAC, IRC, IMC Meeting of ICAR-NRCP, Solapur

IMC Meeting

The 15th Institute Management Committee (IMC) meeting of ICAR-NRCP, Solapur was held on 23.10.2018. The members of the IMC team interacted and discussed on several issues concerned with development of institute management aspects.

Table 3: Institute Management Committee of ICAR-NRCP

	Chairperson		
1.	Dr. (Mrs.) Jyotsana Sharma Director, ICAR-NRCP, Solapur		
	Members		
2.	Director of Horticulture* Govt. of Maharashtra	8.	Dr. Anuradha Sharma, PS, ICAR-NRCG, Pune
3.	Dr. Chitranjan M Patel, JDH, Govt. of Gujarat, Gandhinagar	9.	Dr. K. Dhinesh Babu, PS, ICAR-NRCP, Solapur.
4.	Dr. Prakash K Nagare* Prof. & Head, Hort. Division, DPDKV, Akola	10.	Dr. Manish Srivastava, PS, Hort. Technology Division, ICAR-IARI, New Delhi
5.	Mr. Shahaji Gulchand Pawar, Main Post Office, Tk. North Solapur, Solapur Dist.	11.	The Assistant Director General (HS-I)* ICAR, KAB-II, Pusa, New Delhi 110 012
6.	Mr. Malsingh Shivanand Mugle, Main Post Office Mandrup, Tk. North Solapur, Solapur	12.	F&AO, ICAR-IIRR, Hyderabad
7.	Dr. S.K. Malik, PS,ICAR HQ, Krishi Bhavan, New Delhi	13.	Sh. B.K. Sinha, (S.I. Member) SAO, ICAR-NIASM, Baramati, Pune.
			Member Secretary
		14.	Sh. R.B. Rai Assistant Administrative Officer ICAR-NRCP, Solapur

*Not attended the meeting

Institute Joint Staff Council of ICAR-NRCP

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

Table 4: Institute Joint Staff Council of ICAR-NRCP

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

MERA GAON MERA GAURAV

Under MGMG program the activities carried out in 6 adopted villages covering Karnataka and Maharashtra are given below.

Nimgaon, Madha, Solapur

Interaction with Farmers of Karkambh Pandharpur, Solapur

MGMG Team at Jambaga-B, Kalaburgi

SHC Distribution at Karkhamb, Pandharpur, Solapur Dt.

SHC Distribution at Waghdari, Akkalkot, Solapur

Interaction with Farmers, Karkhamb, Pandharpur, Solapur

Fig. 2: Activities Conducted under MGMG

Table 5: Activities Conducted under MGMG

S. No.	Name of Activity	No. of Activities Conducted	No. of Farmers Participated & Benefitted
1.	Visit to village by teams	17	209
2.	Interface meeting/ *Goshthies*	12	119
3.	Training organized	4	21
4.	Demonstrations conducted (Technique of soil sample collection, training and pruning for juvenile and bearing orchards)	12	110
5.	Mobile based advisories (No of messages)	About 100	100
6.	Literature support provided (Number, including e-material)	55	55
7.	Awareness created (No)	4	200
8.	Quality planting material distributed and Drumstick seeds distributed	450 saplings & 5 kg seeds	10
9.	Soil analysis and soil health card distribution	75	375

HINDI PAKHWADA

ICAR-NRCP, Solapur celebrated Hindi Pakhwada during September 14–28, 2018 and various programme were conducted viz., Elocution, debate,quiz competition, letter writing, story writing, essay writing etc besides Hindi Karyeshala. The concluding ceremony of Hindi Pakhwada was held on October 12, 2018 at 3.30 PM in Auditorium of ICAR-NRCP, Solapur by inviting Dr. Bandopanth Yeshwant Patil, Sahshishak, Solapur as Chief Guest in presence of Dr. Jyostana Sharma, Director (Acting), ICAR-NRCP, Solapur. The Chief Guest highlighted the immense significance of Hindi language in linking other languages besides distribution of certificate and prize to active participants. This event was coordinated by Dr. DT Meshram, Hindi Officer.

Mr. Bandopanth Yeshwant Patil-Chief Guest and Director ICAR-NRCP at Hindi Pakhwada

Dr. D.T. Meshram, Hindi Officer of ICAR-NRCP at Hindi Karyashala

Fig. 3: Activities Conducted under Hindi Pakhwada

SWACHH BHARAT ABHIYAN

ICAR-NRCP observed Swachh Bharat Abhiyan during Dec 16–31, 2018. Several programmes were conducted as part of SBA viz., Swachhta Pledge, Awareness Campaign: Wealth from Waste, Celebration of special day – Kisan Diwas, waste management etc. at nearby villages, Schools etc. to create awareness among students, farmers and citizens about SBA and report was sent to the Council.

SBA Inaugural Meeting

Swachhta Pledge by the Staff

Address by Nodal Officer-SBA, Mr. V.A. Shinde

Campus Cleaning Activity

Awareness Creation among Students

Awareness Creation among Citizens, Shivajinagar Tanda, Solapur

SBA Cleaning Team Members

Kisan Diwas Held as Part of SBA,

Planting of Saplings in Orchard of ICAR-NRC on Pomegranate, Solapur; under Swachhta Pakhwada, 16–31 Dec., 2018

Display of Banner under Swachhta Pakhwada, Dec 16–31, 2018 at ICAR-NRC on Pomegranate, Solapur

Fig. 4: Activities Conducted under Swachha Bharat Abhiyan

VIGILANCE AWARENESS WEEK

ICAR-NRCP, Solapur has observed Vigilance Awareness week from 29.10.2018 to 03.11.2018 under the guidance of Director, ICAR-NRCP, Solapur. As part of program various activities and competition were organized. On 29th October, 21-Staff and 14-Citizen took online pledge and submitted the certificate. On 30th October, Debate competition was organized on theme "Whether we can build corruption free India" 07 participants participated. On 31st October Essay competition was organized on theme "My ideas about Corruption free India" 07 participants participated. One day workshop & Inter-College Elocution Competition was organized on theme "Eradicate corruption: Build a new India" on Nov 01, Dr. Mrunalini Fadnavis (V.C-Solapur University) chaired this occasion as a chief guest. 18 participant from different colleges participated in the competition. On 2nd November, Drawing competition was organized for School students on theme "Eradicate corruption: Build a new India" 11 participants participated. On 3rd Nov, Closing ceremony was organized, Mr. Arun Deoker, DySP, Anti-Corruption Bureau, Solapur chaired as Chief Guest, on the occasion he interacted with staff and students about Corruption and replied queries related office corruption and online frauds. Prizes were distributed to participant of various competitions.

Vigilance Pledge by the Staff, 29.10.18

Ekta Pledge, 31.10.18

Elocution Competition

Dr. Prakash Patil Coordinator of Vigilance Awareness Week, at the Closing Ceremony

Drawing Competition Winner

Debat Competition Winner-Mr. Vipul Sangnure

Fig. 6: Activities Conducted under Vigilance Awareness Week

COMMUNAL HARMONY CAMPAIGN WEEK

ICAR-NRCP, Solapur has observed Communal Harmony Campaign Week from 19th to to 25th November, 2018 under the guidance of Director, ICAR-NRCP, Solapur. As part of program various activities were organized. On 19th November, National Integration Pledge on Communal Harmony was taken by the 28 members of office Staff. On 20th November, we organized guest lecture on

"Stress management and hazards of enviousness in organization" by Mr. V P Mulay from Manshakti Organization, Lonavala, Pune. On 22nd November, we organized 'Flag day' and collected voluntary donation funds from the institute staff and other interested volunteer. In this day, we also distributed pomegranate RTS beverage to 100 leprosy affected peoples of Solapur through Robin Hood Army Foundation. On 24th November, we organized closing ceremony of Communal Harmony Campaign Week. Honorable director Dr. Jyotsana Sharma, ICAR-NRCP chaired this occasion as a Chief Guest. During this program, we had group song on national integration by the school students, speech on communal harmony by the NRCP staff members and teacher from Shankar Rao Mohite Patil Vidyalaya, Kegaon, Solapur.

Communal Harmony Campaign Week 2018 – National Integrity Pledge on Communal Harmony Administered by Director, ICAR-NRCP, Solapur on 19.11.2018

Closing Ceremony of Communal Harmony Campaign Week, 2018 at ICAR-NRCP, Solapur on 24.11.2018

Fig. 7: Activities Conducted under Communal Harmony Week

OTHER ACTIVITIES

Sports Meet

The scientific and technical staff of ICAR-NRCP, Solapur participated in the ICAR-Zonal Sports tournament (South zone) held at ICAR-CTRI, Rajahmundry during September 5–9, 2018 Dr. Shilpa Pashuram, Vijay Lokhande and Govind Salunke represented the sports meet. The event was coordinated by Dr. U.R. Sangle, Chairman, Sports Committee.

Distinguished Visitors

During the period under report, the following eminent personalities visited ICAR-NRCP, Solapur.

Dr. H.P. Singh, Ex-DDG(HS), Visited ICAR-NRCP on 23.07.2018

Shri C. Roul, Secretary, ICAR & Spl. Secretary DARE, Visited ICAR-NRCP, on 20.10.2018

Dr. A.K. Singh, DDG(HS) Addressing the Staff and Farmers Gathered on the Occaation of Foundation Day ICAR-NRCP, Solapurs

Dr. A.K. Singh, DDG(HS) and Dr. R.C. Agrawal, Joint Registrar, PPV FRA Visited NRCP on 25.09.18

Fig. 8: Distinguished Visitors of ICAR-NRCP, during 2018–19

Human Resource Development

TRAININGS ATTENDED

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

Table 1: Trainings Attended by the Staff of ICAR-NRCP

S. No.	Title of Training	Date	Venue	Name of the Participant
a.	**Scientific Staff**			
1.	Hindi Workshop-cum-Training programme	24.04.18–25.04.18	ICAR-CRIDA, Hyderabad	Dr. N.V. Singh
2.	Advanced Bio-informatics tools and its applications in agriculture	25.09.18–29.09.18	ICAR-NAARM, Hyderabad	Dr. Prakash G. Patil
3.	Experimental designs and statistical data analysis	03.01.19–16.01.19	ICAR-IASRI, New Delhi	Mr. Mallikarjun
b.	**Technical Staff**			
1.	Interactive Training session on J-Gate as one stop platform for discovering scholarly journals and articles	09.05.18	ICAR-NRCP, Solapur	D.T. Chaudhari
2.	Good Agricultural Practices (GAPs) for enhancing resource use efficiency and farm productivity	02.01.19–11.01.19	ICAR-IARI, New Delhi	M.S. Gogaon
3.	Motivation, positive thinking and communication skills	13.03.19–19.03.19	ICAR-IISWC, Dehradun	D.T. Chaudhari
c.	**Administrative Staff**			
1.	Hospitality management	19.04.18–25.04.18	ICAR-IIRR, Hyderabad	Mr. R.B. Rai
2.	Hindi Workshop	27.05.18–31.05.18	ICAR-CCARI Goa	Mr. R.B. Rai
3.	Refresher Course on Administration and finance management	10.12.18–14.12.18	ICAR-NIASM, Baramati	Mr. V.A. Shinde

CONFERENCES, WORKSHOPS AND MEETINGS ATTENDED

The scientists of the Centre participated in conferences/workshops and meetings conducted by different organizations in India besides the meetings mentioned in the chapter on institutional

activities. Conferences, seminars, symposia, workshops and important meetings attended during the year are tabulated below.

Table 2: Conference/ Seminar/ Symposia

S. No.	Title of Conference/ Seminar/ Symposia	Date	Venue	Name of the Participant(s)
1.	International Conference on Advances in agriculture and allied sciences technologies for sustainable development	10.02.18–11.02.18	Osmania University, Hyderabad	Sh. Mallikarjun MH
2.	Joint Agresco Meeting of SAUs of M.S.	24.05.18	DBSKKV, Dapoli	Dr. K.D. Babu
3.	34th Hindi Conference & Workshop	28.05.18–30.05.18	ICAR-CCARI, Goa	Dr. N.V. Singh
4.	National Consultation on Making agriculture sustainable and profitable	21.06.18–22.06.18	VAMNICOM, Pune	Dr. K.D. Babu, Dr. U.R. Sangle
5.	National Conference on Strategies and challenges for doubling farmers income through horticultural technologies in subtropics	21.06.18–22.06.18	ICAR-CISH, Lucknow	Dr. Nilesh Gaikwad
6.	27th National Conference on Sustainable management of soil and water resources for doubling the farmers' incomes	24.09.18–25.09.18	AAU, Jorhat	Dr. D.T. Meshram
7.	Seminar on Exportable quality pomegranate production and marketing	03.10.18–04.10.18	SAU, Jodhpur	Dr. Nilesh Gaikwad
8.	National Conference on Arid horticulture for enhancing productivity and economic empowerment	27.10.18–29.10.18	ICAR-CIAH, Bikaner	Dr. U.R. Sangle Dr. Shilpa, P.
9.	International Food Convention (I) on Holistic approached for start-ups, Human Resource Training for agriculture and food Industry	12.12.18–15.12.18	CSIR-CFTRI, Mysuru	Dr. N. Gaikwad
10.	International Conference on Recent trends in image processing and pattern recognition	21.12.18–22.12.18	Solapur University, Solapur	Sh. Mallikarjun. M.H.
11.	XXVII Plant and Animal Genome Conference	12.01.19–16.01.19	San Diego, California, **USA**	Dr. N.V. Singh
12.	National Conference on Contemporary research in life sciences and cancer biology	19.01.19	V.G. Shivdare College, Solapur	Dr. Shilpa, P.
13.	8th Indian Horticulture Congress-2019, Shaping the future of Indian Horticulture	17.01.19–21.01.19	IGKV, Raipur	Dr. K.D. Babu, Dr. N.V. Singh, Dr. A. Maity
14.	28th National Conference on Farmer friendly soil and water conservation technologies for mitigating climate change impact	31.01.19–02.02.19	ICAR-IISWC, Ooty.	Dr. D.T. Meshram
15.	International Symposia on Edible alliums–challenges & opportunities	09.02.19	YASHADA, Pune	Dr. J. Sharma, Dr. K.D. Babu, Dr. Shilpa P.

Table 2 (Contd.)...

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S. No.	Title of Conference/ Seminar/ Symposia	Date	Venue	Name of the Participant(s)
16.	National Agri-business Entrepreneurship Conclave	09.02.19–11.02.19	ICAR RC NEHR Umiam	Dr. Nilesh Gaikwad
17.	Seminar on PHM and value addition in Pomegranate	12.02.19	Dhindhol-Bassi, Jaipur	Dr. Nilesh Gaikwad
18.	International Symposium on Advances in Agrometeorology for managing climate risks of farmers	11.02.19–13.02.19	JNU, New Delhi	Dr. D.T. Meshram
19.	International Conference on Advances in agriculture and allied science research	23.02.19–24.02.19	RAMA University, Kanpur	Dr. Shilpa, P.
20.	National food and nutritional security conclave	25.02.19–27.02.19	MPKV, Rahuri	Dr. A. Maity

Table 3: Workshops

S. No.	Title of Workshop	Date	Venue	Name of Participant(s)
1.	State level Workshop on Biosafety	13.04.18	MPKV, Rahuri	Dr. Prakash G. Patil
2.	Workshop on Quality Production and Processing in Pomegranate: Issues & Strategies	09.07.18	ICAR-NRCP, Solapur	Staff of ICAR-NRCP
3.	One day workshop on Rating of ICAR institutes	20.07.18	ICAR-NAARM, Hyderabad	Dr. K.D. Babu
4.	Workshop on Digital Field Book	10. 08.18	ICAR- IIMR Solapur	Dr. Shilpa P. Ms. Roopa Sowjanya P.
5.	25th Zonal Workshop of KVKs under Zone- IX	07.09.18	JNKVV, Jabalpur	Dr. Nilesh Gaikwad
6.	Workshop on Addressing farmers issues in Pomegranate production, protection and marketing	25.09.18	ICAR-NRCP, Solapur	Staff of ICAR-NRCP
7.	Training Workshop on ICAR- KRISHI Geoportal	04.12.18–05.12.18	ICAR-IASRI, New Delhi	Dr. D.T. Meshram
8.	23rd Research Workers Group Meet of AICRP on Arid Zone Fruits	24.02.19–26.02.19	VNMKV, Parbhani	Dr. K.D. Babu Dr. N. Gaikwad

Table 4: Meetings

S. No.	Title of Meeting	Date	Venue	Name of Participant(s)
1.	Meeting to finalize modified weather triggers for mrig bahar crop of pomegranate, 2018–19	09.05.18	Sakhar Sankul, Shivajinagar, Pune	Sh. Mallikarjun, MH
2.	Meeting on Quality characteristics of crops/ commodities and their availability for commercial Scale Processing and Value Addition in India	15.05.18	NASC Complex, New Delhi	Dr. N.V. Singh
3.	Pomegranate farmers Meet	19.05.18	Bhavaninagar, Indapur	Dr. Nilesh Gaikwad
4.	Half yearly Meeting of National Language Implementation Committee	08.06. 18	BSNL Office, Solapur	Dr. N.V. Singh
5.	Pomegranate meeting by MSPGRA	28.06.18	MPKV, Rahuri	Dr. Nilesh Gaikwad
6.	Scientific Advisory Committee Meeting	06.08.18	KVK, Baramati	Dr. N.V. Singh
7.	Meeting to finalize the modified weather triggers for *mrig bahar* pomegranate–2018	14.08.18	Sakhar Sankul Shivajinagar, Pune	Sh. Mallikarjun M.
8.	Meeting to finalize the modified weather triggers for mrig bahar crop of pomegranate -2018	17.11.18	Sakhar Sankul Shivajinagar, Pune	Sh. Mallikarjun M.
9.	SAC meeting of KVK, Solapur	04.09.18	KVK, Solapur	Dr. D.T. Meshram
10.	Meeting on Doubling farmers income by 2022	07.09.18	MPKV, Pune	Dr. N.V. Singh
11.	Meeting on Pomegranate value addition based enterprises	11.10.18	MKUV Sanstha, Baramati	Dr. Gaikwad Nilesh N.
12.	Meeting on Hailstorm affected pomegranate orchards	02.11.18	Jat, Sangli	Dr. D.T. Meshram
13.	Half yearly Meeting of National Language Implementation Committee	13.11.18	BSNL office, Solapur	Dr. N.V. Singh
15.	Review meeting of CRP on water project	06.12.18–08.12.18	ICAR-IIWM, Bhuvaneshwar	Dr. D.T. Meshram
16.	Meeting to finalize the modified weather triggers for *ambe bahar* crop of pomegranate	17.12.18	Sakhar Sankul Shivajinagar Pune	Sh. Mallikarjun M.
17.	Meeting on Modification and finalization of weather triggers for *ambe bahar* crop pomegranate	01.01.19	Sakhar Sankul, Shivajinagar Pune	Sh. Mallikarjun M.
18.	Review meeting of project -Delineation of potential area for pomegranate cultivation in India using Remote Sensing and GIS techniques	18.01.19	ICAR-NRCP, Solapur	Dr. D.T. Meshram
19.	National Horticulture Fair	23.01.19–25.01.19	ICAR-IIHR, Bengaluru	Dr. Prakash G. Patil Sh. M.S. Gogaon
20.	Meeting on Modification and finalization of weather triggers for mrig and ambe bahar crop of pomegranate	07.02.19	Sakhar Sankul Shivajinagar, Pune	Sh. Mallikarjun M.
21.	Lokmat Agro Exhibition	16.02.19	Paniv and Pandharpur	Dr. N.N. Gaikwad
22.	Scientific Advisory Committee Meeting	05.03.19	KVK, Solapur	Dr. D.T. Meshram

Publications

Table 1: Papers in Research Journals

S. No.	Research Papers	NAAS Rating
1.	Manna, K., Mishra, S., Saha, M., Mahapatra, S., Saha, C., Yenge, G., Gaikwad, N., Pal, R.K., Oulkar, D., Banerjee, K. and Saha, K.D. 2019. Amelioration of diabetic nephropathy using pomegranate peel extract-stabilized gold nanoparticles: assessment of NF-κB and Nrf2 signalling system. *International Journal of Nanomedicine*, 14:1753–1777.	10.37
2.	Chikte, R.G., Paknikar, K.M., Rajwade, J.M. and Sharma Jyotsana. 2019. Nanomaterials for the control of bacterial blight disease in pomegranate: quo vadis? *Applied Microbiology and Biotechnology*. Doi:org/10.1007/s00253-019-09740-z.	9.34
3.	Singh, Pal, S., Pal, R.K., Saini, M.K., Singh, J., Gaikwad, N., Parashuram, S. and Kaur, C. 2019. Targeted metabolite profiling to gain chemometric insight into Indian pomegranate cultivars and elite germplasm. *The Journal of the Science of Food and Agriculture*, Doi:10.1002/jsfa.9751.	8.38
4.	Marathe, R.A., Sharma Jyotsana and Murkute, A.A. 2018. Innovative soil management for sustainable pomegranate cultivation on skeletal soils. *Soil Use and Management*, 34: 258–265.	8.13
5.	Maity, A., Babu, K.D. and Sarkar, A. 2019. Guidelines for fertilizer use in pomegranate orchards based on seasonal uptake and partitioning of nutrients. *Scientia Horticulturae*. 252:138–148.	7.76
6.	Maity, A., Sharma Jyotsana. and R.K. Pal. 2019. Novel potassium solubilizing bio-formulation improves nutrient availability, fruit yield and quality of pomegranate (*Punica granatum* L.) in semi-arid ecosystem. *Scientia Horticulturae*, 255:14–20.	7.76
7.	Meshram, D.T., Gorantiwar, S.D., Singh, N.V. and Babu, K.D. 2019. Response of microirrigation systems on growth, yield and WUE of pomegranate (*Punica granatum* L.) in semiarid regions of India. *Scientia Horticulturae*, 246:686–692.	7.76
8.	Marathe, R.A., Sharma Jyotsana. and Chaudhari, D.T. 2019. Evaluating micro-irrigation systems in pomegranate (*Punica granatum* L.) under the semi-arid tropical climate of India. *Journal of Environmental Biology*. (In press)	6.73
9.	Marathe, RA, Babu, K.D. and Chaudhari, D.T. 2018. Nutrient uptake, growth and yield of pomegranate as influenced by irrigation frequency under light textured soils. *Journal of Environmental Biology*, 39 :143–8.	6.73
10.	Maity, A., Gaikwad, N., Babu, K.D., More, A.K. and Sarkar, A. 2019. Physico-chemical and nutritional characteristics of main pomegranate (*Punica granatum* L.) cultivars grown in Deccan Plateau of India. *Agrochimica*. 63:2 (Accepted).	6.69
11.	Meshram, D.T., Gorantiwar, S.D., Sharma Jyotsana. and Babu, D. 2018. Influence of organic mulches and irrigation levels on growth, yield and WUE of pomegranate (*Punica granatum* L.). *Journal of Agrometeorology*, 20(3):196–201.	6.56
12.	Singh, N.V., Parashuram, S., Sowjanya, R.P., Babu, K.D., Mundewadikar, D.M., Sangnure, V., Sharma Jyotsana and Pal, R.K. 2018. Performance evaluation of plants raised through different propagation methods. *Indian Journal of Agricultural Sciences*. (Accepted).	6.23

Table 1 (Contd.)...

...Table 1 (Contd.)

S. No.	Research Papers	NAAS Rating
13.	Bachake, S.S.; Jadhav, V.B.; Deshpande, P.P.; Tele, A.A.; Banda, M.A.; Adki, V.S.; Gopika, M.K.; Karanjule, P.G.; Birajdar, S.B.; Karwa, N.N.; Mundhewadikar, D.M. and Singh, N.V., 2019. Standardization of *in vitro* propagation protocol for pomegranate cv. Super Bhagwa. *Journal Pharmacognosy and Phytochemistry*, 8(3):2548–2553.	5.21
14.	Tele, A.A., Banda, M.A., Bachake, S.S., Jadhav, V.B., Deshpande, P.P., Adki, V.S., Gopika, M.K., Shinde, N.A., Sharma Jyotsana., Parashuram, S., Sangnure, V.R., Mundewadikar, D.M. and Singh, N.V. 2019. Quality RNA isolation, cDNA synthesis and qPCR validation of differentially expressed gene in (*Punica granatum* L.) under influence of *Xanthomonas axanopodis pv. punicae. Journal Pharmacognosy and Phytochemistry*. 8(3): 2542–2547.	5.21
15.	Meshram, D.T., Chandra, R., Lad, S.R. and Wadane, S.R. 2018. Mathematical model for measurement of leaf area in pomegranate (*Punica granatum* L.). *International Journal of Agricultural Sciences*, 10(14):6669–6671.	4.82
16.	Meshram, D.T., Gorantiwar, S.D., Bake, N. and Wadne, S.R. 2019. Forecasting of air temperature of western part of Maharashtra, India. *International Journal Science, Environment and Technology*, 8(1):201–217.	3.98
17.	Gaikwad, N.N., Raut, S., Yenge, Y., Suryawanshi, S., Babu, K.D. and Pal, R.K. 2018. Enzyme assisted extraction of pomegranate seed oil. *Contemporary Research in India*. 89–94.	3.23

BOOKS

1. Meshram, D., Goarantiwar, S.D. and Wadne, S. 2018. Water management in pomegranate (*Punica granatum* L.). Lambert Academic Publishing. 160p. (ISBN No:10- 978-3-659-70532-8 and ISBN No:10-3659705322).
2. Meshram, D., Gorantiwar, S. and Mittal, H. 2018. Stochastic modeling for reference crop evapotranspiration, Lambert Academic Publishing. 248p. (ISBN No.13-978-3-659-91424-9 and ISBN No:10-365991424X).

BOOK CHAPTERS

1. Babu, K.D., Singh, N.V, Maity, A., Gaikwad, N., Patil, P.G., Shilpa, P., Sharma Jyotsana., Meshram, D.T., Marathe, R.A. and Ali, S. 2019. Orchard establishment and tree management. In: *The Pomegranate: Botany, Production and Uses* (Eds. Zamani, Z., Sarkhosh, A. and Yavari, A.M.), CABI Publishing-Wallingford OX10 8DE, United Kingdom (Submitted).
2. Basak, B.B., Maity, A. and Biswas, D.R. 2018. Cycling of natural sources of phosphorus and potassium in organic agriculture for environmental sustainability. AGU books, Wiley Blackwell (Accepted).
3. Bhora, A., Jha, U.C., Jha, R., Naik, S.J.S., Maurya, A.K. and Patil, P.G. 2019. Genomics interventions for biofortification of food crops. In: *Quality Breeding in Field Crops* (Eds. Qureshi A.M.I.), Springer Publisher. Doi: org/10.1007/978-3-030-04609-5_1.
4. Bhora, A., Pareek, S., Mitchell, J., Jha, U.C., Naik, S.J.S., Kaashyap, M., Patil, P.G., Maurya, A.K., Saxena, R. and Varshney, R.K. 2019. Genomics interventions to improve resilience of pigeonpea in changing climate. In: *Genomic Designing of Climate-Smart Pulse Crops* (Eds. Kole, C.), Springer Publisher. Doi: org/10.1007/978-3-319-96932-9_2.

5. Gaikwad, N.N., Patil, N. and Patil, P. 2019. Processing and Industrialization. In: *The Pomegranate: Botany, Production and Uses* (Eds. Zamani, Z., Sarkhosh, A., Yavari, A.M.), CABI Publishing -Wallingford OX10 8DE, United Kingdom (Accepted).

6. Mallikarjun, 2019. Arthropod pests of pomegranate and their management. In: *The Pomegranate: Botany, Production and Uses* (Eds. Zamani, Z., Sarkhosh, A. and Yavari, A.M.), CABI Publishing-Wallingford OX10 8DE, United Kingdom (Submitted).

7. Meshram, D.T., Gorantiwar, S.D. and Pal, R.K. 2018. Water use efficiency in pomegranate (*Punica granatum* L.). In: *Hi-Tech Horticulture- Advance Techniques*. New India Publishing Agency (NIPA), New Dehli. pp. 217–235.

8. Meshram, D.T., Gorantiwar, S.D., Sangle, U.R. and Bake, N. 2018. Use of micro-irrigation system for optimum production of pomegranate (*Punica granatum* L.). In: *Hi-Tech Horticulture-Advance Techniques*. New India Publishing Agency (NIPA), New Dehli. pp. 203–216.

9. Meshram, D.T., Gorantiwar, S.D., Wadne, S.S. and Arun Kumar, K.C. 2019. Planning, design and construction of series of check dams for soil and water conservation in a micro-watershed. Springer Nature Publisher, Switzerland AG.

10. Sharma Jyotsana., Manjunath, G., Xavier, K.V. and Vallad Gary, E. 2019. Diseases and Management. In: *The Pomegranate: Botany, Production and Uses* (Eds. Zamani, Z., Sarkhosh, A. and Yavari, A. M.), CABI Publishing-Wallingford OX10 8DE, United Kingdom (Submitted).

11. Shilpa, P., Babu, K.D. and Sharma Jyotsana., 2019. Important Pomegranate varieties of India. In: *The Pomegranate: Botany, Production and Uses* (Eds. Zamani, Z., Sarkhosh, A. and Yavari, A.M.), CABI Publishing-Wallingford OX10 8DE, United Kingdom (Submitted).

12. Singh, N.V., Karimi, H.R., Babu, K.D. and Sharma J. 2018. Propagation Techniques and Nursery Management. In: *The Pomegranate: Botany, Production and Uses* (Eds.Zamani, Z., Sarkhosh, A., Yavari, A.M.), CABI Publishing -Wallingford OX10 8DE, United Kingdom (Accepted)

POPULAR ARTICLES

1. Babu, K.D., Meshram, D.T., Maity, A. and Choudhari, D.T. 2019. Badta tapmanache parinam kami karnasathi dalimb pikasathi sallha. *Dalimbvruth,* (Jan.- Mar.), pp. 45–46. (*Marathi*)

2. Maity, A. 2018. Phosphonic acid residues in pomegranate- an export issue. *ICAR-NRCP Newsletter*. 1(1):2–4.

3. Maity, A., Shinde, Y. and Chaudhary, D. 2018. Dalimb madhya phosphonic acidche abases- nirjat samasya. *Mrigadhara*, Sep 8, 2018, p. 5. (*Marathi*)

4. Maity, A., Shinde, Y,R., Chaudhari, D. and Sharma Jyotsana. 2018. Dalimbatil phosphonic acid abases samsya. *Agrowon Sakal,* Dec, 26th, p. 11. (*Marathi*)

5. Meshram, D.T., Pal, R.K. and Lad, S.A. 2018. Dalimb Bageche vewasthapan. *Dalimbvruth*, April-June, pp. 7–10 (*Marathi*)

6. Meshram, D.T., Sharma Jyotsana., Lad, S.A., Waghmode, B. and Wadne, S.S. 2018. Anar ke bagicheko pani dene ki shinchai vidhi. *Bagwani,* 8:23–28 (*Hindi*)

7. Sharma Jyotsana and Meshram, D.T. 2018. Ambiya Bahar Vyvasthapan. *Agrowon*, June 16, p. 11. (*Marathi*)

8. Sharma Jyotsana. and Meshram, D.T. 2018. Ambiya Bahar Vyavasthpan. *Agrowon-Agroplanning,* Jun, 16, 2018, p. 11. (*Marathi*)

9. Sharma Jyotsana., Meshram, D.T. 2018. Dalimbavaril telkat dag rog, ras shoshak patangache niyantran. *Agrowon.* July 25, 2018 p. 11. (*Marathi*)

10. Sharma Jyotsana., Gharate, R. and Singh, N.V. 2018. Dalimb baget baharadarmiyan karawayachi mashagatichi kame. *Mrugdhara* (Kharip Visheshank -1). May, 2018, pp. 64–69. (*Marathi*)

11. Sharma Jyotsana., Gharte, R., Lokhande, V. and Pal, R.K. 2018. Dalimba varil telya rog ani Vyavsthapan. *Dalimbvruth,* Oct.- Dec, pp. 30–35. (*Marathi*)

12. Sharma Jyotsana., Maity, A., Shinde, Y. and Gharte, R. 2019. Dalimb baget bahar darmyan karavayachi mashagatichi kame. *Shetkari Masik*, April, pp. 23–30. (*Marathi*)

13. Sharma Jyotsana., Meshram, D.T. and Wadne, S.S. 2018. Vashpibhavan Daranusar kara Dalimbala Sinchan. *Agrowon,* May, 21, p. 11. (*Marathi*)

14. Sharma Jyotsana., Meshram, D.T., Gharte, R. and Wadne, S.S. 2018. Japa dalimbacha mrug bahar. *Agrowon,* June25, 2018. p. 12. (*Marathi*)

15. Sharma Jyotsana., Meshram, D.T., Gharte, R., Wadne, S.S. and Lokhande, V. 2018. August mahinyatil dalimb bagetil telya rog, pani vyavasthapan va mashagatichi kame. *Baliraja Shetkari Masik,* Aug 2018, pp. 19–20. (*Marathi*)

16. Sharma Jyotsana., Meshram, D.T. and Gharte, R. 2018. Mrig aani Ambiya Bahara Madhil Vyvasthapanavaril Salla. *Agrowon*. July 11, 2018, p. 11.(*Marathi*)

17. Sharma Jyotsana., Singh, N.V., Maity, A., Shinde, Y. and Gharte, R. 2019. Dalimbavaril telya rog ani Vyavasthapan. *Shetkari Masik*, Mar, 2019. pp. 26–27. (*Marathi*)

18. Singh, N.V., Chandra, R., Sahu, P., Chaudhary, D.T., Gharate, R. and Sharma Jyotsana. 2018. Dalimbachya navin bagechi lagwad va Vyasthapan. *Mrugdhara* (Kharip Visheshank -1). May, 2018, pp. 59–63. (*Marathi*)

PRESENTATIONS IN CONFERENCES/ SYMPOSIA/ SEMINAR/ OTHER FORA

ORAL

1. Babu, K.D., Chandra, R., Singh, N.V., Meshram, D.T., Maity, A., Parashuram, S. and Sharma Jyotsana. 2018. Canopy management and crop regulation in Pomegranate. Souvenir, Seminar cum Training programme on Export Quality Pomegranate Production and Marketing, organized by Pomegranate Growers Association Trust, Gobichettipalayam, Erode and Pomegranate Growers Association of India, Pune and KVK, Myrada, Gobichettipalayam, Erode, 6 th -8th September, 2018, pp. 22–32.

2. Babu, K.D., Singh, N.V., Chandra, R., Sharma Jyotsana., Maity, A., Pal, R.K, Jadhav, V.T., Marathe, R.A., Shilpa, P., Gaikwad, N., Meshram, D.T., Patil P.G., Jalikop, S.H., Sampathkumar, P. and Murthy, B.N.S. 2019. Development of new hybrids in pomegranate -Solapur Lal and Solapur Anardana. Souvenir Cum Lead & Oral Paper Abstracts. 8th IHC-2019, Shaping future of Indian Horticulture, IGKVV, Raipur, Chhattisgarh, 17 th -21st Jan, 2019, p. 30.

3. Gaikwad, N.N., Patil, N.B. and Suryavanshi, S.K. 2019. Pomegranate value addition: Opportunities for business start-up. In: Book of lead lectures and abstracts (Eds. Kadirvel, G., Ghatak, S., Roy, S.S., Kumar, A., Firake, D.M., Rajappa, J.J., Baiswar, P., Katiyar. R., Milton, A.A.P. and Babu, S.), Lead paper presented at National Agri-Business Entrepreneurship Conclave, ICAR RC for NEH Region, Umiam, Meghalaya, India, 9 th -11 th February, 2019, pp. 237–240.

4. Maity, A., Gaikwad, N. and Babu, K.D. 2019. Physico-chemical and nutritional characteristics of main pomegranate (*Punica granatum* L.) cultivars grown in Deccan Plateau of India. National food and nutritional security conclave organized jointly by Indian Society of Agricultural Biochemists and MPKV, India.

5. Mallikarjun, M.H. 2018. Major borer and sucking pests of pomegranate and their management. Seminar cum training programme on exportable pomegranate production and marketing, 6–8th September 2018, Gobichettipalayam, Erode, Tamil Nadu, pp. 60–68.

6. Mallikarjun, M.H., Bakthavatsalam, N. and Raghavendra, A. 2018. Isolation, identification and evaluation of sex pheromone compounds against fruit piercing moths of pomegranate. In: Souvenir cum Lead/ Abstract proceeding Book (PP-SPHM-123), International conference on advances in agriculture and allied science technology for sustainable development, 10–11th Feb 2018, Hyderabad. p. 433.

7. Marathe, R.A., Babu, K.D., Choudhari, D.T. and Shinde, Y.R. 2019. Spatial distribution of roots of pomegranate grown in clayey, deep soils of semiarid regions of India. Souvenir Cum Lead & Oral Paper Abstracts. 8th IHC-2019, Shaping future of Indian Horticulture, IGKVV, Raipur, Chhattisgarh, 17 th -21st Jan, 2019, p 99.

8. Meshram, D.T., Gorantiwar, S.D., Babu, K.D. and Wadne, S.S. 2018. Response of pomegranate to partial root zone drying for doubling the farmer income. 27th National Conference of SCSI, New Delhi at AAU, Jorhat, Assam.

9. Meshram, D.T., Gorantiwar, S.D., Babu, K.D. and Wadne, S.S. 2019. Efficient irrigation management for optimization of pomegranate (*Punica granatum* L.) production. 28th National Conference of SCSI, New Delhi at Regional Center of ICAR-IISWC, Udhagamandalam, Ooty.

10. Sangle, U.R. 2018. Biological control of wilt complex problem in Pomegranate. National Conference on "Arid Horticulture for Enhancing Productivity and Economic Empowerment Society for Arid Horticulture and ICAR-Central Institute for Arid Horticulture, Bikaner, Rajasthan, 27 th -29th October, 2018.

11. Singh, N.V., Sowjanya, R.P., Shilpa, P., Patil, P.G., Babu, K.D., Sharma Jyotsana., Pedamma, S.K., Kothandaraman, H., Baral, T., Yellaboina, S., Bommu, L., Tripathi, A., Kumar, B., Reddy, U.K. and Baghel, D.S. 2019. *De novo* genome sequencing and hybrid assembly of *Punica granatum*, a complex fruit genome. Plant and Animal Genome XXVII Conference, San Diego, California, USA, 12th-16th Jan, 2019.

POSTERS

1. Babu, K.D., Singh, N.V., Meshram, D.T., Maity, A., Gaikwad, N., Sharma Jyotsana., Shilpa, P., Mallikarjun, Patil, P.G., Pavhane, S. and Pal, R.K. 2019. Evaluation of pomegranate under different training systems. In: E-souvenir- National Conference on Contemporary research in Life Sciences and Cancer Biology. V.G. Shivdare College of Arts, Commerce and Science, Solapur, 19.01. 2019, p. 35.
2. Babu, K.D., Singh, N.V., Parashuram, S., Maity, A., Gaikwad, N., Sharma Jyotsana., Suryavanshi, S., Patil, P.G., Pavhane, S. and Pal, R.K. 2019. Performance evaluation of pomegranate cultivars under Maharashtra conditions. In (E-souvenir): National conference on contemporary research in Life Sciences and Cancer Biology. V.G. Shivdare College of Arts, Commerce and Science, Solapur, 19.01.2019, p36.
3. Bhoite, A.A., Gaikwad, N.N., Oulkar, D. and Sathe, S.J. 2018. Studies on bioactive compounds in mixed fruit juice fermentation. In: E-Souvenir- International Food Convention on Holistic Approached for Start-ups, Human Resource Training for Agriculture and Food Industry Gemmation, CSIR-CFTRI campus, Mysuru, Karnataka, India, from 12th-15 th Dec, 2018, p. 55.
4. Gaikwad, N.N., Yenge, G.B., Patil, N.B., Suryawanshi, S. and Maity, A. 2018. Utilization of Pomegranate De-Oiled Seed Cake for Development of Functional Cookies. In: E-Souvenir :International Food Convention on Holistic Approached for Start-ups, Human Resource Training for Agriculture and Food Industry Gemmation, CSIR-CFTRI campus, Mysuru, Karnataka, India, 12th-15 th Dec,2018 p. 63.
5. Maity, A., Sharma, Jyotsana. and Pal, R.K. 2019. Novel potassium solubilizing bio-formulation improves nutrient availability and fruit yield of pomegranate in semi-arid ecosystem. In: Book of Abstracts. 8th Indian Horticulture Congress, Jan 17–21, 2019, IGKV Raipur, p.
6. Mallikarjun, M.H. and Pal, R.K. 2018. Laboratory Rearing Protocol for Pomegranate Fruit Borer (*Deudorix isocrates*). In: Souvenir cum Lead /Abstract proceeding Book, International conference on advances in agriculture and allied science technology for sustainable development, 10–11th Feb. 2018, Hyderabad (PP-SPHM-032). p. 382.
7. Patil, N., Gaikwad, N.N., Pal, R.K. and Shakil, N.A. 2018. Extraction of Virgin Pomegranate Seed Oil with Retention of Bioactive Compounds. In:E-Souvenir : International Food Convention on Holistic Approached for Start-ups, Human Resource Training for Agriculture and Food Industry Gemmation, CSIR-CFTRI campus, Mysuru, Karnataka, India, 12th-15 th Dec, 2018. p. 37.
8. Shilpa, P., Shendage, S.N., Singh, N.V., Patil, P.G., Kabade, P.G., Sangnure, V., Thirthakar, M. and Sharma Jyotsana. 2019. *In silico* mining and validation of EST-SSR markers in Pomegranate. In : E-souvenir- National Conference on contemporary research in Life Sciences and Cancer Biology. V.G. Shivdare College of Arts, Commerce and Science. 19th Jan, 2019, p. 64.
9. Singh, N.V., Babu, K.D., Walekar, R.L., Mundewadikar, D.M., Karwa, N. and Birajdar, S. 2019. Biohardening of *in vitro* raised pomegranate saplings for enhancing survival. 8th IHC, Shaping future of Indian Horticulture, IGKVV, Raipur, Chhatisgarh, 17th –21 st Jan 2019, pp. 39–40.
10. Singh, N.V., Sharma Jyotsana., Kumar, A., Babu, K.D., Gharate, R., Chinchure, S., Dongare, M.D. and Mundewadikar, D.M. 2019. Isolation, evaluation and identification of pomegranate endophytes against *Xanthomonas. axonopodis* pv. *punicae*. In: Souvenir cum Lead & Oral Paper Abstracts. 8th IHC, Shaping future of Indian Horticulture, IGKVV, Raipur, Chhattisgarh, 17 th –21 st Jan, 2019, pp. 147–148.

11. Singh, N.V., Sowjanya, R.P., Shilpa, P., Patil, P.G., Babu, K.D., Sharma, J., Kothandaraman, H., Yellaboina, S., Reddy, U.K. and Baghel, D.S. 2019. *De novo* genome sequencing and hybrid assembly of *Punica granatum*, a complex fruit genome. Plant and Animal Genome XXVII Conference, San Diego, California, USA, 12th-16th Jan, 2019.

TECHNICAL/ EXTENSION BULLETINS & FOLDERS

1. Sharma Jyotsana., Babu, K.D., Singh, N.V., Maity, A., Gaikwad, N.N. and Meshram, D.T. 2018. Dalimb pikabaddal varamvar vicharale janare prashn wa uttare. ICAR-NRCP Extension Bulletin, FAQ/ MARATHI/NRCP/2018/3, p. 33. (Marathi).
2. Sharma Jyotsana., Babu, K.D., Singh, N.V., Maity, A., Gaikwad, N.N. and Meshram, D.T. 2018. Anar par aksar puche jane wale prashnouttar. ICAR-NRCP Extension Bulletin, FAQ/HINDI/ NRCP/2018/2, p. 48. (Hindi).
3. Sharma Jyotsana., Babu, K.D., Singh, N.V., Maity, A., Gaikwad, N.N. and Meshram, D.T. 2018. Frequently asked questions on pomegranate. ICAR-NRCP Extension bulletin, FAQ/ENG/NRCP/ 2018/1, p. 21. (English).
4. Meshram, D.T. and Babu, K.D. 2018. Partial root zone drying irrigation in pomegranate. ICAR-NRCP, Solapur, p. 4 (Folder).

ANNUAL REPORT

1. Sharma Jyotsana., Babu, K.D., Maity, A., Singh, N.V. and Gaikwad, N. 2018. ICAR-NRCP Annual Report 2017-18, ICAR-NRCP, Solapur, p. 126.

MANUAL/ COMPENDIUM

1. Mallikarjun, M.H., Sharma Jyotsana., Babu, K.D., Meshram, D.T., Maity, A., Singh, N.V., Gaikwad, N. and Parashuram, S. 2018. Course Compendium of Lectures in Training Programme on "Model Production and Protection Practices in Pomegranate" for staff of EPC Industries Ltd. (A Mahindra Group Company) , 10-12th July, 2018. ICAR-NRCP, Solapur.
2. Meshram, D.T., Sharma Jyotsana., Babu, K.D., Sangle, U.R., Maity, A., Singh, N., Mallikarjun, M.H. and Shilpa, H.B. 2018. Training manual for training programme of tribal farmers on "Optimum pomegranate production in Hasta Bahar for farmer's of Tikkamgad & Bundhelkhand Regions of Madya Pradesh", Oct 9-12, 2018.
3. Singh, N.V., Chandra, Ram, Sharma Jyotsana, Babu, K.D., Meshram, D.T. Maity, Ashis, Gaikwad, N.N. Shilpa, P., Mallikarjun and Pal, R.K. 2018. e- Training Manual on Exposure visit cum training programme of 2nd Year B.Sc. (Ag.) students of I. Ag. Sc., BHU, Varanasi, June21-24,2018 at ICAR-NRCP, Solapur (e-Training Manual No. NRCP/2018/2.) 71 p.
4. Singh, N.V., Chandra, Ram, Sharma Jyotsana, Babu, K.D., Meshram, D.T. Maity, Ashis, Gaikwad, N.N. Shilpa, P., Mallikarjun and Pal, R.K. 2018. e- Training Manual on Propagation, Model Production practices and Value Addition in Pomegranate for Pomegranate Growers and Officers of M.P. from Aug,21-24 2018 at ICAR-NRCP, Solapur (e-Training Manual No. NRCP/2018/3.) 71 p.

E-NEWSLETTER

1. Sharma Jyotsana., Sowjanya, R.P., Babu, K.D., Maity, A., Singh, N.V. and Gaikwad, N.N. 2018. ICAR-NRCP Newsletter, 1(1), p. 8. (e-News on https ://nrcpomegranate. icar. gov.in /files/E-news/1.pdf).

E-PUBLICATIONS

1. Meshram, D.T., Singh, N.V., Maity, A., Chaudhari, D.T., Wadne, S.S., Babu, K.D. and Sharma Jyotsana. 2018. Anar Kisano ki Aye-Dugani karne ke liye ek fasal: Kisano ki safalta ki kahaniya. ICAR-NRCP e-Publication 2018/3, p. 14. (Hindi)
2. Sharma Jyotsana. 2018. Effective Management of Bacterial Blight Disease-Six easy steps. ICAR-NRCP e-Publication 1(1), p. 4.
3. Sharma Jyotsana., Babu, K.D., Sangle, U.R., Meshram, D.T, Maity, A., Singh N.V., Mallikarjun, M.H. and Shilpa, H.B. 2018. Package of practices for pomegranate cultivation and utilization. ICAR-NRCP e-Publication 2018/3, pp. 1-102.
4. Sharma Jyotsana., Meshram, D.T., Gaikwad, N., Babu, K.D., Chaudhari, D.T. and Wadne, S.S. 2018. Dalimb Shetkaryanchyana Duppat Utpan Milvinyansathi Ek peek -Shetkanyanchya Yashogatha. ICAR-NRCP e-Publication 2018/4, p. 14. (Marathi)
5. Sharma Jyotsana., Meshram, D.T., Singh, N.V., Chaudhari, D.T. and Wadne, S.S. 2018. Doguni kisan aay ke liyae anar kisano ki safalta ki kahani, ICAR-NRCP e-Publication 2018/5, pp. 1-14.
6. Sharma Jyotsana., Meshram, D.T., Singh, N.V., Chaudhari, D.T. and Wadne, S.S. 2018. Shetkaryanche duppat uttpannasaathi dalimbachi shetkaryanche yasasvi katha, ICAR-NRCP e-Publication 2018/6, pp. 1-14.
7. Sharma Jyotsana., Meshram, D.T., Singh, N.V., Chaudhari, D.T. and Wadne, S.S. 2018. Pomegranate a crop for doubling farmers income success stories of farmers. ICAR-NRCP e-Publication 2018/1, pp. 1-14. (English)
8. Sharma Jyotsana, Babu, K.D., Sangle, U.R., Meshram, D.T., Maity, A., Singh, N., Mallikarjun, M.H. and Shilpa, H.B. 2018. Pomegranate cultivation, marketing and utilization. ICAR-NRCP e-Publication Technical extension bulletin 2018/4, pp. 1-113.

Awards and Recognition

AWARDS

S. No.	Name of Scientist	Award	Year	Awarding Organization
Fellowship/ Associateship/ Young Scientist/ Other Awards				
1.	Dr. Jyotsana Sharma	Fellow of CHAI	2019	Confederation of Horticulture Associations of India, New Delhi
2.	Dr. K. Dhinesh Babu	Fellow of CHAI	2019	Confederation of Horticulture Associations of India, New Delhi
3.	Mr. Mallikarjun	Young Scientist Award	2018	Genesis, Urban and Rural Development Society (GUARD), Hyderabad
4.	Dr. Shilpa, Parashuram	Young Scientist Award	2019	RAMA University, Kanpur and SVWS, Lucknow at Kanpur, U.P.
5.	Dr. D.T. Meshram	Krishi Kranti Award	2018	R.K. Foundation, Krushi Bhushan Raosaheb Kadlag (Agricultural Ecological Research Organization) at Sangamner, Dist: Ahemednagar, M.S.
6.	Dr. D.T. Meshram	SCSI Award	2019	SCSI, New Delhi
Best Poster Awards				
1.	Dr. N.V. Singh	Best Poster presentation Award	2019	8th IHC-2019: Shaping future of Indian Horticulture, IGKV, Raipur, Chhattisgarh, 17–21 Jan 2019, The Horticultural Society of India
2.	Dr. Shilpa Parashuram	Best Poster presentation Award	2019	Department of Biotechnology, V.G. Shivdare College of Arts, Commerce and Science, Solapur
Best Oral Presentation Awards				
1.	Dr. D.T. Meshram	Best oral paper presentation Award	2018	27th National Conference of SCSI, New Delhi at AAU, Jorhat, Assam
2.	Dr. D.T. Meshram	Best oral paper presentation Award	2019	28th National Conference of SCSI, New Delhi at Regional Center of ICAR-IISWC, Udhagamandalam, T.N.
3.	Dr. N.V. Singh	Invited oral paper	2019	XXVII Plant and Animal Genome Conference, San Diego, California, USA from 12–16 Jan, 2019
4.	Mr. Mallikarjun M.	Best oral presentation paper Award	2018	International Conference on Advances in agriculture and allied sciences technology for sustainable development. organized by Genesis Urban and Rural Development Society (GUARD), Hyderabad, Feb 10–11, 2018

Budget Estimate

Table 1: Financial Outlay 2018–19

Head of Account	Rupees (in Lakhs)	
	2018–19	
	Govt Grant	
	RE	Expenditure
(A) Recurring		
Establishment Charges	339.28	329.82
T.A.	16.29	16.28
Other Charges	480.71	480.20
Total A	836.28	826.30
(B) Non-Recurring		
Equipment	48.23	47.50
Minor Works	24.90	24.87
Library	0.51	0.51
Furniture	10.00	9.96
Information Technology	1.55	1.55
Total B	85.19	84.39
(C) Loan & Advances	35.00	0.00
(D) Pension	51.78	51.47
(E) Vehicles & Vessels	0.00	0.00
Grand Total (A + B + C + D)	**1008.25**	**926.16**

Table 2: Revenue Receipts 2018–19

SI. No.	Items	Amount (Rs.)
1.	Income from farm produce	797028.08
2.	Income from royalty and publications	150816.95
3.	Income from other sources	499254.93
4.	Interest on loans and advances	24121.00
5.	Interest earned on short term deposits	304397.00
6.	Recovery of loans and advances	281000.00
7.	Training programs	190000.00
8.	Analytical testing fee.	10629.20
9.	License fee/ Guest house	75723.83
	Total Revenue Receipt	**2332970.99**

Staff Position, Personnel, Joining/ Promotion/ Relieving

STAFF POSITION

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

PERSONNEL

RMP
Dr. (Mrs.) Jyotsana Sharma
Director (Acting)

Scientific Staff **Dr. K. Dhinesh Babu** Principal Scientist, (Hort.-Fruit Science)	**Mr. Mallikarjun** Scientist (Agrl. Entomology)	**Administrative Staff** **Sh. R.B. Rai** AAO
Dr. U.R. Sangle Principal Scientis, (Plant Pathology)	**Ms. Roopa Sowajanya P.** Scientist, (Genetics & Plant Breeding)	**Sh. Shinde V.A.** AF&AO
Dr. D.T. Meshram Senior Scientist (Land and Water Management Engg.)	**Technical Staff** **Sh. D.T. Choudhari** Technical Officer	**Sh. Kiran Khatmode** LDC
Dr. Ashis Maity Senior Scientist (Soil Science-Pedology)	**Sh. Yuvraj Shinde** Senior Technical Assistant	**Sh. A.S. Babar** LDC
Dr. N.V. Singh Senior Scientist, (Hort.-Fruit Science)	**Sh. Diwakar Sawji** Senior Technical Assistant	**Sh. Vipin Dagar** LDC
Dr. Prakash G. Patil Scientist (Plant Biotechnology)	**Sh. Mahadev Gogaon** Senior Technician	**Supporting Staff** **Sh. Shailesh Bayas** SSS
Dr. N.N. Gaikwad Scientist (Agril. Structures and Process Engg.)	**Sh. Govind Salunke** Senior Technician	**Sh. Vishal Gangane** SSS
Dr. (Mrs.) Shilpa Parashuram Scientist, (Genetics & Plant Breeding)	**Sh. Vijay Lokhande** Senior Technician	

JOINING: NIL

PROMOTION

1. Dr. Ashis Maity, Scientist (Soil Science–Pedology) was promoted to Senior Scientist (Soil Science–Pedology) wef. 08.01.2017.
2. Dr. N.V. Singh, Scientist (Hort.-Fruit Science) was promoted to Senior Scientist (Hort.-Fruit Science) wef. 10.02.2018.
3. Dr. Nilesh Gaikad, Scientist (Agrl. Structures & Process Engineering), 15600-39100+RGP:6000 was promoted to Scientist (Agrl. Structures & Process Engineering), 15600-39100+RGP:7000 wef.23.06.2013.
4. Dr. Prakash G. Patil, Scientist (Plant Biotechnology), 15600-39100+RGP:6000 was promoted to Scientist (Plant Biotechnology), 15600-39100+RGP:7000 wef. 07.01.2013.

RELIEVING

1. Ms. Roopa Sowjanya, P., was relived on study leave to pursue Ph.D. wef. 16.08.2018.

Appendix 1

Table 1: Metrological Parameters 2018–19, ICAR-NRCP, Solapur

Month	Temp. (^{0}C)		Soil Temperature (^{0}C)						WS (kmph)	Sun Shine (h)	E_{pan} (mm)	Rain Fall (mm)	Rainy Days
			Morning			Evening							
	T_{max}	T_{min}	5 cm	10 cm	20 cm	5 cm	10 cm	20 cm					
Apr-2018	41.6	25.5	28.5	29.5	30.5	36.5	34.6	32.8	10.4	10.40	390.0	6.80	1.0
May-2018	41.1	26.5	29.5	30.8	31.8	33.6	32.5	31.2	12.7	10.40	396.0	25.80	3.0
Jun-2018	33.8	23.0	26.5	27.5	28.5	31.4	30.6	29.8	12.6	8.40	366.0	168.8	7.0
Jul-2018	31.3	22.0	25.5	26.5	27.5	31.4	30.2	29.8	13.0	6.30	180.0	46.00	10.0
Aug-2018	32.1	21.1	26.5	27.5	28.5	32.2	31.5	29.9	17.0	7.00	150.0	125.2	9.0
Sept-2018	30.6	20.4	28.5	29.5	29.5	31.5	30.5	29.7	8.66	9.40	210.0	31.60	3.0
Oct-2018	32.0	18.9	29.5	30.5	31.5	32.5	31.5	30.0	8.67	9.20	231.0	47.00	2.0
Nov-2018	32.5	16.4	29.5	30.5	31.5	32.5	31.5	30.5	9.03	9.80	240.0	33.0	1.0
Dec-2018	32.5	15.2	28.5	29.5	29.5	31.5	30.5	29.7	9.55	8.80	201.0	0.00	0.0
Jan-2019	30.9	14.3	29.6	30.5	31.5	31.5	30.5	29.4	8.67	8.60	246.0	0.00	0.0
Feb-2019	34.9	18.3	30.8	31.5	32.5	33.5	32.5	31.4	10.3	9.80	246.0	0.00	0.0
Mar-2019	38.8	23.3	30.5	31.5	32	37.5	36.5	34.5	11.5	10.30	324.0	0.00	0.0
Max.	41.6	26.5	30.8	31.5	32.5	37.5	36.5	34.5	17.0	10.40	396.0	168.8	10.0
Min.	30.8	14.3	25.5	26.5	27.5	31.4	30.2	29.4	8.66	6.30	150.0	0.00	0.0
Mean	34.4	20.4	26.8	28.1	29.6	30.8	30.22	29.90	11.0	9.03	265.0	40.35	3.0
STDev.	3.93	3.92	6.74	5.66	3.29	8.00	6.35	3.32	2.51	1.31	83.42	53.74	3.6

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ICAR-NATIONAL RESEARCH CENTRE ON POMEGRANATE

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

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

ISO 9001:2015

Quality Management System

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

Certificate No. : Q-18032101
UIC : MSCB-159-3113

Date of initial registration	**21-03-2018**
Date of this certificate/ Issue No.	**20-03-2019/03**
Certificate Expiry	**20-03-2020***
Recertification Due	**20-03-2021**

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

This Certificate is valid as per Rules and Regulations of ECL & also the surveillance audits conducted atleast once a year.
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