# वार्षिक प्रतिवेदन
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आज़ादी का अमृत महोत्सव


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

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# Preface

ICAR-National Research Centre on Pomegranate, Solapur, completed 15 years of journey on September 25, 2020. The Centre has accomplished its objectives with visible outcomes during the period and is proud to be the driving force behind the sprawling pomegranate sector in India. The pomegranate sector has recorded constant increase in area, production and productivity since last 8 years. In 2018-19, the pomegranate was cultivated over 2.62 lakh ha, production of 30.04 lakh MT with productivity of 11.58 t/ha and in 2019-20, the export was 80.5 thousand MT.

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

Introduction of pomegranate cultivation in states of north India, is urged to explore the feasibility of pomegranate cultivation in non-traditional areas that paves the way for enhanced production. This would be a boon in improving economic status of the farmers in these states. Though India is the largest producer of pomegranate, its export share in world trade of pomegranate is lesser (around 14%) in comparison to China (34%) and Iran (29%) with respectively 50% and 33% less area than India. The Centre has a challenging task ahead to improve export through breeding large size variety and pesticide residue free production; work on these aspects is in progress. I am sure ICAR-NRCP will continue to move forward with confidence to achieve new milestones and to fulfill the vision of our Honourable Prime Minster of Doubling farmer's income by 2022. To be a part of the institute that aims to raise the standard of living of pomegranate farmers of the country is a matter of great privilege to the staff of ICAR-NRCP.

I place on record my sincere gratitude to Dr. T. Mohapatra, Secretary, DARE and Director General, ICAR for his encouragement. I am obliged to Dr. AK Singh, DDG (HS) for his moral support and guidance, which encourages us to move forward with confidence. The cooperation and support rendered by all the staff members of SMD (HS) to this Centre is thankfully acknowledged. I am



grateful to Hon'ble Chairman and members of RAC for guidance and keen interest shaping the research activities of the institute. The Centre would not have achieved its milestones without constant support and cooperation of all scientific, administrative, technical and supporting staff as well as senior research fellows, young professionals in various research projects. I am grateful to all for their unflinching support and express my sincere thanks for the help rendered in betterment of this Centre.

**Jyotsana Sharma**

Director (Acting)

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# Introduction

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

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

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



As per estimated global pomegranate acreage and production figures available on different internet sites, India is the largest producer with around 50% share globally. India in 2018-19, occupies an area of 2.62 lakh hectares with production of 30.34 lakh tonnes. The other countries after India are China (1.2 lakh ha and 12.0 lakh MT), Iran (0.75 lakh ha and 11.0 lakh MT), Turkey (0.35 lakh ha and 2.2 lakh MT). Rest of the pomegranate growing countries like USA, Tunisia, Morocco, Spain, Israel, Greece, Italy, South Africa etc. have lower area and production. The global pomegranate scenario clearly indicates that India has the advantage to come up with promising pomegranate technologies for the benefit of Indian population. Today estimated more than 2.5 lakh families are earning livelihood from this crop in arid and semi-arid regions of India. Envisaging the economic importance of pomegranate and the significant role of this crop in shaping the economy of the farmers in arid and semi-arid regions, the ICAR-NRCP addressed these hurdles on priority and gave solutions to major challenges. Noteworthy technologies for promotion of pomegranate include:

(i) 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.

(ii) Promising, cost effective, eco-friendly integrated nutrient, disease & insect pest management schedule with the use of bio-formulations and preventive strategies, resulting in quality fruit production.

(iii) Bio-hardened micro-propagation technology for propagation of disease free planting material.

(iv) Novel bio-formulation for potassium fertilizer supplement, with *Penicillium pinophilum,* that reduces70% requirement of potassium to pomegranate, saves ~Rs.40,000/ha on fertilizers cost and increases yield by 25%.

(v) Processing technologies for total utilization of pomegranate for diversification of utilization pattern, and higher returns. These are pomegranate juice and ready to serve drink from low market value fruits; minimally processed pomegranate arils with shelf life of 14 days; high pharmaceutical value seed oil from dried seeds of cv. Bhagawa (28% w/w oil) and Ganesh (26.43 % w/w oil); hi-fibre cookies from de-oiled seed cake of pomegranate; sparkling pomegranate wine from pomegranate juice.



(vi) Bio-fortified pomegranate variety, 'Solapur Lal' developed through breeding matures in 160-165 days, has 25-35% higher yield over cv. Bhagawa and is nutritionally rich with more iron, zinc, ascorbic acid and anthocyanin contents over the ruling cv. Bhagawa. This bio-fortified variety is a boon to combat nutritional deficiencies in human beings and with TSS above 17 is a boon for processing industries too.

(vii) The Centre in collaboration with NBSS&LUP, Nagpur has accomplished mapping of pomegranate growing areas based on soil type and climatic conditions. This will help promote pomegranate cultivation in areas suitable for its cultivation but not yet growing pomegranate, for promoting crop diversification and improving economy of the farmer.

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

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

Within 15 years of inception of the institute, ICAR-NRC on Pomegranate, has developed infrastructure with state-of-art facilities for conducting basic, strategic and applied research and take it to the beneficiaries through extension activities, publications in popular languages, digital apps in multi-languages to fulfil the vision of Honourable Primer Minister of India of Digital India, Doubling Farmer's Income and Atmanirbhar Bharat.



**Mandate**

- Basic, strategic and applied research on genetic resource management, crop improvement, production and protection technology for enhanced and sustained productivity of pomegranate.

- Transfer of technology and capacity building of stakeholders for enhancing and sustaining productivity of pomegranate

**Mission**

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

**Vision**

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

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## कार्यकारी सारांश

विगत वर्षों में अनार की खेती में अभूतपूर्व वृद्धि हुई है जिसके फलस्वरूप २०१८–१९ में अनार का भारत में कुल क्षेत्रफल 2.62 लाख हेक्टेयर एवं उत्पादन 30.04 लाख मेट्रिक टन तथा २०१९–२० में कुल निर्यात ८०,५०० मेट्रिक टन तक पहुँच गया है । इस फसल ने अनिश्चित वर्षा वाले शुष्क तथा अर्ध शुष्क क्षेत्रों में किसानो की आजीविका सुरक्षा में अपने महत्व को दर्शाया है. भा. कृ. अनु. प. –राष्ट्रीय अनार अनुसन्धान केंद्र, सोलापुर ने किसान भाइयों के शोध सम्बंधित मुद्दों का निवारण करने तथा इस फसल से सम्बंधित चुनौतियों का सामान करने में अग्रिणी भूमिका निभाई है ।

रिपोर्ट के वर्ष के दौरान इस केंद्र ने १५ संस्थागत परियोजनाएं, ८ बाह्य वित्त पोषित परियोजनाएं, २ अंतर्संस्थागत परियोजनाएं, १ अनुसूचित जाति उपयोजना एवं १ अनुसूचित जनजाति उपयोजना का क्रियान्वयन किया । पंद्रह संस्थागत परियोजनायों में से १ परियोजना का सफलतापूर्वक समापन भी हुआ. मुख्य उपलब्धियां निम्नांकित हैं

**अनुवांशिक संसाधन :**

- वर्ष के दौरान, किस्मों और जनन्द्रव्यों की बड़ी संख्या में सन्ततियां जीवाणु झुलसा रोग के खिलाफ जांच के लिए विकसित की गयी (मृदुला और वंडरफुल के ४७ बीज जनित संतति, दृढ काष्ठ कर्तन प्रवर्धित ३६ जनन्द्रव्य, ५–ब्रोमोयूरासिल संसोधित १४ अनार के पौध, गामा विकिरणीत भगवा के ३७ M1 पापुलेशन, भगवा के M2 वंशावली के २१ बीज जनित पौधे और गणेश क़िस्म के M१ वंशावली के ५ बीज जनित पौधे) ।

- इन सभी २०७ संततियों में जीवाणु झुलसा रोग के खिलाफ जांच के बाद प्रतिरोधक क्षमता नहीं पाई गयी ।

- अनार के 30 जनन्द्रव्यों के गुणधर्म मूल्यांकन में ६ गुणधर्मों नामतः फल भार (ग्रा), फल आयतन, फल लम्बाई (मिली मी), फल व्यास (मिली मी), १०० दानों का वजन (ग्रा), दाना चौड़ाई (मिली मी) के लिए सार्थक विविधिता पाए गयी. इन जनन्द्रव्यों में फल (पीले–लाल अंश से लाल) और दानों (हल्के पीले से गाढे लाल) के रंग के लिए भी काफी विविधिता पाई गयी ।

- विल्ट सिक प्लाट में मुर्झान रोग (*Ceratocystis fimbriata,* रूट नाट सुत्रकृमि) के खिलाफ १०० से अधिक जनन्द्रव्यों की जांच में कुछ जनन्द्रव्य नामतः Acc- 2; Acc-11, Acc-12 and Acc-4 में २ वर्ष के बाद भी सिर्फ ४-१० % मुर्झान दर्ज की गयी जबकि भगवा (६०.५५%) और सुपर भगवा (८३.३१%) अति संवेदनशील पाए गए ।



- राष्ट्रीय अनार अनुसन्धान केंद्र की नयी संकर किस्मों नामतः NRCPH-4 और NRCPH-14 का आन–साइट DUS परीक्षण रिफरेन्स क़िस्म से तुलनात्मक तरीका से किया गया और समेकित रिपोर्ट पौध क़िस्म और कृषक अधिकार संरक्षण प्राधिकरण को प्रस्तुत की गयी ।

- पचपन एस एस आर आण्विक चिन्हकों को लेकर १२ सूक्ष्म प्रवर्धित पौधों के क्लोनल फिडेलिटी परीक्षण में कोई भी आण्विक बदलाव प्रतीत नहीं हुआ ।
- चौरासी एस एस आर आण्विक चिन्हकों के साथ अनार के ८ जनन्द्रव्यों के आण्विक विशलेष में २५ एस एस आर बहुरूपी पाए गए । पी आई सी और हेट्रोज्यगोसिटी % मूल्यों के आधार पर PgKVR-24, 32, 121 एवं PgSSR-1, 2, 44, 53, 56, 70, 81, 87 आण्विक चिन्हक क़िस्म पहचान हेतु उपयोगी पाए गए ।

- आण्विक विषमता गुणक मूल्यों के आधार पर अनुवांशिक विविधिता ने भगवा और सुपर भगवा के बीच निम्न अनुवांशिक विविधिता (०.०१) दर्शया तथा उसके बाद मृदुला और अर्काट के बीच भी कम अनुवांशिक विविधिता (०.०३). सर्वाधिक अनुवांशिक विविधिता (०.१९) सोलपुर लाल और गणेश के बीच पाई गयी ।

**फसल सुधार :**

- छः वर्ष के सोलपुर लाल और भगवा के मृग बहार की फसल के दौरान तुलनात्मक अध्ययन में सोलापुर लाल १८.५ दिन अगेती और २५.८% अधिक उपज (३५.३२ किग्रा/पेड़) वाला पाया गया तथा अन्य फल गुणात्मक चरित्र भी भगवा से बेहतर पाए गए ।

- छः वर्ष के सोलपुर अनारदाना और अम्लिदाना के मृग बहार की फसल के दौरान तुलनात्मक अध्ययन में सोलापुर अनारदाना में अधिक उपज (२८.९४ किग्रा/पेड़), ज्यादा रस अम्लता (४.८२% अम्लता) और अधिक अन्थोसायनिन (४६०.५ मिली ग्रा/ १०० ग्रा) वाला पाया गया ।

- भा.कृ.अनु. प.–राष्ट्रीय अनार अनुसन्धान केंद्र, सोलापुर द्वारा विकसित बारह संकर किस्मों के मुल्यांकन के दौरान उपज १५.१५– २५.५९ किलो ग्रा/पेड़ के बीच दर्ज की गयी. सर्वाधिक उत्पादन गणेश x नयना (२५.५९ किलो ग्रा./ पेड़) जिसके उपरांत भगवा x नयना (२५.४१ किलो ग्रा./ पेड़) में पाया गया ।

- भा.कृ.अनु. प.–राष्ट्रीय अनार अनुसन्धान केंद्र ने ट्युनिसिया क़िस्म के गुणसूत्र आधारित अधिक बहुरूपी एस एस आर आण्विक चिन्हकों का अनुवांशिक मानचित्रण हेतु विकास किया है ।



- अनार क़िस्म ट्यूनीशिया के आठ छद्म गुणसूत्र अणुओं के साथ उच्च गुणवत्ता वाले जीनोम संयोजन को पुनः प्राप्त करके इन सिलिको विश्लेषण किया गया था। । अनार के तीन अन्य किस्मों यानी दाबेन्ज़ी, ताइशनहोंग और एजी2017 के ड्राफ्ट जीनोम को भी ई-पीसीआर का उपयोग करके पहचाने गए एसएसआर आण्विक चिन्हकों के सत्यापन के लिए पुनः प्राप्त किया गया था।

- एसएसआर की जीनोमआठ ट्यूनीशिया छद्म गुणसू :व्यापी खोज-त्र अणुओं के जीनोमिक अनुक्रम का सर्वेक्षण किया गया। (एमबी अनुक्रमों को छोड़कर 23.49 अज्ञात) एमबी 296.85 परिणामस्वरूप, कुल एमबी जीनोमिक अनुक्रमों से 296.85 पूर्ण एसएसआर की पहचान 365279 की गई जो की कुल लंबाई का एमबी है 5.18 तथा जिसकी आवृत्ति एम/एसएसआर 1230.6बी या केबी और/एसएसआर 812.6घनत्व 17443.55 बीपी एमबी/पाए गयी।

- हेक्सान्यूक्लियोटाइड रीपीट्स %55 के प्रतिनिधित्व के साथ सबसे प्रचुर मात्रा में पाए (201501) गए, इसके बाद di- (55437, (%15, टेट्रा36455) -, (%10, ट्राई29940) -, (%8, मोनो - 27536), (%8और पेंटा 14410), (%4न्यूक्लियोटाइड रीपीट्स पाए गए थे।

- भगवा की जीनोम अनुक्रमण :HiC आधारित गुणसूत्र स्तर असेंबली में अंतिम क्यूरेशन और एकीकरण के बाद भगवा जीनोम अनुक्रमण में 41682mRNAs के साथ जीन 33003पाए गए। जीनोम में आनुवंशिक स्थान लगभग %32.7है, जिसमें कोडिंग स्थान %18.8है, एनोटेशन के बारे में विभिन्न आंकड़ों की गणना जीनोम एनोटेशन जेनरेटर का उपयोग करके की गई है।

- इन सिलिको विश्लेषण के माध्यम से, हम अनार में पौध से लेकर फल विकास के चरणों के लिए विशिष्ट miRNA-SSR आण्विक चिन्हकों के जीनोमव्यापी विकास की रिपोर्ट- करते हैं। 897 miRNA-SSRs और लक्ष्य जीन से 58EST-SSRs का प्रतिनिधित्व करने वाले कुल कार्यात्मक 955 आण्विक चिन्हकों का विकास आनुवंशिक मानचित्रण कार्य के लिए किया गया है। ऐसे सूचनात्मक आण्विक चिन्हकों के विकास पर यह पहली रिपोर्ट है, जो अनार में जीवाणु झुलसा और फलों की गुणवत्ता के लक्षणों के खिलाफ आनुवंशिक मानचित्रण के लिए एक महत्वपूर्ण जीनोमिक संसाधन के रूप में काम कर सकती है।

**पौध प्रवर्धन :**

- सेराटोसिस्टिस फिम्ब्रिएटा, रूट नॉट नेमाटोड और मृदा लवणता के खिलाफ स्क्रीनिंग के लिए और जैविक एवं अजैविक तनावों के लिए जड़वृन्तों की पहचान करने के लिए अनार के २२ जनन्द्रव्यों का गुणन %87.5 से 52.5 की लेयरिंग सफलता के साथ किया गया था।



- वेज कलमसंरक्षित संरचना के : अन्दर नवंबरदिसंबर-, के दौरान विभिन्न संभावित 2020 जड़वृन्तों पर (महीने पुराने 10 लगभग) 'भगवा' शाखवृंत की वेज (मिमी व्यास 10-8 लगभग) कलम सफलता %75.0 से 37.55के बीच प्राप्त हुई।

- *इन विट्रो* गुणन मीडिया और 110 मूल्यांकन किए गए :विकास नियामक संयोजनों के बीच, कम $NH_4NO_3$ के साथ संशोधित एमएस माध्यम और अधिक $NH_4NO_3$ संशोधित WPM माध्यम IAA एवं NAA की कम सांद्रता और 80 मिली ग्रा/ ली तक एडेनिन सल्फेट के साथ अधिकतम प्ररोह बढ़वार करने में सक्षम पाया गया 6.3)सेमी ।(दिनों में 25इस बेसल मीडिया में कम सांद्रता पर बीएपी और या काइनेटिन बहुत कम सांद्रता/पर एनएए तथा 80 मिली ग्रा/ ली तक एडेनिन सल्फेट मिलाने पर अधिकतम साइड शूट प्रति माइक्रोशूट प्रति चक्र की संख्या 4.5प्राप्त हुई।

- *इन विट्रो* जड़न) मीडिया के विभिन्न संयोजनों में :**अर्ध स्थूल सांद्रता** वाला एमएस, डब्ल्यूपीएम और अर्ध स्थूल सांद्रता वाला डब्ल्यूपीएम(, विकास नियामक और सोखने वाले एजेंट में से डब्ल्यूपीएम माध्यम में मिली 1.0 ग्राम ली आईएए पर लगाए गए/प्ररोहों में सर्वप्रथम जड़ अंकुरण 13)दिन(, अधिक जड़ संख्या (%87.50) और उच्चतम जड़ प्रतिशत (2.38)प्राप्त हुआ।

- सूक्ष्म प्रवर्धित पौधों का जैवकठोरीकरण छाया %35 :गृह में रखे गए भगवा सूक्ष्म प्रवर्धित पौधों का माइक्रोबियल उपचार अर्थात् *एस्परजिलस नाइगर* स्ट्रेन ए27-, एएमएफ मुख्य रूप से *ग्लोमस इंट्रैडिसिस, स्यूडोमोनास फ्लोरेसेंस, पेनिसिलियम पिनोफिलम* और *ट्राइकोडर्मा विरिडि* + टी. *हर्ज़ियानम* अकेले या संयोजन में उपयोग किए गए थे। विभिन्न सूक्ष्मजीवीय संयोजनों को दिनों के अंतराल पर दो बार राइजोस्फेरिक मिट्टी में 15ब्रोथ के रूप में डाला गया। अधिकांश रिकॉर्ड किए गए मापदंडों के लिए बायो) प्राइम्ड पौधों ने नियंत्रण-T (15की तुलना में बेहतर प्रदर्शन किया।

- जंगली जड़वृन्तों पर 'भगवा' शाखवृंत की की कलम सफलता %55.00से %80.00तक थी। आईसीएआर एनआरसीपी हाइब्रिड-'सोलापुर लाल' %35शेड नेट हाउस कंडीशन के तहत 'भगवा' की तुलना में काफी जोरदार पाया गया। 'सुपर भगवा' में 'सोलापुर लाल' की तुलना में संरक्षित संरचना के तहत एयर लेयरिंग की सफलता काफी अधिक थी। प्रक्षेत्र परिस्थितियों में लगे हुए मातृ वृक्ष के लिए, 'सुपर भगवा' और 'भगवा' ने 'सोलापुर लाल' की तुलना में बेहतर कटिंग और लेयरिंग सफलता दर्ज की गयी है।



**फसल उत्पादन:**

- पलाश और फॉस्फेट के खनिज स्रोतों का पेनिसिलियम पिनोफिलम पर कोई हानिकारक प्रभाव नहीं पड़ा, बल्कि परिवेश की स्थिति में भंडारण के दौरान इसकी संख्या बढ़ी हुई पाई गयी, इसलिए विकसित जैव उर्वरक के भंडारण समय सीमा को बेहतर बनाने के लिए कुछ एडिटिव्स के साथ पलाश और फॉस्फेट के खनिज का उपयोग किया गया है।

- अमीनो एसिड आधारित सूक्ष्म पोषक तत्वों के फार्मूलेशन I और II के छिडकाव से फूलों की कुल संख्या, उभयलिंगी फूलों की संख्या, फलों के सेट, उत्पादन और निर्यात योग्य ग्रेड फलों के प्रतिशत के अलावा, एरिल प्रतिशत और पोषण संबंधी मापदंडों में व्यापक रूप से उपयोग किए जाने वाले सूक्ष्म पोषक तत्वों (EDTA केलेटेड माइक्रोन्यूट्रिएंट्स) की तुलना में उल्लेखनीय वृद्धि पायी गयी है।

- सत्रह एंडोफाइट्स का परीक्षण किया गया; 13 (टीसी श्रृंखला) ऊतक संवर्धन पौधों के विकास के लिए प्रयुक्त नोडल खंडो से, 1 (बीई 10) *ओसीमम टेनुइफ्लोरम* (पवित्र तुलसी) के तने से, और 3 (बीई-2, बीई-4, बीई-5) ओसीमम बेसिलिकम (मीठी तुलसी) की पत्तियों और तनों से इयसोलेट किये गए। परीक्षण किए गए सभी एंडोफाइट्स (टीसी-2 को छोड़कर) से पौधों पर बैक्टीरियल ब्लाइट आपतन (0-38%) अनुपचारित नियंत्रण (64.33%) की तुलना में काफी कम पाया गया , हालांकि एंडोफाइट्स टीसी-4, टीसी-310 ने 4 स्प्रे के साथ पूरी तरह से जीवाणु झुलसा की रोकथाम की। एंडोफाइट उपचारित पौधों ने अच्छी पर्ण वृद्धि दर्ज की, इसका श्रेय इस तथ्य को दिया जा सकता है कि ये एडोफाइट्स पोटाश और फॉस्फेट सॉल्यूबिलाइज़र काम कर रहे थे जैसा कि इन विट्रो अध्ययनों में देखा गया है।

- वर्ष 2019 के दौरान फ्रूट क्रैकिंग/ फल फटाव (%) के लिए अड़सठ अनार के जर्मप्लाज्म एक्सेसन्स का मूल्यांकन किया गया। एनोवा विश्लेषण ने 1% और 5% सार्थकता स्तरों पर जनन्द्रव्यों के बीच महत्वपूर्ण अंतर दिखाया (F@0.05- 1.40 *; F@0.05-1.61** ) जनन्द्रव्यों में फलों का फटना (%) 0-53.90% के बीच था। आठ जंगली जनन्द्रव्यों में कोई फल फटाव नहीं पाया गया (1201, 1198, IC-318718, IC-318743, IC-318766, IC-318712, IC-318716, Acc. No.-5)। एरिल ब्राउनिंग की घटना 0 से 16.69% तक थी, 'भगवा' में 2.58% एरिल ब्राउनिंग घटना देखी गई थी और विदेशी संग्रह क्रेनेडियो-डी-एल्च (16.69%) में अधिकतम एरिल ब्राउनिंग पाई गई थी। स्पेक्ट्रोरेडियोमीटर का उपयोग करके 67 जनन्द्रव्यों के फटे और स्वस्थ फलों के साथ-साथ 72 अनार के जनन्द्रव्यों के पौधे के छत्र के हाइपरस्पेक्ट्रल हस्ताक्षर भी दर्ज किए गए थे।



- छाया गृह और प्रक्षेत्र परिस्थितियों के तहत प्रथम वर्ष अनार के के विकास के लिए सिंचाई के पानी की आवश्यकता 650 और 6193 ली/पेड़/सीजन अनुमानित की गई थी। भाकृअनुप- राष्ट्रीय अनार अनुसन्धान केंद्र संकर क़िस्म 'सोलापुर लाल' का वानस्पतिक विकास अन्य वाणिज्यिक किस्मों की तुलना में संरक्षित संरचना के तहत बेहतर पाया गया है।

- विभिन्न पीआरजेडडीआई में, 80% *ईटीसी गीली मिट्टी की मात्रा 20% *एएसडब्ल्यूडी के साथ 7 वें वर्ष अनार के बागों के लिए सबसे अच्छा पाया गया है।

**पादप सुरक्षा**

- बैक्टीरियल ब्लाइट के प्रबंधन के लिए स्टेम सोलराइजेशनः 100% ब्लाइट नियंत्रण के साथ सामुदायिक दृष्टिकोण में बैक्टीरियल ब्लाइट को प्रबंधित करने के लिए विकसित की गयी 'स्टेम सोलराइजेशन' तकनीक है। यह पर्यावरण के अनुकूल, किफायती और प्रभावी तकनीक है और यदि सामुदायिक दृष्टिकोण में किया जाए तो रोगज़नक़ को मिटा सकता है। इसका उपयोग जैविक खेती के लिए भी किया जा सकता है। महाराष्ट्र में 6 स्थानों पर फ्रंट लाइन डेमोस्ट्रेसन का कार्य प्रगति पर है इसमें से 3 अहमदनगर के रहाता में और 3 के सोलापुर जिले के मालशीरस तालुका में हैं। भाकृअनुप- राष्ट्रीय अनार अनुसन्धान केंद्र में 3 साल के प्रक्षेत्र ट्रायल की सफलता और 2 साल के लिए अक्कलकोट में 1 किसान के प्रक्षेत्र में किये गए सफल प्रयोग को पिछले वार्षिक रिपोर्ट में 'बैक्टीरिया ब्लाइट को प्रबंधित करने के लिए छह कदम' के रूप में बताया गया है, शोध सलाहकार समिति की सिफारिशों पर प्रौद्योगिकी का नाम बदल दिया गया है।

- जीवाणु झुलसा प्रबंधन हेतु बैक्टीरियोफेजः अनार के पेड़ के फ़ाइलोप्लेन से अवशोषित बैक्टीरियोफेज *इन विट्रो* परीक्षणों में अनार के बैक्टीरियल ब्लाइट रोगज़नक़ *ज़ैंथोमोनस एक्सोनोपोडिस* पीवी *पुनिकि* के प्रबंधन में प्रभावी पाए गए। यूवी प्रोटेक्टेंट्स के साथ फॉर्मूलेशन बनाने और फील्ड ट्रायल हेतु लंबी शेल्फ लाइफ पर अध्ययन प्रगति पर है।

- मौसम आधारित भविष्यवाणी मॉडलः भाकृअनुप-केंद्रीय बारानी कृषि अनुसन्धान संसथान के सहयोग से अनार में बैक्टीरियल ब्लाइट/ जीवाणु झुलसा के लिए मौसम आधारित भविष्यवाणी मॉडल पर काम शुरू किया गया था और भाकृअनुप- राष्ट्रीय अनार अनुसन्धान केंद्र द्वारा 10 वर्षों का साप्ताहिक जीवाणु झुलसा का डेटा उन्हें प्रदान किया गया है।



- नए कीट और प्राकृतिक शत्रुओं की रिपोर्टः जैव नियंत्रण एजेंट-*ब्रैचिमेरिया स्पीशीज, इयूडोरिक्स इयसोक्रेट्स* के लार्वा-प्यूपल परजीवी के रूप में रिपोर्ट किया गया। अनार के अलग-अलग हिस्सों पर अलग-अलग स्तर के नए कीटों के संक्रमण दर्ज किए गए, अनार के सभी भागों पर आक्रामक मिलीबग- *निपेकोकस विरिडिस* जो फलों पर 30-50% क्षति के साथ फलों के सभी चरणों पर नुकसान करता है। *हेलिकोवर्पा आर्मिज़ेरा* 6-8 पौधों पर 2-3 फलों को क्षतिग्रस्त करते पाया गया। साउदर्न ग्रीन बदबूदार बग- *नेज़ारा विरिडुला*, पत्ती पर, कोमल प्ररोहों पर और नए तथा विकासशील फलों पर 5-8% क्षति करता पाया गया है। वायर वर्म (क्लिक बीटल) संरक्षित संरचना में लगाये गए अनार के युवा पौधों के जड़ों पर पाए गए इनके द्वारा 5-6 पौधों में मुरझाने की समस्या भी देखी गयी। 2-3% क्षति के साथ अंकुर पर लाल तना छेदक (*ज़ुज़ेरा कॉफ़ी*) पाया गया। रात के सर्वेक्षण के दौरान अनार के दो सेकेंडरी फल भेदी पतंगे, *ओफ़ुसिया तिरहाका* और *अचिया जनता* भी अनार पर पाए गए।प्रक्षेत्र से एकत्रित और प्रयोगशाला में उगाए गए फल भेदी पतंगों का नर से मादा लिंगानुपात क्रमशः 1.69:1 और 1.78:1 था। थ्रिप्स और फल छेदक के खिलाफ जांचे गए 51 अलग-अलग अनार के जर्मप्लाज्म/ जनन्द्रव्यों में थ्रिप्स और फ्रूट बोरर द्वारा क्रमशः 13.25-75.5% और 8.5-12.75 प्रतिशत के बीच संक्रमण दर्ज किया गया है।

- एमिनोब्यूट्रिक एसिड (गाबा) को बैक्टीरियल ब्लाइट और संबंधित रक्षा प्रतिक्रिया के खिलाफ प्रतिरोध को प्रेरित करने के लिए उपयुक्त पाया गया है। 600 पीपीएम गाबा के साथ रोगनिरोधी स्प्रे के परिणामस्वरूप फलों के आकार और उपज में उल्लेखनीय सुधार के साथ 34.78% की ब्लाइट में कमी दर्ज की गयी थी ।

- लौंग के तेल (0.2%) को जीवाणु झुलसा के प्रबंधन के लिए एक शक्तिशाली रक्षा उत्प्रेरक के रूप में पाया गया। लौंग के तेल के रोगनिरोधी अनुप्रयोग ने रोगजनन-संबंधी (PR) प्रोटीन (PR1, PR4, और PR10), फिनाइल अमोनिया लाइसे, चिटिनेज, कॉलोसेसिंथेज़ 3 और पेरोक्सीडेज़ की एक उच्च सापेक्ष अभिव्यक्ति दर्ज की। कॉपर ऑक्सीक्लोराइड के साथ लौंग के तेल ने झुलसा रोग को 95.5% तक कम किया और 14.04 टन/हेक्टेयर की उच्चतम फल उत्पादन भी दर्ज की, जबकि अनुपचारित नियंत्रण में केवल 4.05 टन/हेक्टेयर उत्पादन मिला था।

- अनार सहिष्णु (IC-318735) तथा बैक्टीरियल ब्लाइट के लिए अतिसंवेदनशील जीनोटाइप की मेटाबोलिक (फेनिलप्रोपेनोइड्स) प्रोफाइल का अध्ययन किया गया था। रोगजनक उपचारित सहिष्णु जीनोटाइप में अतिसंवेदनशील वाणिज्यिक क़िस्म भगवा की तुलना में सात मेटाबोलाइट्स (फेरुलिक एसिड, क्यूमरिन, सिनामिक एसिड, यूजेनॉल, केम्पफेरोल, क्विनिक एसिड और पी-



कौमरिक एसिड) महत्वपूर्ण रूप से अधिक थे। कैम्फेरोल और क्विनिक एसिड को छोड़कर सभी मेटाबोलाइट्स को ब्लाइट पैथोजन के लिए निरोधात्मक पाया गया और यूजेनॉल और सिनामिक एसिड ने उच्चतम निरोधात्मक प्रभाव दर्ज किया था।

- *एक्स एक्सोनोपोडिस* पीवी *पुनीके* के संदर्भ स्ट्रेन एलएमजी 859 के जीनोम अनुक्रम की उपलब्धता ने महामारी विज्ञान और संगरोध अध्ययनों को एक बड़ा प्रोत्साहन दिया है। पहली बार हमने माइक्रो सैटेलाइट्स का जीनोम विस्तृत सर्वेक्षण किया और एक्सएपी जीनोम के लिए विशिष्ट कुल 2746 एसएसआर प्राइमरों को डिजाइन किया। 22 Xap आइसोलेट्स के बीच आणविक विविधता को मान्य और अध्ययन करके उनकी तत्काल उपयोगिता दिखाई गयी है। यह जीनोमिक जानकारियां इस रोगज़नक़ के जनसंख्या गतिशीलता, वर्गीकरण, महामारी विज्ञान और संगरोध पहलुओं पर भविष्य के अनुसंधान हेतु उपयोगी हो सकता है।

- बैक्टीरियल ब्लाइट के प्रबंधन के लिए छह कदम/चरण ब्लाइट प्रबंधन हेतु सबसे किफायती, पर्यावरण के अनुकूल और आशाजनक रणनीति पाई गई जो की बरसात के मौसम (खरीफ) की फसल में बैक्टीरियल ब्लाइट को 80-100% नियंत्रित करने में सफल रहा जहाँ सामान्यतः बगीचों में 50 से 100% तक नुकसान बैक्टीरियल ब्लाइट से होता है । इसका प्रदर्शन भाकृअनुप- राष्ट्रीय अनार अनुसन्धान केंद्र, सोलापुर में एक जैविक ब्लॉक और महाराष्ट्र के सोलापुर और सतारा जिलों में 3 किसानों के बागों में किया गया था। सभी बागों में 75-100% जीवाणु झुलसा नियंत्रण दर्ज किया गया। किसानों के प्रक्षेत्रों में से एक ने पिछले वर्ष की तुलना में, जब ब्लाइट के कारण 75% उपज नष्ट हो गया था, उत्पादन में 305% की वृद्धि और इनपुट लागत में 25% की कमी दर्ज की थी।

**तुड़ाई उपरांत तकनीकी/ फल प्रसंस्करण तकनीकी**

- प्रोबायोटिक अनार का रस और अनार के बीज आधारित माउथ फ्रेशनर के विकास के लिए प्रोटोकॉल मानकीकृत किया गया है।

- अनार की किस्म 'सोलापुर लाल' के लिए परिपक्वता सूचकांक निर्धारित किए गए हैं । उच्चतम कुल घुलनशील ठोस सामग्री (17.7° ब्रिक्स) और टीएसएस-एसिड अनुपात (44.25) के साथ पुष्पन के बाद 160 दिनों में 'सोलापुर लाल' ने परिपक्वता प्राप्त की थी ।

- अम्लिदाना )चेक किस्म खट्टे प्रकार के अनार संकरों से अनारदाना 10 की तुलना में (रिकवरी के निर्धारण से पता चला कि अनारदाना की रिकवरी21.2-17.5 प्रतिशत के बीच थी, यह



'सोलापुर अनारदाना' में सबसे अधिक था (%21.2) , इसके बाद NRCP H- (%20.8) 4में था, अम्लिदाना में रिकवरी सबसे कम (%17.5) पायी गयी थी।

- माइक्रोएनकैप्सुलेशन एक ऐसी तकनीक है जिसके द्वारा गर्मी, नमी, ऑक्सीजन आदि से सक्रिय अवयवों की सुरक्षित पैक किया जाता है। दीवार सामग्री के रूप में कैल्शियम अल्जीनेट का उपयोग करके अनार के बीज के तेल के एनकैप्सुलेशन की प्रक्रिया को मानकीकृत करने का अध्ययन किया गया है। इमल्शन एक्सट्रूज़न तकनीक का उपयोग करके अनार के बीज के तेल का माइक्रोएन्कैप्सुलेशन कि (पीएसओ)या गया। प्रयोग के लिए अनुकूलित प्रक्रिया की स्थिति %10तेल लोडिंग, 350माइक्रोन नोजल व्यास और %3.23सोडियम अल्जीनेट की सांद्रता थी। इनकैप्सुलेशन दक्षता, लोडिंग क्षमता, समतुल्य व्यास, गोलाकार कारक और फटाव बल की प्रतिक्रियाएं क्रमशः %78.03, %7.83, माइक 30.05ोमीटर एन 30.20 और 0.039पायी गयी थीं।

- अनार की किस्म 'सोलापुर लाल' के फलों में परिपक्वता के समय सबसे अधिक घुलनशील ठोस पदार्थ 17.6)° ब्रिक्स (पाया गया था।

- 'सोलापुर अनारदाना' द्वारा अनारदाना रिकवरी का आकलन दस खट्टे प्रकार के (%22.1) अनार के संकरोंमें से दर्ज की गई थी।

**अन्य गतिविधियाँ**

- केंद्र द्वारा महाराष्ट्र, राजस्थान, छत्तीसगढ़, मध्य प्रदेश में अनार की खेती के प्रोत्साहन देने हेतु अनुसूचित जाति उपयोजना, अनुसूचित जनजाति कॉम्पोनेन्ट और मेरा गांव मेरा गौरव के माध्यम से प्रदर्शन प्लाट, इनपुट की आपूर्ति, मृदा स्वास्थ्य कार्ड, प्रशिक्षण और तकनीकी मार्गदर्शन प्रदान करने से लगभग 500 किसानों को सीधी तौर पर लाभ पहुंचा है।

- भा.कृ.अनु.प.-राष्ट्रीय अनार अनुसन्धान केंद्र ने उद्यमियों के लिए तीन प्रौद्योगिकियों का व्यावसायीकरण किया और सात प्रदर्शनियों में अपनी तकनीकी प्रदर्शित की और किसानों, छात्रों और अन्य हितधारकों सहित 900 से अधिक आगंतुकों ने अनार सम्बंधित जानकारीयों के लिए इस केंद्र का दौरा किया।

- इसके अलावा, 9 कर्मचारियों ने मानव संसाधन विकास के तहत 13 प्रशिक्षण कार्यक्रमों में भाग लिया और क्षमता निर्माण गतिविधियों के तहत 37 सम्मेलनों/सेमिनार/संगोष्ठियों और 4 कार्यशालाओं में भी भाग लिया।



- भा. कृ. अनु. प. –राष्ट्रीय अनार अनुसन्धान केंद्र के सभी कर्मचारियों ने स्वच्छ भारत अभियान, सतर्कता जागरूकता सप्ताह, अंतर्राष्ट्रीय महिला दिवस, किसान दिवस आदि के तहत विभिन्न गतिविधियों में सक्रिय रूप से भाग लिया।
- केंद्र ने अनार की खेती में शामिल किसानों और विभिन्न हितधारकों के लिए कार्यशालाओं और प्रशिक्षण कार्यक्रमों का भी आयोजन किया। इसके अलावा, विभिन्न हितधारकों तक भा. कृ. अनु. प. –राष्ट्रीय अनार अनुसन्धान केंद्र की प्रौद्योगिकियों का प्रसार करने के लिए विभिन्न संगठनों के साथ कई इंटरैक्टिव बैठकें भी आयोजित की गईं।

- केंद्र द्वारा पीर रिव्युड पत्रिकाओं में 10 शोध पत्र प्रकाशित किए गए, जिनमें से 1 जर्नल का नास रेटिंग 8 से उप्पर था। इसके अलावा इस दौरान 2 पुस्तक अध्याय, 34 लोकप्रिय लेख भी प्रकाशित किए गए थे। वैज्ञानिकों को सर्वश्रेष्ठ मौखिक/पोस्टर प्रस्तुति पुरस्कारों के अलावा पेशेवर सोसायटियों द्वारा फैलोशिप से भी सम्मानित किया गया था ।

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# Executive Summary

In the recent past, pomegranate recorded a remarkable progress in area of 2.62 lakh ha, production of 30.04 lakh MT in 2018-19and export of 80,500 MT in 2019-20. The crop has shown its importance for improving the livelihood security of the farmers in arid and semi-arid regions of India with erratic rainfall. The ICAR-National Research Centre on Pomegranate, Solapur has been playing pivotal role in solving various researchable issues faced by the pomegranate growers and meeting the challenges of this popular crop.

During the year under report, the Centre has handled fifteen Institutional Projects, eleven Externally Funded Projects, two Inter-Institutional Collaborative Projects, one Schedule Castes Sub Plan (SCSP) and one Tribal Sub-Plan (TSP) Scheme. Out of fifteen Institutional Projects, one project has been completed successfully during the period under report. The major achievements are summarized below.

**Genetic Resources:**

- During the period, a large population of varieties and genotypes consisting 207 progenies (viz., 47 seedlings of Mridula; 47 seedling of Wonderful; HWC raised plants of 36 germplasm accessions;14 plants of 5-bromouracil treated pomegranate; 37 M1 population of gamma irradiated plants of cv. 'Bhagawa'; 21 seedlings of M2 generation of Bhagawa and 5 seedlings of M1 generation of Ganesh) were developed for screening against bacterial blight.
- Screening of above 207 progenies against bacterial blight disease under challenge inoculation condition revealed that none of them was resistant to bacterial blight.
- Evaluation of 30 genotypes of pomegranate showed the presence of a significant differences among the genotypes for six traits *viz.* Fruit weight (g), Fruit volume, Fruit length (mm), Fruit diameter (mm), 100 Aril weight (g), Aril width (mm). They have also exhibited prominent variability for fruit colour (Yellow-red tinge to red) and aril colour (Light yellow to dark red) characters.
- Screening of 100 genotypes against wilt (*Ceratocystis fimbriata* and root knot nematode) in wilt sick plot revealed few promising genotypes with less incidence viz., Acc- 2; Acc-11, Acc-12 and Acc-4 recorded 4-10% wilt in 2 years. The check variety Bhagawa (60.55%) and Super Bhagawa (83.31%) were highly susceptible.
- Second year On-site DUS testing of new hybrid varieties from NRCP viz., NRCPH-4 and NRCPH-14 was conducted by comparing with reference varieties by PPV& FRA. And consolidated report submitted.
- Clonal fidelity of 12 *in vitro* raised plantlets of cv. Bhagawa was tested by using 55 SSR primers and has not shown any molecular variations.
- Molecular evaluation of eight pomegranate genotypes using 84 SSR primers showed that 25 SSRs were polymorphic. Based on PIC and Heterozygosity % values PgKVR-24, 32,



121 and PgSSR-1, 2, 44, 53, 56, 70, 81, 87 markers were found useful for cultivar identification.

- The genetic diversity analysis based on molecular dissimilarity coefficient values indicated that Bhagawa and Super Bhagawa (0.01) had least genetic dissimilarity, followed by Mridula and Phule Arakta (0.03). Maximum genetic dissimilarity was observed between Solapur Lal and Ganesh (0.19).

**Crop Improvement:**

- Evaluation of pomegranate variety Solapur Lal in comparison to the ruling variety, Bhagawa during the sixth year of planting in mrig bahar recorded about 18.5 days early maturity, 25.8% higher yield (35.23kg/tree) over Bhagawa besides better fruit quality traits.
- Evaluation of pomegranate variety Solapur Anardana in comparison to Amlidana during the sixth year of planting in mrig bahar was done. Solapur Anardana recorded 28.94 kg/tree fruit yield, 4.82% titrable acidity and 460.5 mg/100g anthocyanin.
- Evaluation of twelve hybrids developed at ICAR-NRCP, Solapur in fifth year of planting revealed that the yield ranged from 15.15-25.59 kg/ tree. The highest yield was recorded by Ganesh x Nayana (25.59kg/tree) which was followed by Bhagawa x Nayana (25.41 kg/ tree).
- NRCP has developed chromosome-specific highly polymorphic SSRs from pomegranate *cv.* Tunisia genome for genetic mapping work.
- *In silico* analysis was performed by retrieving high-quality genome assembly with eight pseudo-chromosome molecules of pomegranate cv. Tunisia. Three other draft genomes of pomegranate cultivars i.e. Dabenzi, Taishanhong and AG2017 were also retrieved for validation of identified SSRs using ePCR.
- Genome-wide discovery of SSR: Genomic sequences of eight Tunisia pseudo chromosome molecules 296.85 Mb (excluding unknown 23.49 Mb sequences) were surveyed. As a result, a total of 365279 perfect SSRs were identified from the 296.85 Mb of genomic sequences, accounting for 5.18 Mb of total length with frequency of 1230.6 SSRs/Mb or 812.6 SSRs/Kb and density of 17443.55 bp/Mb.
- The hexanucleotide repeats were found the most abundant (201501) with a representation of 55 %, followed by di- (55437, 15 %), tetra- (36455, 10 %), tri- (29940, 8%), mono- (27536, 8 %) and penta (14410, 4 %) nucleotide repeats.
- Genome sequencing of Bhagawa : Based on chromosome level assembly using HiC, the final curation and integration led to the validated presence of 33003 genes with 41682 mRNAs. The geneic space in the genome is about 32.7% with the coding space being 18.8% Various statistics about the annotation have been calculated using Genome Annotation Generator.
- Through *in silico* analysis, we report genome-wide development of miRNA-SSR markers specific to seedling to fruit developmental stages in pomegranate. Total 955 functional markers representing 897 miRNA-SSRs and 58 EST-SSRs from target genes were designed for genetic mapping work. This is the first report on development of such informative markers, which could serve as an important genomic resource for genetic mapping against BLB and fruit quality traits in pomegranate.



**Plant Propagation:**

- Twenty two pomegranate genotypes were multiplied with layering success of 52.5 to 87.5 %, for screening against *Ceratocystis fimbriata*, root knot nematode and salinity and to identify rootstocks for biotic, abiotic stresses.
- Grafting: The wedge grafting success of 'Bhagawa' scion (about 8-10mm dia) on different potential rootstocks (about 10 months old) varied from 37.55 to 75.0 % during Nov-Dec, 2020 under protected structure.
- *In vitro* multiplication: Among 110 media and GR combinations evaluated, modified MS medium with reduced $NH_4NO_3$ and modified WPM medium with enhanced $NH_4NO_3$ supplemented with low concentration of IAA, NAA and upto 80mg/l adenine sulphate resulted into maximum shoot elongation (6.3 cm elongation in 25 days). Addition of BAP and/ or Kinetin at low concentration in the mentioned basal media supplemented with very low concentration of NAA and upto 80-100 mg/l adenine sulphate resulted into as high as 4.5 number of side shoots per microshoot per cycle.
- Addition of BAP and/ or Kinetin at low concentration in the above mentioned basal media supplemented with very low concentration of NAA and upto 80-100 mg/l adenine sulphate resulted into as high as 4.5 number of side shoots per microshoot per cycle.
- *In vitro* rooting: Among various combinations of media (half macro MS, WPM and half WPM), growth regulators and adsorbing agent used, shoots inoculated on WPM medium supplemented with 1.0 mg/l IAA took minimum days to root (13 days), produced higher average number of major roots per shoot (2.38) and the highest rooting percent (87.50.%) as compared to other treatments.
- **Bio-priming of *in vitro* raised plants:** For TC plans of Bhagawa maintained under 35% shade, the microbial treatments namely, *Aspergillus niger* strain A-27, AMF predominantly *Glomus intraradices*, *Pseudomonas- fluorescens*, *Penicillium pinophilum* and *Trichoderma- viridis* + *T. harzianum* were used either alone or in combination. The different microbes/ microbial combinations were added in broth form in rhizospheric soil twice at the interval of 15 days. For most of the recorded parameters bio-primed plants performed better than the control (T15).
- The grafting success of 'Bhagawa' scion on wild rootstocks ranged from 55.00 % to 80.00 %. The ICAR-NRCP hybrid 'Solapur Lal' was found to be significantly vigorous than 'Bhagawa' under 35% shade net house condition. The air layering success under protected structure was significantly higher in 'Super Bhagawa' as compared to 'Solapur Lal'. For mother plants maintained under filed conditions, 'Super Bhagwa' and 'Bhagawa' registered better cutting and layering success as compared to 'Solapur Lal'.

**Production**

- Mineral sources of K and P did not have any harmful effect on *Penicillium pinophilum*, rather enhanced its population in the formulation during storage at ambient condition. Hence, they have been used for developing K and P bio-mineral fertilizer with addition of some additives to improve the storage life of developed fertilizer.



- Foliar application of amino acid-based micronutrient formulations I & II significantly increased total number of flowers, number of hermaphrodite flowers, fruit set, fruit yield and per cent exportable grade fruits besides, aril percent and nutritional parameters over the widely used micronutrient formulation (EDTA chelated micronutrients).
- Seventeen bacterial endophytes were tested; 13 (TC series) from nodal segent used for developing tissue culture plants, 1 (BE 10) from stem of *Ocimum tenuiflorum* (holy basil), and 3 (BE-2, BE-4, BE-5) from leaves and stems of *Ocimum basilicum* (sweet basil). All endophytes tested (exept TC-2) recorded bacterial blight incidence (0-38%) significantly lower than untreated control (64.33%), however endophytes TC-4, TC-310 completely checked blight with 4 sprays. Endophyte treated plants also recorded good foliar growth, this could be attributed to the fact that these edophytes were promising potash and phosphate solubilizers as observed in *in vitro* studies.
- Sixty eight pomegranate germplasm accessions were evaluated for fruit cracking (%) during 2019. ANOVA showed significant differences between the genotypes both at 1% and 5% level of significance (F@ 0.05- 1.40 *; F@0.05-1.61**). Fruit cracking (%) among the genotypes ranged from 0-53.90%. Eight wild genotypes showed no fruit cracking (1201, 1198, IC-318718, IC-318743, IC-318766, IC-318712, IC-318716, Acc. No.-5). Aril browning incidence ranged from 0 to 16.69 %, in 'Bhagawa'-2.58 % aril browning incidence was observed and the maximum aril browning was observed in the exotic collection Crenedeo-de-elch (16.69 %). Hyperspectral signatures of plant canopy of 72 pomegranate genotypes along with cracked and healthy fruits of 67 genotypes were also recorded using Spectroradiometer.
- The irrigation water requirement for pomegranate under shade net house and open field conditions were estimated as 650 and 6193 L $tree^{-1}season^{-1}$ for the first year growth of pomegranate plants. The ICAR-NRCP hybrid 'Solapur Lal' was found vigorous under protected structure as compared to other commercial varieties.
- Among the various PRZDI, the 80% *Etc wetted soil volume with 20 % *ASWD is the best for $7^{th}$ year pomegranate orchards

**Crop Protection**

- Stem **solarization to manage bacterial blight :** Developed Stem Solarization technology to manage bacterial blight in community approach with 100% blight control. It is ecofriendly, economical and effective technology and can eradicate the pathogen if done in community approach. It can also be used for organic cultivation plots. FLDs at 6 locations are in progress 3 at Rahata in Ahemadnagar and 3 in Malshirus at Solapur district in Maharshtra. The success of field trials at NRCP for 3 years and 1 farmer's plot at Akkalkot for 2 years have been reported in previous annuals reports as 'Six Steps to Manage Bacterial Blight', on the recommendations of RAC the technology name has been changed.
- **Bacteriophages for blight management:** Bacteriophages from pomegranate tree phylloplane were found effective in bacterial blight pathogen *Xanthomonas axonopodis* pv *punicae* of pomegranate *in vitro* trials. Studies are in progress for making formulation with UV protectants and long shelf life to take field trials.



- **Weather-based prediction model:** Work was initiated on weather-based prediction model for bacterial blight in pomegranate in collaboration with ICAR-CRIDA and weekly blight data for 10 years has been provided by NRCP.
- **3Report of new insect pest and natural enemies:** The biocontrol agent, *Brachymeria sp.* Reported as larva-pupal parasitoid of *Deudorix 21socrates*. The new insect's pest recorded on pomegranate with different level of infestation on different parts of the pomegranate includes invasive mealybug *Nipaecoccus viridis* on all parts and all stages with 30-50% damage on fruits. The *Helicoverpa armigera* with 2-3 fruits damaged on 6-8 plants. The southern green stink bug, *Nezara viridula* on leaf, tinder shoots and with 5-8% damage on young and developing fruits. The wire worm (click beetle) pest on roots young pomegranate plants grown under protected cultivation with withering of 5-6 plants. Red stem borer (*Zuezera Coffeae*) on shoots with 2-3% damage. During night survey two secondary fruit piercing moths of pomegranate *viz., Ophusia tirhaca* and *Achaea janata* were recorded. collected and -of field The male to female sex ratio laboratory reared population fruit piercing moths was 1.69:1and 1.78:1 respectively. Among the 51 different pomegrnate germplasm screened against thrips and fruit borer the infestation varied from 13.25-75.5 % and 8.5-12.75% by thrips and fruit borer respectively.
- γ-aminobutyric acid (GABA) was found to induce resistance against bacterial blight and associated defense response. Prophylactic sprays with 600 ppm GABA resulted in blight reduction by 34.78% with significant improvement in fruit size and yield.
- Clove Oil (0.2%) was found to be a potent defense inducer for management of bacterial blight. Prophylactic application of clove oil recorded a high relative expression of pathogenesis-related (PR) proteins (PR1, PR4, and PR10), phenyl ammonia lyase, chitinase, callosesynthase 3 and peroxidase. Clove oil in combination with copper oxychloride reduced blight by 95.5% and recorded highest fruit yield of 14.04t/ha, whereas control recorded only 4.05t/ha.
- Metabolic (phenylpropanoids) profiling of pomegranate tolerant (IC318735) and susceptible genotypes to bacterial blight was studied. In pathogen treated tolerant genotypes, seven metabolites (Ferulic acid, coumarin, cinnamic acid, eugenol, kaempferol, quinic acid and p-coumaric acid) were significantly induced in comparison to susceptible commercial cultivar compared to Bhagawa. All metabolites except kaempferol and quinic acid were found inhibitory to blight pathogen and eugenol and cinnamic acid recorded highest inhibitory effect.
- The availability of the genome sequence of reference strain LMG 859 of *X. axonopodis* pv. *Punicae* has given a great impetus to epidemiological and quarantine studies. First time we performed genome wide survey of microsatellites and designed a total of 2746 SSR primers specific to *Xap* genome. Showed their immediate utility by validating and studying molecular diversity among 22 *Xap* isolates. The genomic tool generated here could enable future research on population dynamics, taxonomy, epidemiological and quarantine aspects of this pathogen.
- Six steps to manage bacterial blight was found to be the most economical, ecofriendly and promising strategy to check bacterial blight 80-100% in orchards facing above 50 to 100% losses in rainy season (Kharif) crop. This was demonstrated in one organic block at



ICAR-NRCP Solapur and 3 farmers' orchards at Solapur and Satara districts of Maharashtra. All recorded 75-100% blight control. One of the farmers plot recorded 305% increase in yield and 25% reduction in input cost in comparison to previous year when he lost 75% produce due to blight.

**Post-Harvest Technology**

- Protocol standardized for development of probiotic pomegranate juice and pomegranate seed based mouth freshener
- Maturity indices for pomegranate variety Solapur Lal were determined. Solapur Lal attained maturity at 160 days after anthesis with highest total soluble solids content (17.7$^{o}$Brix) and TSS-acid ratio (44.25)
- Determination of anardana recovery from 10 sour type pomegranate hybrids in comparison with Amlidana (Check variety) revealed that anardana recovery ranged from 17.5-21.2%. It was highest in Solapur Anardana (21.2%) closely followed by NRCP H-4 (20.8%). The recovery was lowest in Amlidana (17.5%).
- Microencapsulation is a technique by which active ingredients are packaged for its protection from heat, moisture, oxygen etc. The study has been undertaken to standardize the process of encapsulation of pomegranate seed oil using calcium alginate as wall material. Microencapsulation of pomegranate seed oil (PSO) was carried out using emulsion extrusion technique. The optimized process conditions for the experiment were 10% oil loading, 350 µ nozzle diameter and 3.23% sodium alginate concentration. The observed responses of encapsulation efficiency, loading capacity, equivalent diameter, sphericity factor and rupture force were 78.03%, 7.83%, 30.05 µm 0.039 and 30.20 N respectively.
- Fruits of pomegranate variety Solapur Lal had highest total soluble solids content (17.6$^{o}$Brix) at the time of maturity.
- Assessment of Anardana recovery from arils of ten sour type pomegranate hybrids recorded highest Anardana recovery by Solapur Anardana (22.1%).

**Other Activities**

- The Centre has taken up promotion of pomegranate cultivation in the states of Maharashtra, Rajasthan, Chhattisgarh, Madhya Pradesh through SCSP, TSP and Mera Gaon Mera Gaurav through demonstration, supplying inputs, providing Soil Health Card, imparting trainings and technical guidance benefitting around 500 farmers.
- ICAR-NRCP commercialized three technologies to entrepreneurs and displayed its activity in seven exhibitions and more than 900 visitors including farmers, students and other stakeholders visited the center for information.
- In addition to this, 9 staff underwent 13 training programs under HRD and attended 37 conferences/seminars/symposia and 4 workshops under the capacity building activities.
- All the staff of ICAR-NRCP actively participated in activities under Swachch Bharat Abhiyan, Vigilance Awareness Week, International Women's Day, Farmers' Day etc.



- The Centre also organized workshops and training programmes for farmers and various stakeholders involved in pomegranate cultivation. Apart from this, various interactive meetings were conducted in collaboration with different organizations to disseminate the ICAR-NRCP technologies to different stake holders.
- The Centre published 10 research papers in peer reviewed journals, out of which 1 was in journal with NAAS rating $\geq$ 8. In addition, 2 book chapters, 34 popular articles were published. The scientists also got recognitions from professional Societies viz., Fellowships, besides best oral / poster presentation awards.

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# Research Programmes & Projects

## INSTITUTE RESEARCH PROJECTS

| S. No. | Project title | PI | Co-PIs | Status |
|---|---|---|---|---|
| 1 | Breeding for bacterial blight resistance in pomegranate | Dr. Shilpa P. | Dr. J. Sharma<br>Dr. K. D. Babu<br>Dr. P. G. Patil | Ongoing |
| 2 | Draft genome sequencing of Pomegranate (*Punica granatum* L.) cv. Bhagwa | Dr. Roopa Sowjanya P. | Dr. Shilpa P.<br>Dr. N.V. Singh<br>Dr. P. Patil | Ongoing |
| 3 | Genetic Mapping of Bacterial Blight and Fruit Quality Traits in Pomegranate | Dr. P. G. Patil | Dr. J. Sharma<br>Dr. Shilpa P.<br>Dr. N. V. Singh<br>Dr. K. D. Babu | Ongoing |
| 4 | Propagation, bio-hardening and mass multiplication of elite planting material in pomegranate (*Punica granatum* L.) | Dr. N.V. Singh | Dr. K.D. Babu,<br>Dr. J. Sharma<br>Dr. Shilpa P.<br>Dr. Roopa Sowjanya P. | Completed |
| **5** | Combating stresses and improving quality in pomegranate (*Punica granatum* L.) by exploiting rootstocks | Dr. N.V. Singh | Dr. Roopa Sowjanya P.<br>Dr. Prakash G. Patil<br>Dr. Manjunath N.<br>Dr. K.D. Babu<br>Dr. Somnath Pokhare | Ongoing |
| 6 | Crop regulation practices for improving productivity of pomegranate | Dr. K. Dhinesh Babu | Dr, N.V. Singh<br>Dr A. Maity<br>Dr J. Sharma | Ongoing |
| 7 | Package of practices for organic cultivation of pomegranate | Dr. A. Maity | Dr. J. Sharma<br>Dr. Gaikwad N.N.<br>Dr. Mallikarjun, H. | Ongoing |
| 8 | Development and refinement of integrated production technologies for improved productivity in Pomegranate (*Punica granatum* L.)-Intercropping | Dr. D.T. Meshram | Dr. K. D. Babu<br>Dr. N.V. Singh<br>Dr. A. Maity<br>Dr. J. Sharma | Ongoing |



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|---|---|---|---|---|
| 9 | Sensor based irrigation scheduling for water productivity of Pomegranate (*Punica granatum* L.) | Dr. D.T. Meshram | Dr. K. D. Babu<br>Dr. N.V. Singh<br>Dr. A. Maity<br>Dr. J. Sharma | Ongoing |
| 10 | Post-harvest management and value addition in pomegranate for Entrepreneurship development | Dr. Gaikwad N.N. | Dr. K. D. Babu,<br>Dr. A. Maity | Ongoing |
| 11 | Development of Functional food products and waste utilization from pomegranate | Dr. Namrata A Giri | Dr. Nilesh Gaikwad<br>Dr. A. Maity | Ongoing |
| 12 | Development of technologies for sustainable management of important insect pest of pomegranate | Dr. Mallikarjun | Dr. Manjunatha N<br>Dr. Somnath S. Pokhare<br>Dr. R A Marathe | Ongoing |
| 13 | Studies on wilt complex in Pomegranate | Dr. Somnath Pokhare | Dr. Manjunatha.N<br>Dr.Mallikarjun M.H.<br>Dr.R A Marathe | Ongoing |
| 14 | Epidemiology and sustainable management of economically important phylloplane disease of pomegranate | Dr. Manjunatha N. | Dr.Jyotsana Sharma<br>Dr.Somnath Pokhare<br>Dr. Mallikarjun M.H.<br>Dr.Prakash G Patil<br>Dr. A.Maity<br>Dr.R A Marathe | Ongoing |
| 15 | Flagship project on Integrated approach to eradicate Pomegranate bacterial blight | Dr. Jyotsana Sharma | | Ongoing |

## EXTERNALLY FUNDED PROJECTS

| S. No. | Funding agency | Project | PI | Co-PIs | Status |
|---|---|---|---|---|---|
| 1 | ICAR | ICAR-All India Coordinated Research Project on Arid Zone Fruits | Dr. K. Dhinesh Babu | Dr. N.V. Singh<br>Dr. Mallikarjun | Ongoing |
| 2 | ICAR-Consortia Research Platform on water | Response of pomegranate to deficit Irrigation and partial root zone drying. | Dr. A.K. Nair ICAR-IIHR, Bangalore | Dr. D.T. Meshram | Ongoing |
| 3 | BVG Life Sciences | Effect of BVG Products on growth, pests & diseases | Dr. N.V. Singh | Dr. J. Sharma<br>Dr. | Completed |



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|---|---|---|---|---|---|
| | | incidence & yield of Pomegranate | | Mallikarjun | |
| 4 | NHB, Gurugram | Standardization and demonstration of production technologies for protected cultivation of pomegranate | Dr. N.V. Singh | Dr. Mallikarjun Dr. N.N. Gaikwad Dr. D.T. Meshram | Completed |
| 5 | M/s. Biostadt India Ltd | To study the effect of biozyme Fruit Plus L on yield and quality parameters | Dr. N.V. Singh | Mr. Mahadev Gogaon | Ongoing |
| 6 | NMPB, Ministry of AYUSH Government of INDIA | Utilization of pomegranate for development of functional medical ingredient | Dr. Gaikwad N.N. | Dr. Debi Sharma ICAR-IIHR (CPI) Dr. Krishna Das Saha CSIR-IICB, Kolkata, (CPI) | Ongoing |
| 7 | PPV&FRA, New Delhi | Establishment of DUS centre at ICAR-NRCP, Solapur | Dr. Shilpa P. | Ms. Roopa P. Sowjanya | Ongoing |
| 8 | Bayer Crop Science Limited | Study of residue and persistence of Fosetyl-Al and phosphonic acid in pomegranate fruit after application of Aliette and Profiler | Dr. A. Maity | Dr. (Mrs.) J. Sharma Sh. Vijay Lokhande | Ongoing |
| 9 | InGene Organics | Effect of Cardle, Nanozim drip and Nanozim delite on Pomegranate yield and fruit quality. | Dr. A. Maity | Dr. (Mrs.) J. Sharma Sh. Vijay Lokhande | Ongoing |
| 10 | RKVY, DAC, GoI | Horticulture Crop Pest Surveillance and Advisory Project for Mango, Pomegranate & Banana | Dr. Jyotsana Sharma | Dr. Mallikarjun | Ongoing |
| 11 | Indofil Industries Limited, Mumbai | Evaluation of bio-efficacy and Phyto-toxicity of IFFC016, IFFC017 and IFFC018 against fungal leaf and fruit disease complex in pomegranate | Dr. Jyotsana Sharma | Dr. K.D. Babu | Ongoing |



## TRIBAL SUB-PLAN

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

## SCHEDULED CASTES SUB-PLAN

| S. No. | Project title | PI | Co-PI | Status |
|---|---|---|---|---|
| 1 | Promotion of pomegranate cultivation in SC dominated Tikkamgarh district of M.P. in collaboration with SRIJAN | Dr. N.V. Singh | Dr. Shilpa P. Mr. Yuvraj Shinde Mr. Mahadev Gogaon | Ongoing |
| 2 | Promotion of Pomegranate Cultivation among SC farmers of Maharashtra | Dr. N.V. Singh | Dr. Shilpa P. Mr. Yuvraj Shinde Mr. Mahadev Gogaon | Ongoing |

## INTER-INSTITUTIONAL COLLABORATIVE PROJECTS

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

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# Genetic Resources

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

### 1.1.1. Development of new seedling population from selected hybrids/ mutants/open pollinated seeds of varieties and other experimental plants for screening against BBD

During *mrig* bahar of 2019-20, new screening materials like seedling population of Mridula (47 nos.) and Wonderful (47 nos.); hardwood cutting raised plants of 36 germplasm accessions; 5-bromouracil (14 nos.) treated plants; gamma irradiated M1 mutant plants of cv. 'Bhagawa' (37 nos.); M2 seedlings of cv. Bhagawa (21 nos.) and Ganesh (5 nos.) were developed and screened against Bacterial blight disease under challenge inoculation condition. None of them were promising for the bacterial blight disease.

### 1.1.2. Evaluation and identification of promising pomegranate genotypes for important fruit traits

30 selected pomegranate genotypes (including "Bhagawa" and 'Ganesh' check varieties) from the existing breeding material of ICAR-NRCP, Solapur were evaluated for 10 important fruit characteristics during 2020-21. The statistical analysis of the data carried out by using R package version 0.1.0 & 1.0.1. Analyzed data has showed the presence of a significant differences among the genotypes for six traits *viz.* Fruit Weight (g), Fruit Volume, Fruit length (mm), Fruit Diameter (mm), Aril Weight (g), 100 Aril Weight (g), Aril Width (mm) (Table 1.). They have also exhibited prominent variability for fruit colour (Yellow-red tinge to red) and aril colour (Light yellow to dark red) characters.

Based on the least significant difference (LSD) test, three genotypes (NRCPS-7, NRCPS-8 and NRCPS- 23) were found to be promising with desirable fruit weight, 100 aril weight, aril length, aril width, total soluble solids and acidity content (Table 2). Further they will be evaluated for Bacterial Blight disease reaction under controlled condition.



**Table 1. Statistical significance of the fruits traits evaluated among 28 pomegranate genotypes**

| Traits | Fruit Weight (g) | Fruit Volume | Fruit Length (mm) | Fruit Diameter (mm) | 100Aril Weight(g) | Rind Thickness (mm) | Aril Length (mm) | Aril Width (mm) | Total Soluble Solids (0Brix) | Acidity (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 233.81 | 207.28 | 73.95 | 75.00 | 31.41 | 2.67 | 10.28 | 6.32 | 16.23 | 0.28 |
| Minimum | 144.21 | 120.08 | 64.61 | 64.67 | 19.90 | 1.73 | 8.74 | 4.95 | 14.82 | 0.21 |
| Maximum | 382.18 | 359.33 | 87.61 | 88.04 | 46.24 | 3.70 | 17.34 | 7.14 | 17.51 | 0.48 |
| SE(m) | 26.97 | 26.13 | 2.95 | 3.04 | 3.50 | 0.39 | 1.45 | 0.28 | 0.50 | 0.06 |
| SE(d) | 38.14 | 36.96 | 4.17 | 4.30 | 4.95 | 0.55 | 2.05 | 0.40 | 0.70 | 0.08 |
| CV | 19.98 | 21.84 | 6.90 | 7.02 | 19.29 | 25.23 | 24.45 | 7.75 | 5.29 | 35.99 |
| CD/LSD | 76.35 | 73.98 | 8.34 | 8.61 | 9.90 | 1.10 | 4.11 | 0.80 | 1.40 | 0.16 |
| t.value | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| R Square | 0.73 | 0.73 | 0.68 | 0.67 | 0.68 | 0.52 | 0.35 | 0.59 | 0.46 | 0.46 |
| F value | 5.13** | 5.29** | 4.12** | 3.86** | 2.83** | 1.11 | 1.01 | 2.72** | 1.61 | 1.11 |

## 1.1.3.Screening of generated Experimental Materials against Bacterial Blight

**(a)** **Screening for wilt (*Ceratocystis fimbriata* and root knot nematode) resistance** done in wilt sick plot. Out of 100 accessions, hybrids and varieties, p**romising ones were seedlings of hybrid ACC 2; ACC 11, ACC 12 and** ACC 4 with 4-10% wilt in 2 years. The check variety Bhagawa (60.55%) and Super Bhagawa (83.31%) were highly susceptible.

**(b)** **Screening of germplasm and seedling population for bacterial blight resistance was done**. IC and EC Accessions, some popular varieties, Colchicine, Uracil treated seedling population were screened none was resistant/tolerant, all recorded high blight incidence 80-96% and few 30-40%, none was free or below 30% blight

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# Crop Improvement

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

### 2.1.1.Evaluation of varieties released 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 sixth year of planting in mrig bahar recorded about 19.2 days early maturity, around 25.8% higher yield over Bhagawa besides better fruit quality traits.

**Fig. Comparative evaluation of Solapur Lal vs Bhagawa during sixth year of planting**

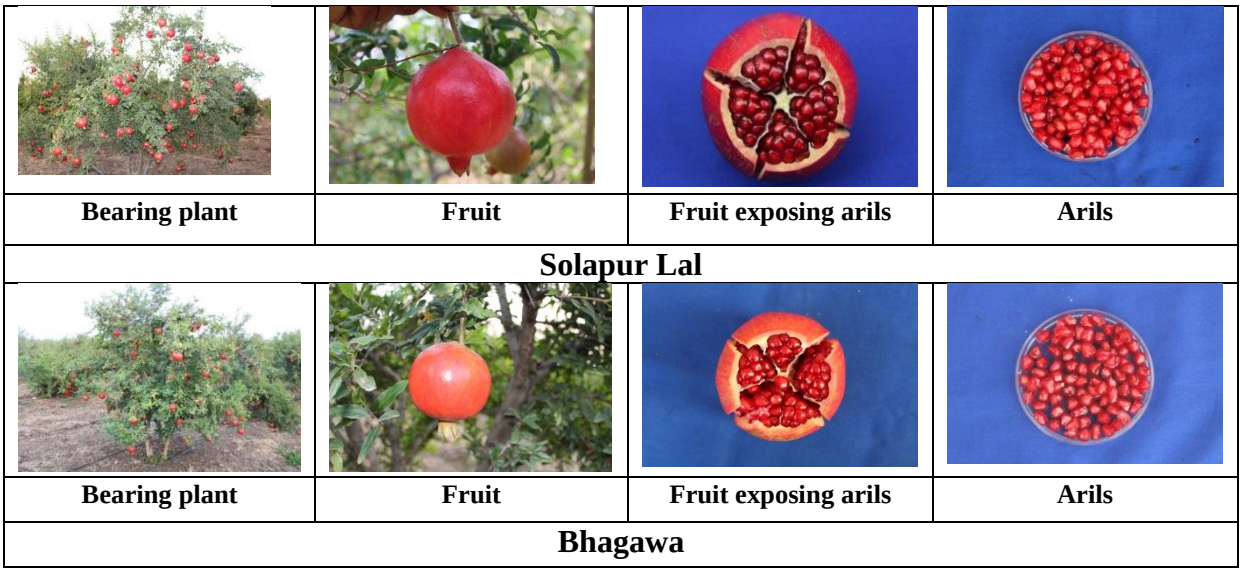



**Table. Comparative evaluation of Solapur Lal and Bhagawa**

| Characters | Solapur Lal | Bhagawa |
|---|---|---|
| Plant height (m) | 2.14 | 1.92 |
| Fruit maturity (days) | 161.2 | 180.4 |
| Fruit weight (g) | 270.2 | 276.6 |
| No. of fruits /tree | 130.4 | 101.2 |
| Yield (kg/plant) | 35.23 | 27.99 |
| Yield (t/ha) | 26.07 | 20.71 |
| Aril colour | Deep red | Red |
| Fruit colour | Red | Red |

| | | |
|---|---|---|
| Rind thickness (mm) | Medium 3.40 | Medium 3.36 |
| Juice (%) | 43.0 | 44.0 |
| TSS ($^{o}$Brix) | 17.56 | 15.76 |
| Titrable acidity (%) | 0.40 | 0.46 |
| Ascorbic acid (mg/100g) | 19.2 | 14.8 |
| Anthocyanin (mg/100g) | 395 | 352 |
| Iron (mg/100g) | 1.50 | 0.90 |
| Zinc (mg/100g) | 0.50 | 0.40 |

### 2.1.1.2. Comparative evaluation of Solapur Anardana

Evaluation of pomegranate variety Solapur Anardana in comparison to Amlidana during the sixth year of planting in mrig bahar was done. Solapur Anardana recorded 28.94 kg/tree fruit yield, 4.82% titrable acidity and 460.5 mg/100g anthocyanin.

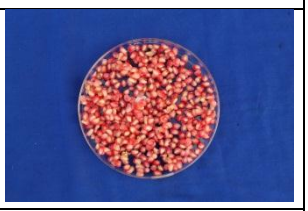
**Fig. Comparative evaluation of Solapur Anardana with Amlidana during sixth year of planting**




| Bearing plant | Fruit | Fruit exposing arils | Arils |
|---|---|---|---|

**Solapur Anardana**



| Bearing plant | Fruit | Fruit exposing arils | Arils |
|---|---|---|---|

**Amlidana**

**Comparative evaluation of Solapur Anardana and Amlidana:**

| Characters | Solapur Anardana | Amlidana |
|---|---|---|
| Plant height (m) | 2.18 | 1.68 |
| Fruit maturity (days) | 145.8 | 150.2 |
| Fruit weight (g) | 274.6 | 230.2 |
| No. of fruits /tree | 105.4 | 74.2 |
| Yield (kg/plant) | 28.94 | 17.08 |



| | | |
|---|---|---|
| Yield (t/ha) | 21.71 | 12.63 |
| Aril colour | Red | Light pink |
| Fruit colour | Red | Yellow |
| Seed texture | Medium | Medium |
| Juice (%) | 42.0 | 40.5 |
| TSS ($^{o}$Brix) | 16.64 | 15.62 |
| Ascorbic acid (mg/100g) | 17.8 | 14.0 |
| Anthocyanin (mg/100g) | 460.5 | 63.5 |
| Titrable acidity (%) | 4.82 | 4.18 |

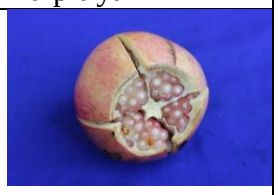
### 2.1.1.3. Evaluation of hybrids developed from ICAR-NRCP:

Twelve hybrids developed at ICAR-NRCP, Solapur were evaluated for yield and quality during fifth year of planting. The yield ranged from 15.15-25.59 kg/ tree. The highest yield was recorded by Ganesh x Nayana (25.59kg/tree) which was followed by Bhagawa x Nayana (25.41 kg/ tree).

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

| Hybrid | Fruit weight(g) | No. of fruits/tree | Yield (kg/tree) | TSS ($^{o}$B) | Titrable acidity (%) |
|---|---|---|---|---|---|
| Bhagawa | 264.5 | 90.3 | 23.88 | 15.7 | 0.46 |
| Bhagawa x Patna-5 | 292.1 | 80.3 | 23.45 | 16.6 | 0.35 |
| Bhagawa x Nana | 214.7 | 70.6 | 15.15 | 14.0 | 2.60 |
| Bhagawa x Daru | 246.1 | 80.3 | 19.76 | 17.0 | 2.80 |
| Bhagawa x Kalpitiya | 282.1 | 85.0 | 23.97 | 14.6 | 0.33 |
| Bhagawa x Nayana | 272.4 | 93.3 | 25.41 | 15.9 | 0.38 |
| Bhagawa x IC-318712 | 235.6 | 85.6 | 20.16 | 14.8 | 2.80 |
| Ganesh x Kalpitiya | 236.8 | 78.0 | 18.47 | 15.7 | 0.46 |
| Ganesh x Nayana | 282.5 | 90.6 | 25.59 | 16.0 | 0.34 |
| Bhagawa x [(Ganesh x Nana) x Daru]-HA | 254.8 | 95.3 | 24.28 | 15.9 | 0.48 |
| Kalpitiya x Ruby | 283.5 | 85.0 | 24.09 | 15.7 | 0.39 |
| Nayana x Ruby | 270.4 | 90.3 | 24.41 | 15.5 | 0.40 |
| Ruby x Nayana | 210.6 | 84.6 | 17.81 | 15.4 | 0.36 |



| | |
|---|---|
|   |   |
| Bhagawax Patna-5 | Bhagawa x Nana |
|   |   |
| Bhagawa x Daru | Bhagawa x Kalpitiya |
|   |   |
| Bhagawa x Nayana | Bhagawa x IC-318712 |
|   |   |
| Ganesh x Kalpitiya | Ganesh x Nayana |
|   |   |
| Bhagawa x [(Ganesh x Nana) x Daru]-HA | Kalpitiya x Ruby |
|   |   |
| Nayana x Ruby | Ruby x Nayana |
| **Fig. Evaluation of pomegranate hybrids developed by ICAR-NRCP** | |

### 2.1.1.4. Evaluation of pomegranate selections:

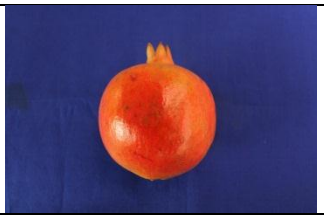
Evaluation of fourteen pomegranate selections in comparison with Bhagawa was carried out during sixth year of planting. The study was carriedout for various physicochemical characters in Mrig bahar. The results revealed that yield ranged from 24.13 to 29.50 kg/tree. The yield was highest in Sln. 348 (29.50 kg/tree) closely followed by Sln. 375 (28.23 kg/tree). Total soluble solids content ranged from 15.7 to 16.7°Brix.

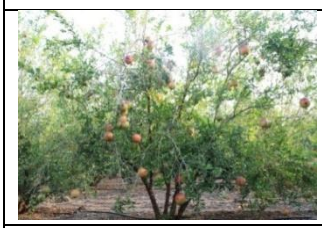
**Table. Evaluation of pomegranate selections**

| Genotype | Fruit weight (g/fruit) | No. of fruits/tree | Yield (kg/tree) | TSS (°B) | Acidity (%) | Fruit Color | Aril Color |
|---|---|---|---|---|---|---|---|
| Bhagawa | 276.6 | 94.0 | 26.08 | 15.7 | 0.46 | Red | Red |
| IC-24686 | 271.2 | 89.0 | 24.13 | 15.9 | 0.43 | Red | Red |
| Sln.934 | 270.1 | 96.3 | 26.01 | 15.9 | 0.37 | Yellowish red | Light red |
| Sln.391 | 270.8 | 93.6 | 25.34 | 15.8 | 0.42 | Yellowish red | Light red |
| Sln.528 | 276.4 | 100.3 | 27.72 | 15.9 | 0.41 | Yellowish red | Red |
| Sln.375 | 279.6 | 101.0 | 28.23 | 16.7 | 0.40 | Yellowish red | Light Red |
| Sln.348 | 280.2 | 105.3 | 29.50 | 15.9 | 0.36 | Red | Red |
| Sln.388 | 269.8 | 99.6 | 26.87 | 16.5 | 0.41 | Yellowish pink | Light red |
| Sln.317 | 268.4 | 97.0 | 26.03 | 16.6 | 0.39 | Yellowish pink | Light red |
| Sln.216 | 273.2 | 92.6 | 25.29 | 16.3 | 0.39 | Yellowish pink | Light red |
| Sln.311 | 284.2 | 99.3 | 28.22 | 16.0 | 0.37 | Red | Red |
| Sln.1128 | 281.5 | 98.0 | 27.58 | 15.9 | 0.38 | Yellowish red | Light red |
| Sln.1129 | 268.6 | 96.3 | 25.86 | 15.8 | 0.41 | Yellowish red | Light red |
| Sln.1121 | 265.4 | 95.6 | 25.37 | 15.9 | 0.39 | Yellowish red | Light red |
| Sln.1130 | 270.5 | 102.3 | 27.67 | 15.9 | 0.41 | Yellowish red | Red |

**Fig. Evaluation of pomegranate selections**



| | | |
|---|---|---|
|  |  |  |
| | **Bhagawa** | |
|  |  |  |
| | **IC-24686** | |
|  |  |  |
| | **Sln. 934** | |
|  |  |  |
| | **Sln. 391** | |
|  |  |  |
| | **Sln. 528** | |
|  |  |  |
| | **Sln.375** | |

| | | |
|---|---|---|
|  |  |  |
| | **Sln.348** | |
|  |  |  |
| | **Sln.388** | |
|  |  | |
| | **Sln.317** | |
|  |  |  |
| | **Sln.216** | |
|  |  |  |
| | **Sln.311** | |
|  |  |  |
| | **Sln.1128** | |



Sln.1129



Sln.1121



Sln.1130

**Identification of promising hybrids for table purpose:**

Evaluation of 25 NRCP hybrids during sixth year of planting led to the identification of NRCP H-14 for table purpose. The salient characters of NRCP H-14 is mentioned below.

| **Characters** | **NRCP H-14** |
|---|---|
| Maturity (days) | 165.0 |
| No. of fruits/plant | 120.4 |
| Fruit weight (g) | 280.2 |
| Fruit yield (kg/plant) | 33.7 |
| 100 aril weight (g) | 32.5 |
| TSS ($^{o}$Brix) | 17.8 |
| Acidity (%) | 0.42 |
| Ascorbic acid (mg/100g) | 19.2 |
| Anthocyanin (mg/100g) | 124.1 |

**NRCP H-14**

**Identification of promising hybrids for processing purpose:**

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

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

| **Characters** | **NRCP H-4** |
|---|---|
| Maturity (days) | 150.0 |
| No. of fruits/plant | 110.2 |
| Fruit weight (g) | 270.5 |
| Fruit yield (kg/plant) | 29.8 |
| 100 aril weight (g) | 30.5 |
| TSS ($^{o}$Brix) | 16.2 |
| Acidity (%) | 5.76 |
| Ascorbic acid (mg/100g) | 18.8 |
| Anthocyanin (mg/100g) | 60.5 |




**NRCP H-4**

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

**Development of chromosome-specific highly polymorphic SSRs from pomegranate (*Punica granatum* L.) *cv.* Tunisia genome for genetic mapping work**

### 2.2.1. *In silico* analysis and genome-wide discovery of SSRs -

*In silico* analysis was performed by retrieving high-quality genome assembly with eight pseudo-chromosome molecules of pomegranate cultivar Tunisia. Three other draft genomes of pomegranate cultivars i.e. Dabenzi, Taishanhong and AG2017 were also retrieved for validation of identified SSRs using ePCR. Genomic sequences of eight Tunisia pseudo chromosome molecules 296.85 Mb (excluding unknown 23.49 Mb sequences) were surveyed for the presence of chromosome specific perfect, compound, and imperfect SSRs repeats. As a result, a total of 365279 perfect SSRs were identified from the 296.85 Mb of genomic sequences, accounting for 5.18 Mb of total length with frequency of 1230.6 SSRs/Mb or 812.6 SSRs/Kb and density of 17443.55 bp/Mb, respectively. The hexanucleotide repeats were found the most abundant (201501) with a representation of 55 %, followed by di- (55437, 15 %), tetra- (36455, 10 %), tri- (29940, 8%), mono- (27536, 8 %) and penta (14410, 4 %) nucleotide repeats.

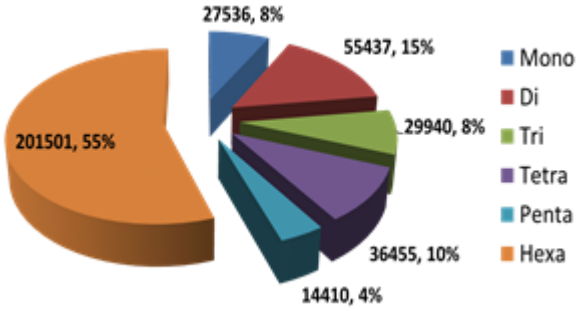



**Fig. 1. The distribution of SSR repeats for mono- to hexa- nucleotide motifs across the Tunisia genome**

### 2.2.2. The intra-chromosomal distribution of SSRs

We further analyzed the distribution of SSRs on each chromosome of Tunisia. The SSR loci identified were further classified on the basis of their repeat motif and distribution over each chromosome**.** We identified a total of 365279 perfect SSRs in comparison to 415716 imperfect SSRs with mean marker densities of 1230.6 and 1400.5 (SSR/Mb), respectively across the eight chromosomes. The highest number of SSRs (60708 perfect, 67141 imperfect) was assigned to the largest chromosome 1 (55.56 Mb) followed by SSRs mapped onto chromosome 2 (44.57 Mb, 56038 perfect, 64041 imperfect) and chromosome 4 (40.13 Mb, 51511 perfect, 58934 imperfect). Less perfect (35868, 37304 and 36241) as well as imperfect SSRs (41094, 42809 and 41901) were assigned to shorter chromosomes Chm_6 (28.33 Mb), Chm_7 (28.78 Mb) and Chm_8 (27.99 Mb) respectively.

**Table 1. The chromosome wise distribution of perfect, compound and imperfect SSRs**

| Chromosome | Total Mb | Perfect | | | | | | | | Compound | | Imperfect | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mono | Di- | Tri- | Tetra- | Penta- | Hexa- | Total | SSRs/Mb | Total | SSRs/Mb | Total | SSR/Mb |
| **Chm 1** | 55.56 | 4289 | 8574 | 4842 | 6141 | 2275 | 34587 | **60708** | 1092.77 | **9090** | 163.62 | **67141** | 1208.57 |
| **Chm 2** | 44.57 | 4278 | 8617 | 4518 | 5459 | 2241 | 30925 | **56038** | 1257.43 | **8573** | 192.37 | **64041** | 1437.01 |
| **Chm 3** | 39.96 | 3486 | 7027 | 3944 | 4863 | 1933 | 26189 | **47442** | 1187.40 | **7138** | 178.65 | **53647** | 1342.70 |
| **Chm 4** | 40.13 | 4082 | 8041 | 4187 | 5072 | 2008 | 28121 | **51511** | 1283.75 | **8036** | 200.27 | **58934** | 1468.74 |
| **Chm 5** | 31.53 | 3053 | 6186 | 3377 | 4006 | 1637 | 21908 | **40167** | 1273.87 | **6115** | 193.93 | **46149** | 1463.58 |
| **Chm 6** | 28.33 | 2746 | 5419 | 3048 | 3701 | 1427 | 19527 | **35868** | 1266.29 | **5506** | 194.38 | **41094** | 1450.79 |
| **Chm 7** | 28.78 | 2933 | 5694 | 2951 | 3685 | 1487 | 20554 | **37304** | 1296.21 | **5716** | 198.62 | **42809** | 1487.50 |
| **Chm 8** | 27.99 | 2669 | 5879 | 3073 | 3528 | 1402 | 19690 | **36241** | 1294.62 | **5662** | 202.26 | **41901** | 1496.81 |
| **Total** | **296.85** | **27536** | **55437** | **29940** | **36455** | **14410** | **201501** | **365279** | **1230.60** | **55836** | **188.11** | **415716** | **1400.52** |

### 2.2.3. Chromosome specific distribution of three major classes of SSRs

In order to understand the chromosome specific distribution of SSRs, we characterized all the SSRs motifs into three major classes based on their different repeats lengths i.e. class I (>30 nt), class II (20-30 nt) and class III (<20 nt). The variation in the three classes of perfect SSRs with regard to the number of repeat units is presented for each pomegranate chromosome in **.** Total 337743 SSRs were considered for classification excluding mononucleotide repeats. As a result, highest number of motifs (301684; 82.59 %) belonged to class III, followed by class II (31056; 8.50 %) and class I (5003; 1.37 %) across all 8 chromosomes. With respect to distribution of total number of SSRs for three classes in each chromosome, the proportions of SSRs within each class are consistent with the total number of SSRs observed across the 8 chromosomes. The overall distribution graph for three major SSR classes for each chromosome revealed, Chm_1, Chm_2 and Chm_4 with higher number of SSRs for three classes, followed by Chm_3, Chm_5, Chm_7 and Chm_6 as shown in the **Figure .**

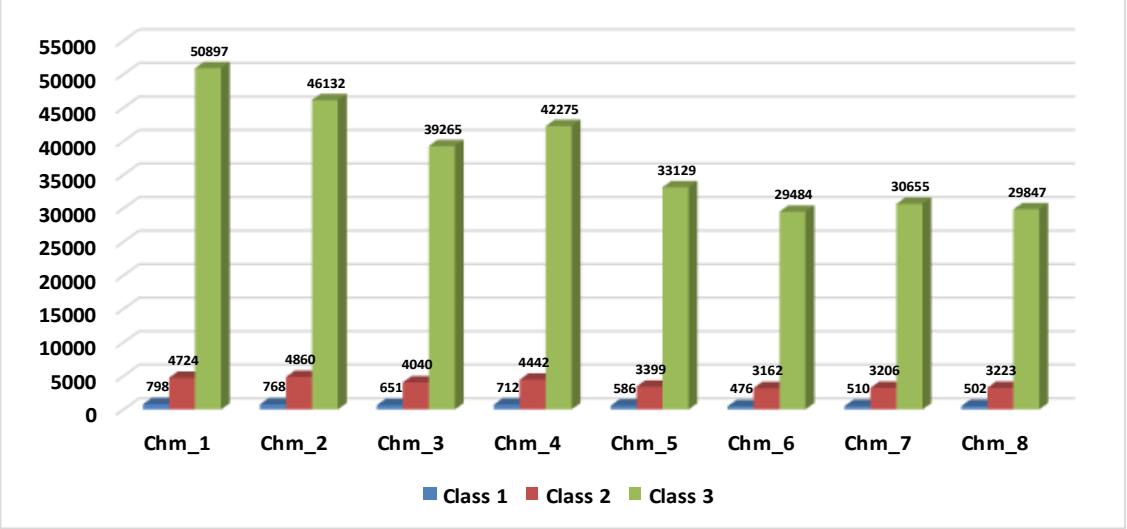
**Table 2. Distribution of three major classes of SSRs in different chromosomes of pomegranate cv. Tunisia**

| Chromosomes | Class I | | | | | | Class II | Class III | Total |
|---|---|---|---|---|---|---|---|---|---|
| | Di | Tri | Tetra | Penta | Hexa | Total | | | |
| **Chm 1** | 547 | 177 | 34 | 11 | 29 | **798** | 4724 | 50897 | **56419** |
| **Chm 2** | 549 | 158 | 31 | 13 | 17 | **768** | 4860 | 46132 | **51760** |
| **Chm 3** | 451 | 146 | 21 | 15 | 18 | **651** | 4040 | 39265 | **43956** |



| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Chm 4** | 494 | 160 | 26 | 11 | 21 | **712** | 4442 | 42275 | **47429** |
| **Chm 5** | 397 | 140 | 31 | 8 | 10 | **586** | 3399 | 33129 | **37114** |
| **Chm 6** | 324 | 104 | 26 | 8 | 14 | **476** | 3162 | 29484 | **33122** |
| **Chm 7** | 377 | 93 | 21 | 6 | 13 | **510** | 3206 | 30655 | **34371** |
| **Chm 8** | 349 | 109 | 24 | 6 | 14 | **502** | 3223 | 29847 | **33572** |
| **Total** | **3488** | **1087** | **214** | **78** | **136** | **5003** | **31056** | **301684** | **337743** |

**Fig. 2. Illustrates the frequency distribution for three major classes of SSRs across all chromosomes of pomegranate *cv.* Tunisia**




These results were finally confirmed through Circos graph based visualization of distribution patterns of the three SSR major classes on different chromosomes **.** As evident from this graphs, the total number of SSRs for three classes (III, II and I) and their motif types (di- to hexa-nucleotides) in each chromosome decreased from inside to outside. The densely placed spots in outer ring represented tract length variations for each repeat motif with specific color code. The di (red spots) tri (blue spots) showed maximum variations which can be exploited for designing chromosome specific hypervariable SSR markers.

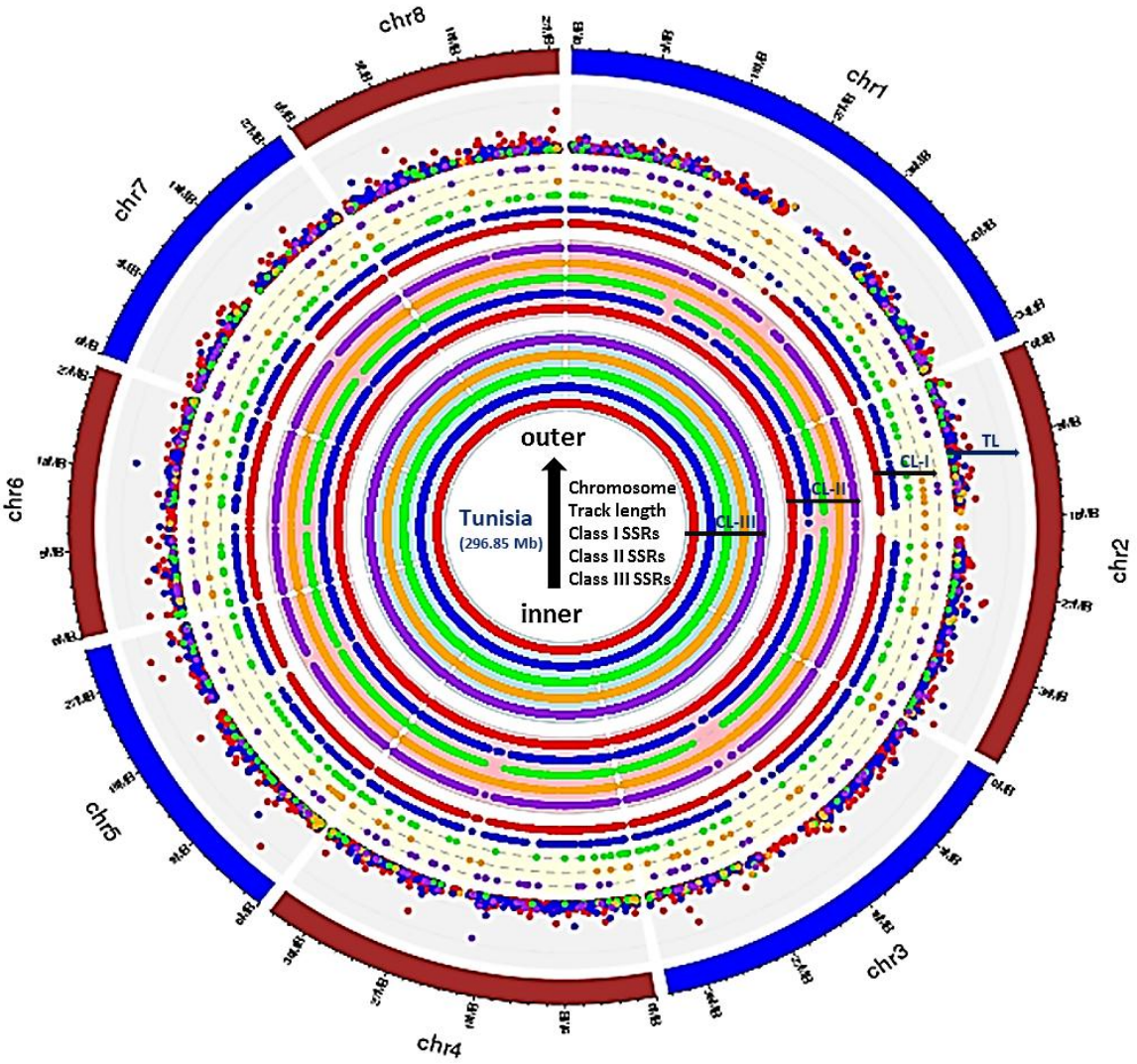



**Fig. 3. Circos graph depicting the chromosome-wide distribution for three major classes for perfect SSRs (excluding mononucleotides). Inner ring represents class III, whereas middle and outer rings correspond to class II and class I, respectively and the densely-placed colored dots depict the tract length for each motif types. All rings from inside to outside have five sub rings representing, di-, tri-, tetra-, penta- and hexa- nucleotides with colour codes red, blue, green, orange and purple, respectively.**

### 2.2.4. Designing of chromosome-specific hypervariable SSR primers

Based on the information of class I SSRs that are distributed across all chromosomes, we successfully designed primers for 3839 out of the total 5003 SSR motifs**.** The maximum primers were for Chm_1 (628), accompanied by Chm_2 (591), Chm_4 (564), followed by Chm_3 (484),

Chm_7 (398), Chm_8 (366) and Chm_6 (351) which was in accordance of their class I motif content. The majority of these primers were specific to di-nucleotide motifs (primers 2825, 73.59%), followed by trinucleotide repeats (698, 18.18%) . For experimental validation, we zeroed in on a set of 906 highly-variable SSRs targeting ≥ 40 nt tract length from each chromosomes through ePCR on four pomegranate genomes**.** And, the majority of SSR primers used for validation were di-nucleotides (616) or tri-nucleotides (228).

**Table 3. Details of chromosome specific Class I SSR primers designed for eight chromosomes of Tunisia**

| | Number of Class I (>30 nt) Primers | | | | | | Highly variable SSRs (≥ 40 nt) primers | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Di** | **Tri** | **Tetra** | **Penta** | **Hexa** | **Total** | **Di** | **Tri** | **Tetra** | **Penta** | **Hexa** | **Total** |
| **Chms_1** | 459 | 112 | 27 | 9 | 21 | 628 | 108 | 35 | 5 | 1 | 10 | 159 |
| **Chms_2** | 444 | 106 | 23 | 5 | 13 | 591 | 92 | 43 | 2 | 2 | 3 | 142 |
| **Chms_3** | 353 | 95 | 16 | 11 | 9 | 484 | 86 | 25 | 4 | 4 | 3 | 122 |
| **Chms_4** | 415 | 106 | 22 | 9 | 12 | 564 | 87 | 39 | 1 | 1 | 3 | 131 |
| **Chms_5** | 330 | 88 | 22 | 8 | 9 | 457 | 77 | 26 | 1 | 1 | 2 | 107 |
| **Chms_6** | 255 | 63 | 17 | 5 | 11 | 351 | 54 | 17 | 1 | 0 | 5 | 77 |
| **Chms_7** | 305 | 62 | 18 | 6 | 7 | 398 | 58 | 21 | 3 | 1 | 2 | 85 |
| **Chms_8** | 264 | 66 | 18 | 6 | 12 | 366 | 54 | 22 | 2 | 1 | 4 | 83 |
| **Total** | **2825** | **698** | **163** | **59** | **94** | **3839** | **616** | **228** | **19** | **11** | **32** | **906** |

### 2.2.5. Chromosome specific distribution of highly variable SSR markers and construction of high-density physical map

We also examined the locations of these SSRs on each chromosome to enable selection the identified SSRs in accordance to their genomic location and informativeness. Based on the information of physical position and start positions of 906 highly variable SSR markers specific to each chromosomes were deployed to generate high density SSR marker based physical map**.** Total 906 markers were placed on individual chromosomes, of which Chm_1 (159 markers), Chm_2 (142) and Chm_4 (131) had higher number of assigned markers, followed by Chm_3 (122) and Chm_5 (107). Most of the SSR markers remained in the range of 41-50 nt tract length (612), followed by 51-60 nt (172), 61-70 nt (63) and >71nt (59) across all 8 chromosomes**.**



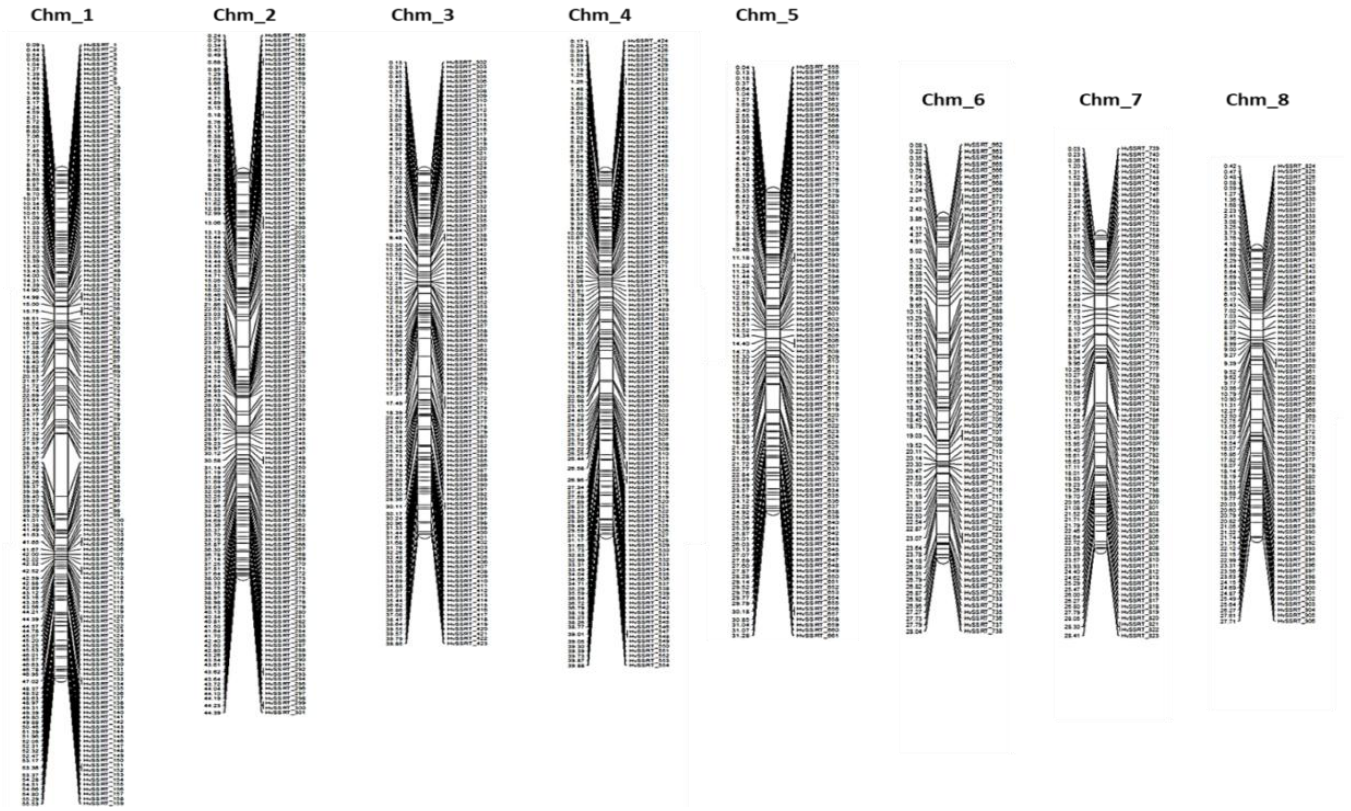



**Fig. 4. A high-density map of 906 HvSSRT markers showing their physical locations on eight chromosomes of pomegranate cv. Tunisia**

**Table 4. Classification of 906 highly variable chromosome specific SSR markers based on their tract lengths**

| Tract Length (nt) | Chm_1 | Chm_2 | Chm_3 | Chm_4 | Chm_5 | Chm_6 | Chm_7 | Chm_8 | Total primers |
|---|---|---|---|---|---|---|---|---|---|
| 41-50 | 111 | 103 | 81 | 92 | 64 | 53 | 57 | 51 | **612** |
| 51-60 | 30 | 17 | 22 | 26 | 25 | 14 | 16 | 22 | **172** |
| 61-70 | 11 | 13 | 11 | 6 | 7 | 5 | 6 | 4 | **63** |
| 71-189 | 7 | 9 | 8 | 7 | 11 | 5 | 6 | 6 | **59** |
| **Total** | **159** | **142** | **122** | **131** | **107** | **77** | **85** | **83** | **906** |

The distribution of each chromosome showed that even though most of SSR markers evenly distributed across each chromosome, the markers placed at middle of chromosomes were more sparsely dispersed as compared to distal ends of each chromosomes.

### 2.2.6. Validation of the identified SSRs across four genomes through ePCR

To assess the amplification efficiency and specificity of the SSRs, initially 3839 class I SSR primers were tested on Tunisia genome through *in silico* analysis. We validated equal proportions of primers across 8 chromosomes and the SSRs produced one to >3 alleles in Tunisia genome**.** Total 1165 (30.34%) of primers yielded a single amplicon of expected size. Whereas, 1263 (32.90%) primers had two alleles, and 1254 (32.66%) and 157 (4.09 %) primers produced three and >3 alleles, respectively. Further, to validate SSRs with tract lengths of >40 nt, located on chromosome map, *in silco* PCR analysis for 906 primers was performed on other three genome assemblies (Dabenzi, Taishanhong and AG2017). Notably, we validated all 906 (100%) primers in Tunisia genome to that of 853 (94.15 %), 832 (91.83%) and 545 (60.15%) in Dabenzi, Taishanhong and AG2017 genomes, respectively**.** A total of 289 (Tunisia), 277 (Dabenzi), 264 (Taishanhong) and 183 (AG2017) SSRs showed single locus amplification.

Further to show the informativeness of these chromosome-specific SSRs, we selected a subset of 289 that was validated in all four genomes. The various amplicons detected through ePCR for these 289 primers across the four genomes were recorded to compute the marker parameters **.** Of these, 265 (91.70 %) SSRs were found polymorphic across the four genomes. Total 719 alleles were obtained across the all 8 chromosomes. We compared all marker parameters at the chromosome level. Among eight chromosomes, chm_8 had lower polymorphic markers (25) and higher average value of Ne (1.83), Shannon's information index (0.72), and PIC (0.51). However, Chm_5 also showed lower number of polymorphic markers (26) and lower average value Ne (1.54), I (0.51), and PIC (0.35). With respect to PIC value remaining all 6 chromosomes (Chm_1, Chm_2, Chm_3, Chm_4, Chm_6 and Chm_7) had mean PIC values of 0.44-0.48.

**Table 5. Chromosome specific marker statistics for 289 highly variable SSR primers assayed through ePCR across the four pomegranate genotypes based on their genome sequences**

| Chromosome | TNP | TPP | Na | MAF | Ne | I | Ho | He | PIC |
|---|---|---|---|---|---|---|---|---|---|
| Chm_1 | 55 | 48 | 2.40 | 0.75 | 1.71 | 0.63 | 0.50 | 0.38 | 0.44 |
| Chm_2 | 42 | 39 | 2.52 | 0.73 | 1.75 | 0.68 | 0.54 | 0.40 | 0.47 |
| Chm_3 | 32 | 31 | 2.69 | 0.72 | 1.78 | 0.71 | 0.56 | 0.42 | 0.48 |
| Chm_4 | 41 | 40 | 2.59 | 0.74 | 1.75 | 0.69 | 0.53 | 0.41 | 0.48 |
| Chm_5 | 35 | 26 | 2.17 | 0.80 | 1.54 | 0.51 | 0.40 | 0.30 | 0.35 |
| Chm_6 | 30 | 29 | 2.67 | 0.73 | 1.73 | 0.70 | 0.53 | 0.41 | 0.47 |
| Chm_7 | 28 | 27 | 2.39 | 0.72 | 1.73 | 0.66 | 0.55 | 0.41 | 0.47 |
| Chm_8 | 26 | 25 | 2.54 | 0.70 | 1.83 | 0.72 | 0.60 | 0.44 | 0.51 |
| **Total/Mean** | **289** | **265** | **2.50** | **0.74** | **1.73** | **0.66** | **0.53** | **0.39** | **0.46** |

**Note *** TNP: total number of primers, TPP: total number of polymorphic primers, Na: number of alleles, MAF: major allele frequency, Ne: number of effective alleles, *I:* Shannon's Information Index, *Ho:* observed heterozygosity, *He:* expected heterozygosity, PIC: polymorphic information content

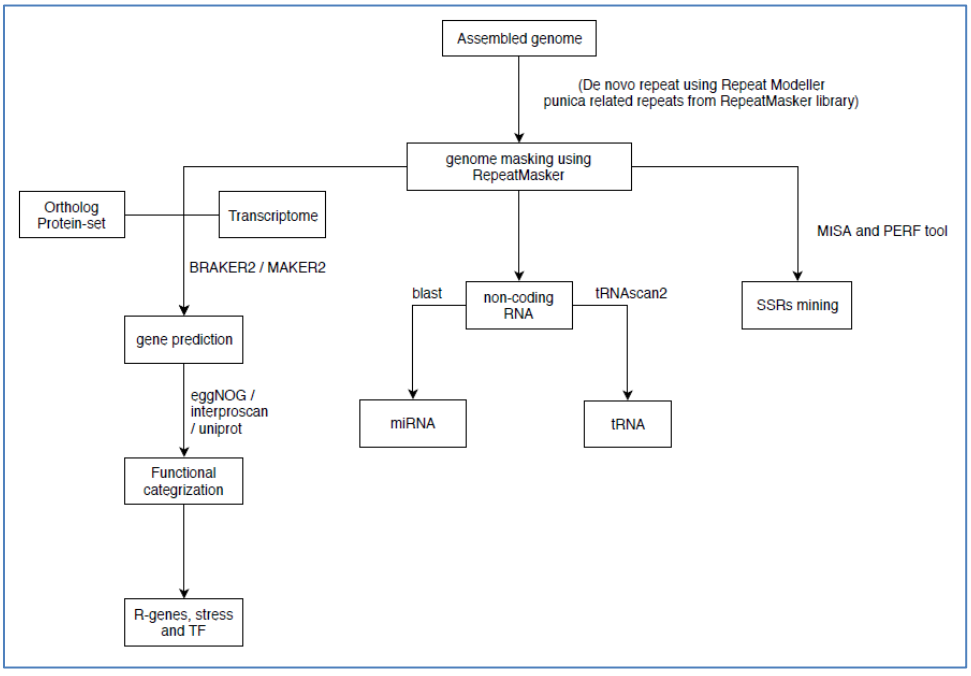


Currently these markers are being validating through wet lab experiments to show their immediate utility for diversity and genetic mapping work for mapping genes/QTLs for fruit quality and Bacterial blight resistance.

## 2.3 PROJECT: DRAFT GENOME SEQUENCING OF POMEGRANATE (*PUNICA GRANATUM* L.) CV. BHAGAWA

### 1.2.1. Structural and functional annotation, Resistance genes and Transcription Factor identification of Bhagawa genome sequence

Proteins from OrthoDBv10 using the Viridiplantae lineage were downloaded. Redundancy in the downloaded dataset were removed to create a Non-Redundant pool. This was done using mmseqs2 by requiring a 90% identity and a 90% sequence match for clustering the proteins and finally extracting proteins that had a minimum length of 10AA. This unique protein set was aligned to the genome using GenomeThreader and BRAKERv2.1.0 was used to create Augustus profiles using multiple optimization rounds. Augustus predicted 38263genes. EvidenceModeler Release 1.1.1 was used to integrate the predictions from Augustus and PASA to create a final genome annotation set.



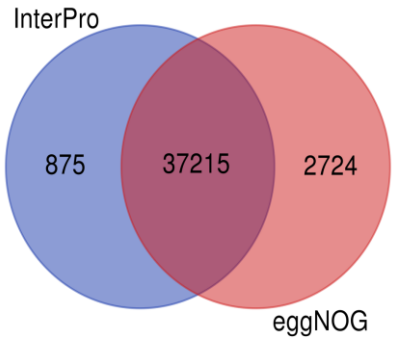

The final curation and integration led to the validated presence of 33003 genes with 41682 mRNAs. The geneic space in the genome is about 32.7% with the coding space being 18.8%

Various statistics about the annotation have been calculated using Genome Annotation Generator.

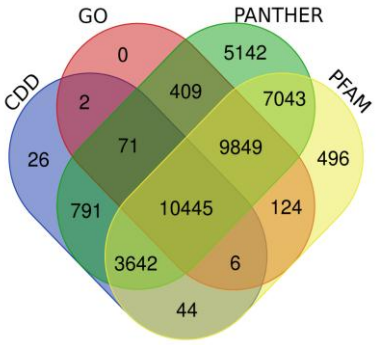
**Table 4. Structural Annotation Summary**

| Annotation Statistics | Values | Annotation Statistics | Values |
|---|---|---|---|
| Total sequence length | 345235241 | Shortest exon | 3 |
| Number of genes | 33003 | Shortest intron | 27 |
| Number of mRNAs | 41682 | Shortest CDS | 150 |
| Number of exons | 228236 | Longest gene | 129861 |
| Number of introns | 186554 | Longest mRNA | 129861 |
| Number of CDS | 41682 | Longest exon | 21002 |
| Overlapping genes | 1756 | Longest intron | 128140 |
| Contained genes | 507 | Longest CDS | 67037 |
| CDS: complete | 41270 | mean gene length | 3422 |
| CDS: start, no stop | 111 | mean mRNA length | 3710 |
| CDS: stop, no start | 269 | mean exon length | 378 |
| CDS: no stop, no start | 32 | mean intron length | 368 |
| Total gene length | 112930051 | mean CDS length | 1554 |
| Total mRNA length | 154643522 | % of genome covered by genes | 32.7 |
| Total exon length | 86332443 | % of genome covered by CDS | 18.8 |
| Total intron length | 68684187 | mean mRNAs per gene | 1 |
| Total CDS length | 64767822 | mean exons per mRNA | 5 |
| Shortest gene | 150 | mean introns per mRNA | 4 |
| Shortest mRNA | 150 | - | - |

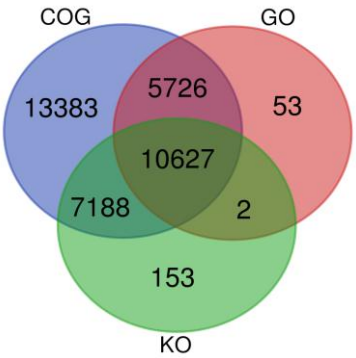
**The predicted proteins were annotated using InterProScan, eggNOG at Viridiplantae lineage.**




**Annotation Venn Diagram for the two complementary approaches**




**InterProScan Annotation Venn Diagram**




**eggNOG Annotation Venn Diagram**



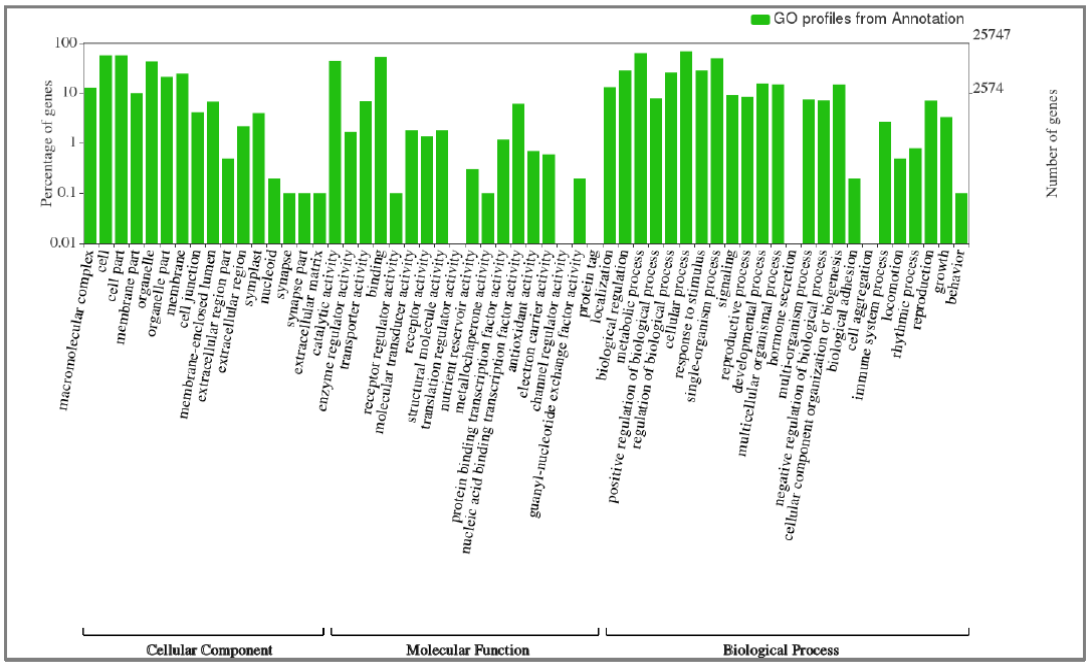



**Fig.7. GO distribution over the various genes**

**nonCoding Genes Annotation**

The chromosomal scale genome was analyzed using the Infernal toolkit: cmscan using the RFAM database to predict the non-coding genes in the Bhagwa genome. We took a threshold score of 60 in order to retain the predicted genes

**Stress related genes and Transcription Factor identification**

Predicted pomegranate protein sequences were performed blastp with Plant Stress Protein Database (PSPDB; http://www.bioclues.org/pspdb/) protein sequences with an e-value cutoff (1e-5), query coverage (50%) and sequence identity (50%). Transcription factors predicted using PlantTFDB (V4.0) taking Arabidopsis as reference.

**Summary of nonCoding Genes Annotation**

| Lnc RNA Features | Counts |
|---|---|
| miRNA | 105 |
| rRNA | 841 |
| snoRNA | 257 |
| snRNA | 88 |
| tRNA | 345 |

**Numbers of protein related genes in pomegranate**

| Type | Number of proteins |
|---|---|
| Antibacterial | 147 |
| Antifungal | 163 |
| Antiviral | 48 |
| Drought | 117 |
| Flooding | 32 |
| Light | 239 |
| Oxidative | 254 |
| Phytohormone | 477 |
| Salt | 10 |
| Temperature | 357 |
| Wounding | 228 |
| Total | 2072 |

**Table 7. Different R gene binding domains of pomegranate**

| Domain | No. of Proteins | Domain | No. of Proteins |
|---|---|---|---|
| CC | 1 | Kinase,LRR,TM | 215 |
| CC,Kinase | 10 | Kinase,NBS,TIR,TM | 1 |
| CC,Kinase,LRR,TM | 12 | Kinase,TM | 585 |
| CC,Kinase,TM | 67 | LRR | 44 |
| CC,LRR | 1 | LRR,NBS | 3 |
| CC,LRR,NBS | 3 | LRR,NBS,TIR | 7 |
| CC,LRR,NBS,TIR | 1 | LRR,NBS,TIR,TM | 57 |
| CC,LRR,NBS,TIR,TM | 5 | LRR,NBS,TM | 44 |
| CC,LRR,NBS,TM | 26 | LRR,TIR | 2 |
| CC,LRR,TM | 12 | LRR,TIR,TM | 2 |
| CC,NBS | 6 | LRR,TM | 192 |
| CC,NBS,TIR | 1 | NBS | 23 |
| CC,NBS,TM | 43 | NBS,TIR | 1 |
| CC,TIR | 1 | NBS,TIR,TM | 28 |
| CC,TIR,TM | 1 | NBS,TM | 70 |
| Kinase | 120 | TIR | 15 |
| Kinase,LRR | 2 | TIR,TM | 18 |

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# Plant Propagation

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

**Multiplication of pomegranate genotypes for screening against biotic and abiotic stresses:** Twenty two different pomegranate genotypes were multiplied and the layering success was found to be varied from 52.5 to 87.5 %. These genotypes will be screened against *Ceratocystis fimbriata*, root knot nematode and salinity, to utilize the promising genotypes as rootstocks with commercial varieties as scion for the further evaluation of grafted plants and understanding stionic influence.

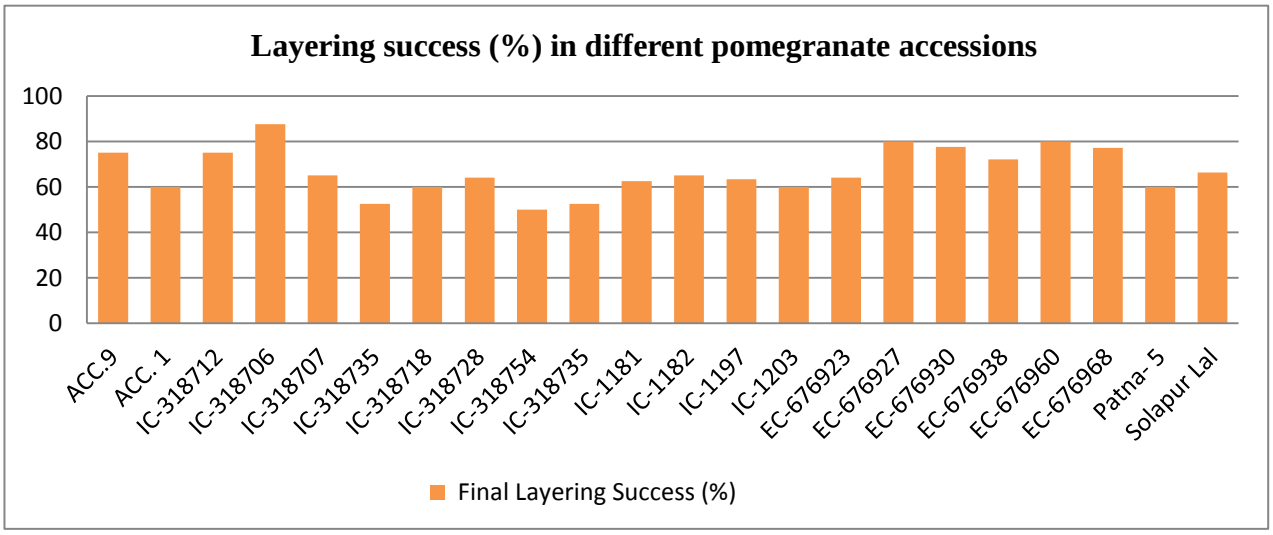
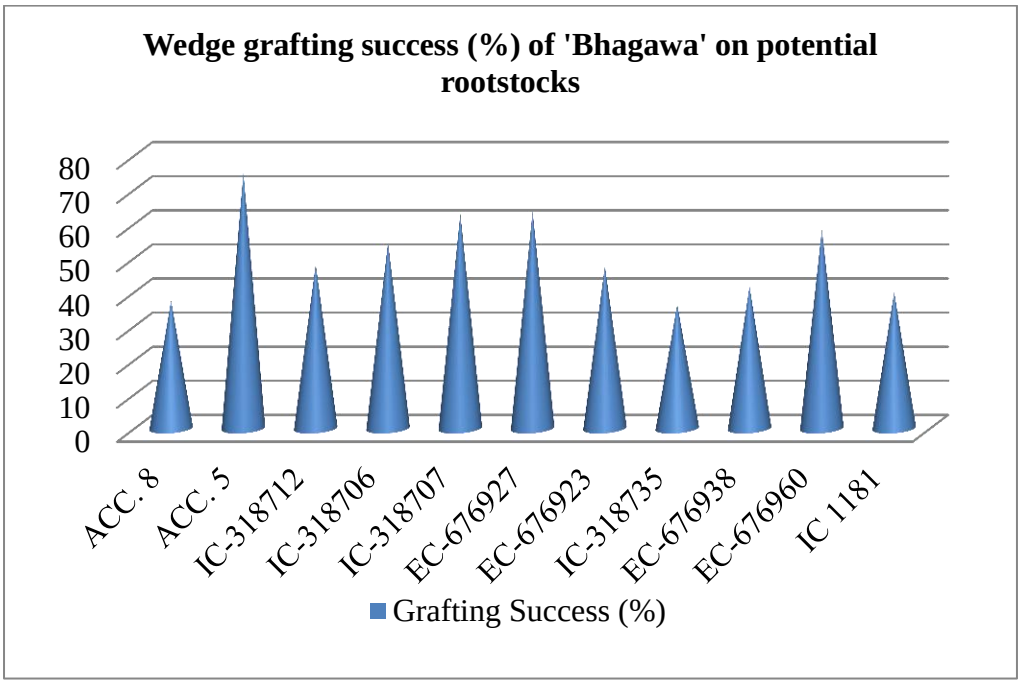



**Fig.1. Layering success (%) in different pomegranate accessions**




**Utilization of promising genotypes as rootstocks and their exploitation through grafting:** The wedge grafting success of 'Bhagawa' scion (about 8-10mm dia) on different potential rootstocks (about 10 months old) varied from 37.55 to 75.0 % during Nov-Dec, 2020 under protected structure. Though *in situ* omega grafting using omega grafting has also been performed, the success was too low. It may be used with more success and ease through bench grafting and stenting.

***In vitro* propagation of pomegranate**

***In vitro* multiplication:** Among 110 media and growth regulator combinations evaluated, modified MS medium with reduced $NH_4NO_3$ and modified WPM medium with enhanced $NH_4NO_3$ supplemented with low concentration of IAA, NAA and upto 80mg/l adenine sulphate resulted into maximum shoot elongation (6.3 cm elongation in 25 days). However, addition of BAP and/ or Kinetin at low concentration in the above mentioned basal media supplemented with very low concentration of NAA and upto 80-100 mg/l adenine sulphate resulted into as high as 4.5 number of side shoots per microshoot per cycle.



***In vitro* rooting:** Inoculation of micro-shoots from cytokinin rich multiplication medium to blank medium (half macro MS, WPM and half WPM) without any growth regulator followed by inoculation on auxin supplemented rooting medium produced better rooting and took lesser days to root without any significant reduction in number of roots, average root length and 53reenness index as compared to microshoots which were directly transferred to rooting medium from multiplication medium. Among adsorbing agents used, microshoots inoculated on medium containing activated charcoal @ 1.5g/l registered higher rooting percentage (58.52 %) and took lesser number of days to root induction (18.54 days) as compared to activated charcoal @ 0.8 g/l (53.90 %, 22.25 days, respectively) and PVP @ 1g/l (50.73 % and 20.47 days) . Basal medium has pronounced effect on rooting of microshoots and WPM (19.9 days to root and 58.13 % rooting) as well half MPM media (18.73 days to root and 59.87 % rooting) performed better than half macro MS medium (22.21 days to root and 45.39 % rooting). As far as type of auxin is concerned, IBA was found superior to NAA in terms of days to rooting (19.03), rooting percent (59.91) and length of roots (4.93 cm) and greenness index ( 3.78) as compared to NAA (21.48, 49.07, 2.61 cm and 3.21, respectively). However, number of major roots were higher in NAA supplemented rooting medium (2.61) and compared to IBA (1.71). Among various combinations of media, growth regulators and adsorbing agent used, shoots inoculated on WPM medium supplemented with 1.0 mg/l IAA took minimum days to root (13 days), produced higher average number of major roots per shoot (2.38) and the highest rooting percent (87.50.%) as compared to other treatments.



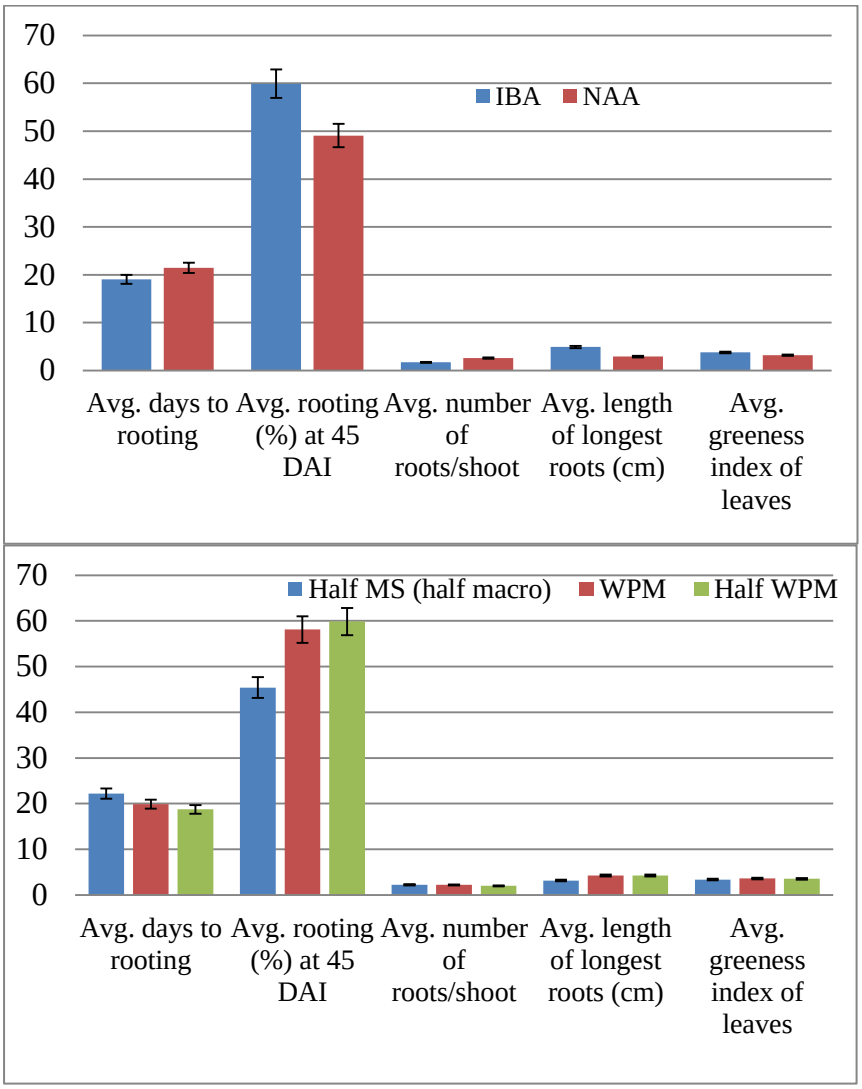



**Fig.3. Influence of basal media and auxins on *in vitro* rooting of pomegranate microshoots**

**Bio-priming of *in vitro* raised plants:** An experiment was initiated in 2020 to reconfirm the impact of different microbial treatments on growth, physiological and biochemical attributes of one and half years old repotted micropropagated plants of pomegranate cv. Bhagawa. The plants were re-potted in 20 kg capacity cemented pots having autoclaved sterile potting mixture (sand : soil: FYM, 2:1:1) and maintained under 35% shade conditions with watering on alternate days. The microbial treatments namely, *Aspergillus niger* strain A-27, AMF predominantly *Glomus intraradices*, *Pseudomonas- fluorescens*, *Penicillium pinophilum* and *Trichoderma- viridis* + *T. harzianum* were used either alone or in combination. The different microbes/ microbial

combinations were added in broth form in rhizospheric soil twice at the interval of 15 days. For most of the recorded parameters bio-primed plants performed better than the control (T15).

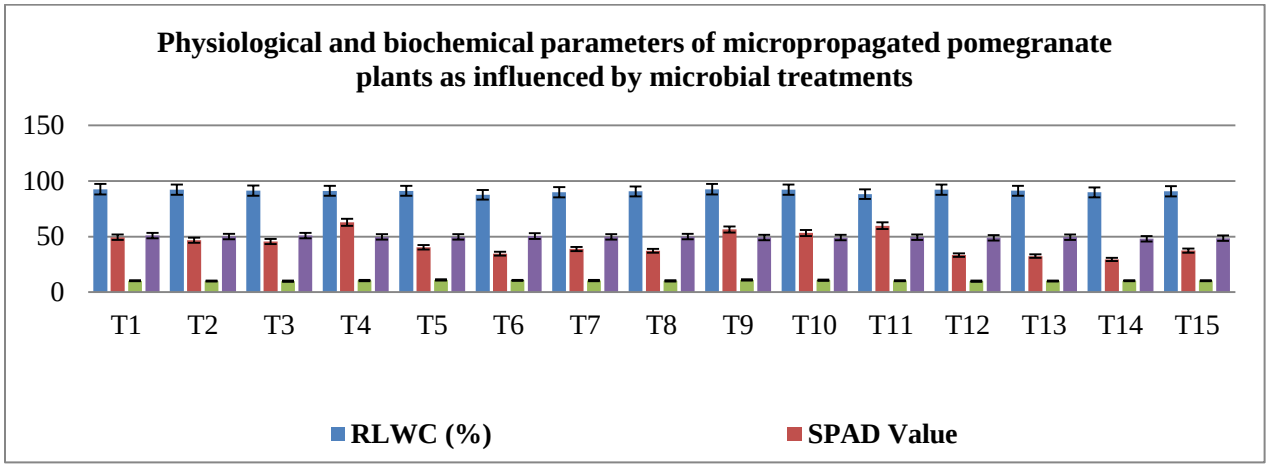



**Fig.4. Physiological and biochemical parameters of micropropagated pomegranate plants as influenced by microbial treatments**

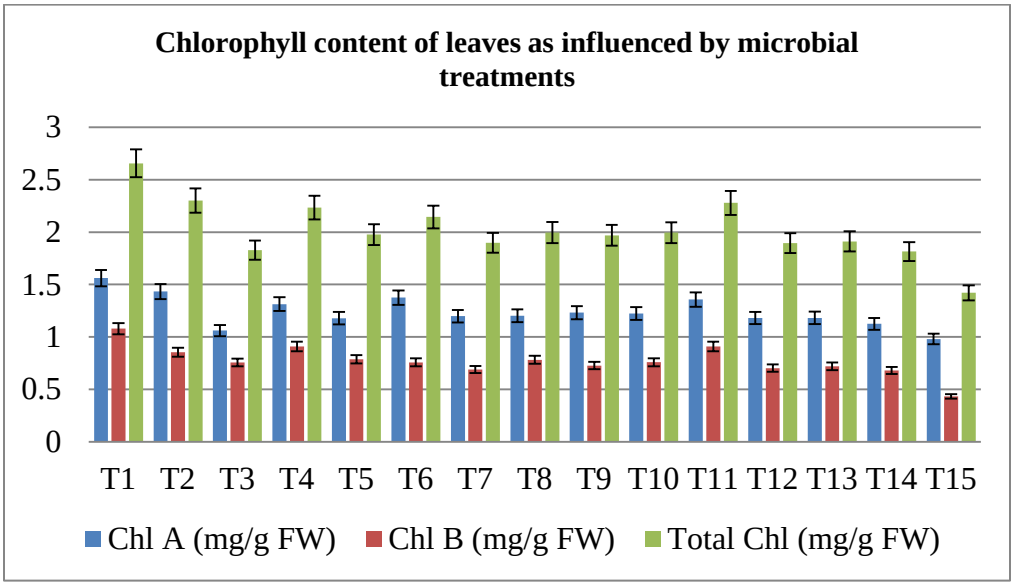



**Fig.5. Chlorophyll content of leaves as influenced by microbial treatments**

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# Crop Production

## 4.1 PROJECT: CROP REGULATION PRACTICES FOR IMPROVING PRODUCTIVITY OF POMEGRANATE

### 4.1.1. Determination of pruning intensity for pomegranate

To standardize the pruning intensity for pomegranate, an experiment was conducted with mature plants of pomegranate variety Bhagawa for the second season. The treatments consisted of 3 levels of pruning (light pruning of 6'' shoots, medium pruning of 12" shoots and heavy pruning of 18' shoots) individually and combined with removal of tertiary shoots which was compared with a control. Fruit weight was highest (283.5g/fruit) in heavy pruning combined with removal of tertiary branches followed by heavy pruning (281.3g/fruit). The highest yield was recorded by light pruning (31.18 kg/tree).

**Table 1. Effect of pruning intensity on flowering and yield of pomegranate**

| Pruning Treatment | Time taken for FBI (days) | No. of bisexual flowers/ Tree | Fruit set (%) | No. of fruits/ tree | Fruit weight (g/tree) | Yield (kg/tree) | TSS (°Brix) | Acidity (%) |
|---|---|---|---|---|---|---|---|---|
| Light pruning | 27.0 | 221.6 | 52.03 | 115.3 | 270.5 | 31.18 | 15.68 | 0.45 |
| Light pruning & removal of tertiary branches | 26.0 | 217.3 | 49.97 | 108.6 | 275.2 | 29.88 | 15.72 | 0.44 |
| Medium pruning | 28.5 | 200.3 | 50.57 | 101.3 | 273.6 | 27.77 | 15.76 | 0.44 |
| Medium pruning & removal of tertiary branches | 27.5 | 201.6 | 48.11 | 97.0 | 276.3 | 26.80 | 15.80 | 0.43 |
| Heavy pruning | 35.5 | 202.6 | 47.18 | 95.6 | 281.3 | 26.89 | 15.84 | 0.43 |
| Heavy pruning & removal of tertiary branches | 35.0 | 199.3 | 46.31 | 92.3 | 283.5 | 26.16 | 15.92 | 0.42 |
| Control (without | 26.5 | 225.6 | 44.01 | 99.3 | 210.2 | 20.87 | 15.24 | 0.47 |



| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| pruning) | | | | | | | | |

| | | |
|---|---|---|
|  |  |  |
| Light pruning | Light pruning & tertiary removal | Medium pruning |
|  |  |  |
| Medium pruning & tertiary removal | Heavy pruning | Heavy pruning & tertiary removal |
| |  | |
| | Control (without pruning) | |

**Fig. 1. Effect of pruning intensity on flowering and yield of pomegranate**

| | | |
|---|---|---|
|  |  |  |
| Light pruning | Light pruning & tertiary removal | Medium pruning |
|  |  |  |
| Medium pruning & tertiary removal | Heavy pruning | Heavy pruning & tertiary removal |
| |  | |
| | Control (without pruning) | |

**Fig. 2. Effect of pruning intensity on flowering and yield of pomegranate**

### 4.1.2. Performance of pomegranate variety Solapur Lal under different fertilizer doses

Solapur Lal is a vigorous, high yielding variety of pomegranate developed through hybridization. To determine the nutrient requirement of Solapur Lal, an experiment was conducted in five year old Solapur Lal with different fertilizer doses viz., 100% RDF, 125% RDF and 150% RDF on ad-hoc basis. The manures and fertilizers were applied in split manner during rest period (immediately after harvesting previous crop), flowering and fruit set period (30DAA)& fruit development period (90 DAA). The results revealed that there was drastic increase in no. of fruits/ plant (138.6), mean fruit weight (278.6g/fruit) and yield (38.61 kg/tree) in 125% RDF compared to 100% RDF. But, beyond 125%RDF, there was not much increase in no. of fruits/tree, fruit weight and yield.

T1 -100% RDF

T2 -125% RDF

T3 -150% RDF

**Fig. 3. Bearing performance of Solapur Lal under different fertilizer dose**

**Table 3. Response of pomegranate var. Solapur Lal under different fertilizer dose**

| Treatment | No. of fruits/tree | Fruit weight (g) | Yield (kg/tree) | Yield (ton/ha) | TSS (°Brix) | Acidity (%) | TSS/ Acid ratio |
|---|---|---|---|---|---|---|---|
| T1 -100% RDF | 123.3 | 262.5 | 32.36 | 23.95 | 17.6 | 0.40 | 44.00 |
| T2- 125% RDF | 138.6 | 280.6 | 38.89 | 28.77 | 17.7 | 0.39 | 45.38 |
| T3- 150% RDF | 141.3 | 282.4 | 39.90 | 29.52 | 17.7 | 0.38 | 46.57 |

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

**Fig. 4. Increase in fruit size of Solapur Lal due to enhanced fertilizer dose**

### 4.1.3. Crop load optimization through thinning in pomegranate variety Solapur Lal

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

**Table 4. Effect of different levels of thinning on yield and quality of 'Solapur Lal' Pomegranate**

| Thinning Level | No. of fruits/ tree | Mean fruit weight (g) | Yield (kg/plant) | Yield (ton/ha) | TSS (°Brix) | Acidity (%) | Ascorbic acid (mg/100g) |
|---|---|---|---|---|---|---|---|
| Control (without thinning) | 140.3 | 251.2 | 35.24 | 26.08 | 17.5 | 0.42 | 19.0 |
| Very light thinning | 126.5 | 263.2 | 33.29 | 24.63 | 17.6 | 0.41 | 19.2 |
| Light thinning | 112.8 | 274.8 | 30.99 | 22.93 | 17.6 | 0.40 | 19.2 |
| Medium thinning | 98.5 | 278.6 | 27.44 | 20.30 | 17.7 | 0.40 | 19.4 |
| Heavy thinning | 84.8 | 281.4 | 23.86 | 17.65 | 17.8 | 0.39 | 19.6 |
| Very heavy thinning | 70.8 | 283.8 | 20.09 | 14.86 | 17.9 | 0.39 | 19.8 |

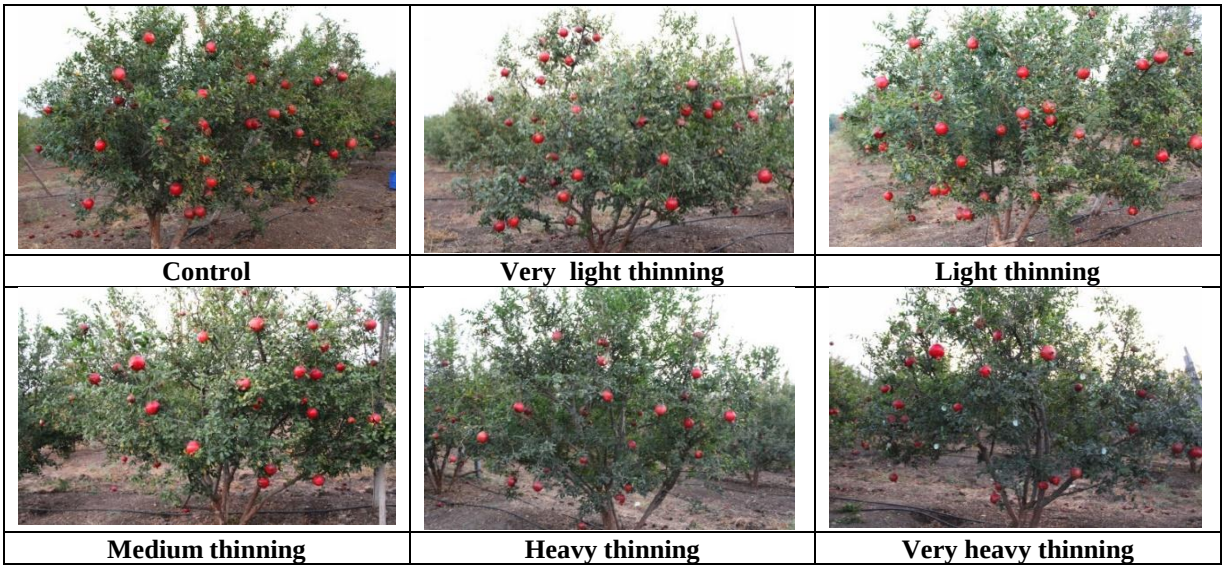



**Fig.5. Crop load optimization through thinning**

### 4.1.4. Effect of 2,4 D on Flower / Fruit Drop

In pomegranate, the crop regulation helps to produce uniform flowering and fruiting. However, there is fruit drop during different stages of fruit growth, especially after fruit set. Fruit drop due to hormonal imbalance could be managed through extraneous application of suitable auxins. An experiment was conducted in pomegranate variety Bhagawa during hasth bahar. Foliar spray of growth regulator: 2,4-D at six concentrations (5,10,15,20,25 and 30ppm) along with a control. The increase in concentration of 2,4-D significantly reduced the flower drop. 2,4-D @20ppm was found to be highly beneficial for management of fruit drop.

**Table 5. Effect of 2,4 D on Fruit set, fruit weight and total yield in Pomegranate**

| Concentration of 2,4-D (ppm) | Total No. of bisexual flowers | No. of bisexual flowers dropped | No. of bisexual flowers retained | Fruit set (%) | No. of fruits/ Plant | Fruit weight (g) | Yield (kg/tree) |
|---|---|---|---|---|---|---|---|
| 5 ppm | 190.0 | 36.6 | 153.3 | 52.58 | 80.6 | 265.4 | 21.39 |
| 10 ppm | 192.6 | 32.0 | 160.6 | 54.98 | 88.3 | 268.6 | 23.72 |
| 15 ppm | 189.6 | 27.3 | 162.3 | 58.29 | 94.6 | 272.2 | 25.75 |
| 20 ppm | 183.0 | 18.3 | 165.0 | 60.18 | 99.3 | 274.8 | 27.29 |
| 25 ppm | 182.3 | 18.6 | 163.6 | 60.38 | 98.6 | 274.2 | 27.04 |
| 30 ppm | 184.0 | 19.3 | 164.6 | 58.93 | 97 | 273.8 | 26.56 |
| Control (Unsprayed) | 187.3 | 45.3 | 142 | 50.21 | 80.3 | 249.5 | 20.03 |

2,4-D@5ppm

2,4-D@10ppm

2,4-D@15ppm

2,4-D@20ppm

2,4-D@25ppm

2,4-D@30ppm

Control

**Fig.6. Effect of 2, 4-D on control of flower drop in pomegranate**

### 4.1.5. Induction of flowering in pomegranate

Crop regulation in pomegranate is done during different bahar viz., mrig, hasth and ambia bahar. Flowering in pomegranate often becomes a problem in hasth bahar due to dropdown of temperature. For induction of flowering in pomegranate, an experiment was conducted during hasth bahar in A4 block, Kegaon, with the following treatments *viz.*, foliar spray of Ammonium nitrate (0.25%, 0.50%, 0.75%), Naphthalene acetic acid (5ppm, 10ppm, 15ppm) and micronutrient mixture *i.e.* Rexolin (0.1%,0.2%,0.3%) along with an unsprayed control. Preliminary results revealed that NAA @ 10ppm concentration was found to be extremely useful for induction of flowering in pomegranate.

**Table 6. Effect of different Plant Growth Regulators and Micronutrient mixture on total yield in Pomegranate**

| Treatments | No. of bisexual flowers /plant | No. of fruits / plant | Fruitset (%) | Fruit weight (g) | Yield (kg/plant) | Yield (t/ha) |
|---|---|---|---|---|---|---|
| Ammonium Nitrate@ 0.25% | 177.3 | 88.3 | 49.80 | 262.4 | 23.17 | 17.15 |
| Ammonium Nitrate@ 0.50% | 184.6 | 93.3 | 50.54 | 269.2 | 25.12 | 18.59 |
| Ammonium Nitrate@ 0.75% | 181 | 94.6 | 52.27 | 270.5 | 25.59 | 18.94 |
| NAA@5ppm | 180.3 | 90.6 | 50.25 | 270.2 | 24.48 | 18.12 |
| NAA@10ppm | 181.6 | 98.3 | 54.13 | 275.3 | 27.06 | 20.03 |
| NAA-@15ppm | 183.3 | 95.6 | 52.15 | 274.5 | 26.24 | 19.42 |
| Micronutrient mixture @0.1% | 180.6 | 86.3 | 47.79 | 260.2 | 22.46 | 16.62 |
| Micronutrient mixture @ 0.2% | 193.3 | 92.6 | 47.90 | 265.6 | 24.59 | 18.20 |
| Micronutrient mixture @0.3% | 187.6 | 93.3 | 49.73 | 266.4 | 24.86 | 18.39 |
| Control (Unsprayed) | 176.6 | 79.6 | 45.07 | 245.3 | 19.53 | 14.45 |




Ammonium Nitrate @0.25%


Ammonium Nitrate @0.50%


Ammonium Nitrate @0.75%


NAA @ 5. ppm


NAA@ 10. ppm


NAA @15 ppm


Micronutrient @0.1%


Micronutrient @0.2%


Micronutrient @0.3%


Control

**Fig. 7. Induction of flowering in pomegranate**

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

**Table 7. Effect of Plant growth Regulators on fruit set and total yield in Pomegranate**

| Treatments | No. of flowers/plant | No. of fruits / plant | Fruit set (%) | Fruit weight (g) | Yield (kg/plant) | Yield (t/ha) |
|---|---|---|---|---|---|---|
| IAA @20ppm | 186.3 | 92.5 | 49.65 | 263.2 | 24.35 | 18.02 |
| 2,4-D@10ppm | 178.6 | 96.2 | 53.86 | 272.4 | 26.20 | 19.39 |
| Daminozide@500ppm | 173.3 | 95.4 | 55.05 | 273.6 | 26.10 | 19.32 |
| Ethephon@700ppm followed by BAP@10ppm at one week later | 177.6 | 92.3 | 51.97 | 268.6 | 24.79 | 18.35 |
| Nitrobenzene 20%@0.2% | 179.6 | 91. 5 | 50.95 | 267.2 | 24.45 | 18.09 |
| Potassium nitrate@1.0%, | 175.3 | 98.2 | 56.02 | 275.4 | 27.04 | 20.01 |
| Silver nitrate @0.01% | 170.6 | 93.5 | 54.81 | 270.5 | 25.29 | 18.72 |
| Micronutrient mixture @0.2% | 184.3 | 90.6 | 49.16 | 260.6 | 23.61 | 17.47 |
| Control | 178.6 | 80.4 | 45.02 | 246.2 | 19.79 | 14.65 |



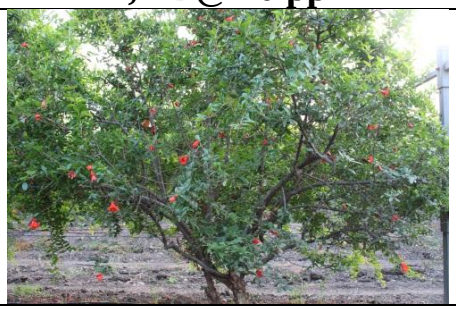
| | | |
|---|---|---|
|  |  |  |
| **IAA @20 ppm** | **2,4-D@ 10 ppm** | **Daminozide@ 500 ppm** |
|  |  |  |
| **Ethrel@1.75 ml /l + BAP@10mg/l after one week** | **Nitrobenzene 20 % @2ml/l** | **Potassium Nitrate@ 1.0%** |
|  |  |  |
| **Silver Nitrate@0.01%** | **Micronutrient mixture@0.2%** | **Control**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

**Fig. 8. Induction of flowering in pomegranate**

## 4.2. PACKAGE OF PRACTICES FOR ORGANIC CULTIVATION OFPOMEGRANATE

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

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

**Table 8. Effect of new formulations (Formulation I and Formulation II) on fruit yield and quality of pomegranate**

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



| | |
|---|---|
|  |  |
| **T2: EDTA micronutrient @ 1 g $l^{-1}$ (three sprays)** | **T3: Formulation I followed by two sprays of Formulation II @ 2.5 ml $l^{-1}$** |
|  |  |
| **T4: Formulation I followed by two sprays of Formulation II @ 1.0 ml $l^{-1}$** | **T5: EDTA micronutrient @ 1 g $l^{-1}$(three sprays) + Gibberellic acid @ 50 ppm (two sprays)** |

**Fig. 9. Effect of new formulations on bearing of pomegranate fruits on trees**

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

A new bio-organic product has been developed and evaluated under pot culture experiment at graded dose in pomegranate. The data revealed that application of newly

developed bio-organic fertilizer has significantly enhanced shoot, root and total biomass, and subsequently the shoot to root ratio. The highest increase in biomass (43.46% increase in shoot, 14.48% increase in root and 35.68% increase in total biomass) was noted with the application of bio-organic fertilizer at the rate of 150 g plant$^{-1}$.

**Table 8. Effect of bio-organic fertilizer on plant biomass partitioning**

| Treatment | Shoot biomass (g plant$^{-1}$) | Root biomass (g plant$^{-1}$) | Total biomass (g plant$^{-1}$) | Shoot-root ratio |
|---|---|---|---|---|
| T1: Control | 165.86$^{c}$ | 60.96$^{bc}$ | 226.82$^{c}$ | 2.73$^{c}$ |
| T2: K solubilizing bio-formulation @ 20 g plant$^{-1}$ | 219.18$^{ab}$ | 61.34$^{bc}$ | 280.52$^{ab}$ | 3.58$^{a}$ |
| T3: Bio-organic fertilizer @ 150 g plant$^{-1}$ | 237.95$^{a}$ | 69.79$^{a}$ | 307.74$^{a}$ | 3.41$^{ab}$ |
| T4: Bio-organic fertilizer @ 300 g plant$^{-1}$ | 222.37$^{ab}$ | 62.46$^{abc}$ | 284.83$^{ab}$ | 3.57$^{a}$ |
| T5: Bio-organic fertilizer @ 600 g plant$^{-1}$ | 211.56$^{b}$ | 57.99$^{c}$ | 269.56$^{b}$ | 3.66$^{a}$ |
| T6: Recommended dose of P and K through chemical fertilizers | 203.64$^{b}$ | 68.35$^{ab}$ | 271.98$^{b}$ | 2.98$^{bc}$ |
| LSDα0.05 | 22.20 | 8.22 | 28.66 | 0.48 |

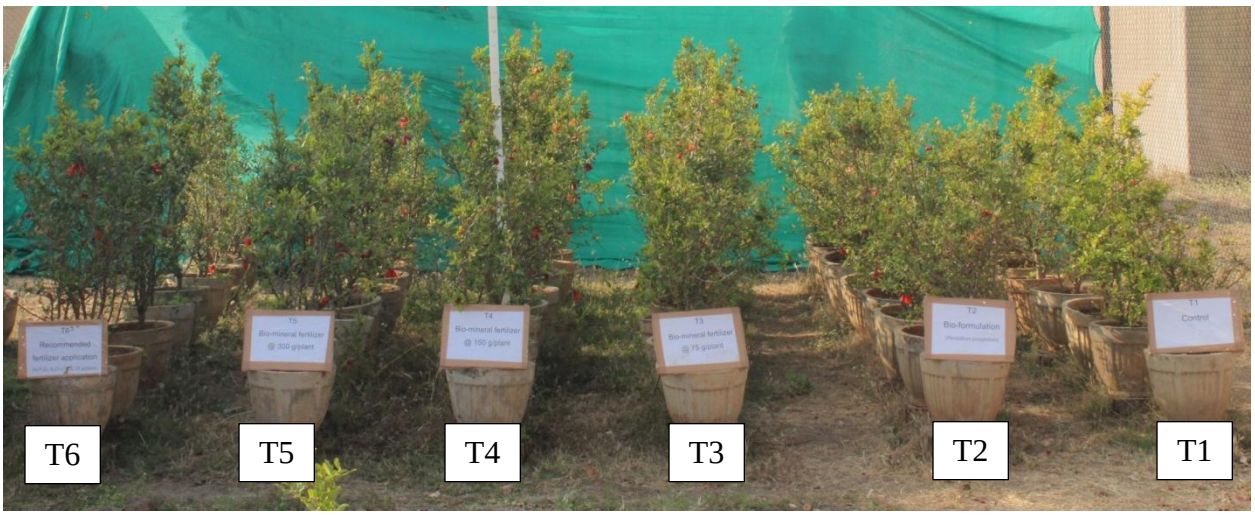
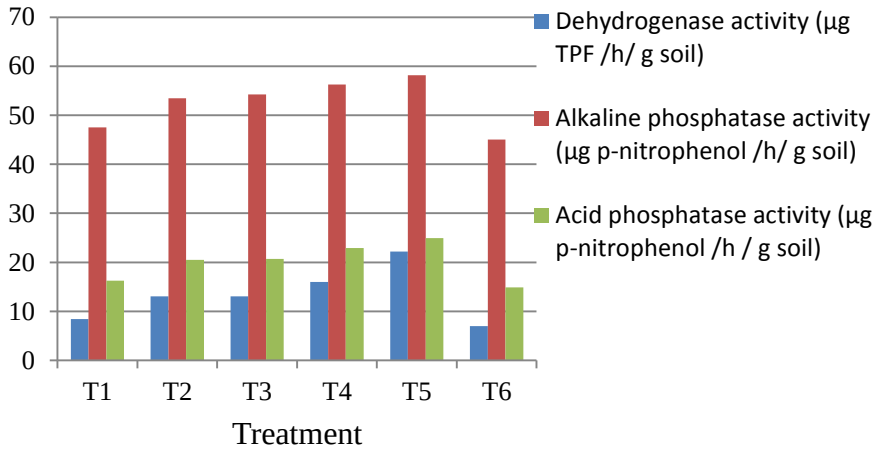
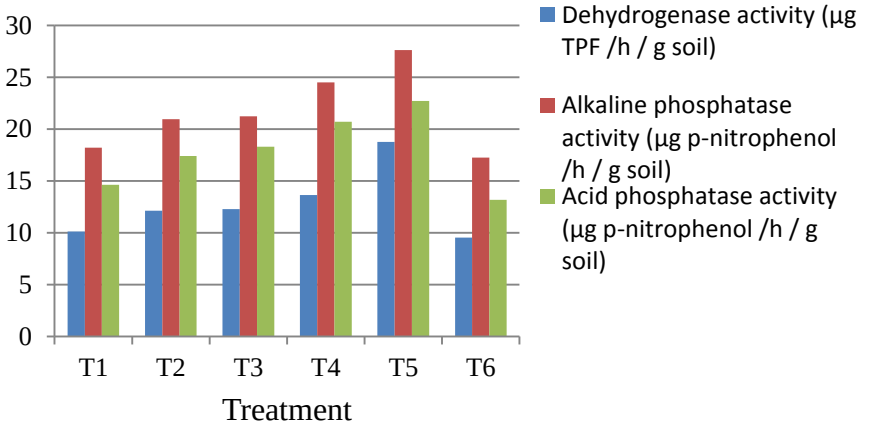



**Fig. 10. Effect of bio-organic fertilizer on plant growth and biomass**

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




(a)




(b)

**Fig. 11. Effect of bio-organic fertilizer on soil enzyme activities at (a) 90 and (b) 150 days after application**

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

**Table 9. Effect of bio-organic fertilizer on nutrient uptake by the plant**

| Treatment | Nutrient uptake (mg plant$^{-1}$) | | |
|---|---|---|---|
| | Nitrogen | Phosphorus | Potassium |
| T1: Control | 1729.41$^{e}$ | 940.78$^{e}$ | 259.05$^{d}$ |
| T2: K solubilizing bio-formulation @ 20 g plant$^{-1}$ | 2470.32$^{b}$ | 1105.54$^{c}$ | 311.88$^{b}$ |
| T3: Bio-organic fertilizer @ 150 g plant$^{-1}$ | 2663.00$^{a}$ | 1245.95$^{a}$ | 345.63$^{a}$ |
| T4: Bio-organic fertilizer @ 300 g plant$^{-1}$ | 2238.90$^{c}$ | 1059.75$^{d}$ | 313.34$^{b}$ |
| T5: Bio-organic fertilizer @ 600 g plant$^{-1}$ | 2058.62$^{d}$ | 1074.57$^{cd}$ | 290.21$^{c}$ |
| T6: Recommended dose of P and K through chemical fertilizers | 2097.57$^{d}$ | 1171.48$^{b}$ | 311.44$^{b}$ |
| LSDα0.05 | 44.45 | 38.85 | 17.02 |

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

A field experiment was conducted to evaluate the efficacy of bio-organic fertilizer in influencing flowering, fruit yield and quality of pomegranate. The data indicated that application of bio-organic fertilizer has significantly increased number of male and hermaphrodite flowers and fruit set per cent. The highest number of hermaphrodite flowers was recorded with the chemical application of P and K fertilizers at recommended dose, while the highest per cent fruit set (69.90%) was noted with the application of bio-organic fertilizer when applied at the rate of 300 and 600 g tree$^{-1}$ which were at par with each other. Application of bio-organic fertilizer significantly increased fruit yield by 48.23-55.32% over the *Penicillium pinophilum* based K-solubilizing bio-formulation application @ 20 g tree$^{-1}$. There was no significant difference in fruit yield with different doses of bio-organic fertilizer application. Even, the fruit yield obtained with the use of bio-organic fertilizer was significantly higher than recorded with the application of P and K chemical fertilizers at recommended dose. Significant improvement in fruit size was also observed with the application of bio-organic fertilizer. The per cent of fruits above 250 g



weight ranged from 38.94-46.47% and the highest per cent of fruits weighing more than 250 g was obtained with the application of bio-organic fertilizer at the rate of 150 g tree$^{-1}$. While only 27.86% fruits was above 250 g weight in K-solubilizing bio-formulation treated trees.

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

**Table 10. Effect of bio-organic fertilizer on flowering, fruit set, yield and fruit size distribution**

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

**T2: K solubilizing bio-formulation @ 20 g tree$^{-1}$**

**T3: Bio-organic fertilizer @ 150 g tree$^{-1}$**

**T6: Recommended dose of P and K through chemical fertilizers**

**Fig. 11. Effect of bio-organic fertilizer applications on bearing of pomegranate fruits on trees**

### 4.2.4. Effect of bio-organic fertilizer on temporal changes in nutrient content of leaves and soil

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

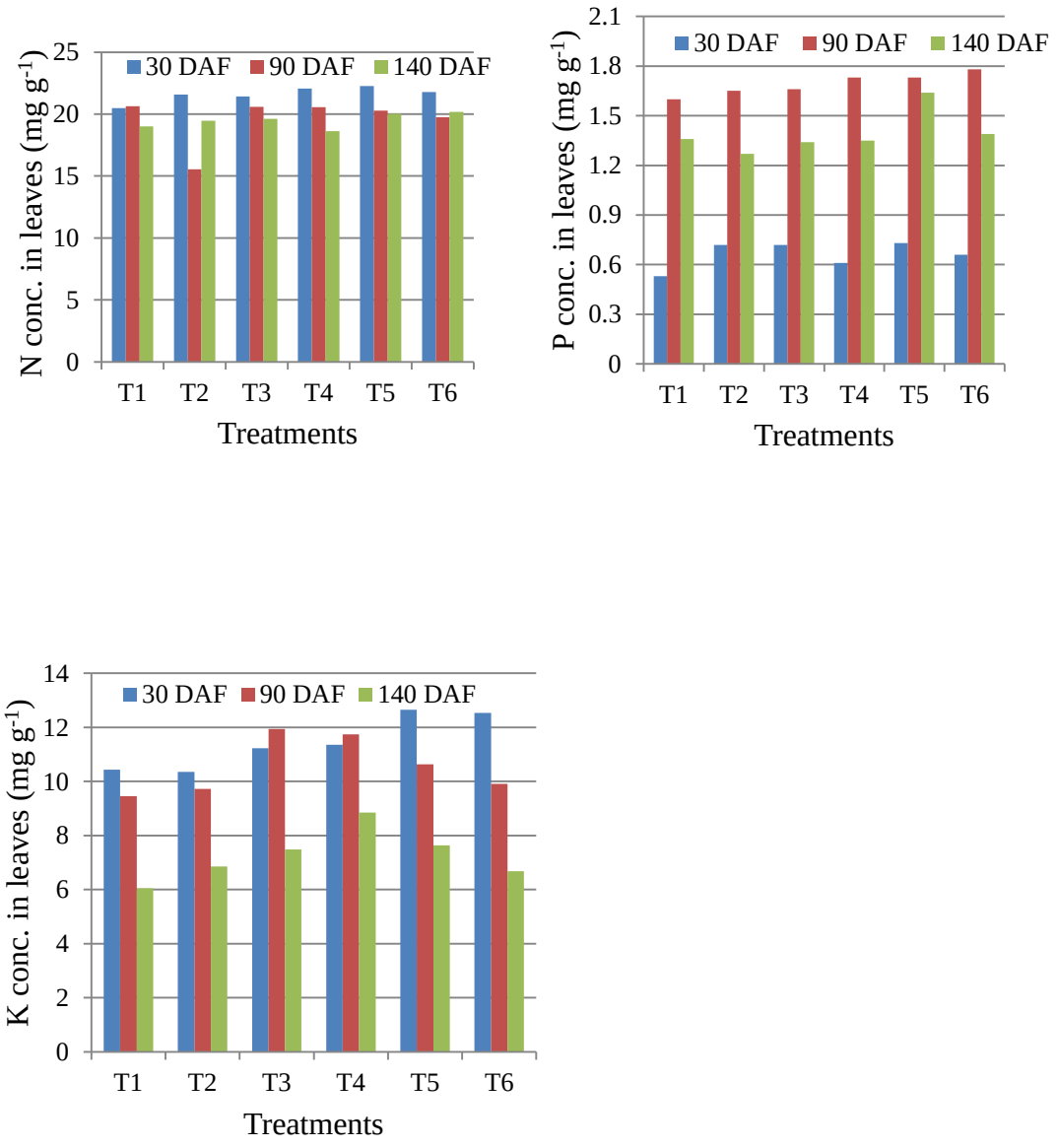
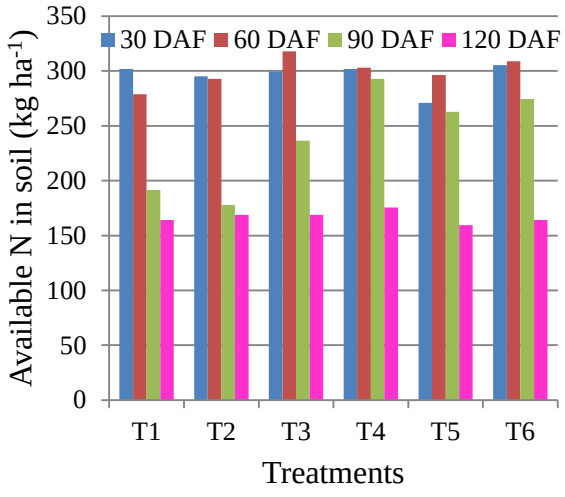


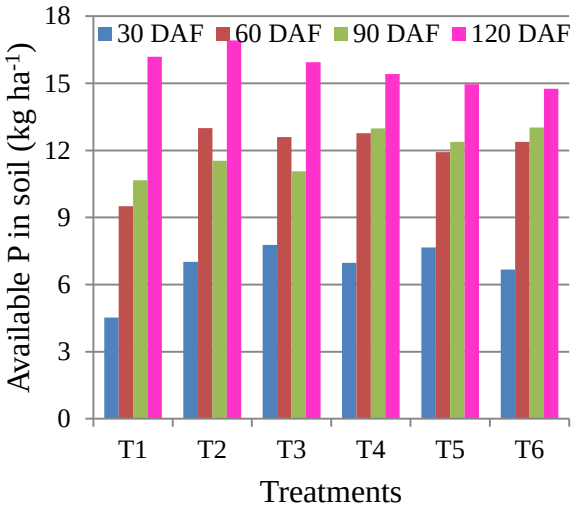

**Fig. 12. Effect of bio-organic fertilizer on temporal changes of N, P and K concentrations in the leaves during fruit growth and developmental stages**

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

content was observed with the application of bio-organic fertilizer @ 300 g tree$^{-1}$ which was even higher than that recorded with chemical P and K fertilizers applied at recommended dose.

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



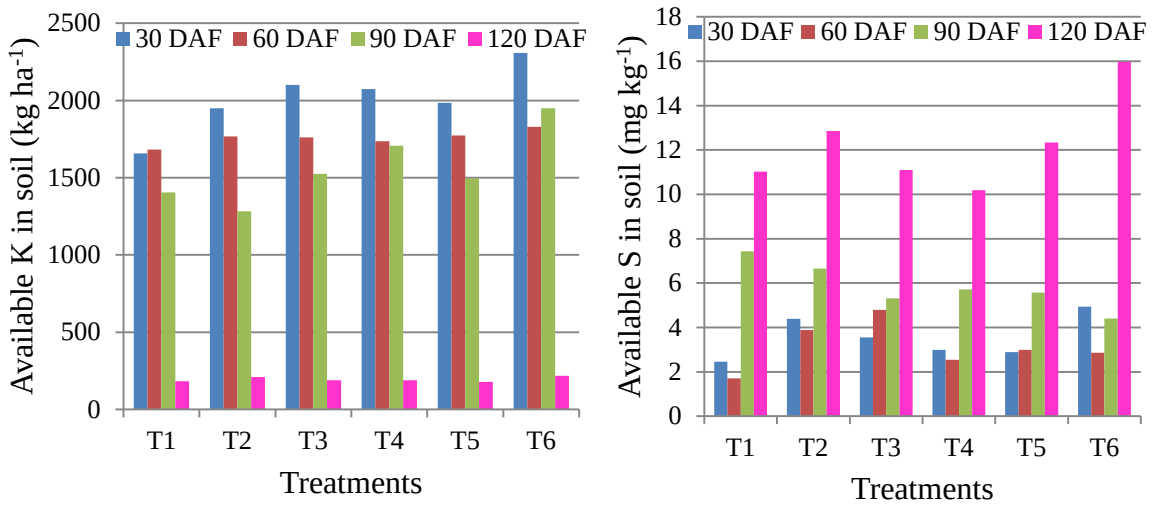



**Fig. 13. Effect of bio-organic fertilizer on temporal changes of soil available N, P, K and S content during the fruit growth and developmental stages**

### 4.2.5. Mustard formulation for fungal pathogens

The modified new mustard formulation prepared at CEPHT, Ludhiana and received in December 2020 was tested against three fungal pathogens of pomegranate *viz. Alternaria alternata* causing heart rot and leaf spot/blight in pomegranate, *Colletotricum gloeosporioides* the anthracnose pathogen and *Ceratocystis fimbriata* pomegranate wilt pathogen. All the 3 pathogens cause severe losses under favourable weather conditions especially under organic cultivation where chemical fungicides available cannot be used. The formulation was tested *in vitro* at 3 doses (1, 2.5 and 5 ml per litre) using 'Poison Food Technique' against these pathogens. All the doses of mustard formulation tested checked the pathogen growth above 37%, however highest inhibition was at 5ml/l dose with 53.77% inhibition of *A. alternate* and 50.68 % inhibition of *C. gloeosporioides* and 79.07% of *C. fimbriata* (Fig.2). The *in vitro* tests were encouraging, however, the formulation will be tested in polyhouse and field trials before arriving at final conclusion. In case the formulation is found effective in field trials in checking these pathogens, it will be a promising formulation for organic pomegranate production. Earlier the mustard formulation was reported effective in insect pest control in pomegranate.

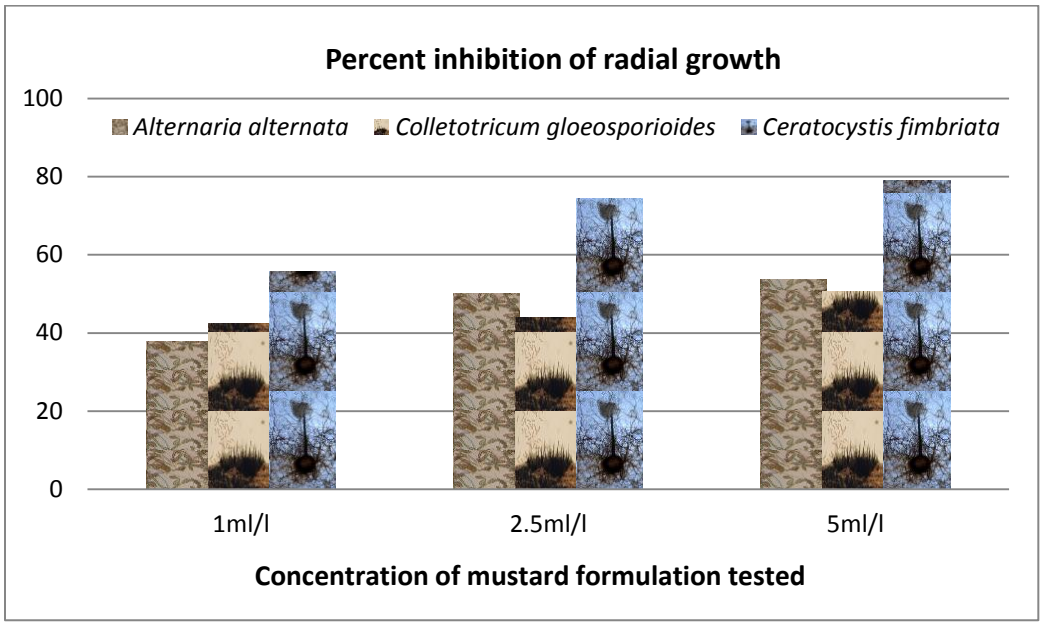
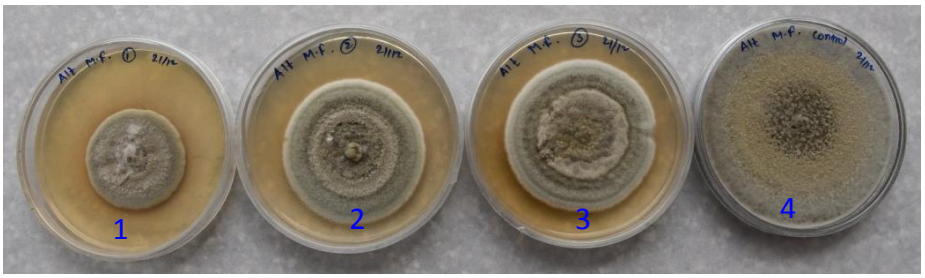
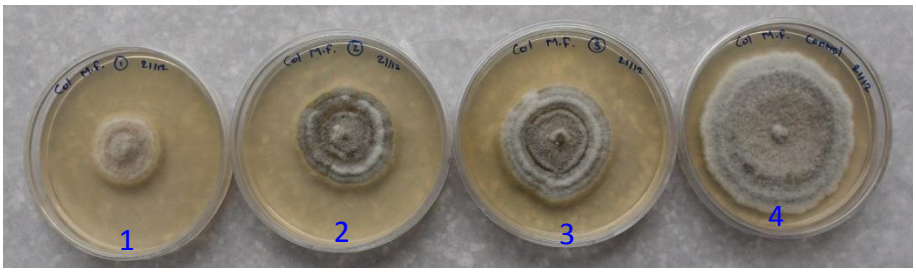


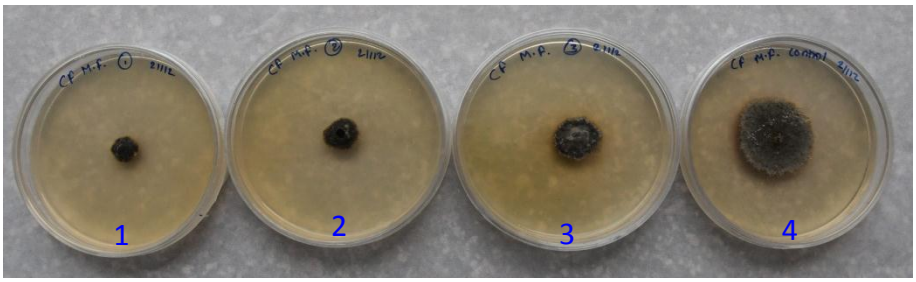

**Fig.14. Percent inhibition of radial growth of the fungal pathogens of pomegranate at 3 different mustard formulation concentrations**




*Alternaria alternata*




*Colletotricum gloeosporioides*




*Ceratocystis fimbriata*

**Plate 1. Radial growth of different pathogens in different concentrations (1) 5ml/l, (2) 2.5 ml/l; (3)1ml/l and (4) Control on Potato Dextrose Agar Media**

## I. Antifungal effect of 2-bromo-2-nitro-1, 3-propanediol (Bronopol)

The commonly used bactericide and immune-modulator 2-bromo-2-nitro-1,3-propanediol (95%) was tested against three economically important fungal pathogens of pomegranate *viz*. *Alternaria alternata* causing heart rot and leaf spot/blight in pomegranate, *Colletotricum gloeosporioides* the anthracnose pathogen and *Ceratocystis fimbriata* pomegranate wilt pathogen using 'Poison Food Technique' under in-vitro conditions at different concentrations. All the concentrations of bronopol tested checked the pathogen growth above 64 % at lower concentration (0.25 g/L). The growth was completely arrested (100 % inhibition) at 0.75 g/l in all tested fungal pathogens (Fig.2 & Plate 2). The *in vitro* tests were encouraging; however, bronopol will be tested in polyhouse and field trials before arriving at final conclusion. In case the bronopol is found effective in field trials in checking these pathogens, it will be a promising chemical to combat bacterial blight and fungal diseases in pomegranate and also an organic alternative. .

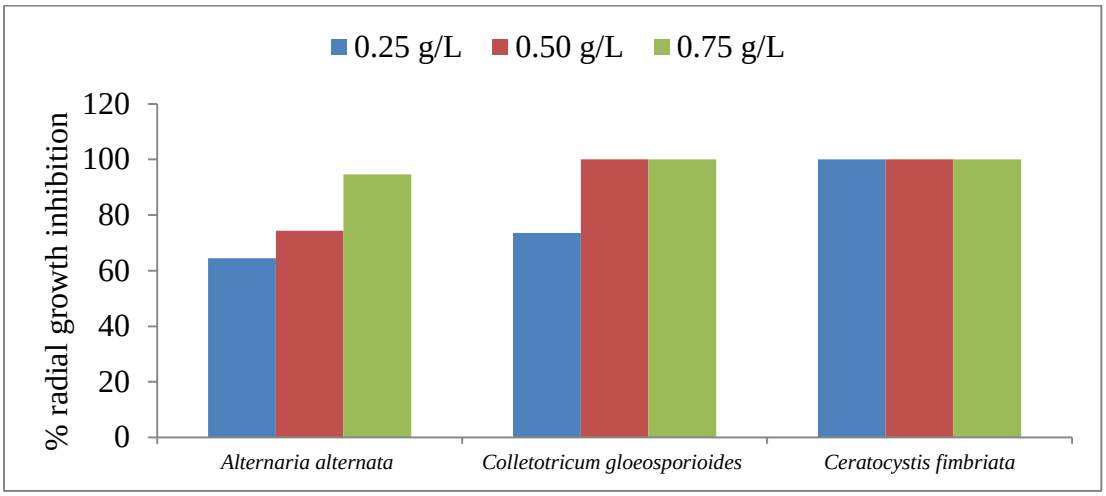
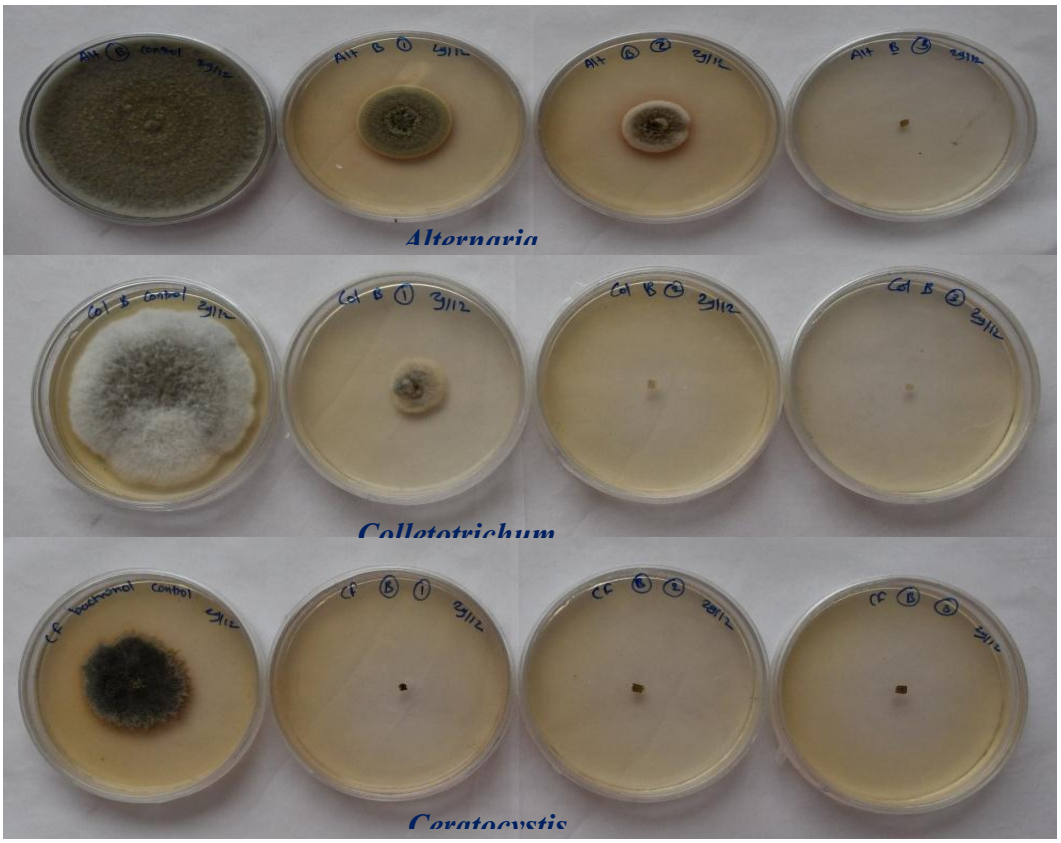



**Fig.15. Percent inhibition of radial growth of the fungal pathogens of pomegranate at 3 different mustard formulation concentrations**




**Control** **0.25 g/L** **0.50 g/L** **0.75 g/L**

**Plate 2. Radial growth of different pathogens at different concentrations of Bronopol (2-Bromo-2-Nitro-1, 3-Propanediol) on Potato Dextrose Agar Media**

### 4.2.6. Bio-efficacy evaluation of the insecticides and biopesticide combinations against the sucking pests and pomegranate fruit borer

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

**Table 12. Bio-efficacy of the insecticides and biopesticide combinations against the sucking pests and pomegranate fruit borer**

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

## 4.2. DEVELOPMENT AND REFINEMENT OF INTEGRATED PRODUCTION TECHNOLOGIES FOR IMPROVED PRODUCTIVITY IN POMEGRANATE (*PUNICA GRANATUM* L.) INTERCROPPING

Layout of experiment in light texture soil at HRF, NRCP, Solapur (latitude $17^0$ 10'', longitude $74^0$42'' and 483.5 m msl) in the Western Part of Maharashtra for assessing the pomegranate based intercropping has been completed.

The field experiment was conducted on comparative performance evaluation of various field crops namely, Marigold (Pusa Narangi Genda); Summer Mung (Western Proto); Sunflower (VSH-405) and Drumstick (PKM-1) to find out the effect of growth performance of intercrops and 2nd year



Super Bhagawa cv. pomegranate orchard. Four treatments were replicated six times in RBD during **Jan, 2020 to Dec, 2020.** Various intercropping treatments encouraged plant growth and also regulated soil temperature. Maximum plant height, branches and stem diameter was recorded in pomegranate plants having Drum stick as unterctop followed by Summer mung, Sun flower and Marigold.

**4.2.1. Estimation of pomegranate and intercrops evapotranspiration (ETp,** litres/week/tree**)**

The alternate day water was applied through drip irrigation system at 90 % efficiency from **Jan to Dec, 2020** which ranged from **46.0 to 98.0 liters/week/tree** for two years old pomegranate trees at 100 % *$ET_c$. At 15 days interval water was delivered through flood irrigation to intercrops and its evapotranspiration in $m^3$ ranged from 290 to 850**..**

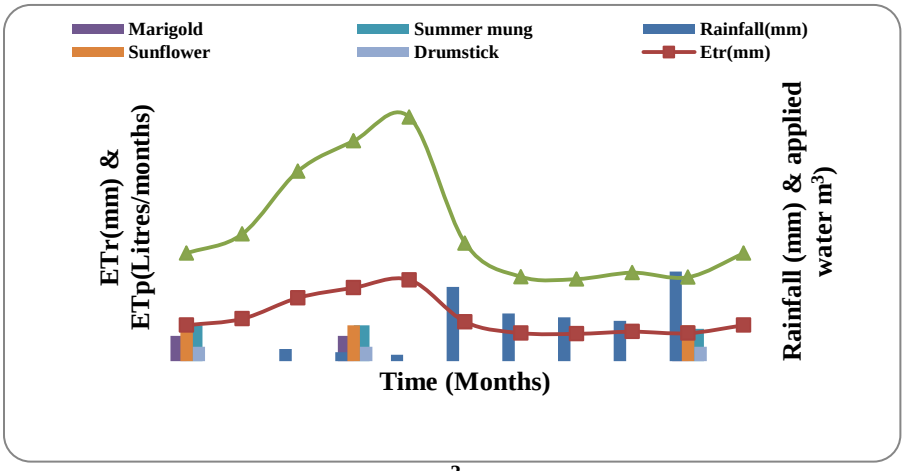



**Fig.16. Water applied in intercrops ($m^3$) and Pomegranate evapotranspiration (liters/week/tree)**

**Growth parameters**

Super Bhagava cv. of pomegranate plants was evaluated for their growth parameters under influence intercropping. Plant height, plant spread (EW & NS), stem diameter, stem girth and thorn length ranged from 73.4 to 92.6 cm, 58.3 to 85.4 cm, 67.8 to 87.5 cm, 1.4 to 2.4 cm, 1.2 to 1.7 cm and 0.6 to 0.9 cm.

**Table 13. Cumulative growth performance and water use in various intercropping during Jan,2020 to Dec,2020**

| Treatmen -ts | Water use (Litrs./$m^3$) | Plant height (cm) | Plant spread (cm) | | Stem dia. (cm) | Stem girth (cm) | |
|---|---|---|---|---|---|---|---|
| | | | EW | SE | | | |



| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $T_1$ | 1910 .00 | 92.6 | 85.4 | 87.5 | 2.4 | 1.7 | |
| $T_2$ | 0560.00 | 78.9 | 58.3 | 67.8 | 1.4 | 1.4 | |
| $T_3$ | 0850 .00 | 76.3 | 77.4 | 76.3 | 1.8 | 1.2 | |
| $T_4$ | 0850 .00 | 73.4 | 69.0 | 78.0 | 2.1 | 1.3 | |
| $T_5$ | 0290.00 | 87.5 | 80.0 | 83.7 | 2.3 | 1.5 | |

(**Note:$T_1$**-Pomegranate; $T_2$-Marigold; $T_3$ – Summer Mung; $T_4$-Sunflower; $T_5$- Drumstick)

**4.2.2. Sensor based irrigation scheduling for water productivity of pomegranate (*Punica granatum* L.).**

Layout of experiment in light texture soil at NRCP, Solapur (latitude $17^0$ $10^{''}$, longitude $74^0 42^{''}$ and 483.5 m msl) to assess the sensor based irrigation system for Bhagwa cv. pomegranate has been completed.

**Estimation of Reference Crop Evapotranspiration ($ET_r$, mm)**

The major factors affecting reference crop evapotranspiration are climatic parameters. 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 weather data for the period of **Jan, 2020 to Nov, 2020** were used to determine daily, weekly and monthly reference crop evapotranspiration ($ET_r$) by using Penman-Monteith Method. The yearly reference crop evapotranspiration ($ET_r$) obtained was **1435.71 mm**. The $ET_r$ was maximum in May (19-21 SMW) and minimum in Nov-Dec (45-52 SMW). The monthly minimum and maximum $ET_r$ was ranged from 75.16 to 225.05 mm.

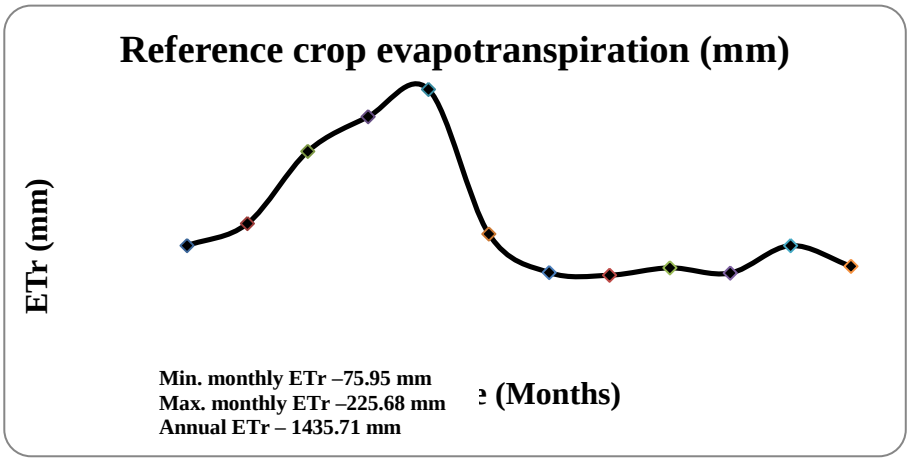



**Fig.17. Monthly $ET_r$ (mm) values from Jan, to Nov, 2020 at Experimental site**

**Estimation of Pomegranate Evapotranspiration (ETp, litres/day/tree)**

The two months average pomegranate evapotranspiration was found to be **4035.78 litres/tree** and water to be applied to pomegranate tree at various treatments ranged from **120.5 to 677.52 liters/tree/month.**

**Growth parameters**

Bhagava cv. of pomegranate was evaluated for their growth parameters in organic and inorganic. Plant height, plant spread (EW & SE), stem diameter, stem girth, thorn length and flowers ranged from 70 to 87 cm, 62 to 79 cm, 64 to 82 cm, 1.4 to 2.1 cm, 1.8 to 2.9 cm and 0.6 to 0.9 cm.

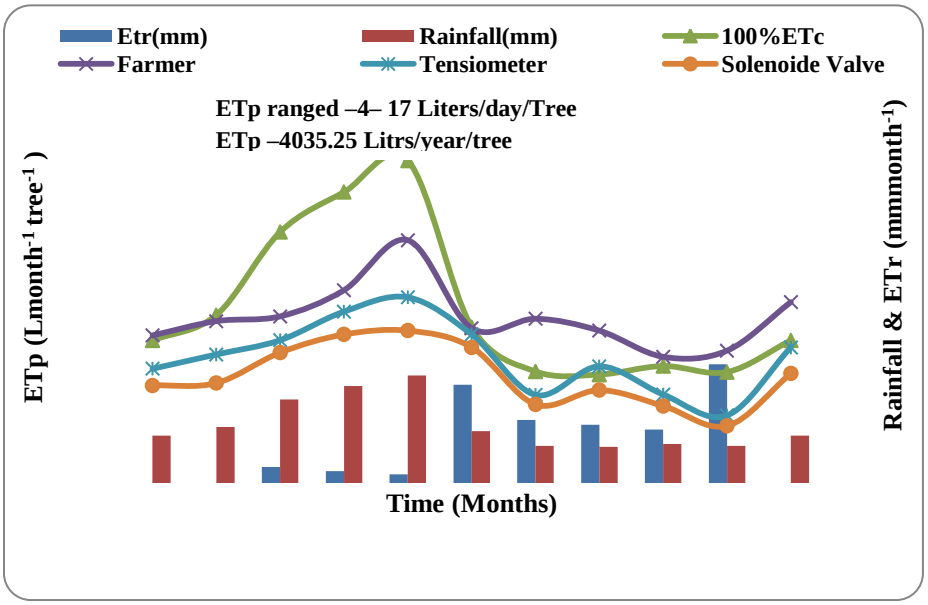



**Fig.18. Monthly pomegranate evapotranspiration (liters month$^{-1}$tree$^{-1}$) for two years old old plants**

**Table 14. Growth performance of experimental plots**

| 1st Year Days | Plant height (cm) | Plant spread (cm) | | Steam diameter (cm) | Steam girth (cm) |
|---|---|---|---|---|---|
| | | EW | SE | | |
| T1 | 87 | 77 | 82 | 2.1 | 2.5 |
| T2 | 85 | 79 | 78 | 1.8 | 2.9 |
| T3 | 80 | 72 | 64 | 1.7 | 2.1 |
| T4 | 70 | 62 | 67 | 1.4 | 1.8 |

( $T_1$-100%*$ET_c$, $T_2$-Tensiometer, $T_3$- Grower practices , $T_4$-Solenoide valve)



# Crop Protection

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

### 5.1.1. Bio-efficacy evaluation of newer insecticides formulations against insect pest of pomegranate and their natural enemies.

**Thrips:** The thrips incidence in all insecticidal treatments was significantly low indicating that all the insecticides were significantly effective against thrips. The treatment comprised of Spinetoram 11.7% SC @ 1 ml/L (1.33 thrips/ 10 cm shoot) was found most effective which was at par with Flonicamid 50 WG @ 1 g/L (1.67 thrips/ 10 cm shoot) and Cyantraniliprole 10.26 % OD @ 1 ml/L (2.01 thrips/ 10 cm shoot). The other insecticides evaluated for their efficacy against thrips also minimized the incidence and order of effectiveness was Tolfenpyrad 15 % EC @ 1 ml/L (2.32 thrips/ 10 cm shoot), Emamectin Benzoate 3 % +Thiamethoxam 12 % WG @ 1 g/L (2.50 thrips/ 10 cm shoot), Diafenthiuron 40.1% + Acetamiprid 3.9% WP @ 1 g/L (2.99 thrips/ 10 cm shoot) and Afidopyropen 50 DC @ 1 ml/L (4.03 thrips/ 10 cm shoot) which was less effective than the other insecticides. Whereas, maximum thrips population was found in control (10.48 thrips/ 10 cm shoot Fig.1)

**Table 1. Detail of the insecticides used for experiment**

| Insecticide and formulation | Dose ml/g/L+ 0.5 ml/L sticker |
|---|---|
| Tolfenpyrad 15 % EC ((T1) | 1 ml |
| Afidopyropen 50 DC (T2) | 1 ml |
| Flonicamid 50 WG (T3) | 1 ml |
| Emamectin Benzoate 3% + Thiamethoxam 12% WG (T4) | 1 g |
| Cyantraniliprole 10.26% OD (T5) | 1 g |
| Diafenthiuron 40.1% + Acetamiprid 3.9% WP (T6) | 1 g |
| Spinetoram 11.7 % SC (T7) | 1 ml |
| Control (T8) | water |



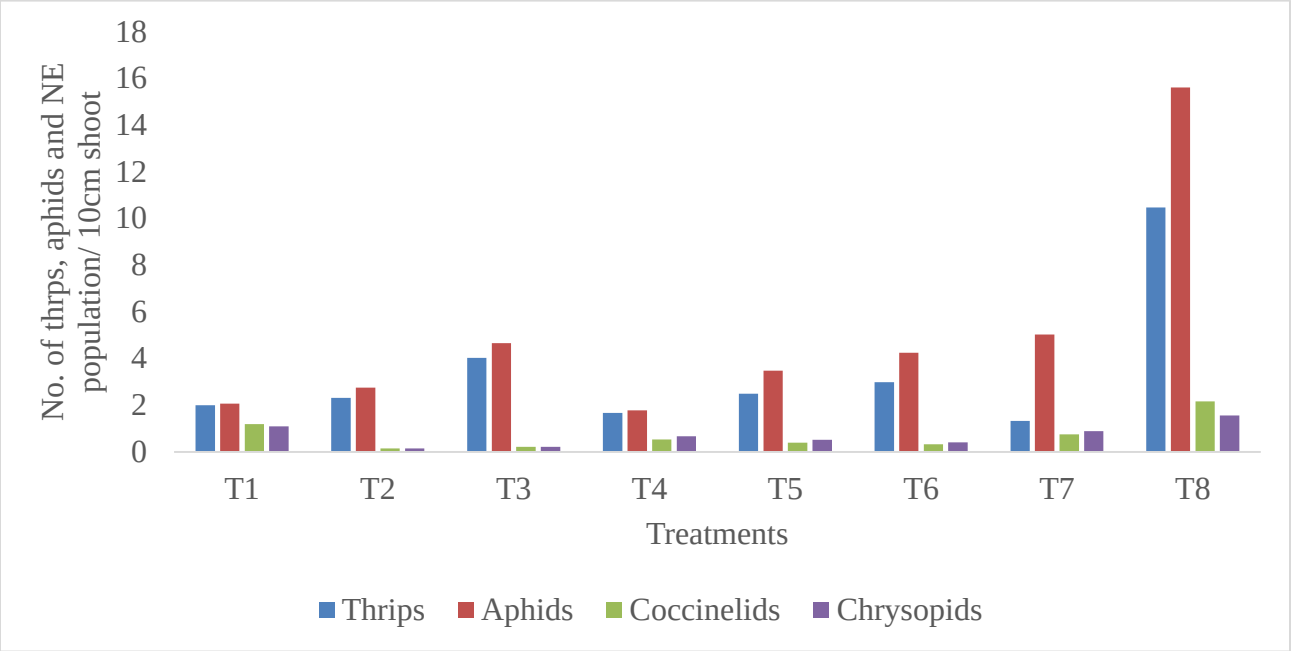



**Fig.1. Cumulative efficacy of insecticides against thrips, aphids, Coccinellids and chrysopids after three spray**

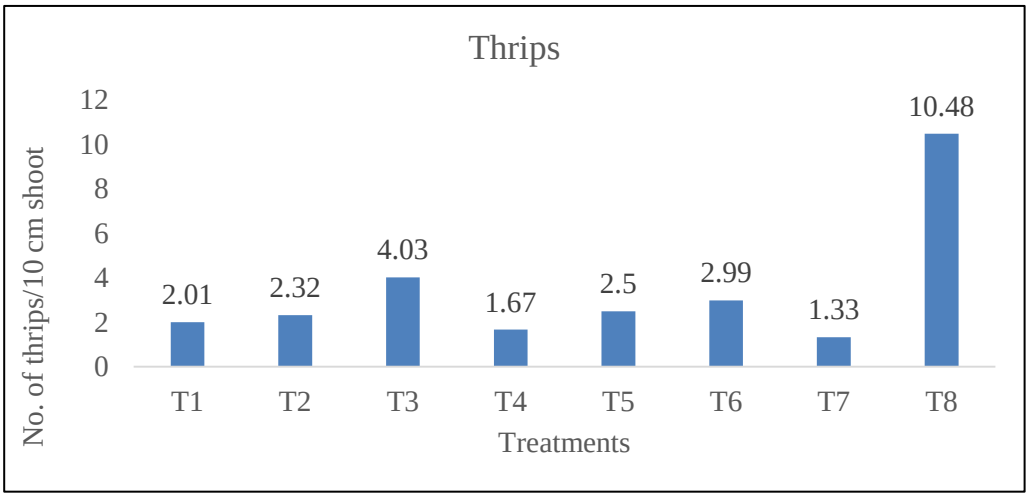



**Fig. 2. Cumulative efficacy of insecticides against thrips after three spray**

**Aphids:** An experiment was conducted to evaluate the bioefficacy of the five newer insecticides and two combi insecticide formulations at 1ml dose with 0.25ml spreader sticker per litre of water for the second season against the borer and sucking pests of pomegranate. Aphid incidence in all insecticidal treatments was significantly low indicating that all the insecticides were significantly effective against aphids. The treatment comprised of Flonicamid 50 WG @ 1 g/L (1.79 aphids/ 10 cm shoot) was found most effective which was at par with Cyantraniliprole 10.26 % OD @ 1 ml/L (2.07 aphids/ 10 cm shoot) and Tolfenpyrad 15 % EC @ 1 ml/L (2.76 aphids/ 10 cm shoot). The other insecticides evaluated for their efficacy against aphids also minimized the incidence and order of effectiveness was Emamectin Benzoate 3 % +Thiamethoxam 12 % WG @ 1 g/L (3.48 aphids/ 10 cm shoot), Diafenthiuron 40.1% + Acetamiprid 3.9% WP @ 1 g/L (4.25 aphids/ 10 cm shoot), Afidopyropen 50 DC @ 1 ml/L (4.67 aphids/ 10 cm shoot) and Spinetoram 11.7% SC @ 1 ml/L (5.04 aphids/ 10 cm shoot). Whereas, maximum aphid population was found in control (15.62 aphids/ 10 cm shoot).

**ii. Effect of newer insecticides formulations on natural enemies.**

**Coccinellids:** It is evident from the cumulative mean data that spray treatments with Cyantraniliprole 10.26 % OD @ 1 ml/L (1.19 Coccinellids/10 cm shoot) and Spinetoram 11.7% SC @ 1 ml/L (0.76 Coccinellids/10 cm shoot) were safest than all other insecticides. The maximum population was recorded in control (2.11 Coccinellids/10 cm shoot) and minimum population of Coccinellids was recorded in Tolfenpyrad 15 % EC @ 1 ml/L (0.16 Coccinellids/10 cm shoot) and Afidopyropen 50 DC @ 1 ml/L (0.22 Coccinellids/10 cm shoot). All treatments observed as non-significant.

**Chrysopids:** It is evident from the cumulative mean data that spray treatments with Cyantraniliprole 10.26 % OD @ 1 ml/L (1.10 chrysopids/10 cm shoot) and Spinetoram 11.7% SC @ 1 ml/L (0.89 chrysopids/10 cm shoot) were safest than all other insecticides. The maximum population was recorded in control (1.56 chrysopids/10 cm shoot) and minimum population of chrysopids was recorded in Tolfenpyrad 15 % EC @ 1 ml/L (0.15 chrysopids/10 cm shoot) and Afidopyropen 50 DC @ 1 ml/L (0.22 chrysopids/10 cm shoot). All treatments observed non-significant.

The experiment was conducted to evaluate the efficacy of the Spinosad 45% SC @ 0.5ml/l water in combination with three different dose @ 1, 2, 3 ml/l water for both Neem and Karanja oil. The results indicate that the combination of Neem Oil + Spinosad+ Sticker (3 +0.50+0.50) recorded the highest mortality (94.33%) followed by Karanja Oil+ Spinosad+ Sticker (1 +0.50+0.50) recorded mortality of (92.16%) 24 hours after treatment. In control treatments no mortality of the insect was recorded under the net house condition.

**Table: 2. Net house evaluation of Spinosad in combination with Neem Oil and Karanja oil against pomegranate aphids**



| Biopesticide | Dose (ml/L) | Total no. of aphids /10 cm | Total Live | Total Dead 24 HAT | % mortality |
|---|---|---|---|---|---|
| Neem Oil+ Spinosad+ Sticker(T1) | 1 +0.50+0.50 | 111 | 12 | 99 | 89.19 |
| Neem Oil + Spinosad+ Sticker (T2) | 2 +0.50+0.50 | 24 | 16 | 88 | 84.62 |
| Neem Oil + Spinosad+ Sticker (T3) | 3 +0.50+0.50 | 121 | 08 | 133 | 94.33 |
| Karanja Oil+ Spinosad+ Sticker(T4) | 1 +0.50+0.50 | 102 | 08 | 94 | 92.16 |
| Karanja Oil+ Spinosad+ Sticker ((T5) | 2 +0.50+0.50 | 87 | 11 | 76 | 87.36 |
| Karanja Oil+ Spinosad+ Sticker ((T6) | 3 +0.50+0.50 | 130 | 16 | 114 | 87.69 |
| Control (T7) | Water | 113 | 113 | 0 | 0.00 |

**5.1.3. First record of invasive mealybug *Pseudococcus jackbeardsleyi* (Newstead) on pomegranate:**

Mealy bugs were found scattered on the leaves, fruits and trunks and were observed sucking the sap from various parts of the pomegranate plants including leaves, stems, flowers and fruits (Fig. 2 and 3). The mealybug was identified as *P. jackbeardsleyi (*Gimpel and Miller), at the National Bureau of Agriculturally Important Insects, Bengaluru through slide mounting techniques (Fig. 4). The invasive mealybug is greyish; has thin filaments around the body, caudal pair about one half of the length of the body, and ovisac covering hind part of the body. This mealybug infests on different parts of the plant viz. Shoots, Flower bud, flower and all stages of the fruits. The per cent of infestation varies from 25-30. If timely proper management practices were not taken its infestation may increase further. The shoots infested by mealybugs exhibits the stunted growth, yellowing of leaves with no or poor flower induction and dropping of flower and drop of young fruits. Symptoms on the maturing, developing and ripening fruits indicates the eruptions, reddening of the rind deformation in shape and browning of arils was recorded.

**Fig. 5 (A). Intial colonisation *P. jackbeardsleyi* on young plant B. Adults and ovisac on tender shoots**

**Fig. 6. *P. jackbeardsleyi* infestation on ripening pomegranate fruits**



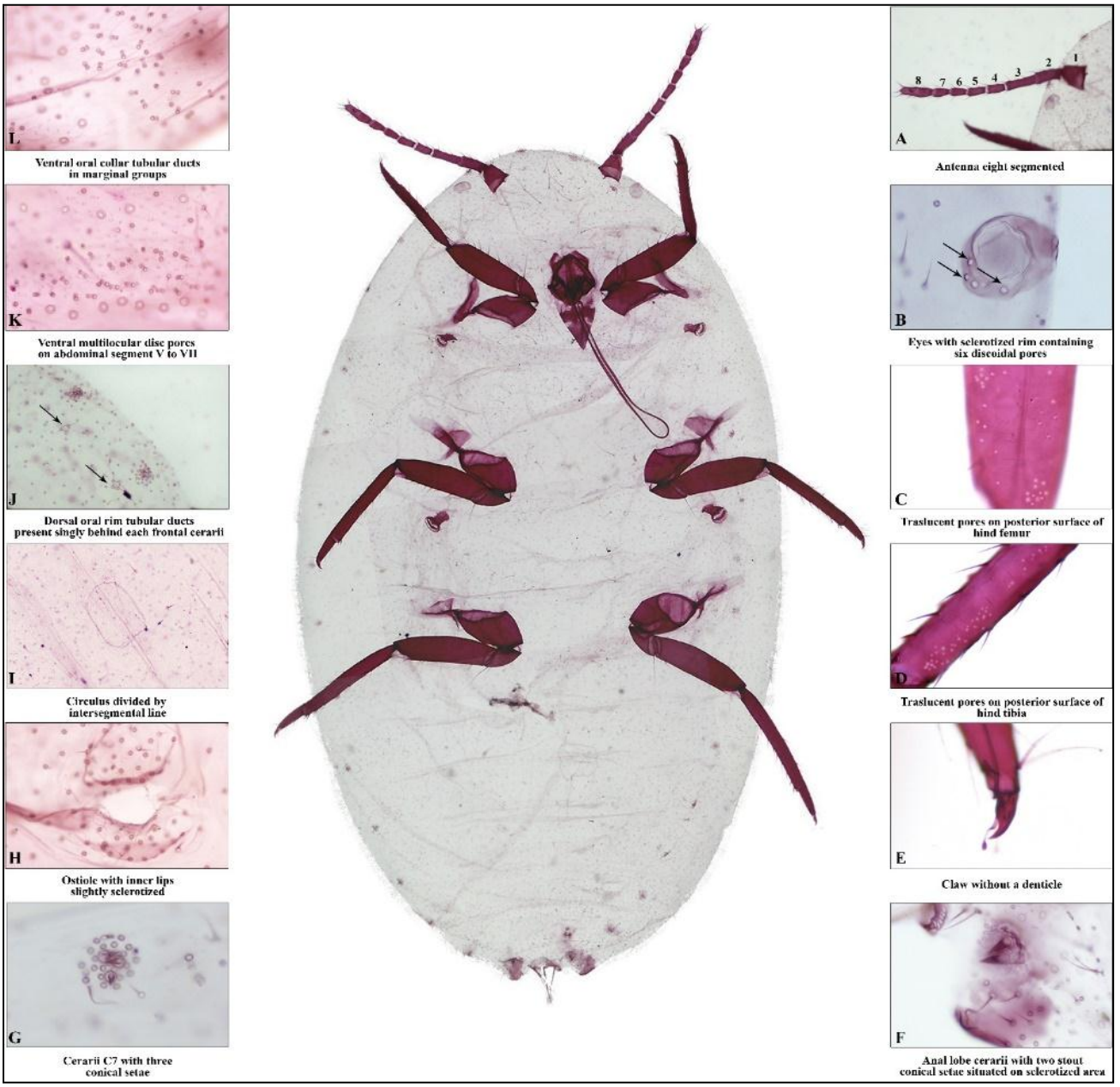



**Fig. .7 Mounted female characters of *Pseudococcus jackbeardsleyi***

### 5.1.4. Report of *scale insect Hemiberlesia lataniae* (Signoret) and *Ceroplastes sp.* damage on pomegranate at NRCP, Solapur

The diapsid and Coccidae scales *Hemiberlesia lataniae* (Signoret) and *Ceroplastes sp.* occasionally infest on a pomegranate but they of minor in status. The hard scales generally infest fruits, twigs, leaf ((Fig 5 and 6) and if allowed to multiply unchecked they will affect the fruit quality and they can kill the terminal growth, and in the case of young trees may threaten their vitality (Fig 4).


**Fig. 8 (A). *Hemiberlesia lataniae infestation* on leaf (B). *H. lataniae* on fruit**

**Fig. 9 Scale insect *Ceroplastes sp.* infestation on the leaf and shoot**

### 5.1.5. First report of scale insect *Aonidiella orientalis* (Newstead) (Hemiptera: Diaspididae) infestation on pomegranate from Gujrat

The infestation of *Punica granatum* by scale insects of the species *Aonidiella orientalis* (Newstead) (Hemiptera: Diaspididae) is reported for the first time from Patan village of Deliyathara taluka, saraswati distci of Gujrat. The pest was initially observed in May-June month of 2020 on 4-6 rows of the road bordering 5-6-year-old pomegranate orchard and on

different parts of the pomegranate plant *viz*., Stem, twigs, leaf, and fruits of different stages and its incidence become severe after the receipt of the rainfall in the month July-August 2020 and pest infestation was recorded on > 1000 plants out of 4500 plants in an area of 15 acres were infested. Out of 100-120 fruits/plant, 30-40% fruit infestation was observed. The scale insects can be identified by the presence of small black swollen spots on the branches and the fruits. Adults and pupa suck the cell sap from the fruit and tender shoots causing drying of branches. In case of severe infestation, the whole tree dries up. The insect's secret honeydew-like substance attracts black sooty mould. As a result, all the leaves and the branches turn blackish affecting the growth of the plant. Heavy infestations resulted in senescence, premature leaf fall, dieback and stunted growth of trees, and dense colonization on fruits (Fig. 10). The infested pomegranate fruits and twigs and leaves were collected. The identity of the oriental scale insect *A. orientalis* was confirmed by microscopic examination from NBAIR, Bengaluru. This pest is known to spread through human-mediated activities, wind, export/import of pomegranate fruits, and exchange of planting material and insect pest has not been observed previously in the Gujrat. Hence the report has special significance for the quarantine department, plant protectionists, agricultural officers, and extension entomologists for taking the necessary action in the future for preventing its spread to new pomegranate growing areas in India and the world. A detailed survey and bio ecology studies need to be conducted to design an effective pest management strategy.

**Fig. 10 Scale insect *Aonidiella orientalis* infestation on maturing and ripening fruits**

### 5.1.6. Report of Leaf eating caterpillar's *Ophusia tirhaca* and *Achaea janata damages* on pomegranate

The damage is mainly caused by caterpillars and the adult moths have been recorded as a secondary feeder on the pomegranate fruits. The caterpillars feed voraciously on pomegranate leaves. Feeding on the edges inwards, leaving behind only the midrib and the stalk. The damage is maximum during Mrig and hasta bahar crops (Fig. 87)

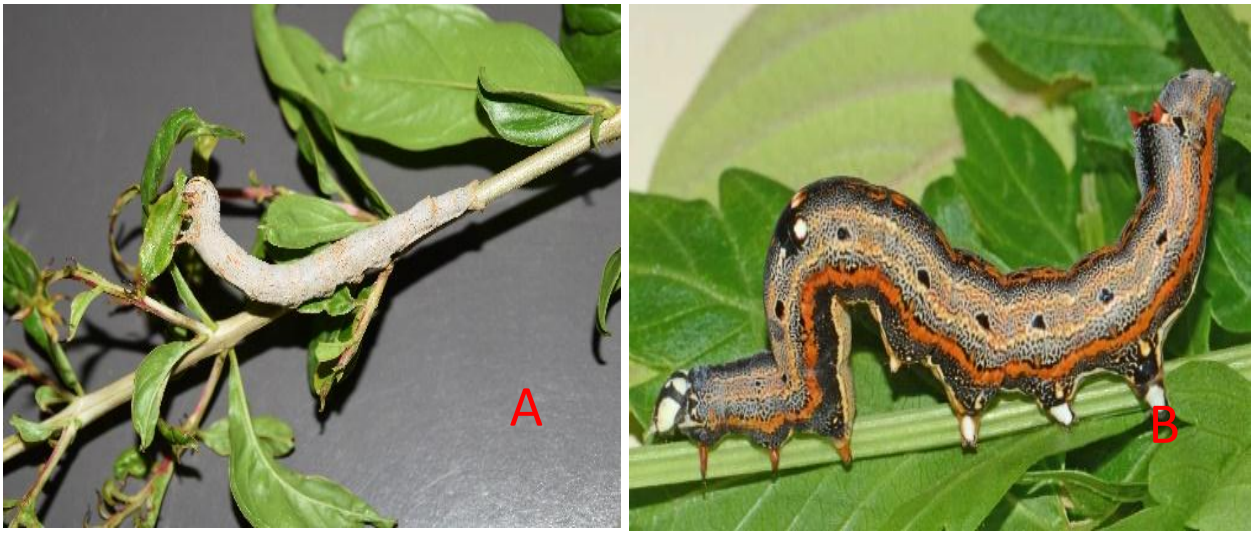



**Fig. 11(A). *Ophusia tirhaca*** **(B). *Achaea janata* damage symptoms**

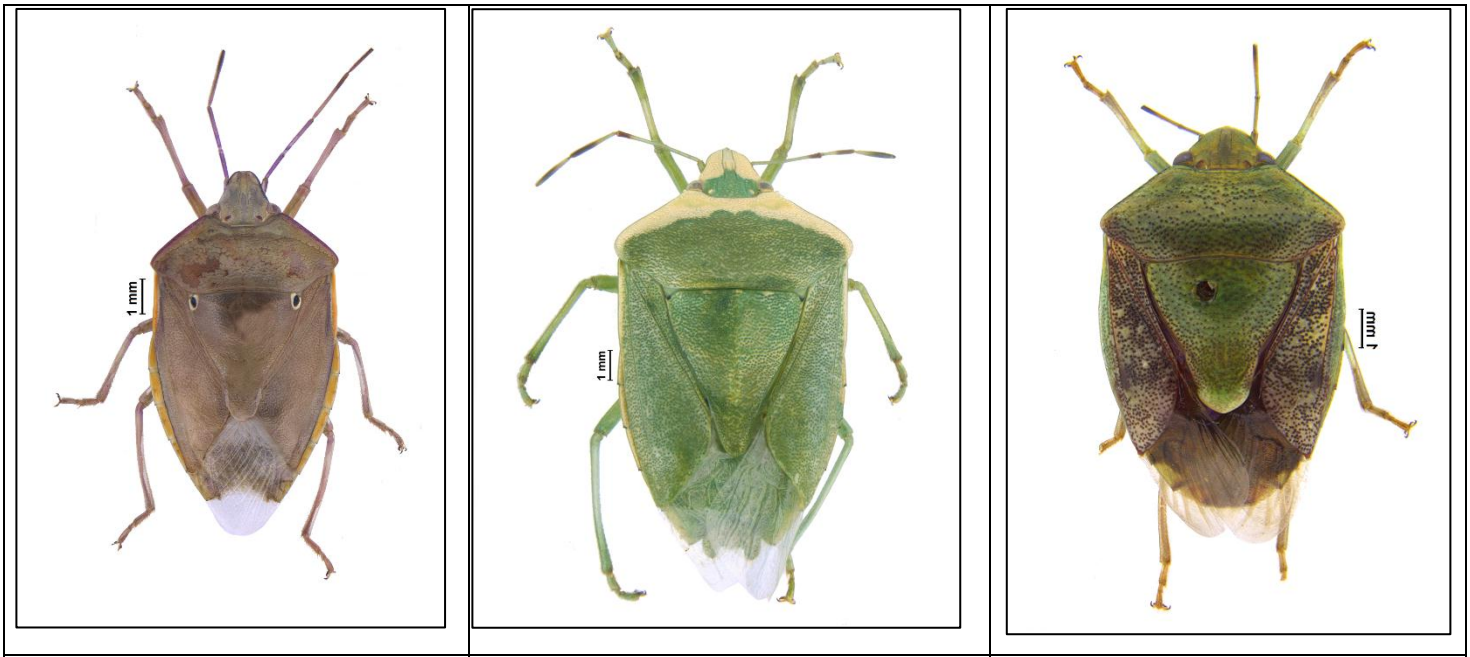
### 5.1.7. First report different speciese of pentatomid bugs infestation on pomegrnate

Five different species of Pentatomidae/stink bugs viz., *Nezara viridula* var. *torquata* (Fabr.), Halyomorpha *picus* (Fabr.), *Plautia crossota* (Dallas), *Bathycoelia indica* (Dallas) and *Nezara viridula* var. *smaragdula* (Fabr.) damaging on pomegranate has been recorded (Table 3 Fig. 10). Stink bug, which belongs to family Pentatomidae, are well-known for the obnoxious odour produced by the scent glands located on the metasternum. Among the several pentatomid pests, the green stink bug, *Nezara viridula* (L.) is perhaps the most important. It is cosmopolitan and highly polyphagous. The nymphs and adults of stink bug sucks the sap from all plant parts, but growing shoots and developing fruits are preferred (Fig. 12). Attacked shoots usually wither, in extreme cases, may die. The damage on fruit from the punctures is hard and later turns to brownish or black spots. These punctures affect the fruit's edible qualities and decidedly lower its market value. Young fruit growth is retarded and the fruit often withers and drops from the plant. The infestation of the fruits varied from 15-18%. The infestation of the bugs was also recorded during the random survey.

**Table 3. Five different species of pentatomid bugs infesting on pomegranate**

| Sl. No. | Scientific name | Higher classification |
|---|---|---|
| 1. | *Nezara viridula* var. *91orquate* (Fabr.) | Hemiptera: Pentatomidae: Pentatominae |
| 2. | *Halyomorpha picus* (Fabr.) | |
| 3. | *Plautia crossota* (Dallas) | |
| 4. | *Bathycoelia indica* (Dallas) | |
| 5. | *Nezara viridula* var. *smaragdula* (Fabr.) | |

**Fig. 12 Nymphs of stink bug feeding on leaf and pomegrnate fruit**




| *Bathycoelia indica* | *Nezara viridula var. torquata* (Fabr.) | *Plautia crossota* |
|---|---|---|

**Fig. 13 Different speciese of pentatomid bugs reported on pomegranate**

**Table 4. Net house evaluation of Spinosad in combination with Neem Oil and Karanja oil against pomegranate aphids**

| Biopesticide | Dose(ml/L) | Total no. of aphids /10 cm shoot | Total Live aphids /10 cm shoot | Total Dead aphids /10 cm shoot 24 HAT | % mortality |
|---|---|---|---|---|---|
| Neem Oil+ Spinosad (T1)+ Sticker | 1 +0.50+0.50 | 111 | 12 | 99 | 89.19 |
| Neem Oil + Spinosad (T2) + Sticker | 2 +0.50+0.50 | 24 | 16 | 88 | 84.62 |
| Neem Oil + Spinosad (T3) + Sticker | 3 +0.50+0.50 | 121 | 08 | 133 | 94.33 |
| Karanja Oil+ Spinosad + Sticker | 1 +0.50+0.50 | 102 | 08 | 94 | 92.16 |
| Karanja Oil+ Spinosad+ Sticker | 2 +0.50+0.50 | 87 | 11 | 76 | 87.36 |
| Karanja Oil+ Spinosad+ | 3 +0.50+0.50 | 130 | 16 | 114 | 87.69 |
| Control (T4) | Water | 113 | 113 | 0 | 0.00 |

The experiment was conducted to evaluate the efficacy of the Spinosad 45% SC @ 0.5ml/l water in combination with three different dose @ 1, 2, 3 ml/l water for both neem and Karanja oil. The

results indicate that the combination of Neem Oil + Spinosad+ Sticker (3 +0.50+0.50) recorded the highest mortality (94.33%) and followed by Karanja Oil+ Spinosad+ Sticker (1 +0.50+0.50) recorded (92.16%) 24 hours after treatment. In control treatment no mortality of the insect was recorded under the net house condition.

### 5.1.8. Evaluation of 3 different light traps for their effectiveness against insect pest of pomegranate.

Evaluated the three different type of light traps viz., Automated electric LED insect trap (1), Solar operated dual UV light automated insect trap with restrictor having regulated crop area illumination (2) and Automated dual CFL colour changing solar insect trap with restrictor having regulated crop area illumination (3) light traps received from ICAR-CISH Lucknow for evaluation against the major insect pest of pomegranate. The traps were installed at A-1, H-13 and H24 blocks of Kegaon, Hiraj-I and Hiraj-II from 28.08.2020 to 04.09.2020 (Fig.14) The details of the insects trapped in each trap are as presentedF below (Table 5)

**Table.5 Total no. of insects of different orders trapped in three different traps installed at A-1, H-13 and H-24 block**

| Count/Trap-1 | Lepidoptera | Coleoptera | Diptera | Hymenoptera | Hemiptera | Orthoptera | Dermaptera |
|---|---|---|---|---|---|---|---|
| **Total** | 52 | 1330 | 1050 | 68 | 288 | 14 | 138 |
| | Crop pests and Natural Enemy Trapped-Stink bug-1, Ladybird beetle-1, Ichneumon Wasp-1 | | | | | | |
| **Count/Trap-2** | 88 | 2696 | 2331 | 124 | 1492 | 22 | 207 |
| | Crop pests and Natural enemy trapped – Stink bug -2 Ladybird beetle-1 | | | | | | |
| **Count/Trap-3** | 62 | 1774 | 1707 | 69 | 332 | 26 | 133 |
| | Crop pests and Natural enemy trapped – Stink bug -2 Ladybird beetle-1 | | | | | | |

**Table. 6 Total no. of insects of different orders trapped in solar operated dual UV light automated insect trap with restrictor having regulated crop area illumination installed at H-13 block.**

| Count | Lepidoptera | Coleoptera | Diptera | Hymenoptera | Hemiptera | Orthoptera | Dermaptera |
|---|---|---|---|---|---|---|---|
| **Total** | 88 | 2696 | 2331 | 124 | 1492 | 22 | 207 |

Crop pests and Natural enemy trapped – Stink bug -2 Ladybird beetle-1

**Table. 7 Total no. of insects of different orders trapped in automated dual CFL colour changing solar insect trap with restrictor having regulated crop area illumination installed at H-24block.**

| Count | Lepidoptera | Coleoptera | Diptera | Hymenoptera | Hemiptera | Orthoptera | Dermaptera |
|---|---|---|---|---|---|---|---|
| **Total** | 62 | 1774 | 1707 | 69 | 332 | 26 | 133 |



Crop pests and Natural enemy trapped - Nil

**Fig. 14 Different light traps installed at different blocks of Kegaon and Hiraj block of NRCP**

### 5.1.8. Population dynamics of sucking pest of pomegranate

**Thrips:** The data on the population of thrips showed that the thrips population ranged from 0.45 to 13.38 thrips/10 cm shoot. During the first week of observation, the thrips population was 9.80 thrips/10 cm shoot and recorded its peak of 13.50 thrips /10 cm shoot. Thereafter the population was declined. The nymphs and adults of thrips were seen under the surface of the leaves, on flowers and fruits. The lacerating and sucking type of feeding by the thrips resulted in shriveling of leaves and fruits. Scarring of rind was also observed on fruits due to desapping, resulting in the decreased market value of fruits.

**Aphids:** The data on the population of aphids revealed that the aphid population ranged from 2.20 to 16.45 aphids/10 cm shoot. During the first week of observation (1$^{st}$ SMW), the aphid population was 9.80 aphids/10 cm shoot and recorded its peak of 16.45 aphid/10 cm shoot at 4$^{th}$ SMW. Thereafter the population went on decreasing. Both nymphs and adults of aphids suck sap from the tender shoots, leaves, flowers and fruits of the pomegranate plant. The infestation resulted in yellowing of leaves and sticky to touch and in a reduction in of quality of fruits and yield.

### 5.1.9. Population dynamics of natural enemies

During the first week of December population of Coccinellids was 1.10 /10 cm shoot. The maximum population of Coccinellids was (3.80 /10 cm shoot) when the sucking pest population was more and the chrysopids population ranged between 0.25 to 3.42 /10 cm shoot on pomegranate. The maximum population of chrysopids was (3.42 /10 cm shoot).

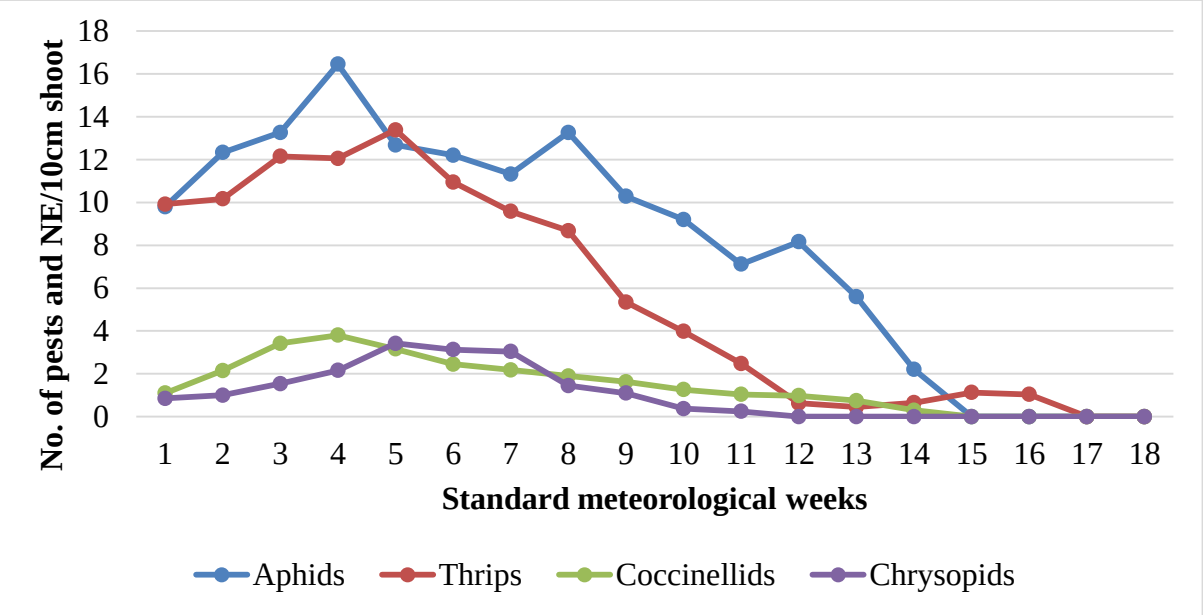



**Fig. 15 Population dynamics of sucking pests and their natural enemies in relation to SMW**

### 5.1.10. Correlation between weather parameters and major sucking pests of pomegranate

**Thrips:** The data showed that the correlation between the thrips population on pomegranate and maximum temperature (r= -0.941) and minimum temperature (r= - 0.894) was negatively correlated. Sunshine (r= 0.001) correlated positively but statistically non-significant. While rainfall (r= -0.359) was negatively correlated with non-significant correlation coefficient. The relationship between thrips and maximum and maximum relative humidity (r= 0.735 and r= -0.732 respectively) was positively correlated. Whereas evaporation (r= -0.856) negatively correlated (Table 8).

**Aphids:** The data showed that the correlation of *Aphis punicae* on pomegranate with maximum temperature (r= -0.821), minimum temperature (r= -0.884) and evaporation (r= -0.695) was negative. The relationship of aphid with maximum and minimum relative humidity (r= 0.481, r= 0.502 respectively) was positively correlated. The relationship of aphids with rainfall (r= -0.460) was negatively correlated. While sunshine (r= 0.183) correlated positively with non-significant correlation coefficient (Table 8).

**Table 8. Correlation coefficient (r) between the incidence of aphid and thrips on pomegranate and meteorological parameters. (**Table: 'r' value = 0.47)

| Pests | Meteorological parameters | | | | | | |
|---|---|---|---|---|---|---|---|
| | Temperature (°C) | | Relative Humidity(%) | | Rainfall (mm). | Sunshine Hrs. (h) | Evaporation (mm) |
| | Max | Min | Max. RH | Min. RH | | | |
| **Aphids** | -0.821 | -0.884 | 0.481 | 0.502 | -0.460 | 0.183 | -0.695 |
| **Thrips** | -0.941 | -0.894 | 0.735 | 0.732 | -0.359 | 0.001 | -0.856 |

### 5.1.11. Population dynamics of fruit sucking moths of pomegranate

The population of fruit sucking moths was monitored from August-October, 2020. Three different species of primary fruit piercing moths (*Eudocima sp.*) and two species of secondary piercers (*Ophusia tirhaca* and *Achaea janata)* were also recorded with the dominance of *E. materna.* A higher number of male moths was recorded in primary piercers. The peak activity of the moths was from 7.30 pm to till 11.30 pm and from the first week of August to September, though reduced activity was observed up to 2.00 am and until October. The sex ratio of the field-collected population (August-October) was recorded in which males are dominant, with male to the female sex ratio of 1.71 from total moths of 510 (males: 325 and female 185). The similar observations were also recorded from the laboratory-reared population from August February where a total of 780 moths were recorded with a sex ratio of 1.80 (males=492; females=288) were recorded.

### 5.1.12. Screening of pomegranate germplasms against sucking pests.

Total 49 different pomegranate germplasm has been screened against sucking pest it was found that none of the germplasm found resistant or tolerant against thrips and mealybugs. Infestation varied between 14.50-73.75 % and 10.50-15.25% by thrips and mealybug borer respectively.

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

**(a) Stem solarization to manage bacterial blight**

Developed Stem Solarization technology to manage bacterial blight in community approach with 100% blight control. It is ecofriendly, economical and effective



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

(b) **Bacteriophages for blight management**

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

**(c) Weather-based prediction model**

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

### 5.2.1. Genome-wide survey of SSRs across eight Xap strains -

Whole genome sequences of eight strains of *X. axonopodis* pv. *punicae*, available at NCBI were searched for microsatellites. For SSR survey, the genome sizes varied between 5.08 Mb (BD0023) and 5.43 Mb (Bagalkot) among eight strains. A total of 4,599 (BD0023) to 4,824 (Bagalkot) perfect SSRs were detected with minimum and maximum frequencies of 887.3 SSRs/Mb (Bagalkot) to 904.4 (LMG7504) and densities of 10,826.6 bp/Mb (Bagalkot) to 11,054.9 bp/Mb (LMG7504), respectively among eight strains (Table 9). Apart from this, we noticed 348 (BD0023) to 364 (LMG859) compound SSRs distributed across the genomes.

**Table 9. *In silico* mining of SSRs in the genomes sequences of eight *Xanthomonas axonopodis* pv. *punicae* strains**

| SSR mining in genomes of different *Xap* strains | LMG859 | LMG7439 | LMG7504 | BD0022 | BD0023 | BD0025 | Bagalkot | NCPPB3563 |
|---|---|---|---|---|---|---|---|---|
| **Examined sequences size (bp):** | 5,137,220 | 5,105,751 | 5,088,472 | 5,087,847 | 5,087,738 | 5,087,838 | 5,436,898 | 5,135,943 |
| **Total number of perfect SSRs:** | 4,645 | 4,617 | 4,602 | 4,600 | 4,599 | 4,601 | 4,824 | 4,619 |
| **Total length of perfect SSRs (bp):** | 56,742 | 56,338 | 56,253 | 56,157 | 56,147 | 56,174 | 58,863 | 56,337 |
| **Relative abundance of SSRs (loci/ Mb):** | 904.2 | 904.3 | 904.4 | 904.1 | 903.9 | 904.3 | 887.3 | 899.4 |
| **Relative density for SSRs (bp/Mb):** | 11,045.3 | 11,034.2 | 11,054.9 | 11,037.5 | 11,035.7 | 11,040.8 | 10,826.6 | 10,969.2 |
| **Total number of compound SSRs** | 364 | 354 | 355 | 349 | 348 | 353 | 362 | 349 |



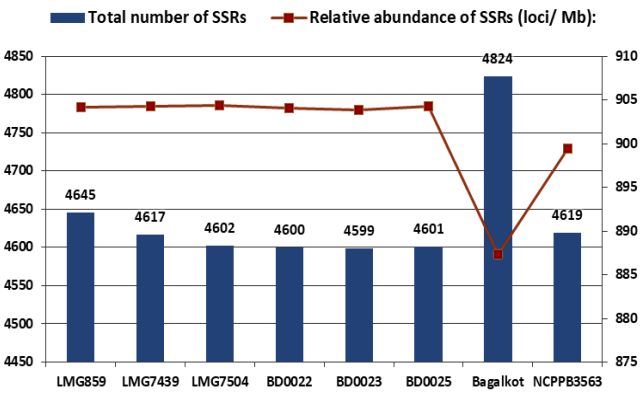
Examination of the number of SSRs and their relative abundance (loci/Mb) across eight *Xap* genomes revealed, that Bagalkot strain had the highest number of SSRs (4,824) compared to all other strains (~ 4,600**)** (Table 10, Fig 16a). However with respect to relative abundance of SSRs, Bagalkot (887.3) and NCPPB3563 **(**899.4) had shown the lowest values as compared to all other strains (~904, 11030). Similarly, the frequency distribution for different SSR repeat units in the eight *Xap* genomes revealed, abundance of -hexa nucleotides, followed by -tri ,- tetra, -di and penta-nucleotides among all the genomes (Fig 16b). It was interesting to note that Bagalkot strain had the higher number of hexa- (4,451), tri- (210), tertra- (90) and penta-nucleotide (23) repeats compared to other strains, however it has maintained the relative abundance same as that of other strains.

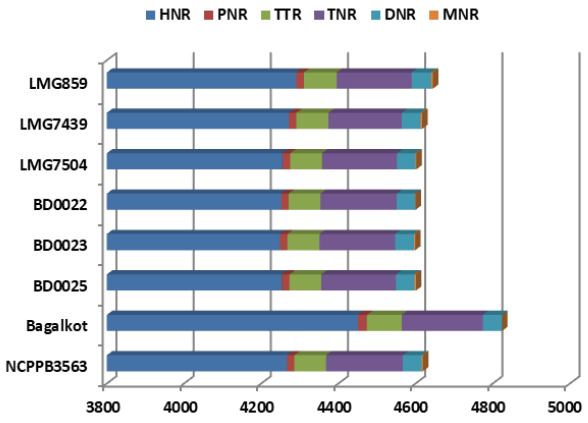
**Table 10. Numbers and density of the SSRs identified in the genomes of eight *Xanthomonas axonopodis* pv. *punicae* strains**

| Different *Xap* Strains | Genome Size (MB) | SSR numbers | | | | | | | Relative Abundance (loci/Mb) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MNR | DNR | TNR | TTR | PNR | HNR | Total | MNR | DNR | TNR | TTR | PNR | HNR | Total |
| **LMG859** | 5.14 | 4 | 51 | 194 | 85 | 20 | 4,291 | 4,645 | 0.8 | 9.9 | 37.8 | 16.5 | 3.9 | 835.3 | 904.2 |
| **LMG7439** | 5.10 | 4 | 49 | 190 | 83 | 19 | 4,272 | 4,617 | 0.8 | 9.6 | 37.2 | 16.3 | 3.7 | 836.7 | 904.3 |
| **LMG7504** | 5.09 | 2 | 48 | 194 | 83 | 20 | 4,255 | 4,602 | 0.4 | 9.4 | 38.1 | 16.3 | 3.9 | 836.2 | 904.4 |
| **BD0022** | 5.09 | 1 | 48 | 197 | 83 | 19 | 4,252 | 4,600 | 0.2 | 9.4 | 38.7 | 16.3 | 3.7 | 835.7 | 904.1 |
| **BD0023** | 5.09 | 3 | 49 | 196 | 83 | 19 | 4,249 | 4,599 | 0.6 | 9.6 | 38.5 | 16.3 | 3.7 | 835.1 | 903.9 |
| **BD0025** | 5.09 | 4 | 48 | 193 | 83 | 20 | 4,253 | 4,601 | 0.8 | 9.4 | 37.9 | 16.3 | 3.9 | 835.9 | 904.3 |
| **Bagalkot** | 5.44 | - | 50 | 210 | 90 | 23 | 4,451 | 4,824 | - | 9.2 | 38.6 | 16.5 | 4.2 | 818.7 | 887.3 |
| **NCPPB3563** | 5.14 | 3 | 49 | 199 | 82 | 19 | 4,267 | 4,619 | 0.6 | 9.5 | 38.7 | 16.0 | 3.7 | 830.8 | 899.4 |

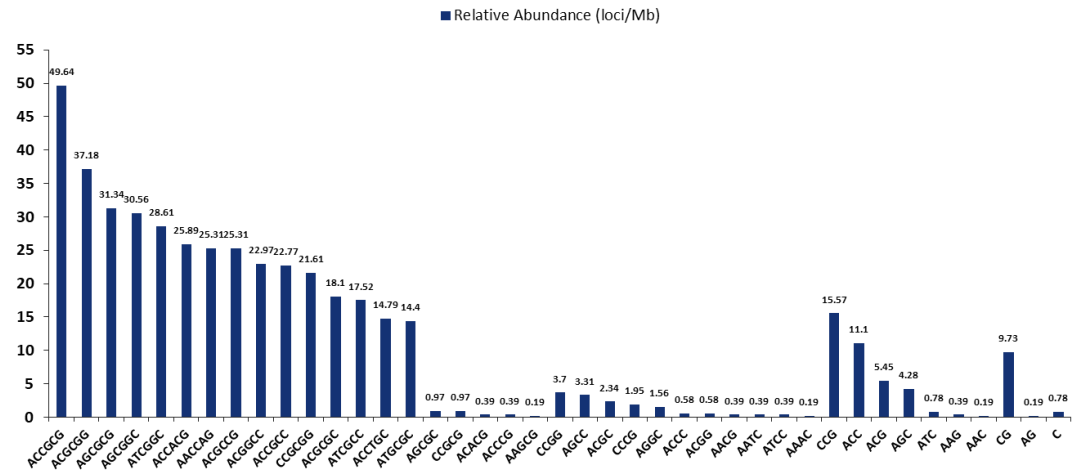
**Note *** MNR, DNR, TNR, TTR, PNR, and HNR indicate mono-, di-, tri-, tetra-, penta-, and hexa-nucleotide SSRs, respectively

In order to find out the frequency distribution for most abundant motif categories in *Xap* genomes, we have analyzed the reference genome sequence of LMG859 strain. As result, we noticed among different motif categories ACCGCG/ACGCGG type had the highest occurrence (9.6%), followed by CCG/ACC (2.95%), CG/AG (1.1%), CCGG/AGCC (0.78 %) and AGCGC/CCGCG (0.22 %) (Fig.16c). Specifically, the major motifs of mono- to hexa-nucleotide repeats were C, CG, CCG, CCGG, AGCGC/CCGCG and ACCGCG, respectively, in which ACCGCG motifs were rich with relative abundance of 49.64 loci/Mb in the genome, followed by CCG (15.57 loci/Mb) and CG (9.73 loci/Mb). SSRs with CG-rich repeats were more dominated in the *Xap* genome.



a) b)




c)

**Fig. 16 Frequency distribution of the different SSR motif types in the *Xap* genomes a) The comparison of perfect SSR number/density among eight *Xap* strains, b) The frequency of mono- to hexanucleotide motifs in the *Xap* genomes, c) Relative abundance of different SSR motif types in the reference *Xap* genome (LMG859)**

### 5.2.2. Designing and ePCR validation of Xap specific SSR primers

Based on the results of SSR survey across eight strains of *Xap*, we selected the first reference genome of LMG859 strain for SSR primer designing. As a result we successfully designed 2,927 Xap_SSR primers. The majority of these primers were specific to hexa-nucleotide motifs (2661 primers, 90.91%), followed by tri- (159, 5.43%), di- (49, 1.67%), tetra- (45, 1.54%) and penta- (13, 0.44%) repeats, respectively. To assess the amplification levels and specificity of the developed Xap_SSRs, *in silco* PCR analysis was performed for 2927 Xap_SSR primers across all the eight *Xap* genome strains. We recorded amplification for an average of 2,906 (99.28 %) primers across the genomes, of which 542 produced one allele, while remaining had more than one allele (920 with two, 1234 with three and 212 with ≥ 4 alleles). Concerning individual genome, total 2,927 SSRs (100%) were validated in LMG859 genome, whereas 2,916 SSRs amplified (99.62 %) in BD0022, BD0023 and BD0025 genomes, 2,903 to 2,904 (99.21%) in LMG7439 and LMG7504, and 2,884 to 2,885 (98.57%) in Bagalkot and NCPPB3563 genomes, respectively. Of these, 522 to 558 primers showed single locus amplifications across the *Xap* genomes. The genome-wise details of four groups of SSRs producing i.e. single, two, three and ≥ four alleles are presented in Table 11.

**Table 11. Experimental validation of Xap_SSRs through ePCR or eMapping across the eight *Xap* genomes**

| Sl.No | Different *Xap* Strains Evaluated for ePCR | e PCR Validation of XAP_SSRs primers across genomes Allele No | | | | | |
|---|---|---|---|---|---|---|---|
| | | Number of LMG859 primers got validated | one | two | three | ≥Four | Total (%) |
| 1 | LMG859 | 2,927 | 545 (18.62%) | 931 (31.81%) | 1,230 (42.02%) | 221 (7.55%) | 100 |
| 2 | LMG7439 | 2,904 | 546 (18.80%) | 933 (32.13%) | 1,214 (41.80%) | 211 (7.27%) | 100 |
| 3 | LMG7504 | 2,903 | 550 (18.95%) | 924 (31.83%) | 1,216 (41.89%) | 213 (7.34%) | 100 |
| 4 | BD0022 | 2,916 | 551(18.90%) | 901 (30.90%) | 1,251 (42.90%) | 213 (7.30%) | 100 |
| 5 | BD0023 | 2,916 | 558 (19.14%) | 894 (30.66%) | 1,251 (42.90%) | 213 (7.30%) | 100 |
| 6 | BD0025 | 2,916 | 542 (18.59%) | 936 (32.10%) | 1,224 (41.98%) | 214 (7.34%) | 100 |
| 7 | Bagalkot | 2,884 | 522 (18.10%) | 920 (31.90%) | 1,242 (43.07%) | 200 (6.93%) | 100 |
| 8 | NCPPB3563 | 2,885 | 524 (18.16%) | 921 (31.92%) | 1,227 (42.53%) | 213 (7.38%) | 100 |
| | Average | 2,906 | 542 | 920 | 1,232 | 212 | |

### 5.2.3. PCR based validation of Xap_SSRs distributed across the genome

We selected a sub set of 66 *Xap* specific primers specifically targeting di- and tri-nucleotides, which are covering the entire *Xap* genome, which was shown through their physical positions on LMG859 chromosome by Circos graph (Fig. 17). Out of 66 primers, 57 (86.36%) showed clear amplifications on eight *Xap* isolates..

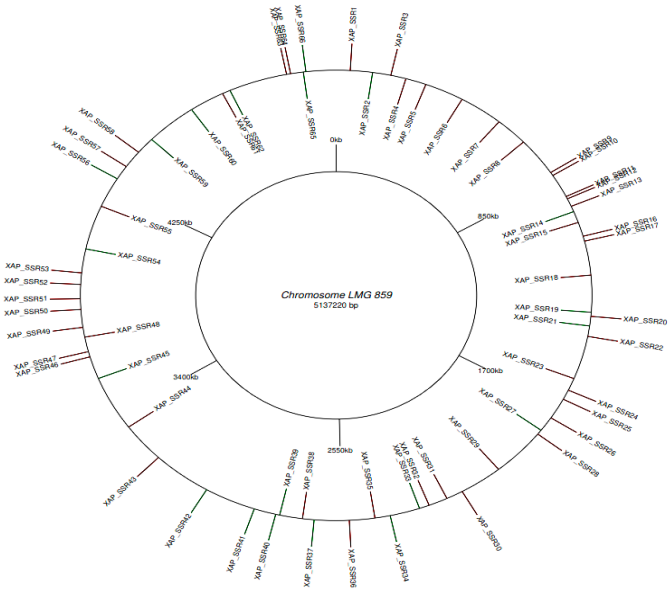



**Fig. 17 Circos graph depicting physical locations of 66 Xap_SSRs on the chromosome of reference strain (LMG859)**

The genomic tool generated here could enable future research on population dynamics, taxonomy, epidemiological and quarantine aspects of this pathogen, which could help to devise eco-friendly and cost-effective control measures to reduce the economic losses caused by this pathogen.

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# Post-harvest Management and Value Addition

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

### 6.1.1. Development of Probiotic Pomegranate Juice

Fruit juices can be considered as suitable products for supplementation with probiotic strains. Although fruits juices are an appropriate matrix for the growth of probiotics, the survival of these probiotic microorganisms in fruit juices is even more complex than in dairy products, because the probiotic bacteria need to protect themselves from the acidic environment and presence of phenolic conditions of the fruit juices. The probiotic bacteria's loses their viability during delivery through the gastro-intestinal tract due to presence of gastric juices. Since, prebiotics are non-digestible food ingredients that stimulate the growth or activity of bacteria in the gastrointestinal tract, hence, may be useful in increasing the number and/or activity of probiotics. Further the encapsulation technology when used for the probiotic culture provides the protection from adverse environmental condition in the host and product. Keeping this in view an experiment was conducted to study the effect of co-encapsulation of prebiotics viz. inulin and GOS (*Galacto oligosachhride*) at various concentrations along with probiotic microorganisms *L.* Casei and *L.* acidophilus in simulated digestive system and pomegranate juice on survivability of probiotic strains.

The slant of pure culture of *L. casei* and *L. acidophilus* from NCIM, Pune were used and inoculated separately in MRS broth and incubated at 37°C for 24 hrs. The culture was then transferred in 95 ml MRS broth and incubated at same conditions to get final microbial cell count of $10^{10}$ cfu/ml. The cells were harvested by centrifugation at 1500 g for 15 minutes at 25°C. These cells were washed with sterile 0.1% peptone solution. The culture was then suspended in 5 ml sterile 0, 0.5, 1.0 and 1.5 % inulin and GOS separately and the mixed with 20 ml of 2% (w/v) sterile sodium alginate solution. The final prebiotic concentration in the emulsion is 0, 0.1, 0.2, and 0.3 %. The cell suspension was then sprayed in the 0.05 M sterile $CaCl_2$ solution through the



200 micron nozzle by using microencapsulator in sterile atmosphere. The beads were hold for 30 minutes in the calcium chloride solution for gelation. The microencapsulated beads prepared with prebiotic (MEPB) and without prebiotic (MEB) were then kept in 0.1% peptone solution at 4°C until used. The survivability of the control, microencapsulated beads (MB) and microencapsulated beads with prebiotics (MEPB) was studied in pomegranate juice. The pomegranate juice was freshly extracted and thermally pasteurized and cooled. The aseptically prepared 1 g microencapsulated beads (MEB), microencapsulated beads with prebiotic GOS 1.5% (MEPB), and control (culture) of *L.* casei and *L. acidophilus* were added per 100 ml of pure juice to ensure minimum $10^{10}$ cfu/ml cell concentration. The packaged bottles of 200 ml were stored at 5 °C in a cold room and samples were drawn at 15 days interval to know the survivability of the microorganisms. The acidity of the juice is also measured during storage at 15 days interval.

**Table 1. Microencapsulation yield of probiotic at different concentrations of prebiotic.**

| Probiotic microorganism | Prebiotic | Conc. (%) | No. of cells (Log cfu/ml) | | Yield (%) |
|---|---|---|---|---|---|
| | | | Before | After | |
| ***L. casei*** | **Control** | 0 | 11.57±0.03 | 11.36±0.01 | 61.46 |
| | **GOS** | 0.5 | 10.45±0.02 | 9.88±0.07 | 26.98 |
| | | 1 | 10.48±0.01 | 10.29±0.04 | 64.05 |
| | | 1.5 | 10.53±0.02 | 10.36±0.03 | 67.00 |
| | **Inulin** | 0.5 | 10.42±0.01 | 10.19±0.02 | 58.75 |
| | | 1 | 10.45±0.01 | 10.25±0.05 | 63.13 |
| | | 1.5 | 10.41±0.02 | 10.19±0.03 | 60.62 |
| ***L. acidophilus*** | **Control** | 0 | 11.31±0.01 | 11.15±0.03 | 68.94 |
| | **GOS** | 0.5 | 10.20±0.04 | 9.79±0.05 | 38.94 |
| | | 1 | 10.25±0.02 | 9.98±0.03 | 53.24 |
| | | 1.5 | 10.24±0.04 | 9.91±0.07 | 47.35 |
| | **Inulin** | 0.5 | 10.18±0.02 | 9.74±0.02 | 36.18 |
| | | 1 | 10.27±0.02 | 9.92±0.06 | 44.72 |
| | | 1.5 | 10.21±0.02 | 9.85±0.04 | 43.33 |

The effect of encapsulation on the per cent yield (cell count in cfu/ml) is depicted in table 1. The initial microbial cell count of the probiotic microorganism was in the range of 10.20 to 11.57 cfu/ml. The per cent yield of cell count varied in the range of 26.98% to 68.94%. It has



been observed that the reduction in the cell count was lower in control samples ie. without prebiotic. The microencapsulated samples with 1and 1.5% concentrations GOS and inulin prebiotic has shown higher encapsulation yield for both the microorganisms. To understand survivability of the probiotics namely *L. casei* and *L. acidophilus* with and without prebiotic (GOS and inulin) in simulated gastric juice and simulated intestinal juice has been shown in Table. The results suggested that the log reduction is highest in control samples and is low in samples with prebiotic for both microorganism and both prebiotics. The lowest log reduction in probiotic count can be observed for *L. casei* in prebiotic GOS 1.5%, followed by Inulin 1.5%, GOS 1% and Inulin 1%. The lowest log reduction in case of *L. acidophilus* was also observed in GOS 1.5% followed by GOS 1%, GOS 0.5% and inulin 1.5%. The higher survivability of the probiotic microorganisms after passing through simulated gastric and intestinal juice has increased the possibilities their presence in large numbers to facilitate colonization in the colon. Thus, the higher survival of the probiotic microorganisms can ensure health benefits of the probiotics to human.

**Table 2. Survivability of the probiotic cells in simulated gastric juice (pH 1.55) at 30, 60, 90 and 120 minutes and followed by 150 minutes in simulated intestinal juice (pH 7.43).**

| | | Number of cell (log cfu $g^{-1}$) | | | | | Log |
|---|---|---|---|---|---|---|---|
| | | 0 min. | 30 min. | 60 min. | 90 min. | 120 min. | Reduction |
| *Lactobacillus casei* | Control | 11.27±0.01 | 4.25±0.1 | 4.15±0.04 | 3.90±0.02 | 3.79±0.06 | 7.48 |
| | GOS 0.5 % | 9.90±0.06 | 3.94±0.06 | 4.00±0.03 | 4.31±0.04 | 4.35±0.03 | 5.55 |
| | GOS 1% | 10.16±0.05 | 3.96±0.03 | 4.11±0.01 | 4.36±0.05 | 4.69±0.01 | 5.47 |
| | GOS 1.5% | 10.09±0.04 | 3.85±0.04 | 4.05±0.06 | 4.30±0.05 | 5.00±0.02 | **5.09** |
| | Inulin 0.5% | 9.97±0.04 | 3.94±0.01 | 4.02±0.02 | 3.94±0.05 | 3.78±0.03 | 6.19 |
| | Inulin 1% | 10.08±0.04 | 3.94±0.06 | 3.78±0.25 | 4.25±0.05 | 4.46±0.01 | 5.62 |
| | Inulin 1.5% | 10.01±0.05 | 3.92±0.03 | 3.96±0.02 | 4.26±0.01 | 4.66±0.01 | 5.35 |
| *Lactobacillus acidophilus* | Control | 11.10±0.04 | 4.21±0.02 | 4.00±0.02 | 3.83±0.19 | 3.67±0.02 | 7.43 |
| | GOS 0.5% | 9.41±0.06 | 3.96±0.03 | 3.95±0.01 | 4.31±0.09 | 4.51±0.05 | 4.90 |
| | GOS 1% | 9.49±0.09 | 3.90±0.01 | 4.05±0.01 | 4.23±0.03 | 4.63±0.02 | 4.86 |
| | GOS 1.5% | 9.44±0.06 | 3.85±0.04 | 3.97±0.02 | 4.25±0.03 | 4.67±0.03 | **4.77** |
| | Inulin 0.5% | 9.19±0.05 | 3.92±0.04 | 3.94±0.02 | 3.95±0.01 | 3.82±0.07 | 5.38 |
| | Inulin 1% | 9.67±0.11 | 3.95±0.04 | 3.92±0.01 | 4.14±0.08 | 4.30±.0.01 | 5.37 |
| | Inulin 1.5% | 9.51±0.07 | 3.92±0.01 | 3.87±0.03 | 4.25±0.06 | 4.59±0.02 | 4.91 |



**Table 3. Survivability of probiotic microorganisms in microencapsulated beads, beads with prebiotic and control**

| Microorganism | Treatment | Log Cfu/ml | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 0th Day | 15th Day | 30th Day | 45th Day | 60th Day | 75th Day | 90th Day |
| *L. casei* | MEB | 10.42±0.07 | 9.63±0.02 | 9.53±0.05 | 9.39±0.06 | 9.25±0.10 | 8.68±0.05 | 8.43±0.10 |
| | Control | 10.68±0.03 | 9.56±0.04 | 9.38±0.06 | 9.14±0.09 | 8.75±0.03 | 8.51±0.06 | 8.16±0.12 |
| | MEBP | 10.45±0.05 | 9.74±0.05 | 9.79±0.02 | 9.80±0.02 | 9.82±0.06 | 9.84±0.04 | 9.85±0.04 |
| *L. acidophilus* | MEB | 10.35±0.05 | 9.65±0.04 | 9.48±0.05 | 9.29±0.03 | 8.91±0.03 | 8.73±0.03 | 8.54±0.09 |
| | Control | 10.72±0.01 | 9.50±0.04 | 9.26±0.06 | 9.06±0.11 | 8.62±0.04 | 8.37±0.09 | 8.13±0.11 |
| | MEBP | 10.40±0.01 | 9.66±0.04 | 9.67±0.04 | 9.69±0.05 | 9.73±0.04 | 9.75±0.03 | 9.75±0.04 |

**Table 4. Per cent acidity of probiotc juice for microencapsulated beads, beads with prebiotic and control**

| Microorganism | Treatment | 0th Day | 15th Day | 30th Day | 45th Day | 60th Day | 75th Day | 90th Day |
|---|---|---|---|---|---|---|---|---|
| *L. casei* | MEB | 0.37±0.02 | 0.41±0.02 | 0.43±0.02 | 0.45±0.03 | 0.48±0.03 | 0.49±0.02 | 0.50±0.02 |
| | Control | 0.35±0.03 | 0.39±0.02 | 0.41±0.05 | 0.44±0.02 | 0.46±0.02 | 0.47±0.02 | 0.48±0.03 |
| | MEBP | 0.42±0.03 | 0.45±0.03 | 0.47±0.02 | 0.48±0.03 | 0.49±0.02 | 0.53±0.04 | 0.54±0.03 |
| *L. acidophilus* | MEB | 0.37±0.02 | 0.42±0.03 | 0.46±0.02 | 0.50±0.02 | 0.51±0.03 | 0.52±0.02 | 0.54±0.03 |
| | Control | 0.36±0.02 | 0.41±0.02 | 0.44±0.02 | 0.46±0.05 | 0.47±0.02 | 0.50±0.02 | 0.53±0.02 |
| | MEBP | 0.42±0.03 | 0.48±0.06 | 0.50±0.04 | 0.51±0.03 | 0.52±0.02 | 0.55±0.02 | 0.57±0.02 |

The survivability of the probiotic microorganisms *L. casei* and *L. acidophilus* in processed pomegranate juice has been studied during storage. Among control samples (were culture of probiotics directly put into the juice), microencapsulated beads (MEB) prepared using sodium alginate, and microencapsulated beads with prebiotic (MEBP), the MEBP has shown highest survival in *L. casei* and *L. acidophilus* followed by MEB and control. The All the samples have shown the mandatory probiotic cell count of $10^8$ and above. The probiotic count on the 90$^{th}$ day of storage in microencapsulated samples with prebiotic (GOS 1.5%) was 9.85 and 9.75 log cfu/ml respectively for *L.* casei and *L. acidophilus* which is significantly higher than that of MEB and control. The increasing trend in the acidity of pomegranate juice can be observed in the all the treatments. The sensory score of the probiotic juice has revealed high acceptability after 90$^{th}$ day of storage for all the treatments.

## 6.1.2. Development of pomegranate seed based mouth freshener



The soft seeded varieties of pomegranate contain seed oil to the tune of 25-26 % (V/W). The pomegranate seed oil contains more than 70 % of conjugated linoleic acid whichis important biocompound from health point of view i.e. heart health, against inflammation, cancer, skin health etc. The seed are also rich source of high quality dietary fibers. The presence of soft fiber provides chew ability to seeds. Thus, nutritious seeds should be utilized for development of high value products such as mouth freshener. The pomegranate seed which are rich in CLNA and dietary fibers, if processed to provide mouth freshening appeal with excellent chewability can be preferred by masses. The use of traditional home spices such as cardamom, clove, mint etc. will provide taste and health benefits too. The experiment was conducted for the development of the mouth freshener which will be digestive and healthy alternative to *panmasala and gutkha*.

The marc (left out portion from juice extraction) is received from pomegranate processing unit and washed in fruit pulper for extracting the clean seeds. The seeds were dried at $40^0$C in tray dryer and dried up to moisture content 7% (db). The dried seeds were packed in polythene bags and stored at $5^0$C in desiccator until used for development of mouth freshner. Sugar syrup was prepared using cane sugar and water in the ratio of 5:4. Sugar syrup and ingredient *viz.*, cardamom, clove, fennel, mint powder and black salt was added as per the treatment details for T1, T2 and T3. This mixture was well mixed manually.

**Table 5. Treatment details for preparation of pomegranate seed based mouth freshener**

| Sl. No. | Ingredients | T1 | T2 | T3 |
|---|---|---|---|---|
| 1 | Seed (g) | 50.00 | 50.00 | 50.00 |
| 2 | Cardamom powder (g) | 1.50 | 1.75 | 2.00 |
| 3 | Clove powder (g) | 2.00 | 2.25 | 2.50 |
| 4 | Fennel powder (g) | 1.00 | 1.25 | 1.50 |
| 5 | Black salt (g) | 0.25 | 0.375 | 0.50 |
| 6 | Mint powder (g) | 0.50 | 0.75 | 1.00 |
| 7 | Sugar (g) | 50.00 | 50.00 | 50.00 |
| 8 | Water (ml) | 40 | 40 | 40 |



After proper mixing treated pomegranate seed were subjected to microwave drying. Sample was Microwave treated at frequency of 2,450 MHz at 720W microwave power for 60s. Microwave treated pomegranate seed mouth freshener was cooled to room temperature. Pomegranate seed based mouth freshener was vacuum packed using vacuum packaging machine and stored at 5°C.

Biochemical parameters for the mouth freshener like moisture content (%), acidity(%), ascorbic acid content (mg/100g),total phenolic content (mg/100ml GAE), total carbohydrate (µg/100ml), total protein (µg/ml), antioxidant activity (mg/100ml AAE), ash content (%), crude fiber (%) and micronutrients were determined as per standard protocols. Further, sensory analysis of developed pomegranate seed based mouth freshener was performed using nine point hedonic scale and panel of 10 judges. The parameters used for analysis were color, texture, taste and flavor, and overall acceptability.

**Table 6. Biochemical analysis of pomegranate based mouth freshener**

| Treatments | Ascorbic Acid (mg/100ml) | Titrable Acidity (%) | Total Phenol (mg/LGAE) | Protein (µg/ml) | Carbohydrate (µg/ml) | Antioxidant capacity (mg/100ml) | Crude Fiber (%) | Ash (%) |
|---|---|---|---|---|---|---|---|---|
| **Control** | 9.066 | 0.113 | 240.6 | 1.64 | 1.01 | 3.24 | 5.45 | 1.01 |
| **T1** | 12.66 | 0.115 | 158.24 | 1.39 | 1.39 | 2.67 | 3.89 | 0.76 |
| **T2** | 13.33 | 0.112 | 189.90 | 1.39 | 1.39 | 2.83 | 4.20 | 0.79 |
| **T3** | 15.33 | 0.115 | 210.84 | 1.38 | 1.38 | 3.17 | 4.33 | 0.82 |

Ascorbic acid content was more in the mouth freshener samples than seeds There was no significant difference found for the titrable acidity for either seeds or different treatments. Total phenol content and antioxidant activity of the developed mouth freshener was less than the fresh seeds, which might be due to the dilution effect by the addition of sugar in case of mouth freshener. Total phenol content and antioxidant activity of among the three developed mouth fresheners increased with the addition of additives, this might be due to the addition of additives which are the rich source of phenolic compounds and essential oils having higher antioxidant capacity. Protein content of the mouth freshener was less than the fresh seeds whereas protein



content among the three treatments was not significantly different. Carbohydrates content of the mouth freshener was more than the fresh seeds which might be due to the addition of sugar. Further there was no significant difference in the carbohydrate content of the different treatments. Crude fiber content and ash of the prepared mouth freshener was less than the fresh seeds.

The sensory evaluation of the three treatment combinations was conducted and depicted with radar plot. The sensory score was given in terms of colour, texture, taste & flavor and overall acceptability. The sensory score was highest for the T1 followed by T2 and T3 in case of all the parameters. The treatment T1 with overall acceptability score of 8.15 was the best treatment.

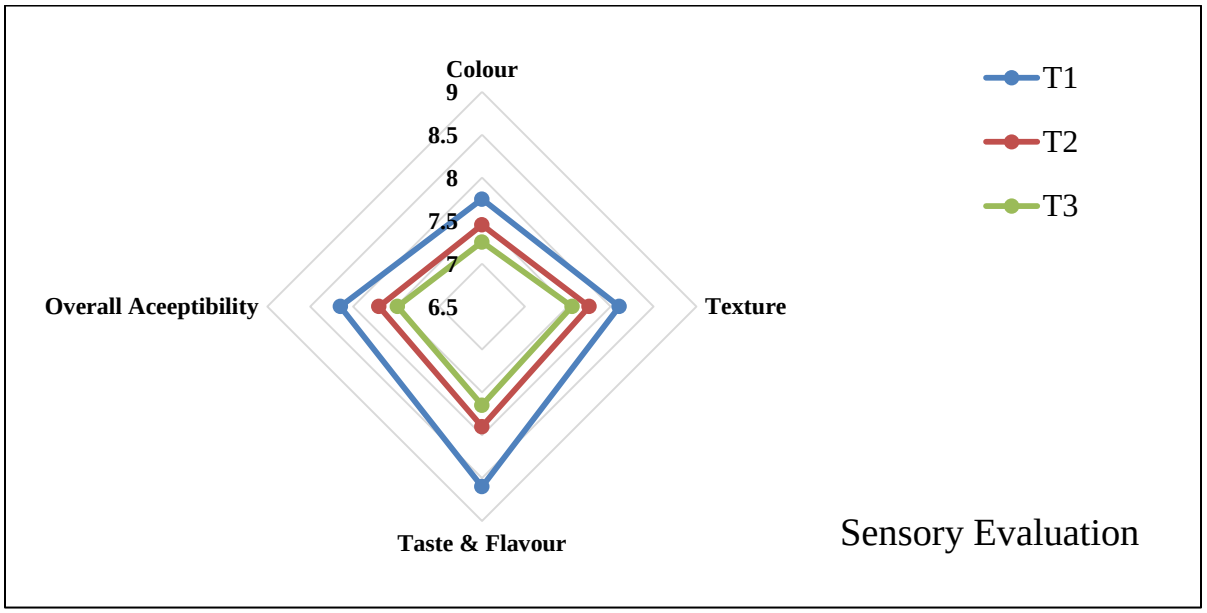



**Fig. 1. Sensory analysis of pomegranate seed based mouth freshener**


**Fig.** 2. **Pomegranate seed based mouthfreshner**

Micronutrient analysis of prepared mouth freshener for the best treatment based on sensory analysis was carried out, calcium (Ca) - 3.20 g/Kg, magnesium (Mg) - 2.88 g/kg, ferrous (Fe) - 310 mg/kg, manganese (Mn)- 26 mg/kg, zinc (Zn)- 67 mg/kg and copper (Cu) - 63 mg/kg was found in the mouth freshener with best treatment.

### 6.1.3. Optimizing the formulation for a pomegranate-lemon-ginger based mixed fruit beverage using D-optimal mixture design (MD) of response surface methodology

Mixed fruit beverages are prepared by the addition of two or more juices having a pleasant taste and dominant flavor. It is, by far, superior to single strength juices containing artificial flavor and color. The palatability and the balanced sugar to acid ratio are one of their unique characteristics in mixed fruit beverages, which contribute towards its high consumer demand. Besides this, it plays a significant role in changing the perception of consumer's towards these commodities by improving sensorial and nutritional properties.

Pomegranate is considered as a super food as it possesses a wide range of phytochemicals and bioactive compounds. Similarly, several studies have noted that lemon is a rich source of nutrients and phytochemicals, including flavonoids, citric acid, vitamin C and minerals, which have numerous health-promoting properties. Ginger can also be used as a whole juice extract and in drink/tea after blending process. The rhizome/stem of ginger, in addition to comprising such proximate components and also has volatile oil of stem that contributes to provide its pleasant aroma. Additionally, ginger contains ascorbic acid, carotene, gingerol,

linalool, paradol, terpinene. The swollen rhizome/stem of ginger has been associated with antimicrobial, anti-inflammatory, and anti-carcinogenic properties.

The optimization of level of pomegranate juice with lemon and ginger juice for development of mixed fruit beverages was performed using D-optimal mixture design of response surface methodology. The levels of three independent factors were considered as Pomegranate juice (70-85%), lemon juice (10-20%) and ginger juice (5-10%). The different responses were considered for experiment as color value (L, a, b), bioactive components (total anthocyanin, total phenols, antioxidant activity), ascorbic acid content and overall acceptability. A total 16 runs were performed to reduce numbers of replications and obtain optimum treatment of mixed fruit beverages of pomegranate-lemon-ginger drink.

Pomegranate fruits (Cv. Bhagawa) were procured from the experimental field of ICAR-NRC on Pomegranate. Juice for mixed fruit beverages from pomegranate, lemon and ginger was prepared as per standard method. The FSSAI specifications with respect to TSS, acidity and per cent juice for mixed fruit beverage were followed. The per cent juice-10%, TSS-15% and acidity-0.35% was maintained in developed mixed fruit beverages. The optimization of different level of pomegranate, lemon and ginger was carried out by fitting the different models such as cubic, linear and quadratic.

**Effect of independent factors level on total phenols (mg/100g GAE)**

Total phenolic content of mixed fruit beverages varied from 192.2 to 236.41 mg/100g GAE for different treatments. The phenolic content was found highest in pomegranate juice as compared to lemon and ginger juice. The increase in level of pomegranate juice in mixed fruit beverage leads to increase the content of phenolic compounds. The independent levels of factors and their interactions were significantly affecting the total phenols. The Model F-value of 321.23 and p value of 0.0001 represents that the cubic model is significant for total phenol content. The counter graph for combined effect of independent factors on total phenol content is shown in Figure 1 (A).

ANOVA of cubic model for total phenol content showed significant model with $R^2$ = 0.99 ($P<0.05$). This model showed non-significant lack of fit. A cubic model was obtained from the ANOVA which had a final equation as follows.



Total phenols= +235.98A + 187.86B + 1932.85C + 48.31 AB – 3078.36 AC- 3092.38 BC + 3064.53 ABC – 63.27 AB (A-B) + 1555 AC (A-C) + 1500.38 BC (B-C).

Where, A: Pomegranate juice; B: Lemon juice; C: Ginger juice

**Effect of independent factors level on anthocyanin content (mg/100g)**

The range of anthocyanin content of pomegranate-lemon-ginger mixed beverage was 2.76 to 4.60 mg/100g. The bioactive components majorly come from pomegranate juice. The different treatment of mixed fruit beverages revealed that, the significant effect of increase in level of pomegranate juice, resulted to increase in anthocyanin content. The quadratic model was shown as significant model with F-value of 29.02 and p value of 0.0001. The counter graph for combined effect of independent factors on anthocyanin content is shown in Figure 1 (B).

ANOVA of quadratic model for total anthocyanin content showed significant model with $R^2$ = 0.93 ($P<0.05$). This model showed non-significant lack of fit. A quadratic model was obtained from the ANOVA which had a final equation as follows.

Total anthocyanin= +4.53A + 2.35B + 8.25C + 3.87AB – 6.66 AC- 7.12 BC

Where, A: Pomegranate juice; B: Lemon juice; C: Ginger juice

**Effect of independent factors level on antioxidant activity (mg/100ml)**

The antioxidant activity of mixed fruit beverages was observed in the rage of 6.08 to 7.65 mg/100ml. The antioxidant activity of beverage represents the free radical scavenging capacity of products. Higher the antioxidant activities, more tendencies to fight against free radical formation in body. Its desirable trait for any products. It is depending on the availability of bioactive components. It was observed that, the as the level of pomegranate juice increased from 70 to 85% in mixed fruit beverage, increase in antioxidant capacity. It might be due to the presence of higher bioactive components in pomegranate juice as compared to lemon and ginger juice.

The quadratic model was shown as significant model with F-value of 135.72 and p value of 0.0001. The counter graph for combined effect of independent factors on antioxidant activity is shown in Figure 1 (C).ANOVA of quadratic model for total antioxidant activity showed



significant model with $R^2$ = 0.98 (P<0.05). This model showed non-significant lack of fit. A quadratic model was obtained from the ANOVA which had a final equation as follows.

Antioxidant activity= +7.54A + 5.96B + 5.54C + 1.21AB + 6.68AC+ 1.17BC

Where, A: Pomegranate juice; B: Lemon juice; C: Ginger juice

**Effect of independent factors level on ascorbic acid content (mg/100ml)**

The ascorbic acid content of mixed fruit beverage was estimated to evaluate the Vitamin C content of beverage. Lemon juice was selected for blending with pomegranate juice in order to improve the ascorbic acid content of beverage. The range of ascorbic acid content found as 1.62 to 2.13 mg/100ml. The blending of lemon juice in pomegranate-ginger beverage significantly affected the ascorbic acid content. The level of independent factors significantly improved the ascorbic acid content rather than interaction of beverages.

The special cubic model was shown as significant model with F-value of 13.80 and p value of 0.0004. The counter graph for combined effect of independent factors on ascorbic acid content is shown in Figure 1 (D).

ANOVA of special cubic model for ascorbic acid content showed significant model with $R^2$ = 0.90 (P<0.05). This model showed non-significant lack of fit. A special cubic model was obtained from the ANOVA which had a final equation as follows.

Ascorbic acid content= +1.70A + 3.18B + 1.42C – 2.56AB + 0.30AC- 3.01BC + 5.78 ABC

Where, A: Pomegranate juice; B: Lemon juice; C: Ginger juice

**Effect of independent factors level on overall acceptability**

The overall acceptability of mixed fruit beverage from pomegranate-lemon-ginger blend was carried out by using 9- point hedonic scale. The panel member scored highest for beverage containing higher per cent of pomegranate juice. The purpose of mixed fruit beverage development was to enhance the organoleptic properties of pomegranate based beverage with nutritive value. The blending of lemon and ginger juice in pomegranate beverage improves the taste, flavor and mouth feel. The panel scores for overall acceptability for beverages ranged from 6.5 to 8.5. The treatment containing 85% pomegranate juice, 10% lemon juice and 05% ginger juice scored highest for overall acceptability by panel members.



The quadratic model was shown as significant model with F-value of 19.03 and p value of 0.0001. The counter graph for combined effect of independent factors on overall acceptability is shown in Figure 1 (E).

ANOVA of quadratic model for overall acceptability of mixed fruit beverages showed significant model with $R^2$ = 0.90 (P<0.05). This model showed non-significant lack of fit. A quadratic model was obtained from the ANOVA which had a final equation as follows.

Overall acceptability = +8.58A + 5.02B – 2.89C + 3.24AB + 11.33AC + 19.67BC

Where, A: Pomegranate juice; B: Lemon juice; C: Ginger juice

**Effect of independent factors level on colour value**

**1. L value**

L value of mixed fruit beverage was varied from 46.77 to 58.78. It represents the lightness of samples. The beverage containing higher level of lemon juice showed the significant higher L value. The cubic model was shown as significant model with F-value of 56.96 and p value of 0.0001. The counter graph for combined effect of independent factors on 'L' value is shown in Figure 1 (F).

ANOVA of cubic model for 'L' value of mixed fruit beverages showed significant model with $R^2$ = 0.98 (P<0.05). This model showed non-significant lack of fit. A cubic model was obtained from the ANOVA which had a final equation as follows.

L value = +53.75A + 81.12B + 2069.25C- 62.82AB – 3714.66 AC – 3559.95 BC + 3659.53 ABC – 8.19 AB (A-B) + 2008.34 AC (A-C) +1406.44 BC (B-C)

Where, A: Pomegranate juice; B: Lemon juice; C: Ginger juice

**2. a value**

The 'a' value represents the redness and it was significantly (P<0.001) affected by level of pomegranate juice. The increasing level of pomegranate juice significantly increased the 'a' value of mixed fruit beverage. The red color of pomegranate juice is due to presence of anthocyanin content.

The cubic model was shown as significant model with F-value of 78.36 and p value of 0.0001. The counter graph for combined effect of independent factors on 'a' value is shown in Figure 1 (G).



ANOVA of cubic model for "a" value of mixed fruit beverages showed significant model with $R^2$ = 0.99 (P<0.05). This model showed non-significant lack of fit. A cubic model was obtained from the ANOVA which had a final equation as follows.

a value = +20.77A – 11.76B – 385.24C + 67.71AB + 854.01AC +765.03 BC – 1121.56 ABC + 10.27 AB (A-B) – 577.30 AC (A-C) – 224.60 BC (B-C).

Where, A: Pomegranate juice; B: Lemon juice; C: Ginger juice

**3. b value**

The 'b' value indicates the yellowness index of sample. The mixed fruit beverage containing lemon juice which pertained to yellowness index of beverage. There was a significant effect of independent factors on 'b' value of beverage. The linear model was shown as significant model with F-value of 11.81 and p value of 0.0001. The counter graph for combined effect of independent factors on 'b' value is shown in Figure 1 (H).

ANOVA of linear model for "b" value of mixed fruit beverages showed significant model with $R^2$ = 0.64 (P<0.05). This model showed non-significant lack of fit. A linear model was obtained from the ANOVA which had a final equation as follows.

b value = +18.35A + 16.92B + 6.84C.

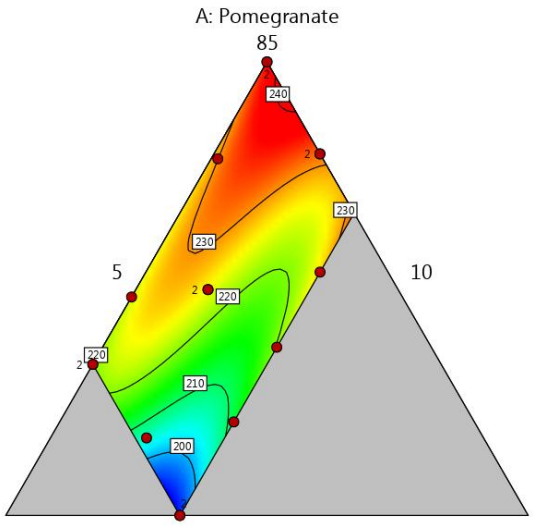
Where, A: Pomegranate juice; B: Lemon juice; C: Ginger juice

**Validation based upon desirability**

The mean values for different responses were calculated using design expert software as total phenols (220.62mg/l GAE), anthocyanin content (3.95mg/100ml AAE), antioxidant activity (6.95mg/100ml), ascorbic acid content (1.82 mg/100g), overall acceptability (7.63), L (54.26), a (19.14) and b (16.02). The selected optimized solution with maximum desirability (0.981) for independent factors were prepared and further evaluated for validating predicted values. Based on the validation experiments, mixed fruit beverage containing 85% pomegranate juice, 10% lemon juice and 05% ginger juice was found overall acceptable which provides total phenols (236.2 mg/l GAE), anthocyanin content (4.61 mg/100ml AAE), antioxidant activity (7.54 mg/100ml), ascorbic acid content (1.80 mg/100g), overall acceptability (8.53), L (53.7), a (21.1) and b (19.2).

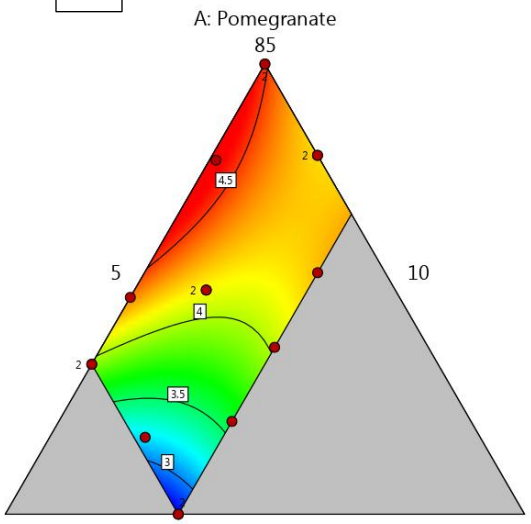


**A**



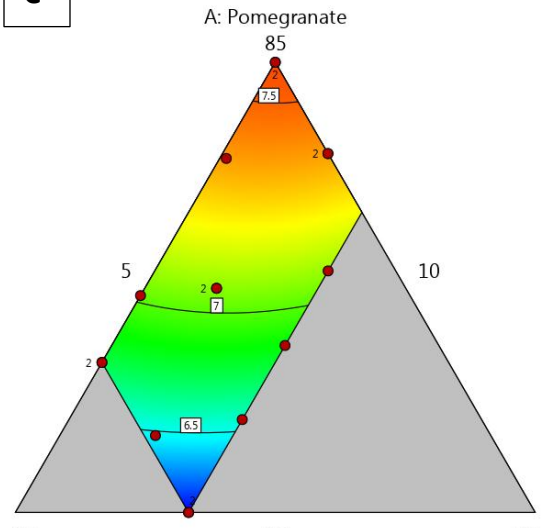

Total phenols ( mg/L GAE)

**B**



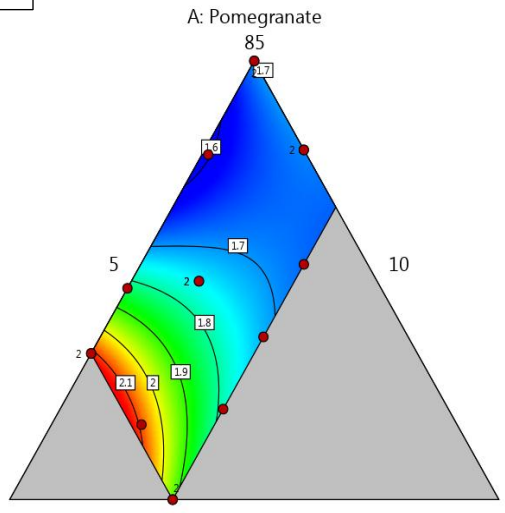

Anthocyanin content (mg/100ml AAE)

**C**




Antioxidant activity (mg/100ml)

**D**




Ascorbic acid content (mg/100g)

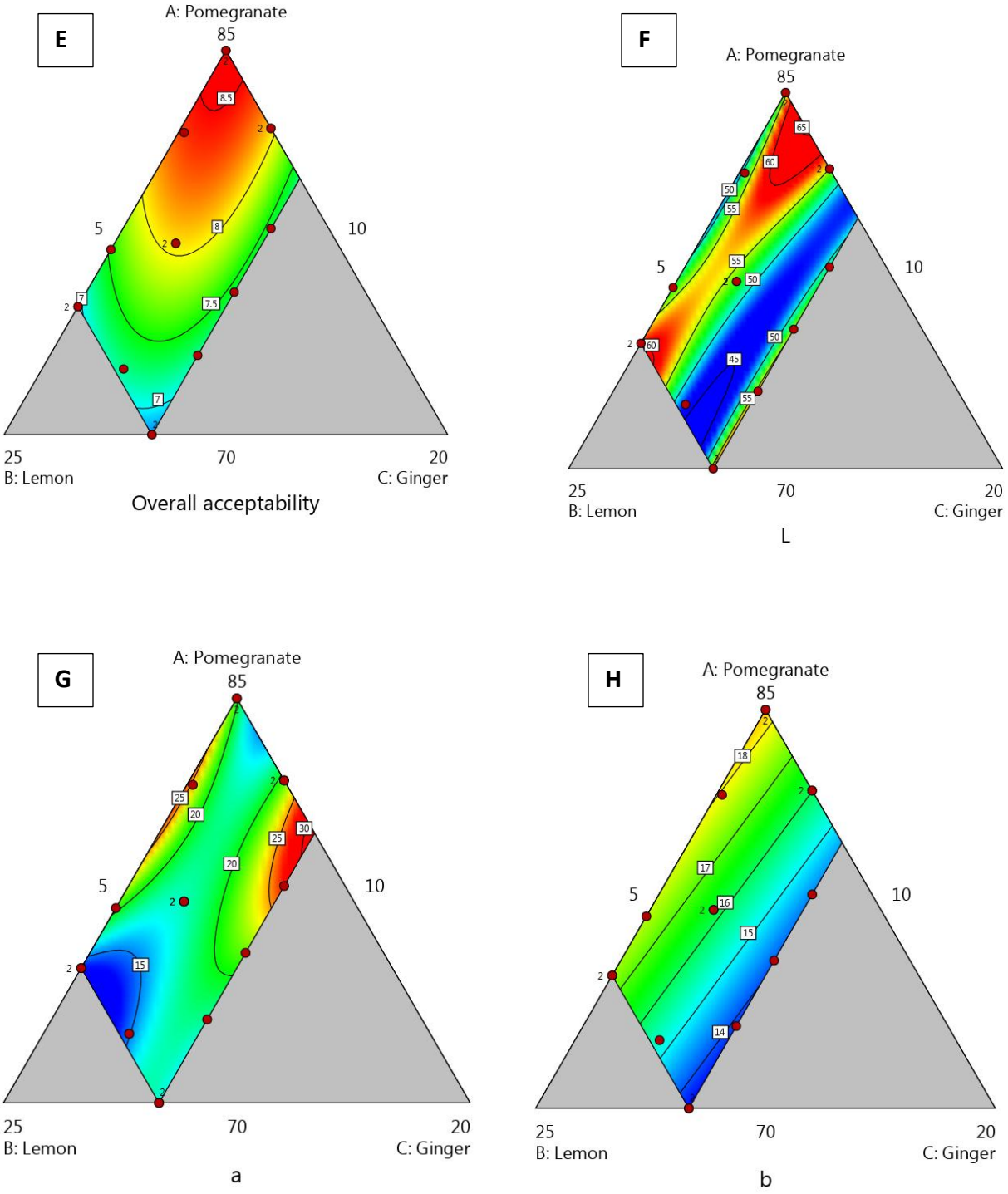



**Fig.2. Response surface graph for combined effect of different levels of pomegranate, lemon and ginger juice on A) Total phenols B) Anthocyanin content C) Antioxidant activity D) Ascorbic acid E) Overall acceptability F) L value G) a value H) b value.**

### 6.1.1. Determination of maturity indices for pomegranate variety Solapur Lal

To determine the maturity indices for harvesting of pomegranate var. Solapur Lal, the flowers were tagged on the day of anthesis. The fruit samples were collected after fruitset at an interval of 15 days. Once maturity is approached, the samples were collected at 5 days interval to fix up the appropriate maturity indices for harvesting. Solapur Lal attained maturity at 160 days after anthesis with highest total soluble solids content (17.7$^{o}$Brix) and TSS/acid ratio (44.25).

**Table 7. Maturity indices for pomegranate variety Solapur Lal**

| Stage of fruit development (Days after anthesis) | Fruit weight (g) | TSS ($^{o}$Brix) | Titrable acidity (%) | TSS/Acid ratio |
|---|---|---|---|---|
| 90 days | 171.3 | 13.2 | 0.58 | 22.75 |
| 105 days | 198.3 | 14.4 | 0.52 | 27.69 |
| 120 days | 222.6 | 15.3 | 0.49 | 31.22 |
| 135 days | 243.6 | 16.2 | 0.46 | 35.21 |
| 150 days | 263.3 | 16.9 | 0.43 | 39.30 |
| 160 days | 272.0 | 17.7 | 0.40 | 44.25 |
| 165 days | 272.4 | 17.7 | 0.40 | 44.25 |

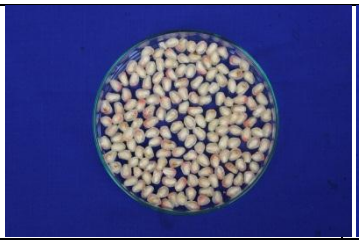
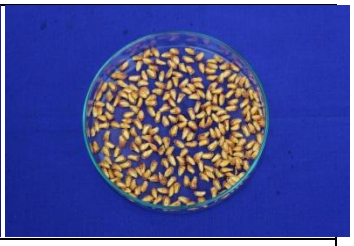
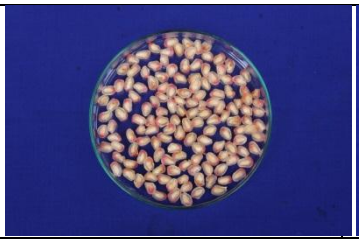
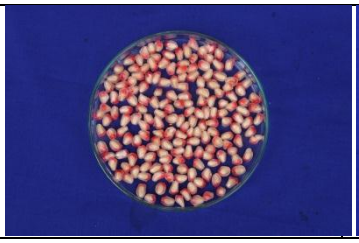
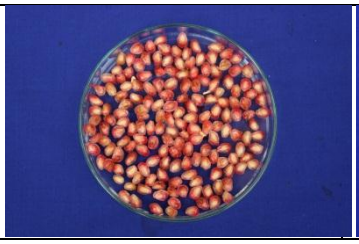
### 6.1.2. Determination of Anardana recovery

Anardana is the dried form of arils. Arils are the edible parts of pomegranate. It is obtained by drying the arils of pomegranate in the hot air oven with air circulation facility. It is useful as souring agent. Assessment of anardana recovery from ten sour type pomegranate hybrids was undertaken. The results revealed that anardana recovery ranged from 17.5-21.2%. Anardana recovery was highest in Solapur Anardana (21.2%) closely followed by NRCP H-4 (20.8%). The recovery was lowest in Amlidana (17.5%).

**Table 8. Anardana recovery from pomegranate hybrids**

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



| | | |
|---|---|---|
|  |  |  |
| **NRCP H-1** | | |
|  |  |  |
| **NRCP H-3** | | |
|  |  |  |
| **NRCP H-4** | | |
|  |  |  |
| **NRCP H-11** | | |



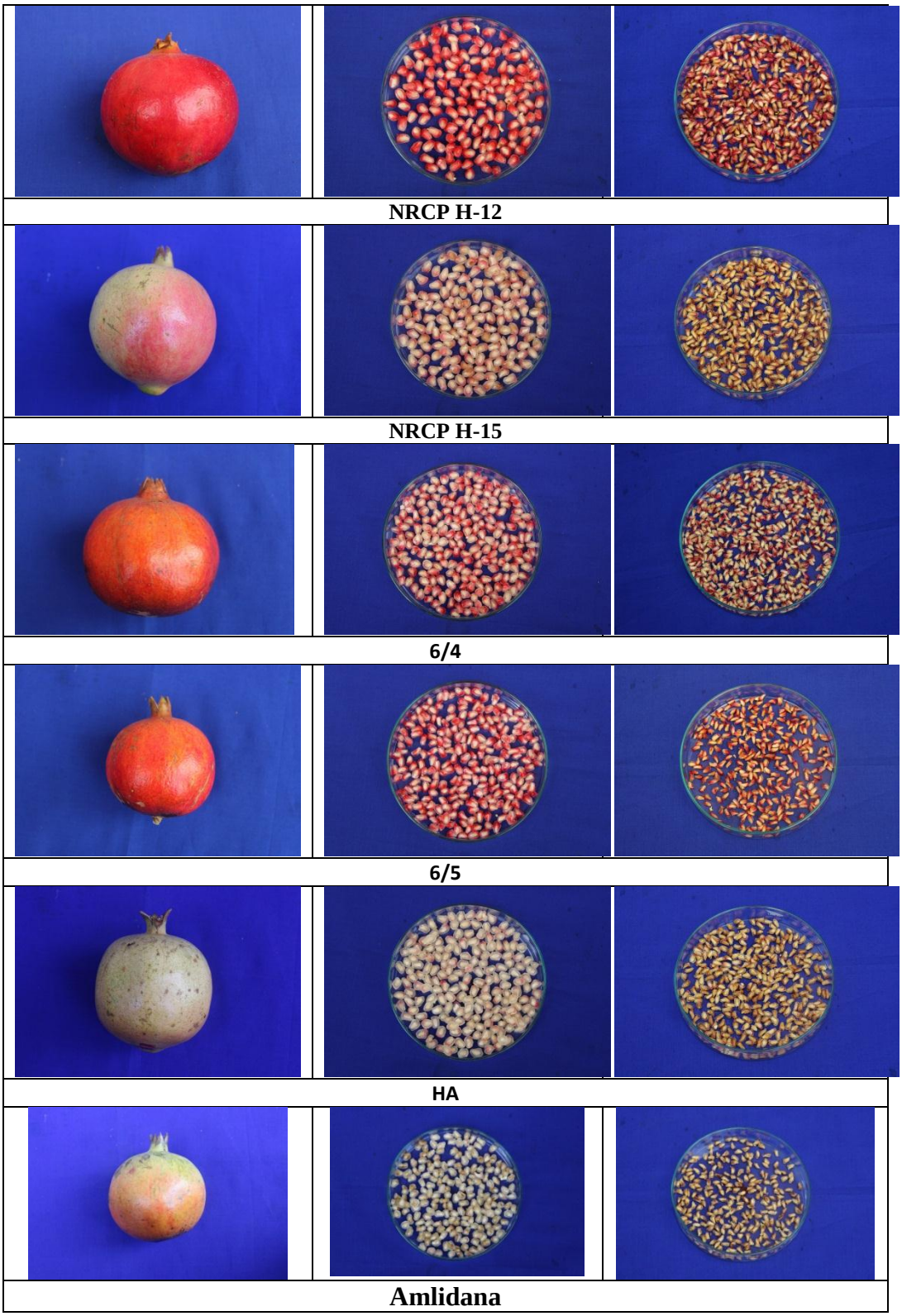



**Fig. 3. Fruit, arils and Anardana obtained from sour type pomegranate varieties**

# Externally Funded/ Collaborative Projects

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

Second year On-site DUS testing of new pomegranate hybrid varieties (NRCPH-4 and NRCPH-14) developed by ICAR-NRCP was conducted on 25 February, 2021 at ICAR-NRCP, Solapur (Fig. 1). The tested candidate varieties found to have very vigorous plant growth habit with distinctive fruit characteristic features for aril colour (Pink) and seed hardiness (Medium hard - hard) in comparison to reference varieties (Light pink, Red arils with soft, medium hard seeds) (Fig. 2). In 2021, also obtained plant variety protection certificate for two pomegranate varieties NRCP H-6 (Solapur Lal) and NRCP H-12 (Solapur Anardana) with the registration number of REG/2016/1747 and REG/2016/1750 respectively.

**Fig. 1:** Second year On-site DUS testing of new pomegranate hybrid varieties (NRCP H-4 & NRCP H-

14) at ICAR-NRCP, Solapur

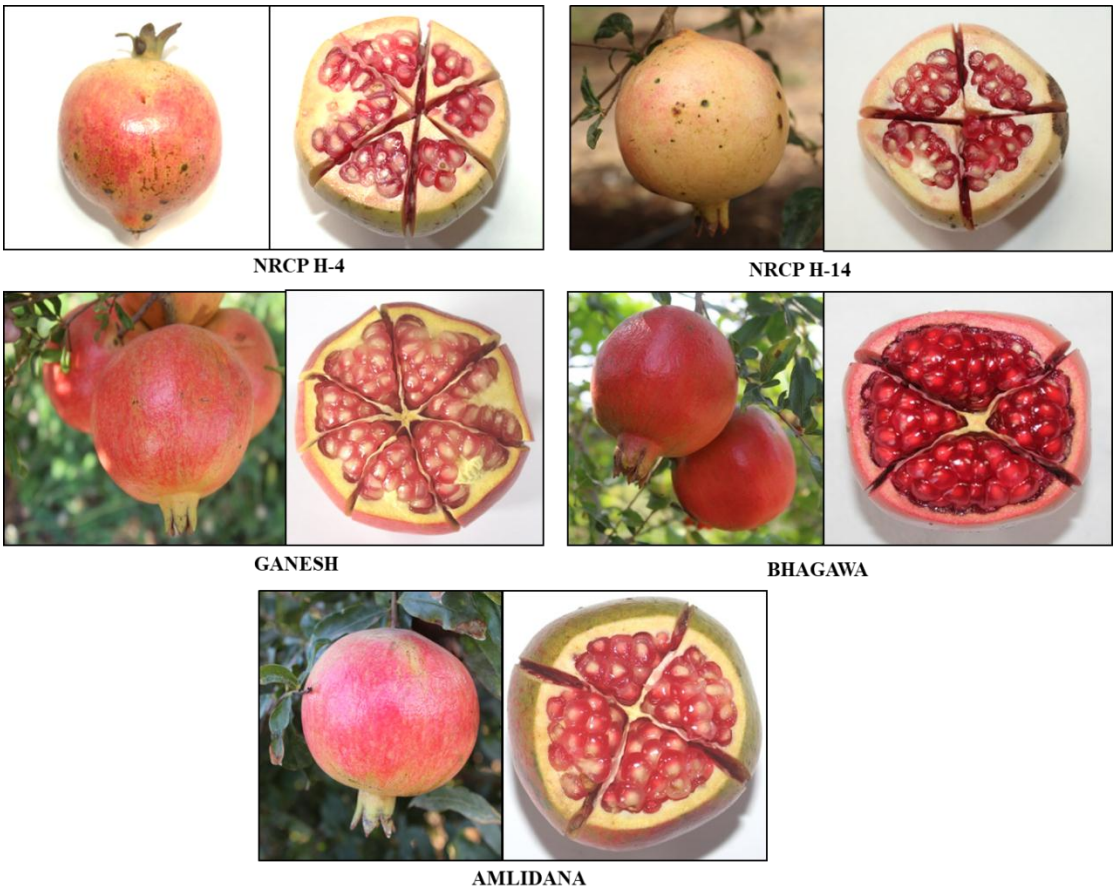



**Fig. 2:** Fruit morphological differences between the tested candidate varieties (NRCP H-4 & NRCP H-14) and reference varieties (Ganesh, Bhagawa and Amlidana)

**Project: Horticulture Crop Pest Surveillance and Advisory Project (HORTSAP) Sub Scheme under Crop Surveillance and Advisory Project (CROPSAP) Scheme (**Funded by Commisionerate of Agriculture (Horticulture Department), Government of Maharashtra, Pune.)

Surveys were conducted in 12 pomegranate growing districts of Maharashtra – Osmanabad, Pune, Beed, Solapur, Ahemadnagar, Nashik, Satara Dhule, Jalgaon, Buldhana, Jalna, Sangli, Aurangabad- covering ~1700 acres and 4 districts of Karnataka –Afzalpur, Vijayapura, Bagalkot and Koppal covering ~288acres. The major problems faced by farmers were *Ceratocytis* wilt, bacterial blight, fruit spots and fruit rots, pin hole and stem borer, sucking pests. Wilt was the major problem faced by farmers due to rains and changing climatic situations. On spot advisory on specific problems of the farmers was issued and also sent in local newspapers and put on NRCP website.

**Project: Utilization of Pomegranate for Development of Functional Medicinal Ingredients Funded By NMPB, Ministry of Ayush, GOI (PI: Dr. Nilesh N. Gaikwad)**

**Storage studies of Encapsulated Pomegranate Seed Oil**

The studies on microencapsulation of pomegranate seed oil (PSO) using ionic gelation technique revealed that the microencapsulation with calcium alginate as coating material can be successfully utilized for encapsulation of pomegranate seed oil. The optimum process conditions for microencapsulation of PSO were 10 % oil loading, 350 µ nozzle diameter and 3.23% alginate concentration. The observed response for optimal conditions were encapsulation efficiency (78.03%), loading capacity (7.83%), equivalent diameter (30.05µm), sphericity factor (0.039) and RF (30.20 N). The storage studies were carried out to understand the effect of microencapsulation on quality of PSO in terms of peroxide value, free fatty acids and iodine value during storage.

The freshly extracted PSO hydraulic cold press at 40$^{o}$C temperature and 550 MPa pressure is used for storage studies. The oil is encapsulated at the optimum process conditions arrived at for microencapsulation of PSO using RSM. The microencapsulated beads and pomegranate seed oil were stored in the glass bottle at 25°C. The oil quality of encapsulated and non-encapsulated oil was studied at the ten days interval for two month. The experimental data on quality studies was analysed for comparing means using the single factor ANOVA in MS Excel.

Peroxide value (PV) is a measure of the amount of primary oxidation products such as peroxides and hydroperoxides formed in the initial stages of lipid oxidation. Although these oxidation products, particularly hydroperoxides are colourless and odorless and produce no off-flavors, are highly toxic and reduce the bioavailability of fatty acids. PV is one of the most widely used tests for the measurement of oxidative rancidity in oils. Both non-encapsulated and encapsulated samples have shown in general increase in the peroxide value . The PV on 10$^{th}$ day of storage was not significantly different for EC and NEC PSO. However, PV for encapsulated PSO were significantly lower ($P<0.05$) on 20$^{th}$ day onwards up to 60$^{th}$ day of the storage as compared to non-encapsulated PSO. The lower peroxide value in encapsulated oil might be because of the low exposure of oil to oxygen as compared to non-encapsulated oil.

The acid value is a measure of the amount of fatty acids which have been liberated by hydrolysis from the glycerides due to the action of moisture, temperature and lypolytic enzyme lipase. AV is a relative measure of rancidity as free fatty acids are normally formed during decomposition of oil glycerides. The acid value of the all the samples were in general increased during storage (Fig.1). The encapsulated PSO has shown significantly lower free fatty acids or acid value ($P<0.05$) as compared to non-encapsulated PSO on 10$^{th}$ day up to 60$^{th}$ day of storage. This shows the encapsulation being able to improve the stability of PSO decreases rancidity due to barrier properties of the calcium alginate shell.



The iodine value is a measure of the relative degree of unsaturation (number of double bonds) in an oil. The important parameters such as oxidative stability and melting point were related to degree of unsaturation. The initial higher IV (167.25) suggests the higher degree of unsaturation in PSO. Further, the level of unsaturation and corresponding IV of the PSO goes on decreasing during storage and is 149.35 and 134.06 for the EC and NEC PSO, respectively on 60$^{th}$ day of storage. The EC PSO has significantly higher ($P<0.05$) IV than NEC on 10$^{th}$ day onwards up to 60$^{th}$ day of storage. Thus, it is clear that the encapsulation can maintain the level of unsaturation in the PSO.

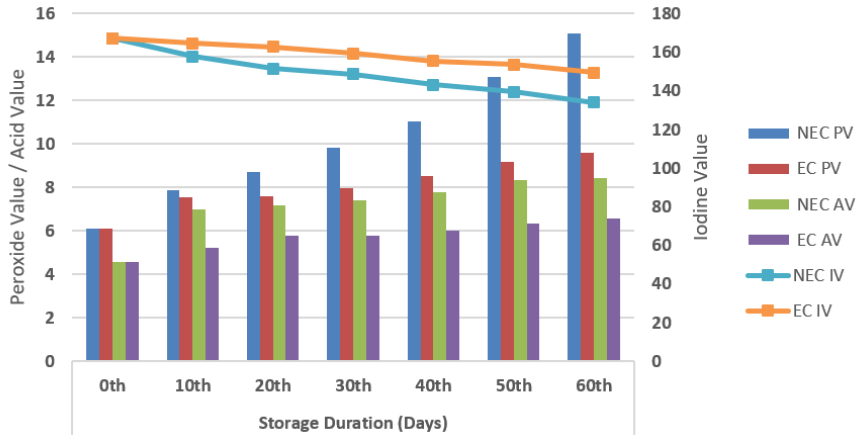



**Fig. 1. Effect of microencapsulation on PSO quality (PV, AV and IV) during storage**

(Where NEC: Non Encapsulate, EC: Encapsulated, PV: Peroxide value, AV: Acid value, IV: Iodine value)

The storage studies revealed that the PSO encapsulated by calcium alginate capsules by ionic gelation method has better quality in terms of peroxide value, free fatty acids and iodine value during storage. Thus, encapsulation of PSO using calcium alginate will be useful in utilization of PSO for food, pharmaceutical and cosmetic applications.

**Project : All India Coordinated Research Project on Arid Zone Fruits**

- **MLT on Pomegranate variety Solapur Lal**

Performance evaluation of Solapur Lal, planted in Nov 2018 was carried out in comparison with Ganesh, Bhagawa and Phule Bhagawa Super. Vegetative growth (plant height, EW spread, NS spread) was better in Solapur Lal compared to others. Solapur Lal recorded the highest plant height (167.9cm), East-West Spread (160.0cm), North-South Spread (152.1cm), stem girth (12.9cm) at the end of 2 years.

| Variety | Plant height (cm) | Plant spread East-West (cm) | Plant spread North-South (cm) | Stem girth (cm) |
|---|---|---|---|---|
| Ganesh | 156.4 | 149.3 | 144.3 | 12.3 |



| | | | | |
|---|---|---|---|---|
| Solapur Lal | 167.9 | 160.0 | 152.1 | 12.9 |
| Phule Bhagawa Super | 140.7 | 136.4 | 130.7 | 9.6 |
| Bhagawa (Check var) | 136.4 | 131.4 | 125.7 | 9.0 |

| | | | |
|---|---|---|---|
|  |  |  |  |
| Ganesh | Solapur Lal | Phule Bhagawa Super | Bhagawa |

- **MLT on pomegranate variety Solapur Anardana:**

Performance evaluation of Solapur Anardana in comparison with Amlidana and IC-1181 was carried out. Vegetative growth (plant height, EW spread, NS spread) was better in Solapur Anardana. Solapur Anardana recorded the highest plant height (175.0cm), East-West Spread (165.7cm), North-South Spread (158.6cm), stem girth (12.5cm) at the end of 2 years.

| Variety | Plant height (cm) | Plant spread E-W (cm) | Plant spread N-S (cm) | Stem girth (cm) |
|---|---|---|---|---|
| IC-1181 | 145.7 | 138.6 | 132.1 | 11.5 |
| Solapur Anardana | 175.0 | 165.7 | 158.6 | 12.5 |
| Amlidana | 98.6 | 95.0 | 92.5 | 6.40 |

| | | |
|---|---|---|
|  |  |  |
| IC-1181 | Solapur Anardana | Amlidana |



**Project: Unraveling mechanism and developing mitigation strategies for aril browning and fruit cracking in pomegranate**

**Screening of genotypes against fruit cracking and aril browning**

**Fruit cracking:** During the field evaluation of important pomegranate genotypes for their response to fruit cracking for late *mrig bahar* season fruits, it has been found that the genotypes 'Nakha' (54.04%), 'Jodhpur Collection' (53.33%), 'Kabuli Yellow' (48.15%), 'Bedana Thinskin' (43.96%), 'Utkal' (37.44%), 'Yercaud' (30.10%), 'Ganesh' (30.10 %), 'Kabul' (22.01%) and 'Jallore Seedless' (21.96%) were found to be highly sensitive to fruit cracking. However, no cracking was observed in 'Mridula', 'GKVK-1', IC-318793, IC-318754, IC-1196, and IC-1205 whereas in 'Bhagawa' cracking upto 1.7% was observed.

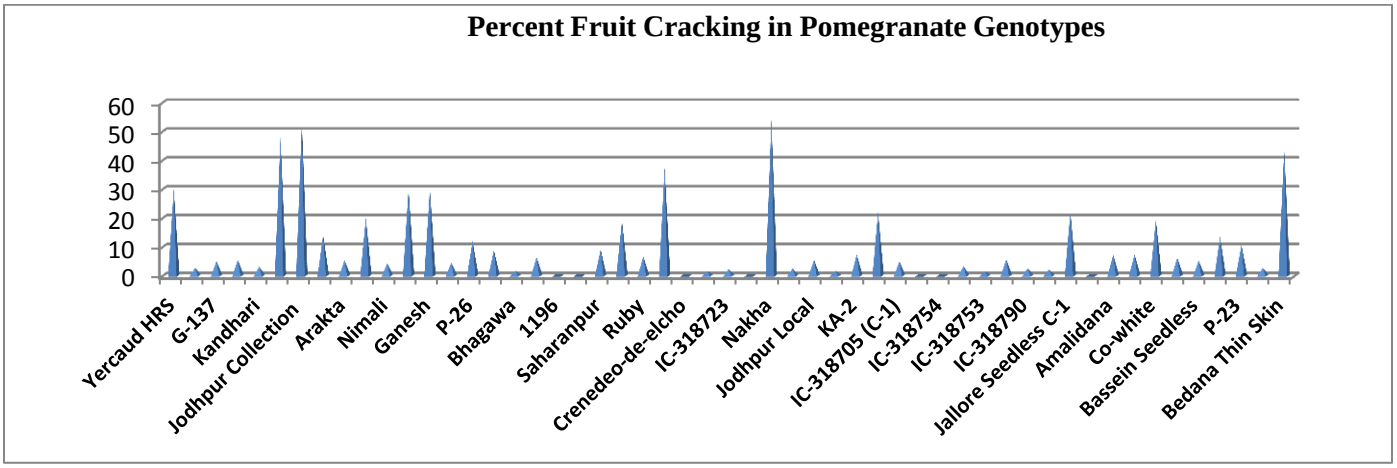



**Fig. 1. Percent Fruit Cracking in Pomegranate Genotypes**

Out of various fruit morphological traits only Rind/Aril ratio was found to be negatively correlated with fruit cracking. Rind to aril ratio was found to be negatively correlated with fruit weight.

**Table 1. Correlation matrix of fruit cracking along with other important fruit morphological traits**

| Variables | Correlation Matrix | | | | |
|---|---|---|---|---|---|
| | Fruit Cracking | Fruit Shape Index | Rind Thickness | Rind/Aril ratio | Fruit weight |
| Fruit Cracking (FC) | 1.000 | -0.176 | -0.101 | **-0.362*** | 0.093 |
| Fruit Shape | -0.176 | 1.000 | 0.036 | -0.028 | 0.039 |



| | | | | | |
|---|---|---|---|---|---|
| **Index (FSI)** | | | | | |
| **Rind Thickness (RT)** | -0.101 | 0.036 | 1.000 | **0.382*** | **0.295*** |
| **Rind/Aril (R/A) ratio** | -0.362 | -0.028 | 0.382 | 1.000 | **-0.343** |
| **Fruit Weight (FW)** | 0.093 | 0.039 | 0.295 | -0.343 | 1.000 |

| Student's T Test | | | |
|---|---|---|---|
| **Variables Tested** | **T Value** | **T Table** | **Significance at 5%** |
| FC-FSI | 1.265 | 2.008 | NS |
| FC-RT | 0.757 | 2.008 | NS |
| FC-R/A ratio | 2.816 | 2.008 | S |
| FC-FW | 0.707 | 2.008 | NS |
| FSI –RT | 0.21 | 2.008 | NS |

| Student's T Test | | | |
|---|---|---|---|
| **Variables Tested** | **T Value** | **T Table** | **Significance at 5%** |
| FSI –R/A | 0.14 | 2.008 | NS |
| FSI –FW | 0.222 | 2.008 | NS |
| RT –R/A ratio | 2.976 | 2.008 | S |
| RT-FW | 2.164 | 2.008 | S |
| R/A-FW | 2.62 | 2.008 | S |

**Aril Browning:** During the same period aril browning by aril weight (%) was observed the highest in 'Crenedeo-de-elcho' (16.7%) followed by Tabesta R-7 (7.7%) and 'P-13' (7.5%). Aril browning was found considerably high in 'Ruby' also (6.2%). However, in 'Bhagawa' only 2.6 % aril were affected by aril browning. In genotypes 'Kabuli Yellow', Jodhpur Collection, 'Jallore Seedless', Saharanpur, Utkal, IC-318723, Nakha, KA-2, IC-318754, IC-318779, IC-318720, IC-318790, Yercaud Local, EC-24686 and 'Bedana Thin Skin' no aril was observed.



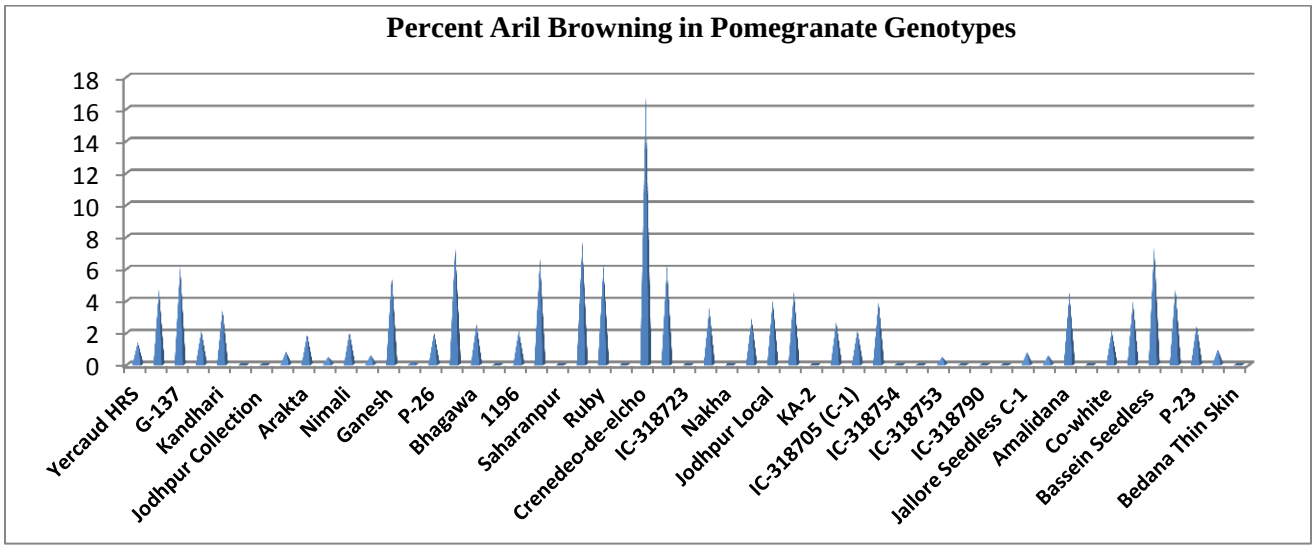



**Fig. 2. Percent Aril Browning in Pomegranate Genotypes**

**Photosynthesis, greenness Index total leaf chlorophyll content of pomegranate genotypes:** The higher greenness of leaves as suggested by SPAD values were found in Patna-5 and IC-318573 but photosynthesis (µmol $CO_2/m^2/s$) was found the highest in Tabesta. Among the compared genotypes, the photosynthesis, SPAD and total leaf chlorophyll content was found the lowest in the genotype 'Kabul' and the genotype was also having considerably high fruit cracking percent.

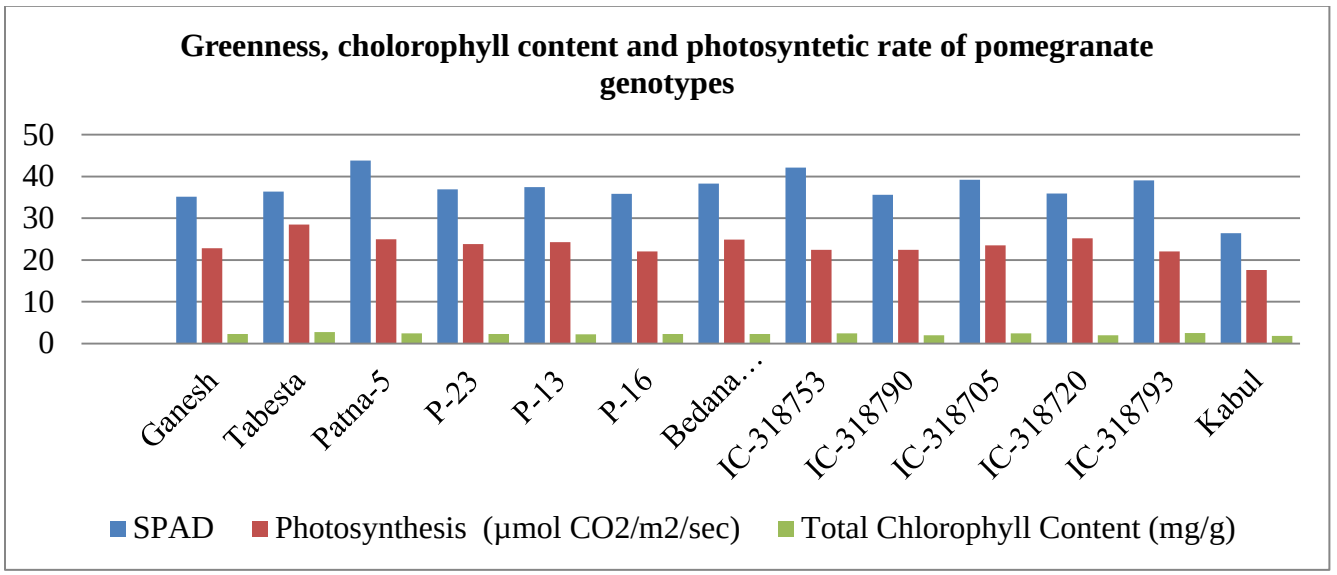



**Fig. 3. Greenness, cholorophyll content and photosyntetic rate of pomegranate genotypes**

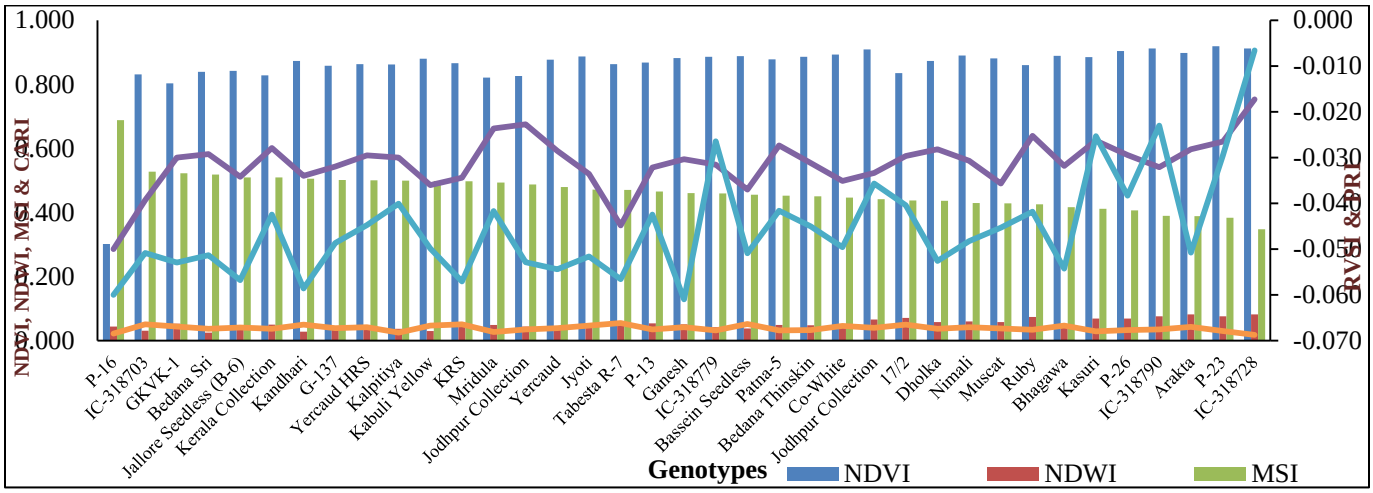
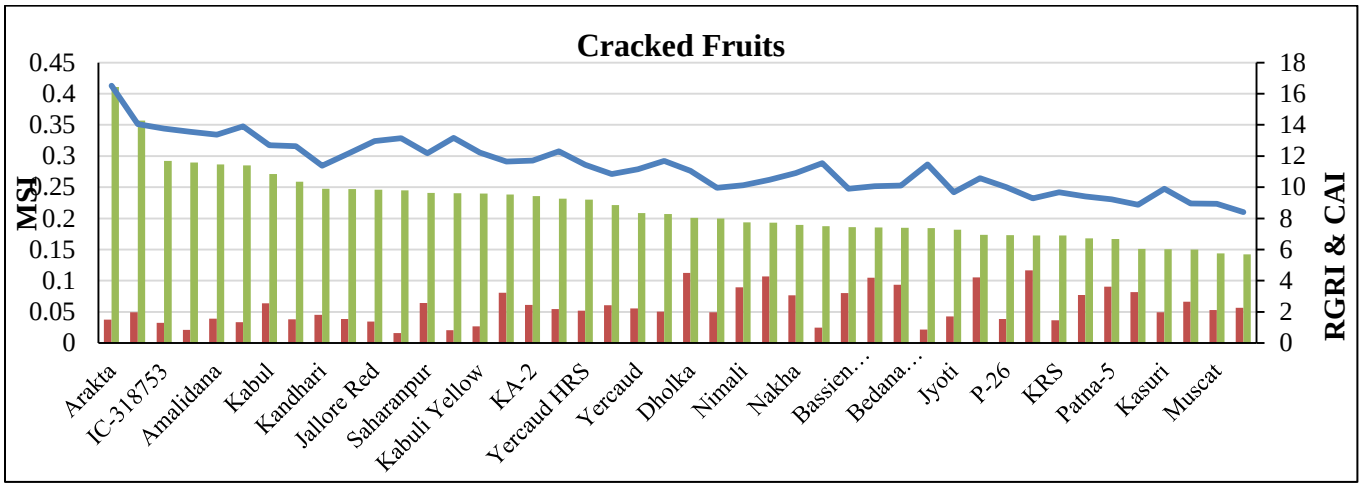



**Fig. 4. Hyperspectral signature comparison of plant canopies of different pomegranate genotypes**



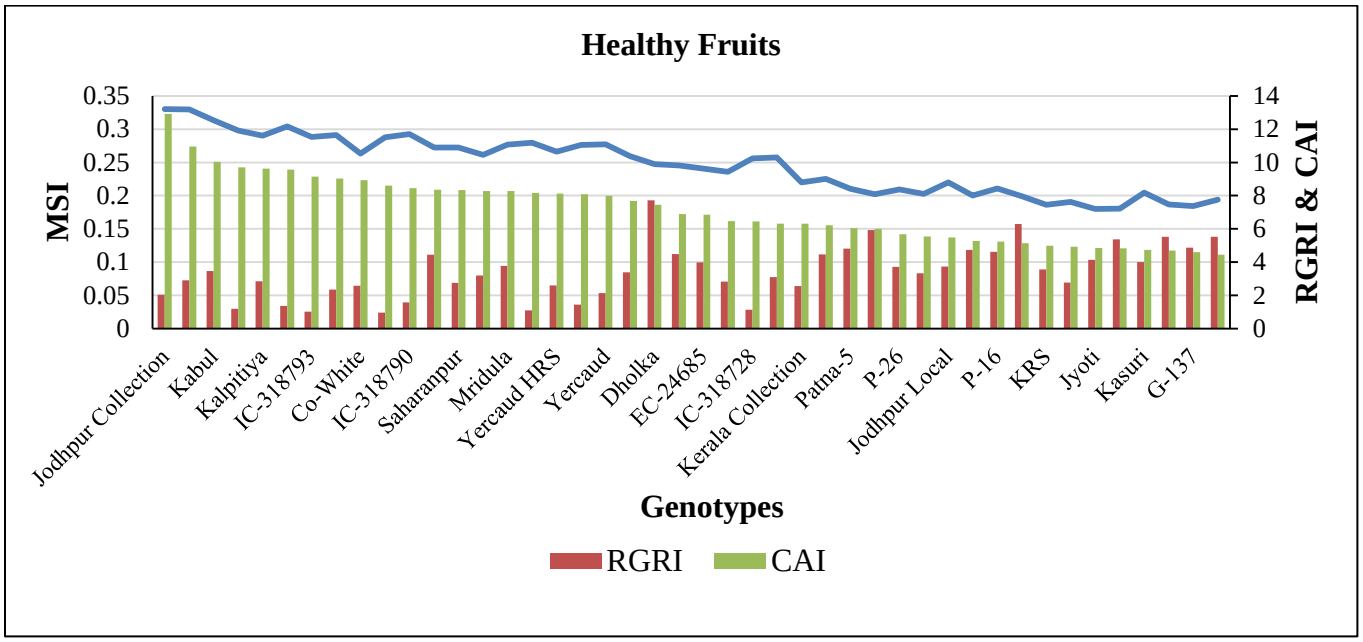



**Fig. 5. Hyperspectral signature comparison of healthy and cracked fruits of different pomegranate genotypes**

Hyperspectral signatures of plant canopy of different pomegranate genotypes along with the signatures of healthy and cracked fruits were recorded using Spectroradiometer. The moisture stress index of P-13 and IC-318703 was found high and as the result, normalized difference vegetation index (NDVI, an indicator of canopy greenness) of P-13 was found the lowest. When moisture stress index (MSI) of healthy and cracked fruits of different pomegranate genotypes were compared, it was found that the cracked fruit were having higher water stress as compared to healthy fruits.

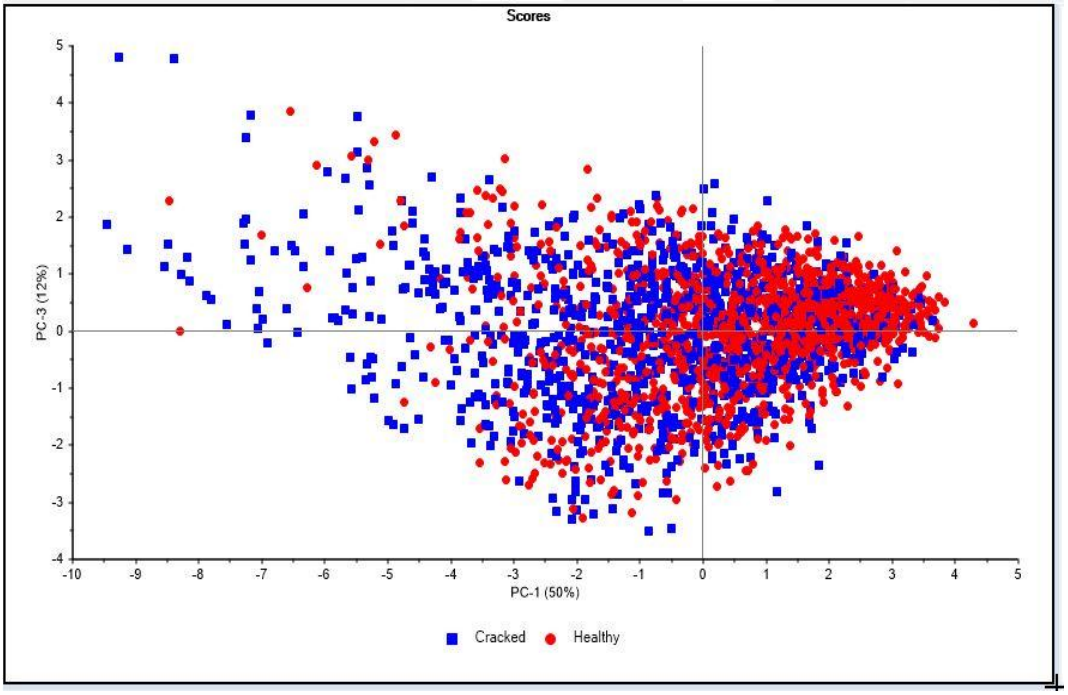



**Fig. 6. Principal component analysis of healthy and cracked fruits**

Two clusters/groups were formed through PCA technique using hyperspectral signatures of cracked and healthy pomegranate fruits of different genotypes. Blue dots indicate cracked pomegranate fruits while red dots indicate healthy fruits. Merging of blue and red dots probably represents those fruits which are about to crack.

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

Field experiment was conducted during Jan, 2020 – Dec, 2020 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 systems at different 129espectively stages (*i.e.* new leaf initiation, development, maturity and harvesting period) of pomegranate. Layout of experiments at different spacings i.e., 4.5 X 2.0 m; 4.5 X 3.0 m and 4.5 X 4.0 m have been given below.

| | | |
|---|---|---|
|  |  |  |
| Spacing 4.5 x 2.0 m | Spacing at 4.5 x 3.0 m | Spacing at 4.5 x 4.0 m |

**Effect of DI on vegetative growth performance**

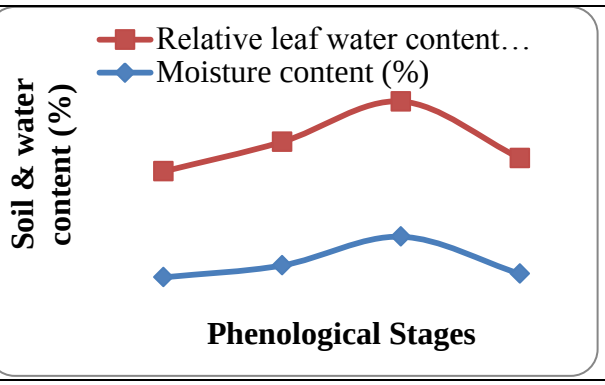
The result showed that, the performance evaluation of DI systems at 80 % irrigation level is the best for 7 years old age pomegranate orchards. Under DI system plants attained maximum plant height, branches and flowers at 80 % irrigation level**.**

**Table 1.** Effect of deficit irrigation on growth characteristics of 7 years old pomegranate tree

| **Treatments** | **Plant height (cm)** | **LAI (%)** | **Plant spread(cm)** | |
|---|---|---|---|---|
| | | | **E-W** | **N-S** |
| **Irrigation Level** | | | | |
| $I_1$*50% | 165.40 | 2.45 | 1.38 | 1.38 |
| $I_2$*60% | 168.33 | 2.75 | 1.40 | 1.41 |
| $I_3$*70% | 172.45 | 2.84 | 1.44 | 1.45 |
| $I_4$*80% | 178.45 | 2.95 | 1.42 | 1.39 |
| $I_5$*90% | 176.72 | 2.29 | 1.41 | 1.42 |

**Effect of DI on soil moisture and relative leaf water content in % age**

The performance evaluation of **DI** systems reduced soil moisture content and relative leaf water content in % age is presented in **the figure**. The moisture content and relative leaf water content in % age at various 130espectively stages varies between 20.45 to 46.34 and 66.74 to 84.57 % age, respectively.




Soil moisture and relative leaf water content in % age

**Effect of DI on yield and water use efficiency**

The results revealed that pomegranate yield responded differently to different quantities of water applied through drip irrigation**.** The best irrigation level recorded the mean yield is **19.39** kg tree$^{-1}$ at 80 per cent irrigation level for 7 years old pomegranate trees. Irrigation level at 80 per cent recorded higher number of fruit, weight of fruits and yield because of consistent optimum moisture regime. As regard to the best deficit irrigation level, maximum water use efficiency was recorded at 3.33 kgm$^{-3}$ at 80 per cent.

**Table 2. Effect of deficit irrigation on yield and water use efficiency for 7$^{t}$ years old pomegranate tree**

| Treatments | Nos. of Fruits | Fruit weight (g) | Yield (kg) | WU($m^3$) | WUE ($Kgm^{-3}$) |
|---|---|---|---|---|---|
| $I_1$*60% | 28.20 | 266.50 | 7.52 | 3.40 | 2.21 |
| $I_2$*70% | 41.30 | 273.70 | 11.30 | 4.43 | 2.50 |
| $I_3$*80% | 62.50 | 310.30 | 19.39 | 5.82 | 3.33 |
| $I_4$*90% | 53.20 | 295.5 | 15.72 | 5.96 | 2.63 |
| $I_5$*100% | 48.50 | 290.25 | 14.77 | 6.85 | 2.15 |

(Note: $I_1$-50, $I_2$-60, $I_3$-70, $I_4$-80 and $I_5$-90%*($ET_r$) for 6$^{th}$ and $I_6$ -100%*$ET_r$ (Control))

**Effect of PRZDI on vegetative growth characteristics**

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



**Table 2.** Effect of partial root zone drying on growth characteristics of 6 year old pomegranate plants

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

Layout of partial root zone drying irrigation system

**Effect of PRZDI on soil moisture and relative leaf water content**

The performance evaluation of **PRZDI** systems on soil moisture content and relative leaf water content is presented in the figure. The soil moisture content and relative leaf water content at various 132espectively stages varies between 22.41 to 43.30 and 69.4 to 86.2 %, respectively.

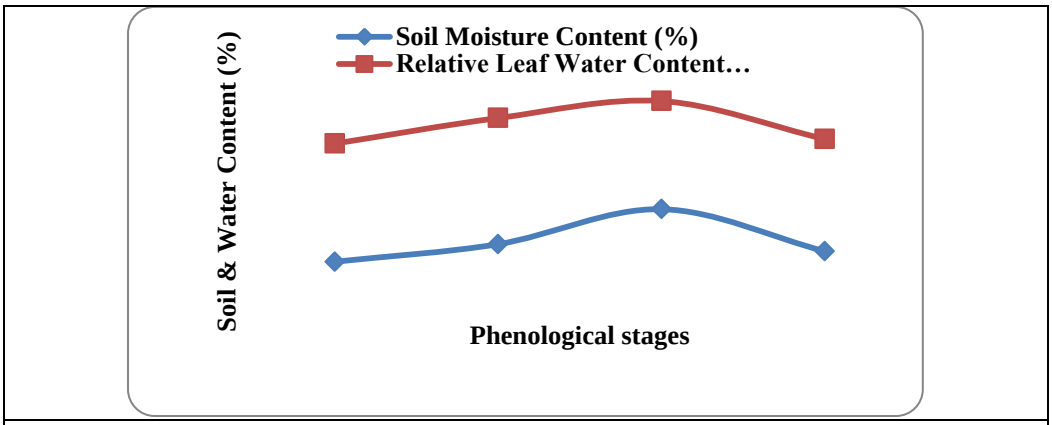



**Fig. 1.** Soil moisture content and relative leaf water content in % age

**Effect of PRZDI on yield and water use efficiency**

The results revealed that pomegranate yield responded differently to different quantities and alternate side wetting and drying of the plants through drip irrigation**.** The best irrigation level was recorded with the mean yield of 31.24 kg tree$^{-1}$ at 80 per cent irrigation levels with shifting at 20 % ASWD. Irrigation level at 80 per cent with 20 % shifting of ASWD had recorded better number of fruits, weight of fruits and yield because of drip irrigation PRZDI provided a consistent moisture regime in the root zone of plants. The best deficit irrigation level had recorded the maximum water use efficiency of 2.59 kgm$^{-3}$.

**Table 3.** Effect of PRZDI on yield and water use efficiency for 7$^{th}$ year pomegranate tree

| Treatments | Nos. of Fruits | Fruit weight (g) | Yield (kg) | WU(m$^3$) | WUE (Kgm$^{-3}$) |
|---|---|---|---|---|---|
| $I_1$*40% | 38 | 297 | 11.28 | 7 | 1.64 |
| $I_2$*60% | 65 | 250 | 16.25 | 9 | 1.81 |
| $I_3$*80% | 88 | 355 | 31.24 | 12 | 2.59 |
| $I_4$*100% | 58 | 320 | 18.50 | 15 | 1.23 |

(**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)



**Project: Standardization and demonstration of production technology for protected cultivation of pomegranate (*Punica granatum* L.) (NHB/30AGA/0TD/000059/2016-17/2474; HYPM Project Code: OXX O4402)-Co-PI**

An experiment was conducted during Jan, 2020 – Nov, 2020 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 % and 50 % (shading effect) shade net houses and control (open field) with RBD. The size of the each shade net and open filed was 40 m x 20 m. The size of the each plot was 6 m x 16 m. The plant to plant and row to row spacing is 3.0x2.0 m. Fertigation and crop protection measures were adopted as per the package of cultivation practices. The varieties of pomegranate (***i.e.*** 'Super Bhagwa', 'Bhagwa', 'Solapur Lal' for 35 % shade net and 'Ganesh', 'Arakta', 'Mrudula' for 50 % shade net) was cultivated under shade net of an experimental has been given in**.**

**Water requirement of the shade net**

The daily water to be applied through drip irrigation system from Jan, 2020 to Dec, 2020 ranged from **3.4–40.20 $Ld^{-1}t^{-1}$** for three years old pomegranate plants at 0.50*$ET_r$, which was gradually increased or decreased during different development stages of pomegranate plants due to the variation in reference crop evapotranspiration, pan coefficient, wetted area and crop coefficient values. Lower $K_c$ values represent slower plant growth and lower plant canopy cover, indicating lower $ET_p$. The pomegranate evapotranspiration for shade net and open field water to be applied to pomegranate tree ranged from **711.20 to 6662.35 $ltree^{-1}$.** The water requirement in $lday^{-1}tree^{-1}$ including number of days for pomegranate Bhagawa cv. For open field and shade net (***i.e.*** 35 % & 50 %)

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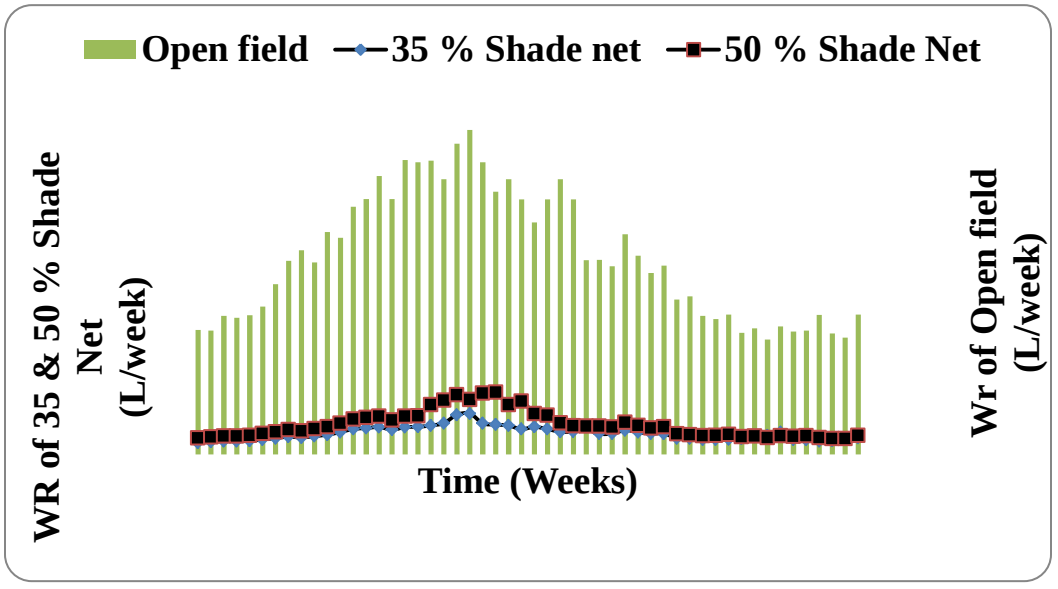


**Fig. 2. Water requirement of open field and shade net (*i.e.* 35 % & 50 %) in lweek$^{-1}$tree$^{-1}$**

**Effect of shading percentage of shade net on biometric observations Growth parameters**

Bhagava cv. Of pomegranate was evaluated for their growth parameters in 35 % and 50 % (shading effect) shade net houses and open field. Plant height, plant spread (EW & NS), stem diameter, stem girth and thorn length ranged from 141 to 189 cm, 120 to 167 cm, 100 to 159 cm, 2.1 to 3.8 cm, 8.8 to 15 cm,1.4 to 2.8 cm, respectively.

**Table 4.** Growth performance under 35**%, 50 %** (shading effect) **shade net** house and **open field** of experimental plots

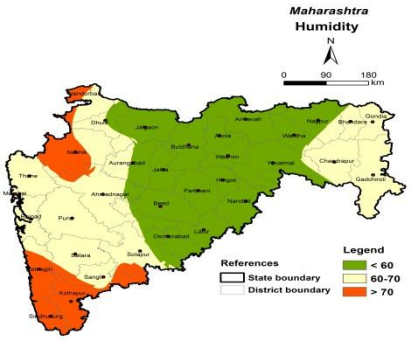
| 3rd Year Days | Plant height (cm) | Plant spread (cm) | | Stem diameter (cm) | Stem girth (cm) | Thorn length (cm) |
|---|---|---|---|---|---|---|
| | | EW | NS | | | |
| **35 % Shade net** | | | | | | |
| $T_1$ | 189 | 128 | 134 | 3.8 | 11.8 | 2.4 |
| $T_2$ | 167 | 134 | 115 | 2.9 | 10.32 | 1.8 |
| $T_3$ | 141 | 120 | 100 | 2.2 | 9.31 | 2.7 |
| **50 % Shade net** | | | | | | |
| $T_1$ | 159 | 159 | 183 | 2.7 | 12 | 1.8 |
| $T_2$ | 182 | 150 | 144 | 2.1 | 11 | 1.7 |
| $T_3$ | 177 | 165 | 152 | 3.1 | 13 | 1.6 |
| **Open Field** | | | | | | |
| $T_1$ | 169 | 161 | 155 | 3.7 | 15 | 1.4 |
| $T_2$ | 157 | 161 | 137 | 2.9 | 13 | 2.3 |
| $T_3$ | 162 | 167 | 159 | 2.8 | 8.8 | 2.8 |

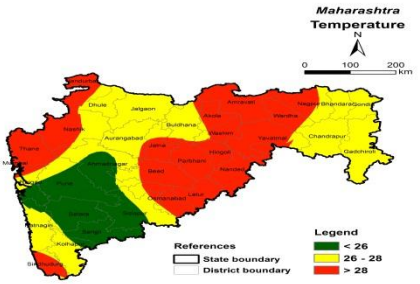
(**50% %** (shading effect) **shade net house**- $T_1$- Ganesh, $T_2$-Arakata, $T_3$-Mrudula; **35 %** (shading effect) **Shade net house**-$T_1$-Super Bhagwa, $T_2$-Bhagwa, $T_3$-Solapur Lal and $T_4$-Control)

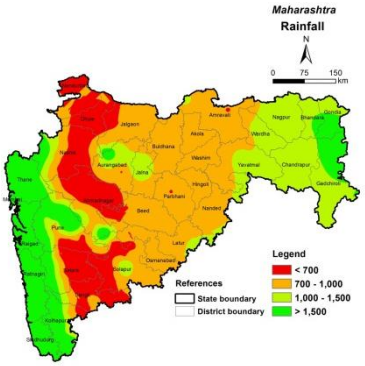


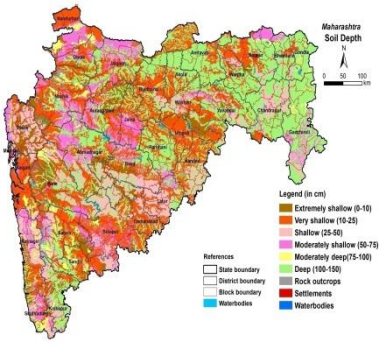
**Project: Delineation of potential areas for pomegranate cultivation in India using Remote Sensing and GIS Techniques**

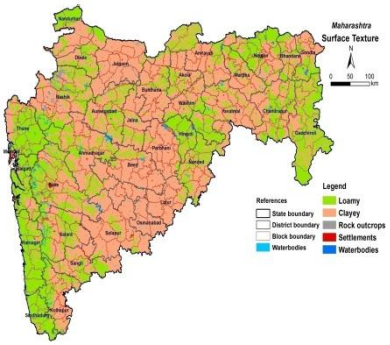
The potential areas for pomegranate cultivation have been identified with respect to different categories into highly suitable, moderately suitable, marginally suitable, not suitable, built-up, forest and water bodies for Maharashtra states, these suitability classifications were based on various thematic maps of humidity, temperature, rainfall, soil depth, surface texture, drainage, soil reaction, and slope pattern

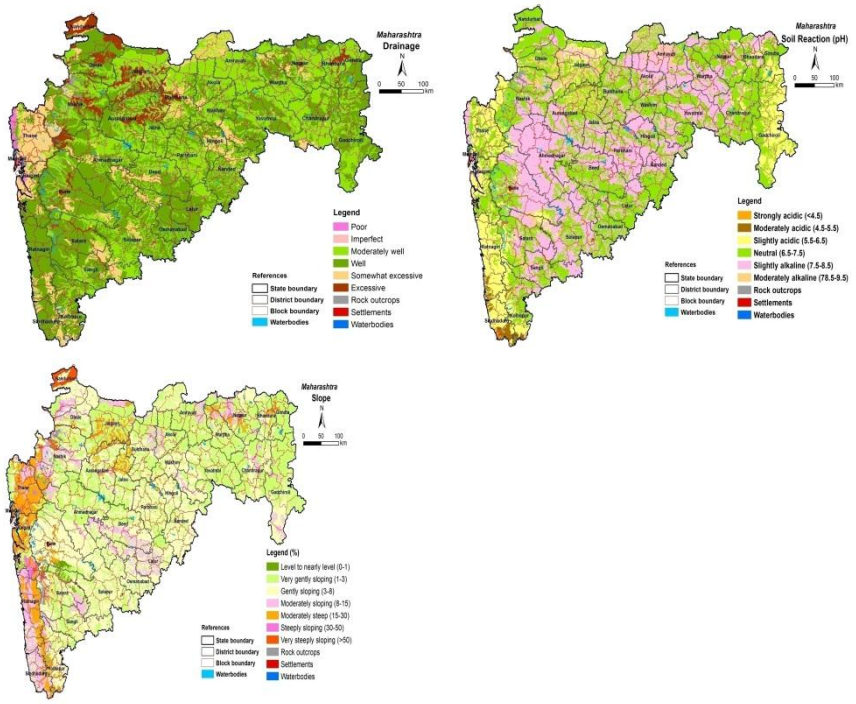


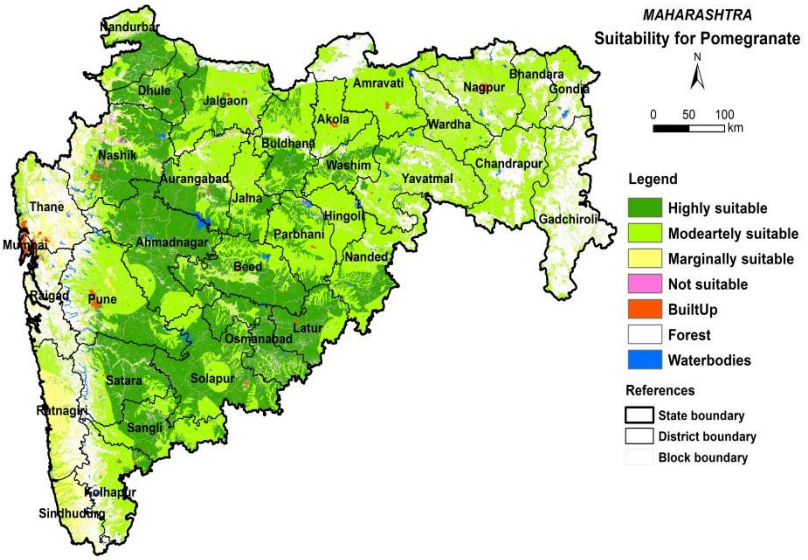





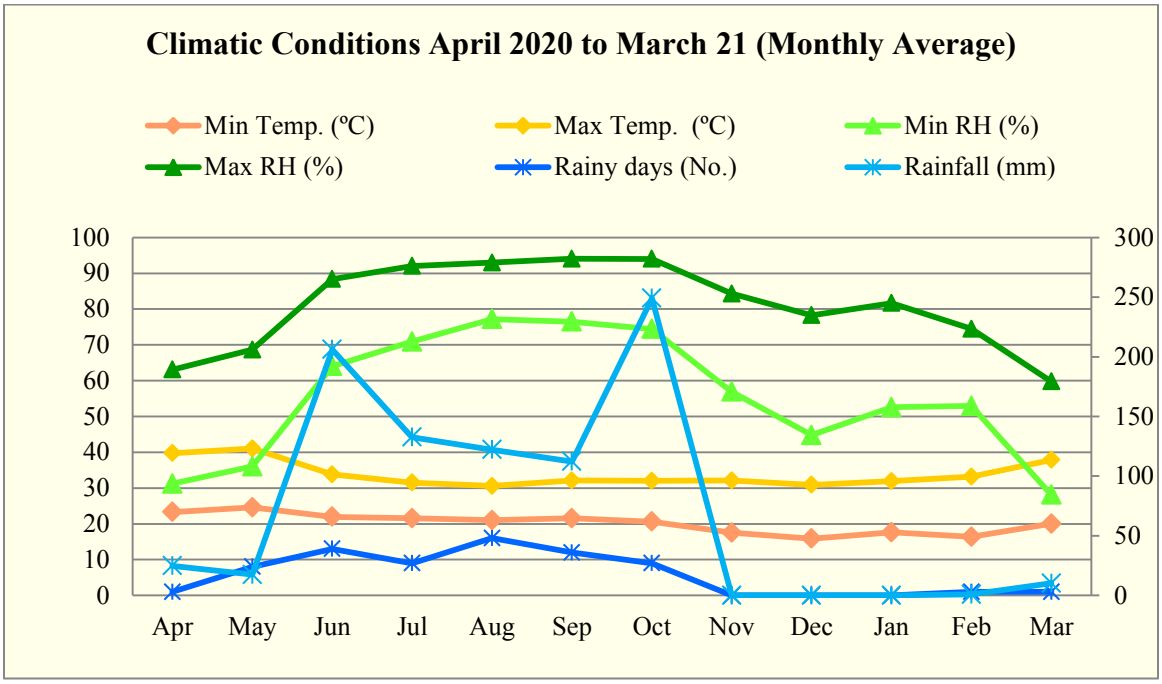

Prepared various thematic maps of humidity, temperature, rainfall, soil depth, surface texture, drainage, soil reaction, and slope for identification of potential areas of pomegranate cultivation in Maharashtra, India




Prepared final map of potential areas of pomegranate cultivation in Maharashtra, India

**Meteorological Data:**

Daily weather data was recorded manually from the Weather Station located at ICAR-NRCP, Kegaon farm and monthly average data is presented below.




## Contract Research Project

**Project: Evaluation of bio-efficacy and Phyto-toxicity of IFFC016, IFFC017 and IFFC018 against fungal leaf and fruit disease complex in pomegranate (Indofil Industries Limited, Mumbai).**

Three products **IFFC016, IFFC017 and IFFC018** (138espectively Triacylazole 45%+Hexaconazole 10%WG, Mancozeb 75% WP and Zineb 75% WP) were tested in rainy season which experienced abnormal rainfalls hence the pest and disease problems like scab and fruit rot were more during the trials. The products tested gave significantly better control of diseases caused by *Cercospora*, *Alternaria*, *Colletotrichum* except fruit scab caused by *Sphaceloma* for which Metiram 55% + Pyraclostrobin 5% WG @3g/l was highly effective.

**Project: Bio-efficacy evaluation of Spinetoram 12%SC w/v (11.7w/w) SC against *Scirtothrips dorsalis***

Three combi insecticide formulations were evaluated against the pomegranate thrips at three different doses viz., 05. 1.0 and 2.0 ml/ l water. Among the three formulations the combination of Chlorantraniliprole 8.8% + Thiamethoxam 17.5% found to be very effective with average thrips population of 1.60, 4.40, 3.86 in first, second and third spray @ 0.5ml/l water. The average population of 1.81, 3.71 and 3.18 in the first, second and third spray at the dose of 1.0 ml/l water. The average population of 1.78, 3.24 and 3.18 was recorded in first, second and third spray @ 2.0 ml/ l water. The result indicated the combi formulation was effective at 1 and 2ml/ l water against the thrips and all the sprays at different days' interval observations. Followed by (Thiamethoxam 12.6% + Lambda- Cyhalothrin 9.5%) combi formulation with average thrips population of 1.75, 3.68, 4.0 in first, second and third spray @ 0.5ml/l water. The average population of 1.71, 3.60 and 4.0 in first, second and third spray @ 1.0 ml/l. The average population of 1.40, 3.46 and 3.44 at first, second and third spray @ 2.0 ml/ l water. The result indicated the combi formulation was effective at 1.0 and 2.0ml/ l water against the thrips at all the sprays at different days' interval observations.

**Table. 1 Bioefficacy evaluation of combi insecticides formulations against insect pest of pomegranate**

| Treatments details | Dose (ml/g/l) |
|---|---|
| Chlorantraniliprole 9.3% + Lambda- Cyhalothrin 4.6% (T1) | 0.50 |
| Chlorantraniliprole 9.3% + Lambda- Cyhalothrin 4.6% (T2) | 1.0 |
| Chlorantraniliprole 9.3% + Lambda- Cyhalothrin 4.6%(T3) | 2.0 |
| Chlorantraniliprole 8.8% + Thiamethoxam 17.5% (T4) | 0.5 |
| Chlorantraniliprole 8.8% + Thiamethoxam 17.5%(T5) | 1.0 |
| Chlorantraniliprole 8.8% + Thiamethoxam 17.5%(T6) | 2.0 |
| Thiamethoxam 12.6% + Lambda- Cyhalothrin 9.5% (T7) | 0.5.0 |
| Thiamethoxam 12.6% + Lambda- Cyhalothrin 9.5% (T8) | 1.0 |
| Thiamethoxam 12.6% + Lambda- Cyhalothrin 9.5% (T9) | 2.0 |
| Control (T10) | Water |

**Project: Effect of Cardle, Nanozim drip and Nanozim delite on Pomegranate yield and fruit quality** (Funded by InGene Organics, Division of Biostadt India Limited)

A field trial was conducted to evaluate the effect of sea weed (*Ascophyllum nodosum*) extract based products *viz.* Cradle, Nanozim drip and Nanozim delite in a fully grown 7 year old pomegranate cv. Bhagawa orchard. The trees were at the spacing of 15 ft. (row to row) x 10 ft. (tree to tree). These products were used in addition to the application of recommended dose of fertilizers *i.e.* 40 kg well decomposed farmyard manure, 625 g N, 250 g $P_2O_5$ and 500 g $K_2O$ per



tree. Their effects were compared only with the application of recommended dose of fertilizers. The results of first season trial are summarized below –

- Treatments T1, *i.e.* basal application of Cradle @ 2 kg/acre, Nanozim drip @ 1 ml/l and foliar sprays of Nanozim delite @ 1g/l recorded the highest number of hermaphrodite flowers, male flowers and total number of flowers.
- The treatment T1 and T2, *i.e.* use of Cradle @ 2 kg/acre, Nanozim drip @ 1 ml/l and Nanozim delite @ 1-2 ml/l significantly increased the number of fruits and fruit set per cent. The highest number of fruits/tree was noted in T1 treatment while the highest per cent fruit set was recorded for T2 treatment.
- The treatment T1 and T2 recorded significant increase in marketable fruit yield and the fruit yield obtained from these two treatments were at par with each other. Application of sea weed extract based products also improved the fruit size and resulted significant increase in per cent fruit weighing $\geq$ 250 g *i.e.* exportable grade fruits.
- The treatment T1 resulted significant increase in aril per cent in fruit while the treatment T3 (i.e. use of Cradle @ 2 kg/acre, Nanozim drip @ 2 ml/l and foliar spay of Nanozim delite @ 1 g/l) improved the 100 arils test weight and rind thickness, and the treatment T4 enhanced the juice per cent in fruit in addition to increased 100 arils test weight.
- Fruits produced with T3 treatment *i.e.* basal application of Cradle @ 2 kg/acre, Nanozim drip @ 2 ml/l and foliar sprays of Nanozim delite @ 1 g/l, have shown higher P, K, Ca and Mg content than obtained with recommended dose of fertilizer.
- Use of sea weed extract based products (Cradle, Nanozim drip and Nanozim delite) have significantly increased Fe content in fruits, and the highest Fe content was noted with the T3 treatment. Fruits obtained from T3 treatment were also found to have higher content of Fe, Mn and Cu.
- Application of sea weed extract based products has also significantly increased the Mg concentration in leaves at flowering stage, and the highest Mg concentration was recorded with T1 treatment. Treatment T3 registered higher Fe, Mn and Cu concentration in leaves and the highest Mn concentration was noted in trees of T1 and T2 treatments which were at par with each other.
- Significant increases in the concentration of secondary nutrients *viz.* Ca, Mg and S in leaves were found in some of the treatments of sea weed extract based products. The treatments T1 and T2 gave rise to increase in foliar Ca concentration, while treatment T2, T3, T4 and T5 resulted increase in foliar Mg concentration. Similarly, higher S concentration was noted with T1, T2 and T4 treatments. The trees under T1 treatment recoded the highest concentration of Fe, Mn and Zn in leaves at harvesting.



- The soil of T2 treatment was found to have the highest content of available N, P, K and S. Not only that, it also recorded higher content of DTPA-extractable Fe and Mn content than those recorded with recommended fertilizer dose.

| | |
|---|---|
|  |  |
| T1: Basal application of Cradle @ 2 kg/acre + Nanozim drip @ 1 ml/l + foliar spay of Nanozim delite @ 1 g/l + RFD | T2: Basal application of Cradle @ 2 kg/acre + Nanozim drip @ 1 ml/l + foliar spay of Nanozim delite @ 2 g/l + RFD |
|  |  |
| T5: Basal application of BIOVITA Gr @4kg/acre + Four times foliar spray of BIOVITA liquid @ 2 ml/l. | T6: Recommended fertilizer dose (RFD) |

**Fig. Effect of sea weed extract based formulations on bearing of pomegranate fruits in trees**

**Study of residue and persistence of Fosetyl-Al and phosphonic acid in pomegranate fruit after application of Aliette and Profiler (**Funded by Bayer CropScience Limited)

This study determined the residues of Fosetyl-Al and Phosphonic acid in/on pomegranate in India following treatment with Aliette (Fosetyl-Al 80% WP), Profiler (Fluopicolide 4.44% + Fosetyl-Al 66.67% WG) and Potassium phosphonate. Field trials were carried out during the 2019-2020 crop seasons at the field of ICAR-National Research Centre on Pomegranate, Solapur (Maharashtra).

**Table 1: Treatment details on pomegranate**

| | Days After Defoliation | | | |
|---|---|---|---|---|
| **Treatment** | **25** | **30** | **50** | **70** |
| T1 | Untreated Control | -- | - | - |
| T2 | Aliette (Soil Drenching) | Aliette (Foliar Spray | | |
| T3 | Aliette (Soil Drenching) | Aliette (Foliar Spray | Aliette (Foliar Spray | Profilar (Foliar Spray) |
| T4 | Potassium Phosphonate (Soil drenching) | Potassium Phosphonate (Foliar Spray) | Potassium Phosphonate (Foliar Spray) | Potassium Phosphonate (Foliar Spray) |

Aliette (Fosetyl-Al 80% WP), Profiler (Fluopicolide 4.44% + Fosetyl-Al 66.67% WG) and Potassium phosphonate were applied to pomegranate by soil drenching and foliar spray after defoliation. Residue analysis was carried out at ICAR-NRCG, Pune, which targeted estimation of fosetyl-Al and phosphonic acid in pomegranate by validated method. The results are described below.

**Linearity**

The Analyst® software automatically derives the calibration curve using the area response (y) versus the concentration (x) of the external standards for all standards injected with the chromatographic set. The calibration curves were found to be linear with correlation coefficients greater than 0.999 when tested in the range of 0.001 to 0.100 mg/kg for Fosetyl-Al and Phosphonic acid.

**Fortification recoveries**

The method for fosetyl-Al and phosphonic acid was validated for pomegranate leave, fruit and aril samples fortified at 0.01 mg/kg, 0.05 mg/kg and 0.10 mg/kg. Recovery data from the method validation were acceptable. The average recoveries of fosetyl-Al at each fortification level were within 76.67-81.80% for leaves, 80.70-89.67% for fruits and 73.80-79.94% for arils, while



recoveries of phosphonic acid were 84.65-89.34% in leaves, 83.26-86.32% in fruit and 75.75-79.94% in arils showed with relative standard deviations of <10%.

**Residues**

The residues of fosetyl-Al were analyzed in pomegranate fruit, leaves and arils samples treatment wise (T2, T3 and T4) and it was found to be below limit of quantification (BLQ).

The analysis of pomegranate samples collected on day 0 showed 9.32, 34.3 and 39.1 mg/kg of phosphonic acid residue in T2, T3, and T4 applications, respectively. The residue levels on 14$^{th}$ day, were 5.68, 23.2 and 22.5 mg/kg in T2, T3 and T4 applications, respectively. At the time of harvest, the residues had further dissipated to 0.5, 1.0 and 4.87 mg/kg for T2, T3 and T4 applications respectively. In pomegranate leaves, phosphonic acid residues were found to be BLQ (<0.01 mg/kg) and 9.45 mg/kg in T1 and T2 applications, respectively. At the time of harvest in aril samples residues of phosphonic acid were found BLQ, 0.16, 0.23, and 1.54 mg/kg, in T1, T2, T3 and T4 applications, respectively.

**Half life**

The dissipation of fosetyl-Al metabolite *i.e.* phosphonic acid residue in pomegranate samples with treatments T2, T3 and T4 was found to be gradually decreased with time. This indicated a linear pattern of degradation and it implied that the simple 1$^{st}$ order kinetics is adequate to explain the dissipation behavior in pomegranate. The half-life values for treatment plots T2, T3 and T4 were 19, 32 and 24 days, respectively.

**Conclusion**

No residues of Fosetyl-Al were detected in any of the samples across different treatments. However, the dissipation behavior of phosphonic acid in pomegranate showed that the residues declined gradually with time indicating 1$^{st}$ order kinetics. The treatments T2, T3 and T4 showed a half-life of 19, 32 and 24 days, respectively. At the harvest, the residues of Fosetyl-Al were found BLQ in all treatments and the residues of phosphonic acid were found to be 0.500, 1.00 and 4.870 mg/kg for treatments T2, T3 and T4, respectively.

**Project: Effect of BVG Products on growth, pests and diseases incidence and yield of pomegranate**

The highest marketable yield and total aril weight was registered in plants treated with T3-Agro Nutri Spray @ 1 ml/ lit + IDIPM Schedule (17.58 kg/plant and 169.03 g, respectively), however,



treatment T2- Agro Magic spray @ 2 ml/lit + IDIPM Schedule and T8- IDIPM schedule were also produced at par results. All other treatments produced significantly lesser marketable yield. The total rind weight of fruit was registered highest in T2- Agro Magic spray @ 2 ml/lit + IDIPM Schedule which was at par with rind weight registered in T3, T5 and T7. All the other fruit quality parameters were found to be not influenced by different treatments significantly.

As far as damage of fruits by scab and *Cercospora* spots were concerned, the lowest scab was observed in T2-Agro Magic spray @ 2 ml/lit + IDIPM Schedule (32.64 and 3.97 %, respectively) and but T3, T4 and T8 treated fruits also able to manage scab and registered at par results with T2. Fruits in remaining treatments have significantly higher scab than the best treatment. IDIPM schedule (T8) sprays were able to manage fruit rots significantly better than other treatments except T7 and T2, which also produced at par results. None of the treatments could able to significantly manage thrips attack on fruits which ranged between 82.27- 84.25 %. For the management of fruit borer again T2 sprayed plants registered significantly lesser damage (4.45%) than other treatments except T3 and T8, which also produced at par results.

So, it can be concluded from the findings that treatments T2-Agro Magic spray @ 2 ml/lit + IDIPM Schedule, T3-Agro Nutri Spray @ 1 ml/ lit + IDIPM Schedule and T8-IDIPM schedule could significantly increase yield, fruit quality and manage the incidence of pests and diseases better than all other treatments and were at par among themselves for the majority of parameters. But, none of the individual or combi BVG product treatments without IDIPM were able to have significant effect on yield increment, improving fruit quality and managing disease and pest incidences. However, Agro-Nutri and Agro-Magic along with regular IDIPM schedule of ICAR-NRCP had significant influence on yield, quality and disease and insects-pests incidence.



## Activities under Tribal Sub-plan / STC

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

| State | District | Sub-district | Village | ST population benefit-ed | Year of adoption | Status as on 31.12.2020 |
|---|---|---|---|---|---|---|
| Maharashtra | Gadchirauli | Sironcha | | | 2015-16 | Agri inputs given, poultry farming promoted, pomegranate orchards established. |
| Madhya Pradesh | Anuppur | Kotma | Manmari, Baskhala, Reula, Reusa, Baskhali, Behratola, Baskhali, Jamuniya, Chapani, Chaka, Pathrodi, Dhurvasin, Thouda | 120 | 2018-19 | Agri-inputs and minor farm implements and sprayers given, trainings organized, technical inputs provided, some orchards are in fruiting stage |
| Chhattisgarh | Koriya | Manendragarh | Dorki, Kerabehara | 12 | 2017-2018 & 2018-19 | Agri inputs given, trainings organized, technical inputs provided, some orchards in fruiting stage |





**Agri-input distribution and training at Kotma, Anuppur, Madhya Pradesh under TSP scheme**

More than 150 Frontline Demonstrations on quality planting material and package of practices including IDIPM standardized by ICAR-NRCP in under progress at Anuppur, M.P. in collaboration with SRIJAN and Amarkantak Horticulture Producer Company Ltd.

**Table 2. Farmers adopted by ICAR-NRCP, Solapur under SCSP scheme**

| State | District | Sub-district | Village | SC population benefitted | Year of adoption | Status as on 31.12.2020 |
|---|---|---|---|---|---|---|
| Maharashtra | Solapur, Osmanabad, | Madha, Akkalkot, Tuljapur | Solankarwadi, Nimgaon, Waghdari, Mundhewadi, Malumbra | 40 | 2018-19 and 2019-20 | Agri-inputs, minor farm implements and sprayers given, trainings organized, technical inputs provided, some orchards are in fruiting stage |
| Madhya Pradesh | Tikkamgarh | Jatara | Dor, Tal Lidhora, Barmadang | 80 | 2019-20 | Agri-inputs, minor farm implements and sprayers given, |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | trainings organized, technical inputs provided, orchards are in bearing stage |
| Rajasthan | Barmer Alwar | Balotra, Ramghar, Umren | Roopbas, Sherpur, Rajeshwar Nagar | 12 | 2018-19 | Agri-inputs, minor farm implements and sprayers given, trainings organized, technical inputs provided, one orchards is in bearing stage and one in juvenile phase |



**Agri-input distribution to SC farmers adopted under SCSP scheme at Tikkamgarh, M.P.**

**Agri-input distribution to SC farmers adopted under SCSP scheme**


**Adopted farmer under SCSP scheme**

More than 100 Frontline Demonstrations on quality planting material and package of practices including IDIPM standardized by ICAR-NRCP in under progress at Tikkamgarh, M.P. in collaboration with SRIJAN.

**Table 3. Training programmes/ workshop/farmers' field day organized for tribal and SC farmers under SSCP / STC**

| S. No. | Name of the training programme | Place | Date | SC Farmers benefited (Nos.) |
|---|---|---|---|---|
| 1 | Farmers' Field Day-cum-Training Progarmme under SCSP scheme at Balotra, Barmer, Rajasthan | Balotra, Barmer, Rajasthan | 07.01.2020 | 100 |
| 2 | Farmers' Field Day-cum-Training Progarmme under SCSP scheme at Roopbas, Alwar, Rajasthan | Roopbas, Alwar, Rajasthan | 09.01.2020 | 150 |
| 3 | Farmers' Field Day-cum-Training Programme under TSP scheme at Kotma, Anuppur, M.P. | Kotma, Anuppur, M.P. | 11.01.2020 | 73 |
| 4 | Farmers' and field staff training of SRIJAN and identification of beneficiaries at Tikkamgarh, M.P. under SCSP | Jatara, Tikkamgarh, M.P. | 12.01.2020-13.01.2020 | 50 |

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# Outreach Activities

## TRAININGS/ WORKSHOPS/ FARMERS FAIR/ FIELD DAY

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

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

| S. No. | Title of Trainings/ Workshops/ Farmers Fair/ Field Day/ FLD | Venue | Date | No. of participants |
|---|---|---|---|---|
| 1. | *Anar Utpadan Aur Mulya Samvardhan : Adhunik Takniki* | ICAR-NRCP, Solapur, through online mode | 04.08.2020 | 100 farmers |
| 2. | National Webinar for Pomegranate Farmers in Different Regions of India on *Hasta Bahar* Crop of Pomegranate: Package of Practices, Problems and Practical Solution | ICAR-NRCP, Solapur, through online mode | 08.09.2020-10.09.2020 | 100 farmers |
| 3. | Pomegranate Processing and Entrepreneurship. Training on Hi-Tech production technology of Pomegranate | KVK Baramati. | 18.05. 2020 | 180 farmers |
| 4. | Post-harvest technology in Pomegranate" in online workshop on "Advances in Pomegranate Production" for farmers of Gujarat. | Krishi Vigyan Kendra, Sardarkrushiinagar Dantiwada Agriculture university, Deesa, Dist-Banaskantha (Gujarat) | 20.05.2020 | 80 farmers |
| 5. | Pomegranate value addition in Training for Rural Youth in Food Processing Techniques | Online organized by KVK Dhule and ATMA Dhule. | 17.10.2020 | 15 farmers |
| 6. | Post-Harvest Technology and value addition in pomegranate to Agril. Asst., Agril. Circle officers etc. in training programme on Export Oriented Pomegranate Production and Post-Harvest Technology | Online organized by RAMETI Kolhapur, Govt. of Maharashtra. | 20.10.2020 | - |
| 7. | Training programme on Value Addition of Pomegranate in Kisan Mela | KVK Gudamalani | 24.02.2020 | 5000 farmers |



## SCIENTIFIC AGRO ADVISORIES

In response to queries of farmers, information on pomegranate was provided to the farmers through e-mail and phone. Scientific agro-advisories were sent to more than 2900 pomegranate growers through the “m-Kisan portal” during the period under report.

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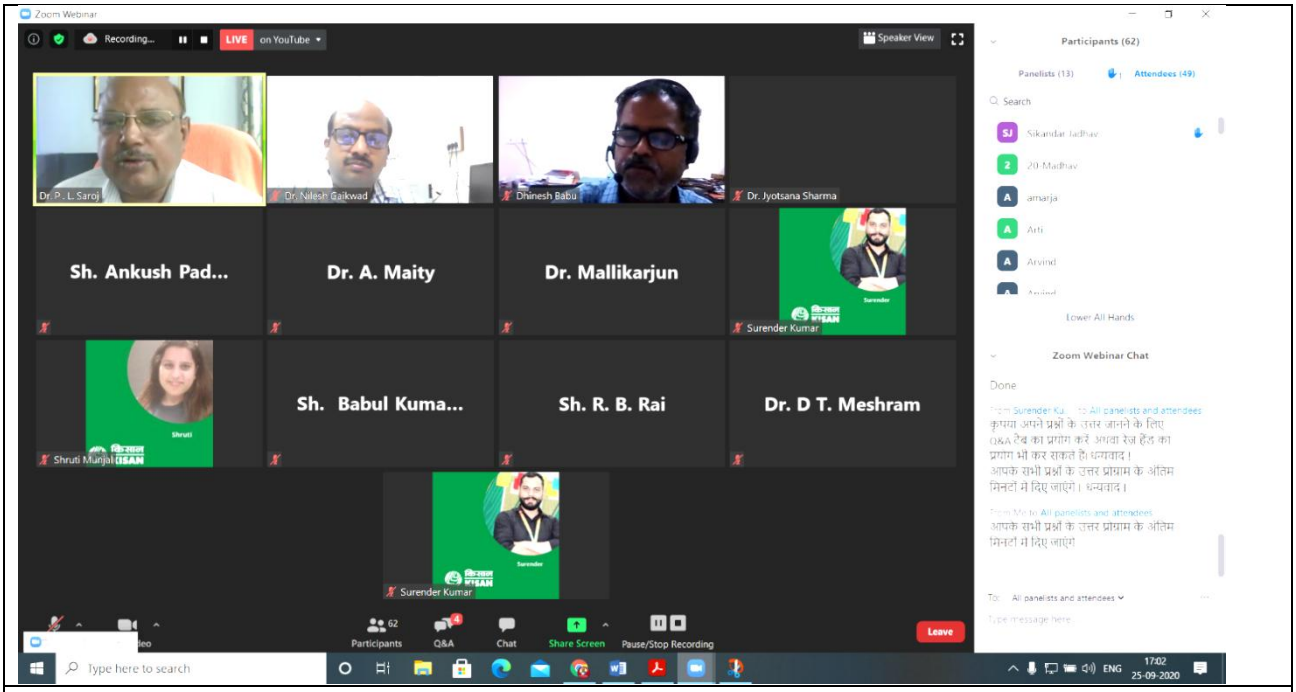
## Transfer of Technology and Entrepreneurship Development

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

Table 1: Trainings conducted by ICAR-NRCP, Solapur

| S. No. | Name of Training Programmes (Duration: 3 or more days) | No. of participants | Period |
|---|---|---|---|
| 1 | National Webinar for Pomegranate Farmers in Different Regions of India on Hasta Bahar Crop of Pomegranate: Package of Practices, Problems and Practical Solution | 100 | 8 -11th January 2020 |
| 2 | National Webinar on Scenario of Pomegranate Cultivation in India on the occasion of Sixteenth Foundation Day of ICAR-NRC on Pomegranate | 150 | 24-26th September 2020 |




National Webinar on Scenario of Pomegranate Cultivation in India on the occasion of Sixteenth Foundation Day of ICAR-NRC on Pomegranate, Solapur 25 th September 2020

## AGREEMENT WITH VARIOUS STAKEHOLDERS

### For Entrepreneurs

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

**Table 3: MoU with Entrepreneurs**

| S. No. | Technology transferred | Address of beneficiary | Date of signing MoU | Revenue received (Rs.) |
|---|---|---|---|---|
| 1 | Propagation of Pomegranate var. Solapur Lal through air layering / hardwood cutting | Shri Bawake Patil, M/s. Bawake Patil Nursery, Sakure, Tk.-Rahata, Dist.-Ahmednagar | 07.08.2020 | Rs.90,000+ GST@18%= Rs.1,06,200 |
| 2 | Propagation of Pomegranate var. Solapur Lal through air layering / hardwood cutting | Shri. Sikandar K Jadhav, M/s. Smart Crop Nursery, Tk. & Dist.-Aurangabad. | 10.11.2020 | Rs.90,000+ GST@18%= Rs.1,06,200 |
| 3 | "Two step Hardwood cutting protocol of pomegranate including biohardening" | Bawake Patil Nursery, A/P Sakori, Tal-Rahata, Dist: Ahmednagar, Maharashtra, India | 07.08.2020 | Rs. 20000 + GST@ 18% |



MoU between ICAR-NRCP & **M/s. Bawake Patil Nursery**, Sakure, Rahata Tk, Ahmednagar Dist., for propagation of pomegranate variety **Solapur Lal** though air layer/HWC, 07.08.2020

MoU between ICAR-NRCP & **M/s. Smart Crop Nursery** (Prop: Mr. Sikkandar Jadhav), Aurangabad Tk.and Dist. for propagation of pomegranate variety **Solapur Lal** though air layer/HWC, 10.11.2020

## For Students

**Table 4: MoU with Academic Institutions**

| S. No. | Programme | Address of beneficiary | Date | Revenue generated (Rs.) |
|---|---|---|---|---|
| 1 | M.Sc (Biotechnology) | Karunya Institute of Technology & Sciences (Deemed to be University), Karunya Nagar, Coimbatore- 641 114, Tamil Nadu | 03.01.2020 | - |
| 2 | M.Sc (Industrial Microbiology) | School of Life Sciences, Devi AhilyaVishwavidhyalaya, Indore, Madhya Pradesh | 09.03.2020 | - |
| 3 | M.Sc (Hort.) / Ph.D | Andhra Pradesh Horticulture University, Tadepallikudem, A.P. | 07.11.2020 | - |
| 4 | Collaborative Research on semio-chemical research | CSIR – Indian Institute of Chemical Technology, Hyderabad -500 007, Telangana State | 18.11.2020 | - |

**Table 5: Exhibitions**

| S. No. | Name of the exhibition | Organizer | Venue | No. of participants | Date |
|---|---|---|---|---|---|
| 1 | Participated in Kisan Mela and showcased ICAR-NRCP technologies to farmers | KVK, Gudamalani, Barmer II, Krishi Vishwa Vidyalay, Jodhpur | KVK, Gudamalani | 5000 farmers | 24.02.2020 |

**Kisan Mela at KVK Gudamalani, 24.2.2020 Dr. Nilesh Gaikwad, Sr. Scientist showcasing pomegranate wine and juice to Shri. Kailash Chaudhari, Hon. Minister of State for Agriculture and Farmer Welfare of Government of India.**

## POMEGRANATE GROWERS/ VISITORS TO ICAR-NRCP, SOLAPUR

Following beneficiaries/ visitors visited this Centre during 2020

**Table 6: Visitors to ICAR-NRCP, Solapur**

| S. No. | Date | Organization/ Place of beneficiaries | Category | No. of beneficiaries |
|---|---|---|---|---|
| 1 | 07.02.2020 | UAHS, Bagalkot | Farmers & Officers | 28 |
| 2 | 10.02.2020 | KVK, Vijayapur | Farmers & Scientists | 52 |
| 3 | 10.02.2020 | KVK, Gangavathi | Farmers & Scientists | 102 |
| 4 | 24.02.2020 | KVK, Gangavathi | Framers & Scientists | 52 |
| 5 | 11.09.2020 | ICAR-KVK, Chitradurga | Farmers | 50 |
| 6 | 23.09.2020 | ICAR-KVK, Vijayapura, Karnataka | Farmers | 50 |

| | |
|---|---|
|  |  |
| **UAHS, Bagalkot (7th Feb.,2020)** | **KVK, Vijayapur (10th Feb.,2020)** |
|  |  |
| **KVK, Gangavathi (10th Feb.,2020)** | **KVK, Gangavathi (24th Feb., 2020)** |

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# Institutional Activities

## COMMITTEE MEETINGS (RAC, IRC, IMC, IJSC)

### Research Advisory Committee (RAC) Meeting

The fourteenth Research Advisory Committee (RAC) meeting of ICAR- National Research Centre on Pomegranate was held through **'virtual mode'** from November 6-7, 2020 at ICAR-NRCP, Solapur under the Chairmanship of Dr. N Kumar, Vice Chancellor, TNAU, Coimbatore. The RAC members, Dr. B.K. Pandey, I/c ADG (HS-II), ICAR, Ex-Officio Member, Shri. Shahaji G. Pawar, Progressive Pomegranate Farmer (MS) and Shri. M.S. Mugle, Progressive Pomegranate Farmer (MS) could not attend the meeting due to pre-occupation elsewhere. Among NRCP Scientists, Dr. Namrata Giri could not attend the meeting as she was on child care leave in her hometown where internet connectivity problem was there. The RAC members and scientists of ICAR-NRCP, Solapur who participated in the meeting are given below:

**Table 1. Research Advisory Committee of ICAR-NRCP, Solapur**

| | | | |
|---|---|---|---|
| | **Chairman** | | |
| **1.** | Dr. N. Kumar<br>Vice- Chancellor<br>TNAU, Coimbatore | **6.** | Dr. Madan Pal<br>PS, ICAR-IARI<br>New Delhi. |
| | **Member** | | |
| **2.** | Dr. D.P.Waskar<br>Director of Research<br>VNMKV, Parbhani. | **7.** | Dr. (Mrs.). Jyotsana Sharma<br>Director Acting<br>ICAR-NRCP, Solapur |
| **3.** | Dr. V.V. Sulladmath<br>Ex-PS, ICAR-IIHR<br>Bengaluru | **8.** | Mr. Shahajirao Gulchand Pawar,<br>Progressive Farmer<br>Mardi, North Solapur |
| **4.** | Dr. S. K.Panda<br>Ex-Head, OUAT<br>Bhubaneshwar | **9.** | Mr.Malsingh Shivanand Mugle,<br>Progressive Farmer<br>Madrup, North Solapur |
| | | | **Member Secretary** |
| **5.** | Dr. R.A.Marathe<br>PS (Soil Sc.)<br>ICAR-NBSSLUP, Nagpur. | **10.** | Dr. K Dhinesh Babu<br>PS (Hort,- Fruit Sc.)<br>ICAR-NRCP, Solapur |

The virtual technical meeting of the first day started on Nov 6, 2020 at 2.30pm. Dr. K. Dhinesh Babu, Principal Scientist (Hort.-Fruit Sci.), ICAR-NRCP & Member Secretary, extended a warm

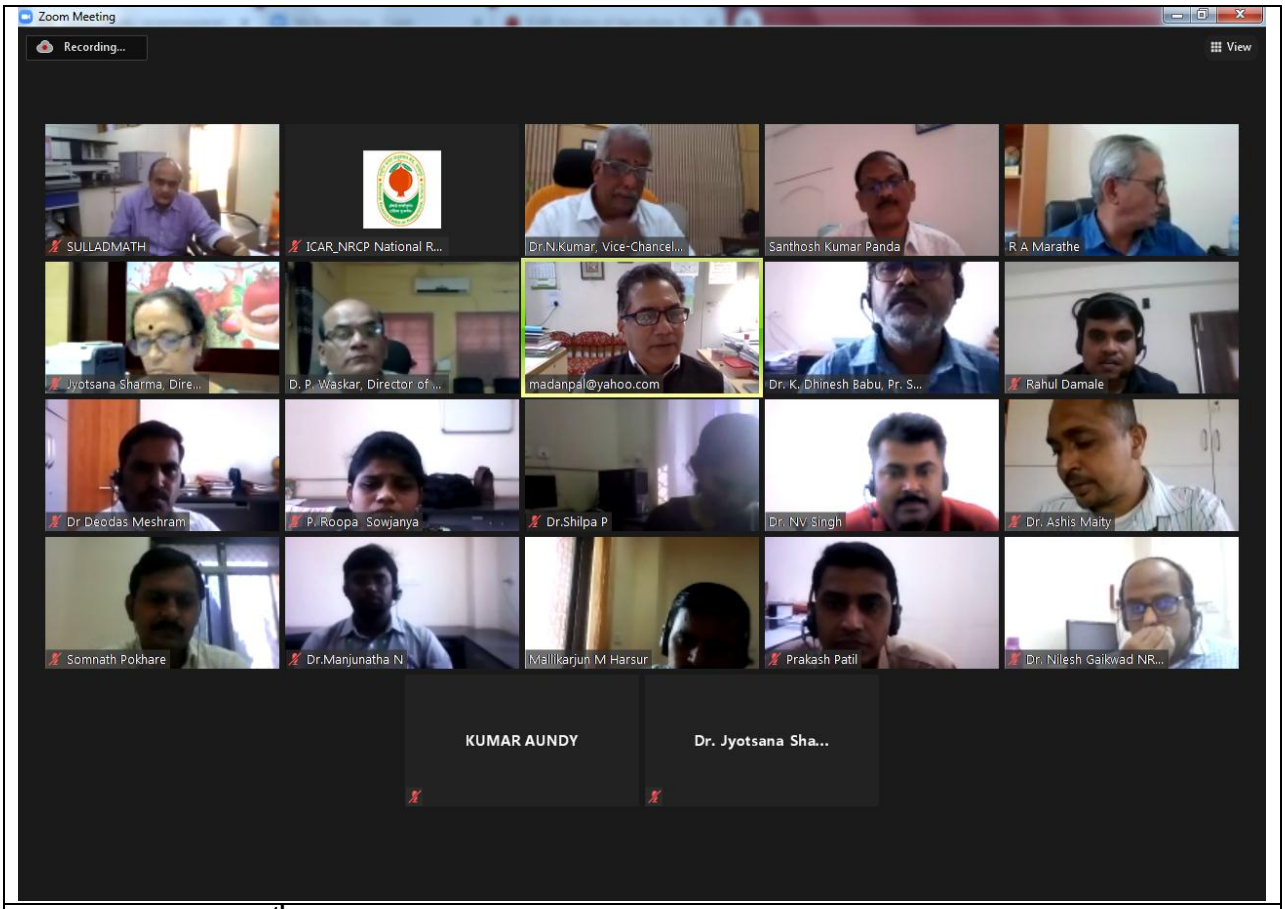


welcome to the Hon'ble Chairman and esteemed members of RAC. This was followed by introduction of new scientists of the centre joined through transfer / posting to the RAC members. This was followed by presentation by Dr. Jyotsana Sharma, Director (Acting). She presented a detailed report on Fifteen Years Journey of ICAR-NRCP, Solapur, and highlighted the achievements and technologies developed and commercialized by the centre since its establishment. The Action Taken Report on recommendations of the 13$^{th}$RAC (Annexure 1) held on 22-23 Nov, 2019 was presented by the Member Secretary. Members of the committee were then invited by the Chairman for their comments on presentations. The committee members appreciated the research efforts made by the centre and gave their specific views on achievements and ATR. At the end of the opening session, the Chairman addressed the house. The technical session started thereafter with the presentation on detailed work done during 2019-20 by the Principal Investigators of nine ongoing projects.

On the next day- Nov 07, 2020, the session started at 10.30am with the presentations of remaining three on-going projects. This was followed by review of five newly proposed research projects in the 15$^{th}$ IRC meeting held during August 19-20, 2020. Dr. N. Kumar, Chairman and all members of RAC interacted with scientists and provided various suggestions and recommendations for betterment of on-going research projects. After a thorough deliberation and interactions following suggestion and recommendations have emerged.

**Recommendations of 14$^{th}$ RAC held during Nov., 6-7, 2020**

- Development and demonstration of a bio-intensive plant protection schedule by integration of different biomolecule for management of diseases and insect pests.
- Strategize a time bound breeding programme for developing varieties resistant to bacterial blight and wilt by screening large population of elite genotypes.
- As genetic base of pomegranate is narrow, it is essential to increase variability / diversity by introduction of species viz., *Punica protopunica* from Socotra Island.
- Development of complete package of practices for new varieties 'Solapur Lal' and 'Solapur Anardana' of pomegranate by ICAR-NRCP, Solapur.
- Demonstration of the Six Step technology capsule for the management of bacterial blight disease of pomegranate under farmers' field in collaboration with other organizations.
- Revenue generation and Entrepreneurship development through commercialization of NRCP technologies among stakeholders.




**14th RAC meeting of ICAR-NRCP, Solapur Nov., 6-7, 2020**

**Institute Research Council (IRC) Meeting**

The meeting of the fifteenth Institute Research Council (IRC) of ICAR- National Research Centre on Pomegranate was held through **'online mode'** during August 19-20, 2020 at ICAR-National Research Centre on Pomegranate, Solapur under the guidance of Hon'ble DDG (HS), ICAR, Dr. A.K. Singh and chairmanship of Dr. Jyotsana Sharma, Director (Acting), ICAR-NRCP, Solapur and guidance of external experts. The following experts and Scientists/ IRC members attended the meeting.

**Table 2. Institute Research Council of ICAR-NRCP, Solapur**

| | **Chief Guest & Invited Expert** | | **Invited Expert** |
|---|---|---|---|
| **1.** | Dr. A.K. Singh<br>DDG (HS)<br>ICAR, New Delhi | **2.** | Dr. B.K. Pandey<br>In-charge ADG (HS-II)<br>ICAR, New Delhi |
| | **Chairman** | | |

| | | | |
|---|---|---|---|
| **3.** | Dr.(Mrs.) Jyotsana Sharma<br>Director (Acting) &Principal Scientist (Plant Pathology)<br>ICAR-NRCP, Solapur | | |
| | **Member** | | |
| **4.** | **Dr. Aundy Kumar**<br>Pr. Scientist (Pl.Path.)<br>ICAR- IARI, New Delhi | **12.** | Dr. Mallikarjun Hasnur<br>Scientist (Entomology)<br>ICAR-NRCP, Solapur |
| **5.** | Dr. D.T. Meshram<br>Senior Scientist (L&WME)<br>ICAR-NRCP, Solapur | **13.** | Dr. Roopa Sowjanya<br>Scientist (Pl. Breeding)<br>ICAR-NRCP, Solapur |
| **6.** | Dr. Manjunath, G.<br>Assoc. Prof. (Pl.Path.)<br>University of Hort. Sci, Bagalkot | **14.** | Dr. N. Manjunatha,<br>Scientist (Plant Pathology)<br>ICAR-NRCP, Solapur |
| **7.** | Dr. Ashis Maity<br>Senior Scientist (Soil Sc.)<br>ICAR-NRCP, Solapur | **15.** | Dr. Somnath S Pokhare<br>Scientist (Nematology)<br>ICAR-NRCP, Solapur |
| **8.** | Dr. P.G. Patil<br>Senior Scientist (Plant Biotech)<br>ICAR-NRCP, Solapur | **16.** | Dr. Namrata A Giri<br>Scientist (Food Technology)<br>ICAR-NRCP, Solapur |
| **9.** | Dr. N.V. Singh,<br>Senior. Scientist (Fruit Science)<br>ICAR-NRCP, Solapur. | **17.** | Dr. Rahul Damale<br>Scientist (Biochemistry)<br>ICAR-NRCP, Solapur |
| **10.** | Dr. N.N. Gaikwad<br>Senior Scientist (AS &PE),<br>ICAR-NRCP, Solapur | | |
| | | | **Member Secretary** |
| **11.** | Dr. Shilpa Parashuram<br>Scientist (Plant Breeding)<br>ICAR-NRCP Solapur | **18.** | Dr. K. Dhinesh Babu<br>Principal Scientist (Hort.- Fruit Sci.)<br>ICAR-NRCP, Solapur |

At the outset, Dr. K. Dhinesh Babu, Principal Scientist & Member Secretary IRC extended a warm welcome to the invited experts, Dr. A.K. Singh, DDG (HS), Dr. B.K. Pandey, I/c ADG (HS-II) Dr. Jyotsana Sharma, Director (Acting) and all scientists of ICAR-NRCP, Solapur. He also introduced four new scientists who joined ICAR-NRCP in 2020. Then, the Director (Acting) addressed the experts and members of IRC and made a presentation on the technologies developed and commercialized during the15 year journey of this Centre. This was followed by Action Taken Report on general recommendations of 14$^{th}$ IRC held on 29.07.2019 by Member Secretary. This was followed by the address of the Chief Guest, Dr. A.K. Singh, DDG (HS), ICAR, New Delhi. Hon'ble DDG appreciated the achievements made by ICAR-NRCP in the

short duration of its establishment and expressed his views on future roadmap for pomegranate research. He encouraged scientists to take long and short term projects to improve export quality production through use of environmentally safe agrochemicals and find suitable replacement of banned pesticides. He expressed his concern on increase in pomegranate area with monoculture and asked scientists to promote diversification in pomegranate varieties to overcome present and future challenges. Sir also suggested working jointly with other research organizations and universities and also economists to address local problems and develop sustainable business model and bring publication on this. As pomegranate is known for health benefits, he asked concerned scientists to explore new health benefits of pomegranate. Scientists through research should address problems of farmers, investors, traders and consumers. He also advised to get more germplasm from other countries. The centre should try to promote their technologies/products developed through demonstrations in cluster approach. The new varieties developed should be protected. Looking into the future of agriculture, he also emphasized for research on prospects of protected cultivation of pomegranate. Concluding his address he conveyed his best wishes to the Centre for developing new technologies to fulfill current demand and also his full support to NRCP.

Dr. BK Pandey, ADG (HS) addressed the scientists on second day and emphasized on biological control of wilt using CISH, Lucknow product 'Fusicon', he also suggested use of *Neem* oil with insecticides, methyl Eugenol traps and also asked to standardize lowest number of traps/ha required. Presentations on salient achievements of 12 ongoing research projects besides 6 new research project proposals and future line of work were made by scientists on Aug 19-20, 2020.

## Institute Management Committee (IMC) Meeting

**Table 3. Institute Management Committee of ICAR-NRCP, Solapur**

| | | | |
|---|---|---|---|
| | **Chairperson** | | |
| 1. | Dr. (Mrs.) Jyotsana Sharma<br>Director (Acting), ICAR-NRCP, Solapur | | |
| | **Members** | | |
| 2. | Director of Horticulture<br>Govt. of Maharashtra | 8. | Dr. Anuradha Sharma<br>PS, ICAR-NRCG, Pune |
| 3. | Dr. Chitranjan M Patel, JDH | 9. | Dr. K. Dhinesh Babu |

| | | | |
|---|---|---|---|
| | Govt. of Gujarat, Gandhinagar | | PS, ICAR-NRCP, Solapur |
| 4. | Dr. Prakash K Nagare<br>Prof. & Head, Hort. Division<br>DPDKV, Akola | 10. | Dr. Manish Srivastava<br>PS, Hort. Technology Division<br>ICAR-IARI, New Delhi |
| 5. | Mr. Shahaji Gulchand Pawar<br>Main Post Office, Tk.- North Solapur<br>Dist.- Solapur | 11. | The Assistant Director General (HS-I)<br>ICAR, KAB-II<br>Pusa, New Delhi 110012 |
| 6. | Mr. Malsingh Shivanand Mugle<br>Main Post Office-Mandrup, Tk.-North Solapur, Dist.-Solapur | 12. | F & AO, ICAR-IIRR<br>Hyderabad |
| 7. | Dr. S.K. Malik<br>PS, ICAR HQ<br>Krishi Bhavan | 13. | Sh. B.K. Sinha (S.I. Member)<br>SAO, ICAR-NIASM, Baramati, Pune |
| | | | **Member Secretary** |
| | | | Sh. R.B. Rai<br>Assistant Administrative Officer<br>ICAR-NRCP, Solapur |

## Institute Joint Staff Council

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

**Table 4. Institute Joint Staff Council of ICAR-NRCP**

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



## MERA GAON MERA GAURAV

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

**Table 5. Activities carried out under MGMG programme**

| S. No. | Name of activity | No. of activities conducted | No. of farmers participated & benefitted |
|---|---|---|---|
| 1. | Awareness created | 4 (Soil Health, Social Distancing, Sanitation and Government Schemes) | 166 |
| 2. | Demonstrations conducted | 16 | 166 |
| 3. | Interface meeting/ *Goshthies* | 9 | 166 |
| 4. | Literature support provided | 6 | 100 |
| 5. | Training organized | 2 | 53 |
| 6. | Visit to village by teams | 10 | 166 |
| 7. | Mobile based advisories and newspaper based and through *m-Kisan portal* | -- | 2100 |
| Total | | | 2917 |


**Soil Health Card Distribution to the Adopted Farmer at Nimgaon**

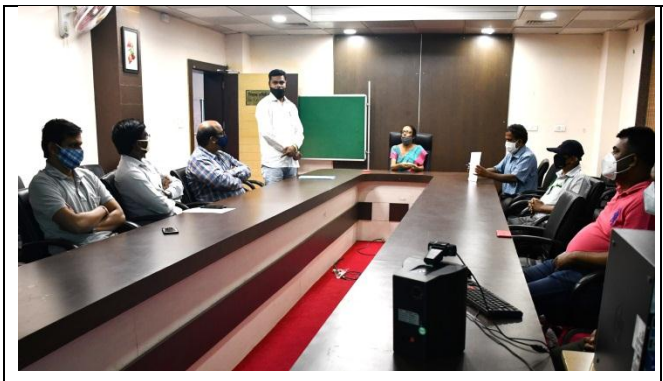
**Established Pomegranate Orchard**


**Adopted Pomegranate Orchard having 'Solapur Lal' Plants at Nimgaon**


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

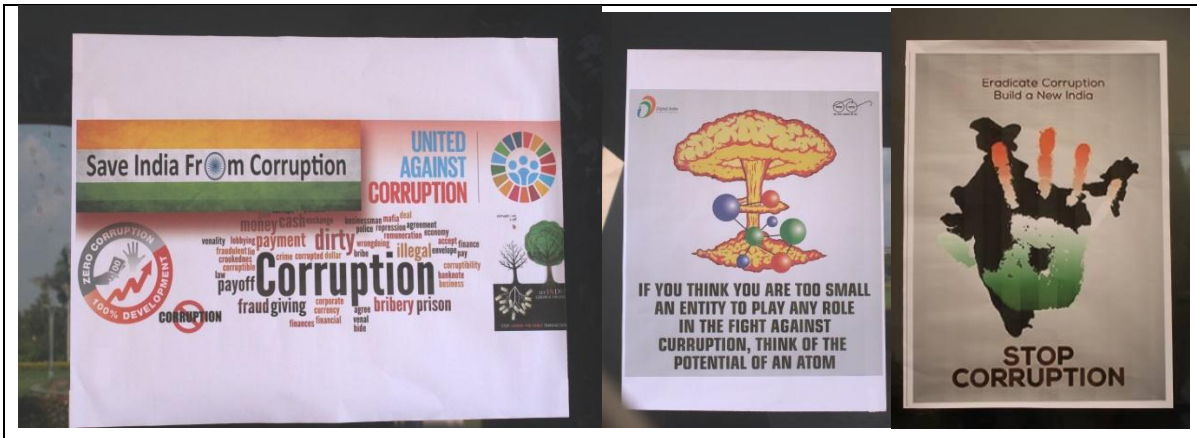
## VIGILANCE AWARENESS WEEK

The scientific, technical and administrative staff of ICAR- National Research Centre on Pomegranate, Solapur gathered in the Director's Board Room on 27.10.2020. At the outset, Mr. Vishwanath Shinde, Coordinator of VAW-2020, extended welcome to staff of the institute. Short videos related to vigilance awareness were presented. Under the leadership of Dr. Jyotsana Sharma, Director (Acting), Integrity pledge for Individual and Organization was taken by staff of ICAR-NRCP.



**Discussion about Vigilance Awareness Week 27.10.2020**

**Vigilance Awareness Week 2020 – Integrity Pledge taken by ICAR-NRCP Staffs on 27.10.2020**




**Posters displayed in the building of ICAR-NRCP, Solapur on 28.10.2020**


**Short video on Vigilance Awareness, being watched by Director & Staff, ICAR-NRCP, Solapur**

**Dissemination of anti-corruption messages:**

Anti-corruption messages were chosen by Mr. Vishwanath Shinde, Coordinator of Vigilance Awareness Week, for creation of awareness among farmers and citizens. These messages were sent through Whatsapp / SMS / E-mail to staff of ICAR-NRCP. Besides, anti-corruption messages were disseminated through Whatsapp group of farmers under *Mera Gaon Mera Gaurav* scheme. About 500 messages were disseminated to create awareness on Vigilance Awareness Week. The concluding ceremony of Vigilance Awareness Week-2020 was held on 02.11.2020 at 4.00 pm - 5.00 pm. Programme Coordinator, Mr. Vishwanath Shinde, AF&AO of the Centre extended welcome to Director and staff of the institute. Dr. K. Dhinesh Babu, vigilance officer of the centre delivered lecture on “Satark Bharat, Samriddh Bharat” besides, explaining the activities concerned with Vigilance as per the Annexure-A proforma circulated by the council. Dr. Jyotsana Sharma, Director, ICAR-NRCP interacted with staff on vigilance awareness and highlighted the importance of Vigilance Awareness Week.

## OTHER ACTIVITIES

### INTERNATIONAL WOMEN'S DAY

ICAR-NRC on Pomegranate celebrated International Women's Day on 10.03.2020. The chief guest of the function was Mrs. Chandrika Chauhan, Member, Maharashtra State Women's Commission, Founder, Udyogwardhini. The Guest of honour was Mrs. Shanta, who is successful entrepreneur. Mrs. Chandrika Chauhan delivered speech on her experiences in handling women's issues and building an enterprise with support of women's. The enterprises she established led to empowered and self-reliant women's. She also conducted few games for women's with message for them regarding how to have cooperation and coordination in achieving organizational goals. The guest of honor Mrs. Shanta Take also apprised about her experience in building her enterprise despite being women from traditional family and her lower education. The participants also shared their views on the occasion of women's day.


**Celebrating International Women's Day at ICAR- NRCP, Solapur**

**FARMERS' DAY 2020**

The group of pomegranate farmers from Barmer visited ICAR-NRCP. Dr. Nilesh Gaikwad, Sr. Scientist and team of scientist apprised farmers about the pomegranate pack-house operations, processing and value addition, plant protection along with special reference to nematode control in sandy soils of Barmer during entrepreneurship development workshop. The farmers were advised to undertake pomegranate postharvest management, packaging for export of pomegranate. The value addition of pomegranate was emphasized for juice and RTS beverage. The farmers were keen to formulate FPO for the primary processing and value addition of pomegranate at Barmer, Rajasthan.


**Group of pomegranate farmers from Barmer visited ICAR-NRCP, Solapur**

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# HUMAN RESOURCE DEVELOPMENT

## TRAINING ATTENDED

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

**Table 1: TRAINING ATTENDED BY THE STAFF OF ICAR-NRCP, SOLAPUR**

| S. No. | Name of training | Date | Venue | Name of participant |
|---|---|---|---|---|
| a. | **Scientific staff** | | | |
| 1 | Management Development Programme on Leadership Development (a pre – RMP programme) organized by ICAR-NAARM Hyderabad | 08.12.20-19.12.20 | Online mode | Dr. Jyotsana Sharma<br>Dr. P. Shirgure |
| 2 | Training on e-office organized by ICAR Headquarter | 01.05.20 | Online mode | Dr. Gaikwad N.N. |
| 3 | Online training course on "Advances in Smart Food Processing Technologies" Organized by Centre for Advanced Agricultural Science and Technology (CAAST) on Climate-Smart Agriculture and Water Management (CSAWM), MPKV Rahuri. | 04.06.20-15.06.20 | Online mode | Dr. Gaikwad N.N. |
| 4 | Workshop cum Training Programme on " Intellectual Property Right in Agricultural research & Education in India" organized by NAHEP and IP & TM Unit, ICAR Hqrs, Pusa Campus, New Delhi | 12.09.20-28.09.20 | Online mode | Dr. Gaikwad N.N. |
| 5 | Emerging trends in Seed production technology and quality control framework for effective seed supply chain of horticultural crops organized by University of Horticultural | 28.12.20-06.01.21 | Online mode | Dr. Shilpa P. |



| | | | | |
|---|---|---|---|---|
| | Sciences, Bagalkot | | | |
| 6 | Internet of Things organized by Engineering staff college of India, Hyderabad | 14.12.20-18.12.20 | Online mode | Dr. Shilpa P. Dr. Roopa Sowjanya, P |
| 7 | Recent Physio-Molecular Digital tools in Abiotic stress Management for crop Modelling organized by 2020 CAAST-VNMKV, Prabhani(MS) | 29.06.20-03.07.20 | Online mode | Dr. Roopa Sowjanya, P |
| 8 | Recent advances in entomology-New Dimensions to Invigorate the insect Pest Management organized by Department of Entomology College of Horticulture Bidar. | 07.12.20-18.12.20 | Online mode | Dr. Mallikarjun, H. |
| 9 | Foundation on Agricultural Research Service | 07.01.20-18.03.20 | ICAR-NAARM, Hyderabad | Rahul Devidas Damale |
| 10 | Institute Orientation Programme | 21.05.20-22.06.20 | ICAR-NRC on Pomegranate, Solapur | Rahul Devidas Damale |
| 11 | Professional Attachment Training | 28.08.20-11.12.20 | ICAR-NRC for grape, Pune | Rahul Devidas Damale |
| **b.** | **Technical staff** | | | |
| **c.** | **Administrative staff** | | | |
| 1 | Programme on "Administrative and Financial Management" for Administrative and Finance Officers of ICAR organized by ICAR-NAARM, Hyderabad | 23.11.20-27.11.20 | Online mode | Mr. R. B. Rai Mr. V. A. Shinde |
| 2 | Capacity Building Programme for CJSC Members of ICAR HQ's and ICAR-Institutes | 27.01.20-31.01.20 | ICAR-NAARM, Hyderabad | Mr. R. B. Rai |

## CONFERENCES, WORKSHOPS AND MEETINGS ATTENDED

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

**Table 2. Conference/ Seminar/ Symposia, *etc.* attended**

| S. No. | Title of Conference/ Seminar/ Symposia | Date | Venue | Name of the participant(s) |
|---|---|---|---|---|
| 1 | National Webinar on Under-utilized Crops for Augmenting Farmers' Income in Abiotic Stress Region | 10.08.2020 | Online, by NIASM, Baramati & SARAS, Baramati | Dr. K. Dhinesh Babu |
| 2 | International Colloquium on Crop Physiology (ICCP-2020) | 26.11.2020-27.11.2020 | Online, by Dept. of Crop Physiology, TNAU, Coimbatore | Dr. K. Dhinesh Babu |
| 3 | Webinar cum FDP series on "Current Progress and Future Prospects of Biotechnology", organized by CBIT, Hyderabad | 08.06.2020-13.06.2020 | Online | Dr. N.V. Singh |
| 4 | National Webinar on "Quality Production of Pomegranate in Arid Region during COVID-19", organized by SKRAU Bikaner | 02.07.2020-03.07.2020 | Online | Dr. N.V. Singh<br>Dr. Gaikwad N.N.<br>Dr. Shilpa P. |
| 5 | RCRC Voices from the Field Webinar with ICAR Leadership organized by SRIJAN and ICAR. | 03.07.2020 | Online | Dr. Jyotsana Sharma<br>Dr. N.V. Singh |
| 6 | National Webinar on "Present Status of PPVFRA, 2001 and Commercialization of Varieties Registered under PPVFRA, 2001" organized by MPKV, Rahuri | 11.08.2020 | Online | Dr. N.V. Singh |
| 7 | Webinar on "Advance Production Technology of Sub-Tropical Fruits (Mango, Litchi, Guava, Kinnow and Pomegranate) for Students, Farmers & Entrepreneurs under NAHEP" organized by Maharana Pratap Hort. Univ., Karnal | 04.09.2020-06.09.2020 | Online | Dr. N.V. Singh |
| 8 | Webinar on Career in Cosmetics Technology and Opportunities. Organized by Punyashlok Ahilyadevi Holkar Solapur Vidyapeeth, Solapur. | 23.07.2020 | Online | Dr. Gaikwad N.N. |
| 9 | National Webinar on Entrepreneurship opportunities in processing of fruits and vegetable of | 02.09.20 | Online | Dr. Gaikwad N.N. |

| | | | | |
|---|---|---|---|---|
| | the arid region organized by College of Horticulture, Sardarkrushiinagar Dantiwada Agriculture University, Jagudan (Gujarat) | | | |
| 11 | National Webinar for Pomegranate Farmers in Different Regions of India on Hasta Bahar Crop of Pomegranate: Package of Practices, Problems and Practical Solution. | 08.09.20-11.09.20 | Online | Dr. Gaikwad N.N.<br>Dr. Shilpa P. |
| 12 | International e-Conference on 'Genetics and Plant Breeding Research in Post Covid -19 Era' organized by Ch. Charan Singh University, Meerut, Uttar Pradesh, India. | 13.06. 20-14.06.20 | Online | Dr. Prakash G Patil |
| 13 | International e-Conference on 'Advances and Future Outlook in Biotechnology and Crop Improvement for Sustainable Productivity', organized by College of Horticulture, Bengaluru (University of Horticultural Sciences, Bagalkot) | 24.11.20-27.11.20 | Online | Dr. Prakash G Patil<br>Dr. Roopa Sowjanya, P |
| 14 | National webinar on "Importance and utilization of genetic resources in crop improvement" organized by Phoenix academy, Mysore, Karnataka | 05.09.20 | Online | Dr. Shilpa P. |
| 15 | International webinar on DUS testing data management /automation/image analysis Protection of Plant Varieties and Farmers' Rights Authority, New Delhi | 06.10.20-07.10.20 | Online | Dr. Shilpa P. |
| 16 | International webinar on Soft Skills: Create a positive and productive work environment organized by Biogene company | 03.11.20 | Online | Dr. Shilpa P. |
| 17 | International E-Conference on 'Advances and Future Outlook in Biotechnology and Crop Improvement for Sustainable Productivity' organized by Department of Biotechnology and Crop Improvement, College of | 24.11.20-27.11.20 | Online | Dr. Shilpa P.<br>Dr. Mallikarjun |



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| | Horticulture, Bengaluru | | | |
| 18 | 107 Indian Science Congress | 03.01.20-07.01.20 | UAS, GKVK, Bengaluru | Dr. Roopa Sowjanya, P |
| 19 | Women Science Congress | 06.01.20-07.01.20 | UAS, GKVK, Bengaluru | Dr. Roopa Sowjanya, P |
| 20 | National Conference on Climate Resilient Agriculture for Sustainable Production and Nutritional Security | 01.02.20-02.02.20 | UAS, DWD | Dr. Roopa Sowjanya, P |
| 21 | Webinar on Genomics for Food, Health and Nutrition organized by ICRISAT, Hyderabad | 14.05.20 | Online | Dr. Roopa Sowjanya, P |
| 22 | International web conference on Science, Engineering & Technology (IWCSET -2020) organized by Society For Technologicaly Advanced Materials Of India | 15.05.20-16.05.20 | Online | Dr. Roopa Sowjanya, P |
| 23 | Webinar on International Day of Biological Diversity organized by Biotecnika | 22.05.20 | Online | Dr. Roopa Sowjanya, P |
| 24 | Webinar on Microbiologist In Everybody organized by Biocon Academy and Biotecnika | 03.06.20 | Online | Dr. Roopa Sowjanya, P |
| 25 | International Webinar on Climate Smart Agriculture organized by NAHEP (ICAR)- CAAST, MPKV, Rahuri | 22.07.20 | Online | Dr. Roopa Sowjanya, P |
| 26 | Webinar on Advances in strawberry production organized by Department of Horticulture, Annamalai University | 24.07.20 | Online | Dr. Roopa Sowjanya, P |
| 27 | National Webinar on Abiotic Stress in Agriculture: Geospatial Characterization and Management Options | 27.08.20 | Online | Dr. Roopa Sowjanya, P |
| 28 | Future Perspectives in Agricultural Education organized by NAHEP (ICAR)- CAAST, IARI, New Delhi | 05.09.20 | Online | Dr. Roopa Sowjanya, P |
| 29 | Multidisciplinary approaches for plant disease management for achieving sustainability in agriculture organized by College of Horticulture, | 06.10.20-09.10.20 | Online | Dr. Roopa Sowjanya, P |



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| | Bengaluru (University of Horticultural Sciences, Bagalkot) | | | |
| 30 | International Webinar Series-Advances in Basic Plant Research in Relation to Climate Change organized by CAAST-CSAWM, MPKV, Rahuri | 08.10.20-09.10.20 | Online | Dr. Roopa Sowjanya, P |
| 31 | National Webinar Series on "Plant Health Management" Challenges - Interventions – Advances organized by Acharya N. G. Ranga Agricultural University S.V. Agricultural college, Tirupati | 21.12.2020 | Online | Dr. Mallikarjun |
| 32 | International colloquium on crop (ICCP 2020) physiology | 26.11.20-27.11.20 | Online | Dr. Mallikarjun |
| 33 | RAISE 2020 - Responsible AI for Social Empowerment organized by the PMO office | 05.10.20-09.10.20 | Online | Dr. Mallikarjun |
| 34 | World Food Day organized by the PMO office | 16.10.20 | Online | Dr. Mallikarjun |
| 35 | Krishi Mela MPAUT | 29.12.20 | MPAUT, Udaipur, Rajasthan | Dr. Mallikarjun |
| 36 | International Seminar on Transboundary Pests (ISTPM 2020) | 04.03.20-05.03.20 | Centre for Plant Protection Studies, Tamil Nadu Agricultural University Coimbatore, Tamil Nadu | Dr. Mallikarjun |
| 37 | National Webinar on "Hydroponics, Aeroponics and Vertical Gardening-New Approaches in Horticulture" organized by MHU, Karnal | 05.11.20-06.11.20 | Online | Dr. Mallikarjun |

**Table 3. WORKSHOPS ATTENDED**

| S. No. | Title of Workshop | Date | Venue | Name of Participant(S) |
|---|---|---|---|---|
| 1 | How to set up your food processing industry Organized by AFST(I) | 23.05.20 | Online Mode | Dr. Gaikwad N.N. |

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| | NIFTEM Chapter & ALABHYAM-NIFTEM Technical Society (NTS), NIFTEM, Sonepat | | | |
| 2 | Workshop on Gender Sensitization to Celebrate Seventh Anniversary of Notification of Act-The Sexual Harassment of Women at Workplace (Prevention, Prohibition and Redressal) Act, 2013 organized by Indian Council of Agricultural Research, New Delhi | 15.12.20 | Online Mode | Dr. Shilpa P. |
| 3 | Indian Pomegranate based antivirus medicine-AVIR" organized by ICAR-NRCP, Solapur | 17.10.20 | Online Mode | All scientists of ICAR-NRCP, Solapur |
| 4 | Vaishwik Bharatiya Vaigyanik Summit (VAIBHAV) organized by the PMO | 02.10.20-31.10.20 | Online Mode | Dr. Mallikarjun |

**Table 4. MEETINGS ATTENDED**

| S. No. | Title of meeting | Date | Venue | Name of participant(s) |
|---|---|---|---|---|
| **1** | Review meeting of All India Coordinated Research Project on Arid Zone Fruits (AICRP-AZF) / Online mode | 19.12.2020 | Online mode, by ICAR-CIAH, Bikaner | Dr. K. Dhinesh Babu, Dr. NV Singh, Dr. Mallikarjun H. |
| **2** | 24th Research Workers Group Meet, All India Coordinated Research Project on Arid Zone Fruits (AICRP-AZF) / Online mode | 28.02.2020-01.03.2020 | Online mode, by TNAU, Coimbatore | Dr. K. Dhinesh Babu Dr. Mallikarjun |
| **3** | Meeting called by the District Collector to tackle COVID-19 situation in Solapur | 25.05.2020 | Online | Dr. Jyotsana Sharma Dr. N.V. Singh |
| **4** | Third party evaluation of schemes-Technology Audit Meeting called by the DDG, ICAR | 16.09.2020 | Online | Dr. N.V. Singh |
| **5** | Drakshvadaalimb phal baag sheti ch plastic acchhadaan va nuksaangrast shadenet saathi plastic chandanchya anudaan babat baithak | 14.10.2020 | Online | Dr. Jyotsana Sharma Dr. N.V. Singh |
| **6** | Meeting with pomegranate growers of Maharashtra of Maharashtra Pomegranate Growers Association | 16.04.2020 | Online mode through Kisan Samvad | Dr. Gaikwad N.N. |
| **7** | Meeting with pomegranate growers of Maharashtra of Maharashtra | 23.04.2020 | Online mode through Kisan | Dr. Gaikwad N.N. |



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| | Pomegranate Growers Association | | Samvad | |
| **8** | Audio conference meeting with Sh. Subhash Deshmukh Former Minister for Cooperatives, Govt. of Maharsashtra and pomegranate growers of Solapur | 29.04.2020 | Online mode through Solapur Social Foundation, Solapur | Dr. Gaikwad N.N. |
| **9** | Delivered presentation on Pomegranate Processing to members of MahaFPO | 04.08.2020 | Online mode | Dr. Gaikwad N.N. |
| **10** | Delivered presentation Pomegranate value addition opportunities through facebook live. | 03.06.2020 | Online mode through Solapur Social Foundation, Solapur | Dr. Gaikwad N.N. |
| **11** | Delivered presentation on Entrepreneurship Opportunities in Pomegranate processing to students of Shriram College of Agril Engg. Paniv | 31.08.2020 | Online Mode | Dr. Gaikwad N.N. |
| **12** | *Meeting on modification of weather triggers for ambia bahar crop of pomegranate* | 15.02.2020 | *Central building commissioner of Agriculture Pune, Maharashtra* | Dr. Mallikarjun |
| **13** | 1st Meeting of the export promotion forum for pomegranate | 04.09.2020 | Video conference/ Virtual | Dr. Mallikarjun |
| **14** | *Meeting on modification of weather triggers for Mrig and ambia bahar crop of pomegranate* | 03.12.2020 | *Central building commissioner of Agriculture Pune, Maharashtra* | Dr. Mallikarjun |
| **15** | *Meeting on modification and finalization of weather triggers for Mrig and ambia bahar crop of pomegranate* | 18.12.2020 | *Central building commissioner of Agriculture Pune, Maharashtra* | Dr. Mallikarjun |
| **16** | *ICAR-NRC on grapes, Pune 23rd foundation day-cum Scientist-farmers interaction* | 24.01.2020 | *ICAR-NRC for Grape, Pune* | Dr. Mallikarjun |



**Table 5. TRAINING ORGANIZED**

| S. No. | Period | Name | Affiliated C | Duration | Guide | Title of training |
|---|---|---|---|---|---|---|
| 1 | 2020-21 (01.02.20 to 01.05.20) | Mr. Shubham Padwale | Lokmangal College of Agril. Biotechnol., Wadala | 3 months | Dr. N.V. Singh | "Molecular characterization of cultivated pomegranate variety using ISSR marker" |
| 2 | 2020-21 (01.02.20 to 01.05.20) | Ms. Reshma Kokare | Lokmangal College of Ag. Biotechnol., Wadala | 3 months | Dr. N.V. Singh | "Effect of biohardening on morphological, physiological and biochemical attributes of *in vitro* raised plants of pomegranate cv. Bhagawa" |
| 3 | 2020-21 (01.02.20 to 01.05.20) | Ms. Komal Kare | Lokmangal College of Ag. Biotechnol., Wadala | 3 months | Dr. N.V. Singh | "Influence of Plant growth regulators, media additives and their composition on rooting of pomegranate microshoots cv. Super Bhagawa" |
| 4 | 2020-21 (01.02.20 to 01.05.20) | Mr. Shinde M. Hanumant | College of Ag. Biotechnol., Loni | 3 months | Dr. N.V. Singh | "Plant beneficial microbes as effective bio-hardening agents for pomegranate saplings" |
| 5 | 2020-21 (01.02.20 to 01.05.20) | Mr. Bhosale S. Shatrughna | College of Ag. Biotechnol., Loni | 3 months | Dr. N.V. Singh | "Molecular characterization of wild and cultivated pomegranate genotypes using SSR markers" |
| 6 | 2020-21 (01.02.20 to 01.05.20) | Mr. Shinde S. Ankush | College of Agril. Biotechnol., Loni | 3 months | Dr. N.V. Singh | "Influence of media composition, plant growth regulators and supplements on micro-shoot multiplication efficiency of pomegranate cv. Super Bhagawa" |



## Guide/Co-guide for College Students 2020-21

| Degree | Subject | Year | Name of Student | College/university | Guide/ Co-Guide | Dissertation /Thesis Title/Status |
|---|---|---|---|---|---|---|
| B.Sc | Agricultural Biotechnology | 2020 | Snehal Hari Gund | Lokmangal College of Agricultural Biotechnology, Wadala | Dr. J. Sharma | Studies on bacteriophages for the control of pomegranate bacterial blight pathogen *Xanthomonas axonopodis* pv *punicae*, **(completed)** |
| **M.Sc** | Microbiology | 2020 | Sakshi Dave | Karunya Institute of Technology and Sciences, Coimbatore | Dr. J. Sharma | Soil Bacteriophages: Promising agents for management of bacterial blight of pomegranate caused by Xanthomonas axonopodis pv.punicae (**completed)** |
| | Plant Pathology | 2020 | Jaydip Sirsat | Vasantrao Naik Marathwada Krishi Vidyapeeth (VNMKV), Parbhani, Maharashtra | Dr. J. Sharma | Studies on Heart Rot of Pomegranate caused by Alternaria alternata (Fr.)Keissl ( Enrolled in March 2021, **work Initiated**) |
| | Agricultural Entomology | 2017 to 2020 | Sharad Shinde, | COA, Agril. Univ., Jabalpur | Dr. J. Sharma | Studies on pomegranate thrips *Scirtothirps dorsalis* Hood and its role in the epidemiology of bacterial blight,(Completed in 2020) |

Note: In addition to above other scientists of NRCP guided/ are guiding 10 B.Sc; 5 M.Sc and 2 Ph.D student.



# Publications

**Table 1: Papers in research journals**

| S. No. | Research paper | NAAS Rating |
|---|---|---|
| 1 | Singh, N.V., Shilpa, P., Sharma J., Roopasowjanya, P., Babu, K.D., Pal, R.K. and Patil, P.G. *et al.*, 2020. Comparative transcriptome profiling of pomegranate genotypes having resistance and susceptible reaction to *Xanthomonas axonopodis* pv. *punicae. Saudi Journal of Biological Sciences*, https://doi.org/10.1016/j.sjbs.2020.07.023 | 8.82 |
| 2 | Patil, P.G., Singh, N.V., Parashuram, S., Bohra, A., Sowjanya, R., Gaikwad, N., Mundewadikar, D.M., Sangnure, V. R., Jamma, S. M., Injal, A. S., Babu, K. D. and Jyotsana, S. 2020. Genome-wide characterization and development of simple sequence repeat markers for genetic studies in pomegranate (*Punica granatum* L.). *Trees structure and Function*, https://doi.org/10.1007/s00468-020-01975-y. | 7.80 |
| 3 | Patil, P. G., Jamma, S. M., Singh, N. V., Bohra, A., Parashuram, S., Injal, A. S., Gargade, V. A., Chakranarayan, M. G., Salutgi, U.D., Babu, K. D. and Sharma, J. 2020. Assessment of genetic diversity and population structure in pomegranate (*Punica granatum* L.) using new hypervariable SSR markers. *Physiology and Molecular Biology of Plants*, 26, 1249-1261. | 7.54 |
| 4 | Patil, P.G., Singh, N.V., Shilpa, P., Bohra, A., Mundewadikar, D.M., Sangnure, V.R., Babu, K.D. and Sharma, J. 2019. Genome wide identification, characterization and validation of novel mi-RNA based SSR markers in pomegranate (*Punica granatum* L.). *Physiology and Molecular Biology of Plants*, doi: 10.1007/s12298-020-00790-6. | 7.54 |
| 5 | Gaikwad, N.N., Kalal, A.Y., Suryavanshi, S.K., Patil, P.G., Sharma, D. and Sharma, J. 2021. Process optimization by response surface methodology for microencapsulation of pomegranate seed oil. *J Food Process Preserv.*, 00:e15561. https://doi.org/10.1111/jfpp.15561 | 7.41 |
| 6 | Kumar, A., Sharma, J., Munjal, V., Sakthivel, K., Thalor, S.K., Mondal, K.K., Chinchure, S. and Gharate, R. 2020. Polyphasic phenotypic and genetic analysis reveals clonal nature of *Xanthomonas axonopodis pv. punicae* causing pomegranate bacterial blight. *Journal of Plant Pathology* 69, 347–359, Doi: 10.1111/ppa.13128 | 7.15 |
| 7 | Meshram, D.T., Babu, K.D., Nair, A.K., Panigrahi, P. and Wadne, S.S. 2020. Response of Pomegranate (*Punica granatum* L.) to deficit irrigation System under field conditions. *Journal of Agrometeorolog*, 22, 126-135. | 6.47 |
| 8 | Singh, N.V., Parashuram, S., Sowjanya, R.P., Babu, K.D., Mundewadikar, D.M., Sangnure, V., Sharma, J. and Pal, R.K. 2020. Performance evaluation of plants raised through different propagation methods. *Indian Journal of Agricultural Sciences.* 90 (4), 685–88 | 6.25 |



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| 9 | Bhattacharya, D., Mohanta, P.K., Mishra, D., Sethy, K.C., Sharma, J., Pradhan, P.K., Samadiyan, V., Pouyanfar, M. and Mohamadpour, P. 2020. Punica granatum Vs COVID – 19 Fruit to Drug. *Research Journal of Pharmacology and Pharmacy* (ISSN:2572-8377),1-19. | IF 0.266 |
| 10 | Singh, N.V., Sharma, J., Dongare, M. D., Gharate, R., Chinchure, S., Parashuram, S., Patil, P.G., Babu, K.D. Mundewadikar, D.M., Tele, A.A., Birajdar, S.B., Karwa, N.N., Tetiya, M., Salutagi, U. and Kumar, A. 2020. Exploring the biocontrol potentiality of endophytes against pomegranate bacterial blight and endophyte mediated host plant response upon external application. *International Journal of Pest Management* **(**Under Review**).** | IF 1.907 |

| S.No. | BOOK CHAPTERS |
|---|---|
| 1 | Ahmad Pervez, Omkar, and Mallikarjun M. Harsur, 2020. *Coccinellids* on Crops: Nature's Gift for Farmers. In: Innovative Pest Management Approaches for the 21st Century Harnessing Automated Unmanned Technologies (Eds Akshay Kumar Chakravarthy), Spinger publishing Springer Nature Singapore Pte Ltd. 2020. |
| 2 | Basak, B.B., Maity, A., Biswas, D.R. 2020. Cycling of natural sources of phosphorus and potassium in organic agriculture for environmental sustainability. In: Biogeochemical Cycles: Ecological Drivers and Environmental Impact, Geophysical Monographs (Eds Dontsova K, Balogh-Brunstad Z, Le Roux G), John Wiley & Sons, Ins. pp. 285-299. |

| S.No. | POPULAR ARTICLES |
|---|---|
| 1 | Meshram, D.T., Babu, K.D., Wadane, S.S. and More, B.A. 2020. Water management in pomegranate (*Punica granatum* L.) during *hasta* Bahar. *Agriculture Observer*. 1(5), 26-31 |
| 2 | Singh, N.V., Patil, P.G., Shilpa, P., Babu, K.D. and Sharma, J. 2020. Elite pomegranate saplings-imperative for sustainable production. *Agriculture Observer*, 1(3), 95-98. |
| 3 | Singh, N.V., Patil, P.G., Babu, K.D. and Sharma, J. 2020. Model pomegranate orchard establishment for sustainable production. *Agriculture Observer*, 1(3), 38-42. |
| 4 | Singh, N.V., Maity, A., Mallikarjun, M.H., Sharma, J. Chaudhari, D.T. and Shinde, Y. 2020. *Mrig bahar/early mrig bahar*. *Agrowon*, 21st April, 2020: 8 |
| 5 | ज्योत्सना शर्मा, निलेश गायकवाड, आणि स्वाती सूर्यवंशी 2020. डाळींबाचे आरोग्यदायी गुणधर्म आणि प्रक्रिया उदयोग संधी, शेतकरी मासिक, मार्च २०२०, अंक १२, १९-२०. |
| 6 | Namrata A. Giri, Nilesh Gaikwad and Shilpa Parshuram 2020. Pomegranate (*Punica granatum* L.) medicinal fruit for human health. Kerala Karshakan e-Journal, P 20-25. |
| 7 | Patil, P.G., Singh, N.V. and Jyotsana, S. 2020. Genome-wide mining of SSR markers specific to Bacterial blight of pomegranate (*Xanthomonas axonopodis* pv. *punicae*). *Indian Phytopath News,* 3(2), April-June 2020. |

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| 8 | Patil, P.G., Parashuram, S., Singh, N.V. and Jyotsana, S. 2020. Marker technology for pomegranate genetic improvement. *Agriculture Observer*, 1 (3), August 2020. |
| 9 | Patil, P.G., Singh, N.V., Parashuram, S., Babu, K.D. and Jyotsana, S. 2020. Recent advances in pomegranate genomics. *Agriculture Observer*, 1 (3), August 2020. |
| 10 | Patil, P.G., Singh, N.V., Parashuram, S., Babu, K.D. and Jyotsana, S. 2020. Recent Developments in microRNA Research in Pomegranate. *Agriculture Observer*, 1(4), September 2020. |
| 11 | Roopa Sowjanya, P., Bharath Kumar, P., Jambagi and Shilpa, P. 2020, Pseudo testcross: Mapping Population for Tree Species. *Agriculture Observer*. 1(3), 92-95. |
| 12 | Roopa Sowjanya, P., Shilpa Parashuram, Bharath Kumar, P.Jambagi and Gazala Parveen. 2020. Plant Breeding and its Role in Pomegranate Improvement. *Agriculture Observer*, 1(6), 69-72 |
| 13 | Jyotsana Sharma, Ashish Maity, Mallikarjun, and Dinkar Chaudhary. 2020. Dalimba Falbageche Hamgamnihaya Niyoojan. Agrowon 27th October 2020. |
| 14 | Jyotsana Sharma, Ashish Maity, Mallikarjun, and Dinkar Chaudhary. 2020. Dalimbatil Burshijanya Mar Rogache Vyavstapan. Agrowon 29th October 2020. |
| 15 | Jyotsana Sharma, Ashish Maity, Somnath Pokhare, Mallikarjun, and Dinkar Chaudhary. 2020. Dalimb Pikatil Rogamche Vyavstapan. Agrowon 28th December 2020. |
| 16 | Jyotsana Sharma, Ashish Maity, Somnath Pokhare, Mallikarjun, and Dinkar Chaudhary. 2020. Dalimb Pikatil Baharnihay annadravyaye, Kid Vyavstapan. Agrowon 26th December 2020. |
| 17 | Jyotsana Sharma, Ashish Maity, Somnath Pokhare, Mallikarjun, and Dinkar Chaudhary. 2020. Dalimbavaril Roganche niyantran. Agrowon 27th October 2020. |
| 18 | Jyotsana Sharma, Ashish Maity, Somnath Pokhare, Mallikarjun, and Dinkar Chaudhary. 2020. Dalimb Baaget Annadravyacha Vaapar Kid Niyantran. Agrowon 18th August 2020. |
| 19 | Maity, A. and Sharma, J. 2020. IDIPM schedule: key to manage the bacterial blight disease in pomegranate. *Biotica Research Today*, 2(10), 1010-1015. |
| 20 | Maity, A., Choudhary, D.T., Wadne, S.S., Amrutsagar, V.M. 2020. Niryatyogya darjdar dalimb utpadansati santulit poshak purbath-sutra. Mrugadhara 79, 40-46. |
| 21 | Sharma, J., Maity, A., Mallikarjun, H. and Choudhary, D.T. 2020. Dalimb phalbagache hangamnihay niyojan. Agrowon page no.11. |
| 22 | Singh, N.V., Maity, A., Mallikarjun, M.H., Sharma, J. Chaudhari, D.T. and Shinde, Y. 2020. *Mrig bahar/early mrig bahar*. *Agrowon*, 21st April, 2020 page no. 8 |
| 23 | Sharma, J., Maity, A., Mallikarjun, H. and Choudhary, D.T. 2020. Dalimb phalbagache hangamnihay niyojan. Agrowon, 27th October, 2020 page no.11. |
| 24 | निलेश गायकवाड, के .दिनेश बाबु, स्वाती सुर्यवंशी व ज्योत्सना शर्मा) .२०२१ (डाळिंबाची प्रतवारी व साठवणूक. *शेतकरी मासिक*, जानेवारी २०२१ , अंक १०, २७- २९. (Marathi language) |
| 25 | शर्मा ज्योत्सना (2020) अनार का जीवाणु झुलसा रोग *Xanthomonas axonopodis* pv punicae : In: प्रकाश कुमार, रजेंदर सिंह तथा रशीद खान (संपादक), प्रोप मार्गदर्शिका) कृषि जलवायु खंड-2 बी) प्रकाशक- सूचना अनुभाग, कृषी निदेशालय, जयपुर, राजस्थान :615): pp 572- |



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| | 573. |
| 26 | शर्मा ज्योत्सना (2020) अनार का उकथा या मुरझान रोग (Pomegranate Wilt –*Ceratocystis fimbriata*) In: प्रकाश कुमार, रजेंदर सिंह तथा रशीद खान (संपादक), प्रोप मार्गदर्शिका) कृषि जलवायु खंड-2 बी) प्रकाशक– सूचना अनुभाग, कृषी निदेशालय, जयपुर, राजस्थान :615): pp 574 |
| 27 | शर्मा ज्योत्सना (2020) अनार का मूल ग्रंथि रोग (रूट कनॉट-*Meloidogyne incognita*) **In:** प्रकाश कुमार, रजेंदर सिंह तथा रशीद खान (संपादक), प्रोप मार्गदर्शिका) कृषि जलवायु खंड-2 बी) प्रकाशक– सूचना अनुभाग, कृषी निदेशालय, जयपुर, राजस्थान :615): pp 575 |
| 28 | शर्मा ज्योत्सना (2020) अनार का सूर्य आतपदाहा (Sun Scald) In: प्रकाश कुमार, रजेंदर सिंह तथा रशीद खान (संपादक), प्रोप मार्गदर्शिका) कृषि जलवायु खंड-2 बी) प्रकाशक– सूचना अनुभाग, कृषी निदेशालय, जयपुर, राजस्थान :615): pp 576 |
| 29 | शर्मा ज्योत्सना (2020) अनार का जीवाणु झुलसा रोग *Xanthomonas axonopodis* pv punicae : In: प्रकाश कुमार, रजेंदर सिंह तथा रशीद खान (संपादक), प्रोप मार्गदर्शिका) कृषि जलवायु खंड-2 बी) प्रकाशक– सूचना अनुभाग, कृषी निदेशालय, जयपुर, राजस्थान :615): pp 572-573 |
| 30 | शर्मा ज्योत्सना 2020. अनार का उकथा या मुरझान रोग (Pomegranate Wilt –*Ceratocystis fimbriata*) In: प्रकाश कुमार, रजेंदर सिंह तथा रशीद खान (संपादक), प्रोप मार्गदर्शिका) कृषि जलवायु खंड-2 बी) प्रकाशक– सूचना अनुभाग, कृषी निदेशालय, जयपुर, राजस्थान :615): pp 574. |

## PRESENTATIONS IN CONFERENCES/ SYMPOSIA/ SEMINAR/ OTHER FORA

| S.No. | ORAL PRESENTATIONS |
|---|---|
| 1 | Mallikarjun, H. 2020. Insect pests of pomegranate and their Integrated management in online training programme on Disease and Insect pest management of pomegranate in climate change (Havaamaanad Eruperinalli Dalimbe Roga Mattu Keet Nirvahane), June 26th 2020, organised by University of Horticultural Sciences (UHS) Bagalkot-Horticulture Extension Unit, Bengaluru, Karnataka. |
| 2 | Mallikarjun, H. 2020. Insect pests of pomegranate and their Integrated management in National webinar on quality production of pomegranate in arid regions, July 02-03rd 2020, organised by Swami Keshwananda Rajasthan Agricultural University, Bikaner, Rajasthan. |
| 3 | Mallikarjun, H. 2020. Exportable Indian Verities and Crop Management Strategies for |



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|---|---|
| | Export Qualities of Pomegranate Production in Online Webinar Exportable Indian Verities and Crop Management Strategies for Export Qualities of Pomegranate Production, July 28-28th 2020, organised by Regional Agriculture Management Extension Training Institute (RAMETI), Pune. |
| 4 | Mallikarjun, H. 2020. Important insect pests of Pomegranate and their Integrated management (Anaar Utpadan Aur Mulya Samvardhan: Adhunic Taknike), September 8-11th 2020, organized by ICAR-National Research Centre on Pomegranate, Solapur In Collaboration with Kisan Samwad, Pune ICAR- ATARI, Pune, Karnataka & Rajasthan, All India Pomegranate Growers Association, Pune, Akhil Maharashtra Dalimb Utpadak Sangh, Pune RajasthanPomegranate Growers Association, Bhilwara. |
| 5 | Mallikarjun, H. 2020. Important insect pests of Pomegranate and their Integrated management in Webinar on Advanced Production Technology of Sub-Tropical Fruits (Mango, Litchi, Guava, Kinnow and Pomegranate) for Students, Farmers and amp; Entrepreneurs under NAHEP, September 4-6th 2020, organized by Maharana Pratap Horticultural University (MHU) Karnal, Haryana, CCS HAU, Hisar Campus. |
| 6 | Maity, A. 2020. Phosphonic acid and other residues in pomegranate - An export issue. In: Workshop on Export oriented pomegranate production from arid region: issues and strategies, 8th January, 2020, organized at ICAR-Central Arid Zone Research Institute. |
| 7 | Maity, A. 2020. Nutrition management in pomegranate. In: National Webinar on Quality Production of Pomegranate in Arid Region during COVID-19, organized by SKRAU Bikaner. |
| 8 | Sharma Jyotsana 2020. Pomegranate Bacterial Blight Advances in Research and Management (YL NENE Memorial Award Lecture -2020). In: ISMPP 41 Annual Conference and National e-Symposium "Innovative Approaches in Plant Health Management**,** organized by Indian Society of Mycology & Plant Pathology, Udaipur, Rajasthan, India Jan 28-31, 2021 |
| 9 | Sharma Jyotsana 2020. Pomegranate Ancient Fruit in Modern Horticulture'In: Souvenir - International e-Symposium on: Diversification of Indian Agriculture: Ancient to Modern (DIAAM-2020); Eds Ronin RS et al., Publ. by Suresh Gyan Vihar University, Mahal Jagatpura, Jaipur: 13-14.(Keynote Address) |
| 10 | Jyotsana Sharma, Manjunatha N, Somnath S. Pokhare, Ramakant Gharte and Vijay Lokhande 2021. Six Step management practices: An effective, economical and eco-friendly technology to control bacterial blight in Pomegranate. National e-Conference: Plant Health and Food Security: Challenges and Opportunities, March 25-27, 2021, Indian Phytopathology Society, NEW DELHI, INDIA. |
| **S.No.** | **POSTERS** |
| **1** | Patil, P. G., Singh, N. V., Bohra, A., Raghavendra, K. P., Mundewadikar, D. M., Babu, K. D. and Sharma, J. 2020. "Chromosome Specific SSR markers development on Pomegranate". In: International e-Conference on Genetics and Plant Breeding Research in Post Covid -19 Era, Department of Genetics and Plant Breeding, Ch. Charan Singh University, Meerut, Uttar Pradesh, India, 13th -14th June, 2020. |
| **2** | Patil, P. G., Singh, N. V., Bohra, A., Raghavendra, K. P., Mane, R., Mundewadikar, D. M., Babu, K. D. and Sharma, J. 2020. "Genome-wide characterization of chromosome |



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| | specific hypervariable SSR markers for pomegranate genetic improvement". In: International e-Conference on Advances and Future Outlook in Biotechnology and Crop Improvement for Sustainable Productivity, Department of Biotechnology and Crop Improvement, College of Horticulture, Bengaluru (UHS), Karnataka, India, 24th -27th November, 2020. |
| **3** | Roopa Sowjanya P., Gangappa, E. and Ramesh**,** S. 2020. "Identification of good general combiners for grain crude protein and amino acid composition in maize (*Zea mays* L.) inbreds". In: National Conference on Climate Resilient Agriculture for Sustainable Production and Nutritional Security, Feb., 1-2, 2020, UAS, Dharwad. |
| **4** | Roopa Sowjanya P., N V Singh, Shilpa Parashuram and Patil, P.G. 2020. "Genetic diversity analysis of pomegranate genotypes by using molecular markers" under the session on the theme Plant Genetic Resource Management and Utilization. In: International E-Conference on Advances and Future Outlook in Biotechnology and Crop Improvement for Sustainable Productivity, organized by the Department of Biotechnology and Crop Improvement, College of Horticulture, Bengaluru during 24-27th November, 2020. |
| **5** | Jyotsana Sharma, Manjunatha N., Vijay Lokhande and Anita S. Aralimar, Bacteriophages as promising agents for the biological control of bacterial blight disease (*Xanthomonas axonopodis* pv. *punicae*) of pomegranate. National e-Conference: Plant Health and Food Security: Challenges and Opportunities March 25-27, 2021, ICAR-IARI, New Delhi |
| **6** | Manjunatha N., Jyotsana Sharma, Ramakant Gharte and Vijay Lokhande 2021. Harnessing endophytes as biological control agents for bacterial blight disease (*Xanthomonas axonopodis* pv. *punicae*) in pomegranate. National e-Conference: Plant Health and Food Security: Challenges and Opportunities, March 25-27, 2021, ICAR-IARI, New Delhi |
| **7** | Jyotsana Sharma, Manjunatha N., Vijay Lokhande and Anita S. Aralimar 2021. Bacteriophages as promising agents for the biological control of bacterial blight disease (*Xanthomonas axonopodis* pv. *punicae*) of pomegranate. National e-Conference: Plant Health and Food Security: Challenges and Opportunities, March 25-27, 2021, ICAR-IARI, New Delhi. |

| **S.No.** | **ANNUAL REPORT** |
|---|---|
| 1 | Maity, A., Babu, K.D., Singh, N.V., Patil, P.G., and Gaikwad, N. (Eds.) 2020. ICAR-NRCP Annual Report 2019, ICAR-National Research Centre on Pomegranate, Solapur – 413 255, Maharashtra. p.132 |

| **S.No.** | **MANUAL / COMPENDIUM/ OTHERS** |
|---|---|



| | |
|---|---|
| 1 | Sharma, J. and Singh, N.V., Compiled and information for Third Party Evaluation for my technology and also for NRCP contributions. |
| 2 | Singh, N.V., Sharma, J. *et al*., 2021. Promotion of pomegranate FLDs in MP and Chhattisgarh. *Krishi Science* 2(2): 26-30 (A report on TSP/STC) |
| 3 | Sharma, **J.** and Singh, N.V., Compiled and information for Third Party Evaluation for my technology and also for NRCP contributions. |

| S.No. | E-NEWSLETTER / E-PUBLICATIONS |
|---|---|
| 1 | Jyotsana Sharma, Mallikarjun, Babu, K.D., Somnath Pokhare and Debi Sharma 2020. Adhoc list of Agrochemicals with EU MRL and PHI for Pomegranate production 2020. nrcp website |
| 2 | Mallikarjun, Somnath, Pokhare and Jyotsana Sharma 2020. Trade/Brand/Commercial Names of Agro-Chemicals 2020. |
| 3 | Jyotsana Sharma, Ashis Maity, Mallikarjun, Dinkar Chaudhary, and Yuvraj Shinde 2020. Bimonthly Pomegranate Advisory in English for April-May 2020. |
| 4 | Jyotsana Sharma, Ashis Maity, Mallikarjun, Dinkar Chaudhary and Yuvraj Shinde 2020. Bimonthly Pomegranate Advisory in English for June-July 2020. |
| 5 | Jyotsana Sharma, Ashis Maity, Mallikarjun, Dinkar Chaudhary and Yuvraj Shinde 2020. Tingal Dalimbe Belege Salahe (Kannada). June-July 2020. |
| 6 | Jyotsana Sharma, Ashis Maity, Mallikarjun, Dinkar Chaudhary, and Vijay Lokhande 2020. Bimonthly Pomegranate Advisory in English for August- September 2020. |
| 7 | Jyotsana Sharma, Ashis Maity, Mallikarjun, Dinkar Chaudhary and Yuvraj Shinde 2020. Tingal Dalimbe Belege Salahe (Kannada). August-September (2020) |
| 8 | Jyotsana Sharma, Ashis Maity, Mallikarjun and Dinkar Chaudhary 2020. Bimonthly Pomegranate Advisory in English for October- November 2020. |
| 9 | Jyotsana Sharma, Ashis Maity, Mallikarjun and Dinkar Chaudhary, 2020. Tingal Dalimbe Belege Salahe (Kannada). October-November (2020) |
| 10 | Jyotsana Sharma, Ashis Maity, Mallikarjun, Somnath S. Pokhare and Dinkar Chaudhary 2020. Bimonthly Pomegranate Advisory in English for Dec. 2020-Jan. 2021. |

| S.No. | VIDEOS |
|---|---|
| | **ETV programs for Farmers** |
| 1 | Sharma Jyotsana. 2020. Management of Bacterial blight disease in Pomegranate: ETV facebook live program on Sakal Agrowon on 03.11.2020. Interacted with 'Agrowon' |



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|---|---|
| | Leading Agriculture Organisation in Maharashtra |
| 2 | Sharma Jyotsana. 2020**.** Management of Bacterial blight disease in Pomegranate: ETV facebook live program on Sakal Agrowon on 03.11.2020. Interacted with 'Agrowon' Leading Agriculture Organisation in Maharashtra |

**Passport Data of Plant Varieties:**

| S.No. | Passport Data of plant variety |
|---|---|
| 1 | Dhinesh Babu, K., Singh, N.V., Chandra, R., Sharma Jyotsana, Maity, A., Jadhav, V.T., Pal, R.K., Marathe, R.A., Jalikop, S.H., Sampathkumar, P. and Murthy, B.N.S. 2020. Passport Data of new pomegranate variety NRCP H-6 (Solapur Lal). Plant Variety Journal of India. 14 (5), 13-14. |
| 2 | Dhinesh Babu, K., Singh, N.V., Chandra, R., Sharma Jyotsana, Maity, A., Jadhav, V.T., Pal, R.K., Marathe, R.A., Jalikop, S.H., Sampathkumar, P. and Murthy, B.N.S. 2020. Passport Data of new pomegranate variety NRCP H-12 (Solapur Anardana). Plant Variety Journal of India. 14 (5), 15-16. |

**Patent:**

| | |
|---|---|
| 1 | Gaikwad Nilesh N. and Pal Ram Krishna "A Process of Extraction of Virgin Pomegranate Seed Oil with retention of bioactive compounds" Patent Filed Application No. 201611011366 E-2/528/2017/DEL. (Granted awaiting NBA agreement) |

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# Awards and Recognition

## AWARDS

| S.No. | Name of Scientist | Name of award | Year of award | Awarding organization |
|---|---|---|---|---|
| **Fellowship/ Associateship/Young Scientist/ other awards** | | | | |
| 1 | Dr. R.A. Marathe | Fellow of Society for Advancement of Research on Pomegranate – 2020 | 2021 | Society for Advancement of Research on Pomegranate (SARP), Solapur |
| 2 | Dr. K. Dhinesh Babu | Fellow of Society for Advancement of Research on Pomegranate - 2020 | 2021 | Society for Advancement of Research on Pomegranate (SARP), Solapur |
| 3 | Dr. Mallikarjun H. | Fellow of the Society for Biocontrol Advancement-2020 | 2020 | Society for Bio-control Advancement, ICAR-National Bureau of Agricultural Insect Resources, Bengaluru, Karnataka |
| **Best poster awards** | | | | |
| 1 | Dr. Prakash G. Patil | Best poster Award | 2020 | Department of Biotechnology and Crop Improvement, College of Horticulture, Bengaluru (UHS), Karnataka, India |

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# Budget Estimate

**Table 1: Financial outlay in 2020-21**

| Head of account | Rupees (in lakhs) | |
|---|---|---|
| | 2020-21 | |
| | Govt. Grant | |
| | RE | Expenditure |
| **(A) Recurring** | | |
| Establishment charge | 340.61 | 340.10 |
| T.A. | 5.47 | 5.47 |
| Other charges | 472.53 | 472.28 |
| **Total A** | 818.61 | 817.85 |
| **(B) Non-recurring** | | |
| Equipment | 17.26 | 17.10 |
| Minor works | 30.76 | 30.76 |
| Library | 0.00 | 0.00 |
| Furniture | 0.00 | 0.00 |
| Information technology | 4.21 | 4.21 |
| **Total B** | 52.23 | 52.06 |
| **(C) Loan & advances** | 0.00 | 0.00 |
| **(D) Pension** | 36.32 | 9.02 |
| **(E) Vehicles & vessels** | 0.00 | 0.00 |
| **Grand total (A+B+C+D)** | **907.16** | **878.93** |

**Table 2: Revenue receipt in 2020-21**

| S. No. | Items | Amount (Rs.) |
|---|---|---|
| 1. | Income from farm produce | 404400.00 |
| 2. | Income from royalty and publications | 27083.00 |
| 3. | Income from other sources | 2118155.00 |
| 4. | Interest on loans and advances | 16451.00 |
| 5. | Interest earned on short term deposits | 0.00 |
| 6. | Recovery of loans and advances | 287400.00 |
| 7. | Training programs | 170000.00 |
| 8. | Analytical testing fee | 19188.00 |
| 9. | License fee/ Guest house | 153651.00 |
| | **Total revenue receipt** | **3196328.00** |

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# Staff position & Personnel

## Joining/ Promotion/ Relieving

### STAFF POSITION

| Category | Sanctioned during XIIIth Plan | Staff position | Vacant |
|---|---|---|---|
| RMP | 1 | 0 | 1 |
| Scientific | 10 | 12 | -2 |
| Technical | 6 | 6 | 0 |
| Administrative | 11 | 5 | 6 |
| Supporting | 2 | 2 | 0 |
| **Total** | 30 | 25 | 5 |

### PERSONNEL

| **RMP** | | |
|---|---|---|
| Dr. (Mrs.) Jyotsana Sharma<br>Director (Acting) | | |
| **Scientific staff** | **Technical staff** | **Administrative staff** |
| Dr. K. Dhinesh Babu<br>Principal Scientist (Hort.-Fruit Science) | Sh. D.T. Chaudhari<br>Technical Officer | Sh. R.B. Rai<br>AAO |
| Dr. U.R. Sangle<br>Principal Scientist (Plant Pathology) | Sh. Yuvaraj Shinde<br>Technical Officer | Sh. V.A. Shinde<br>AF&AO |
| Dr. D.T. Meshram<br>Senior Scientist (Land and Water Management Engg.) | Sh. Diwakar Sawji<br>Technical Officer | Sh. Kiran Khatmode<br>LDC |
| Dr. Ashis Maity<br>Senior Scientist (Soil Science-Pedology) | Sh. Vijay Lokhande<br>Technical Assistant | Sh. A.S. Babar<br>LDC |
| Dr. N.V. Singh<br>Senior Scientist (Hort.-Fruit Science) | Sh. Mahadev Gogaon<br>Senior Technician | Sh. Vipin Dagar<br>LDC |
| Dr. Prakash G. Patil<br>Senior Scientist (Plant Biotechnology) | Sh. Govind Salunke<br>Senior Technician | **Supporting staff** |
| Dr. N.N. Gaikwad<br>Senior Scientist (Agril. Structures and Process Engg.) | | Sh. Shailesh Bayas<br>SSS |
| Dr. (Mrs.) Shilpa P.<br>Scientist (Genetics & Plant Breeding) | | Sh. Vishal Gangane<br>SSS |



| | | |
|---|---|---|
| Dr. Mallikarjun<br>Scientist (Agril. Entomology) | | |
| Ms. Roopa Sowajanya P.<br>Scientist (Genetics & Plant Breeding) | | |

**JOINING:**

Mr. Rahul Damale, Scientist (Biochemistry) joined ICAR-NRCP, Solapur on 04.04.2020 due to posting by ASRB

Dr. Somnath Pokhare, Scientist (Nematology) joined ICAR-NRCP, Solapur on 13.08.2020 due to transfer from ICAR- NRRI, Cuttack

Dr. Manjunatha, Scientist (Pathology) joined ICAR-NRCP, Solapur on 17.08.2020 due to transfer from ICAR- IGFRI, Jhansi

Dr. Namrata Ankhush Giri, Scientist (Food Technology) joined ICAR-NRCP, Solapur on 03.08.2020 due to transfer from ICAR-CTCRI, Thiruvananthapuram.

Dr. PS Shirgure, Principal Scientist (L&WME) joined ICAR-NRCP, Solapur on 12.11.2020 due to transfer from ICAR-CCRI, Nagpur

**PROMOTION**

Mr. Diwakar Sawaji, Sr. Technical Assistant promoted to Technical Officer wef. 15.04.2018

Mr. Yuvraj Shinde, Sr. Technical Assistant promoted to Technical Officer wef. 04.06.2020

Mr. Vijay Lokhande, Sr. Technician promoted to Technical Assistant wef. 03.06.2020

**RELIEVING**

Dr. UR Sangle, Principal Scientist (Pathology) relieved on 17.08.2020 due to transfer from ICAR-NRCP to ICAR- IGFRI, Jhansi

Dr. DT. Meshram, Principal Scientist (L&WME) relieved on 11.11.2020 due to transfer from ICAR-NRCP to ICAR-CCRI, Nagpur.

Mr. Diwakar Sawaji, Sr. Technical Assistant relieved on 07.08.2020 due to transfer from ICAR-NRCP to ICAR- CICR, Nagpur.

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

Agrisearch with a human touch

Solapur Lal

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