वार्षिक रिपोर्ट

Annual Report

2012-13

राष्ट्रीय अनार अनुसंधान केन्द्र

National Research Centre on Pomegranate

(भारतीय कृषि अनुसंधान परिषद)

(Indian Council of Agricultural Research)

सोलापुर – 413 255

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PREFACE

National Research Centre on Pomegranate was established at Solapur, Maharashtra in 2005 by the ICAR to augment the production, productivity and utilization of pomegranate through basic, strategic and applied research. For a stop gap arrangement, the centre was temporarily housed at the premises of Centre for Rabi Sorghum, Shelgi, Solapur. As the new office-cum-Laboratory building of the NRCP has been constructed, the centre is functioning at its new building at Kegaon, Solapur since June-July, 2012. Hi-tech polyhouses have been developed for mass multiplication of planting material produced through tissue culture and screening of germplasm for bacterial blight resistance. In view of global energy crisis, renewable sources of energy like solar energy (for operating solar street lamps) are being utilized. Besides, dug wells and bore wells, water harvesting structures and automated fertigation system have been developed for irrigation purpose.

The centre is committed to tackle some of the core challenges in pomegranate viz. availability of healthy and disease free planting material, developing varieties resistant/ tolerant to biotic and a biotic stresses, etc. The Centre has a collection of 345 germplasm (both indigenous and exotic) as field gene bank. Bacterial blight is one of the major biotic threats to production and productivity of pomegranate in India. Timely action, community approach and scientific awareness are the major remedies prescribed for wiping out bacterial blight in pomegranate. An Integrated Disease and Insect-Pest management (IDIPM) schedule developed by NRCP has been recommended as immediate mitigation measures. The adoption of IDIPM schedule had demonstrated successful management of bacterial blight in the states of Maharashtra, Karnataka and Andhra Pradesh. New research leads were provided by the institute in the areas of crop improvement, crop protection, post harvest technology and value addition of pomegranate with the establishment of nine state-of-the-art laboratories. Technologies for maximizing nutrient and water use efficiencies with respect to dry land horticulture are being developed. The NRCP has successfully developed the tissue culture protocol for mass production of healthy and disease free planting material. Bio-hardening protocol of tissue culture plants has been standardized. Production of disease free planting materials through hard wood cuttings with standardization of sanitation protocol exhibited a great promise for future. The institute website has been totally reconstructed as a show-window of technology to the world as well as an effective tool for interaction and dissemination of information on pomegranate research to all the stakeholders. During the period under report, one of the major contributions of NRCP was to build confidence among the pomegranate growers through interaction with large number of farmers, providing advisory services and organizing training programmes.

I express my sincere thanks to Dr. S. Ayyappan, Secretary, DARE and Director General ICAR for providing me an opportunity to serve this institute to the best of my capacity. I express my deep sense of gratitude to Dr. N.K. Krishna Kumar, DDG (Horticulture) for his unstinted support and guidance. I am thankful to Dr. C.D. Mayee, former Chairman ASRB and Chairman, RAC of NRCP and IMC members for taking keen interest in providing valuable guidance and suggestions for overall development of the Institute. Last but not the least, I am thankful to all the scientific, technical, administrative and supporting staff of the institute for their wholehearted support and cooperation.

June 29, 2013
Solapur

(R.K. Pal)
Director

NRCP : AN INTRODUCTION

India is one of the leading countries in pomegranate acreage and production worldwide. The area under cultivation of Pomegranate in India has grown by 10.73 per cent during last seven years from 96.9 thousand hectare to 107.3 thousand hectare. Maharashtra experienced a very rapid growth in Pomegranate area during the last 20 years from 4.6 thousand ha to 82.0 thousand ha and accounts for 76.40 per cent of the total cultivated area under pomegranate in the country.

Other major pomegranate growing states are Karnataka (13.6 thousand ha), Andhra Pradesh (2.8 thousand ha) and Gujarat (5.8 thousand ha). In recent years, pomegranate cultivation has also been started in Rajasthan, Orissa, Chhattisgarh, Uttarakhand and Madhya Pradesh. Although India is the largest producer of pomegranate in the world, its productivity (6.9 t/ha) is far below to Turkey (27.25 t/ha), Spain (20.00 t/ha), USA (16.7 t/ha), Israel (12.5 t/ha) and Iran (10.8 MT/ha). During the year 2011-12 India exported 30,000 MT of Pomegranate to the global market as compared to 86,000 MT by Turkey and 60,000 MT by Iran. Therefore, India has a tremendous potentiality to bridge this huge yield and export gaps.

National Research Centre on Pomegranate was established at Solapur, Maharashtra in 2005 by the ICAR to augment the production, productivity and utilization of pomegranate through basic, strategic and applied research. For a stop gap arrangement the centre was temporarily housed at the premises of Centre for Rabi Sorghum, Shelgi, Solapur. But the new office-cum-laboratory building of the NRCP has been constructed and the centre is functioning at its new building at Kegaon, Solapur since June-July, 2012. The centre has developed experimental farms sprawling over 46.26 ha area at Kegaon and Hiraj villages out of which 7 ha area has already been brought under pomegranate orchards. Hi-tech polyhouses have been constructed for R&D work on mass multiplication of planting material produced through tissue culture and screening of germplasm for bacterial blight resistance. The experimental farms encompass the state-of-the-art of automatic fertigation facilities and water harvesting structures. The Centre has an excellent collection of pomegranate germplasm at its field gene bank comprising of wild pomegranate accessions, indigenous collections from North-Eastern state, Western Himalayas and 92 exotic collections from California, Afghanistan and Iran. Major thrust areas of research on pomegranate at NRCP are Crop Improvement, Crop Production, Crop Protection and Post-harvest Technology.

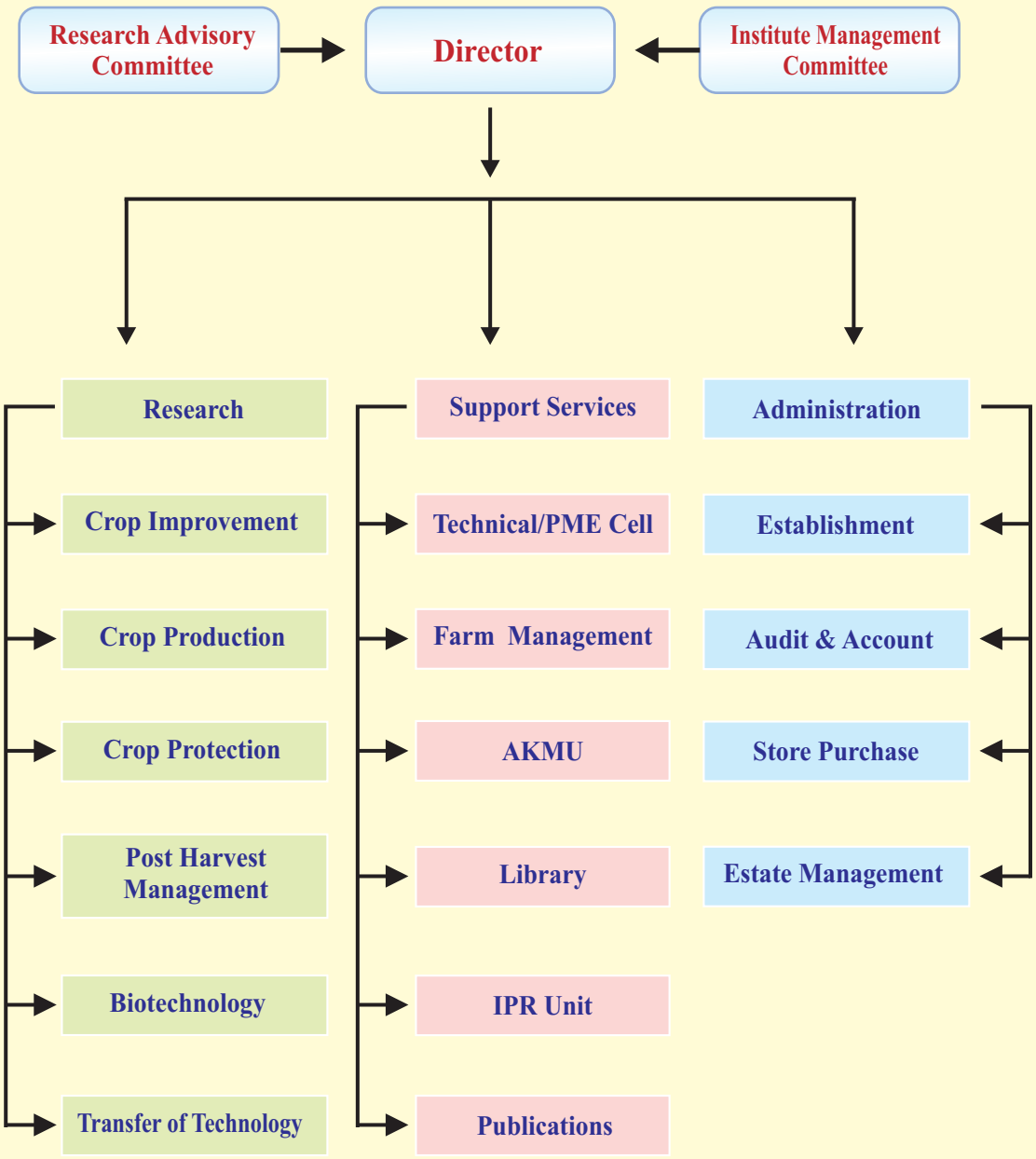
The mandates of the centre are as follows

- To develop suitable varieties with high yield potential and quality fruits having resistance to biotic and abiotic stresses
- To undertake basic, strategic and applied research for developing sustainable technologies for quality fruit production and post harvest value addition
- To transfer technology to pomegranate growers and other stakeholders

NRCP had made significant contribution in identifying the pathogen causing bacterial blight and wilt and their mitigation using Integrated Disease and Pest Management Schedule (IDIPM). For the first time technology for production of low cost disease free planting material through hard wood cutting with 85% success has been standardized. Similarly, a package of practice for establishment of orchard through tissue culture plants is in the process of development. NRCP is closely associated with the All India Pomegranate Growers' Association and Maharashtra Pomegranate Growers' Association. A large number of farmers are regularly visiting the centre for regular technological guidance on various aspects of pomegranate cultivation. The centre also

has close collaboration with State Department of Horticulture, State Agricultural Universities, KVKs and other stakeholders associated with pomegranate cultivation. The centre has reconstructed its website with all the relevant information on pomegranate research and extension research and extension with photogallery, videogallery, farmers' corner and free downloadable publications. During the short span of six months more than 9800 hits on this website have been recorded both at national and international level.

National Research Centre on Pomegranate



Organizational Structure

कार्यकारी सारांश

भाभा परमाणु अनुसंधान केंद्र की सहायता से 'गणेष' किस्म में बीजों के गामा विकिरण के उपरान्त, प्रयोगात्मक प्रक्षेत्र परिस्थितियों में फल गुणवत्ता मापदण्डों के आधार पर छः उत्तम प्रदर्शन करने वाले उत्परीवर्ती प्राप्त हुए (पौध संख्या 320, 348, 375, 388, 391, 528)।

उत्पादन (कि.ग्रा./पेड़) की दृष्टि से व्यवसायिक किस्म 'जी-137' (12.90 कि.ग्रा.), 'गणेष' (12.53 कि.ग्रा.) तथा 'जेलोर सीडलेस' (11.20 कि.ग्रा.) का प्रदर्शन 'भगवा' (10.20 कि.ग्रा.) की तुलना में ज्यादा बेहतर पाया गया। फल क्वालिटी, कुल घुलनशील ठोस / अम्ल अनुपात 'जेलोर सीडलेस' (36.11), 'रुबी' (34.56), 'अरक्ता' (34.44) एवं 'मृदुला' (33.92) में 'भगवा' (31.90) की तुलना में ज्यादा पाया गया। फलों के भौतिक-रासायनिक मापदण्डों के आधार पर रा.अ.अनु.के संकरों का मूल्यांकन करने पर संकर 6 एवं 14, 'भगवा' की तुलना में ताज़े सेवन हेतु ज्यादा बेहतर पाये गए।

रा.अ.अनु.के संकर 6 में सबसे ज्यादा कुल घुलनशील ठोस/ अम्ल अनुपात (39.88) तथा इसके बाद 'संकर 14' में (39.53) पाया गया। छः संकरो में अम्लता 3.0 प्रतिशत से ज्यादा पायी गई। इन संकरों का इस्तेमाल (रा.अ.अनु.के.संकर) अनारदाना के लिए किया जा सकता है।

जिन 12 जननद्रव्यों को कैलिफोर्निया, संयुक्त राज्य अमेरिका से लाया गया था उनको रा.पा.अ.स. ब्युरो, भोवाली से रा.अ.अनु.के., सोलापुर में इस वर्ष स्थानांतरित किया गया है। इसके फलस्वरूप प्रक्षेत्र जीन कोष में अनार जननद्रव्यों की कुल संख्या बढ़कर 282 हो गयी है। इज़रायल तथा संयुक्त राज्य अमेरिका कि मुख्य किस्म 'वंडरफुल' के कर्तनों को पौधशाला में व्यवस्थित तरिके से रखा गया है।

'भगवा' के प्रक्षेत्र परिवर्त के अलावा किसान प्रक्षेत्र में अच्छा प्रदर्शन करने वाले एक परिवर्त को पटकुल, जिला, सोलापुर से एकत्रित किया गया है। इस प्ररिवर्त का मुल्यांकन रोग आपतन तथा तीव्रता के लिए किया जाएगा।

आठ उपयोगी जननद्रव्यों को दृढ़ काष्ठ कर्तन द्वारा प्रवर्धित किया गया तथा इनमें से आई सी 1194, आई सी 1204 एवं आई सी 1205 का प्रदर्शन कर्तन सफलता की दृष्टि से (85.00, 83.33, एवं 81.67% क्रमशः) बालू, नारियल के छिलके तथा केंचुए की खाद के मिश्रण पर संतोषजनक पाया गया। बीस से.मी. लम्बे 'भगवा' के कर्तनों ने बालू, नारियल के छिलके तथा केंचुए की खाद के मिश्रण पर 82.5% कर्तन सफलता अर्जित की जो यह इंगित करता है कि, कर्तन सफलता 20 तथा 15 से.मी. लम्बे कर्तनों के बीच गैर सार्थक रुप से भिन्न है।

'भगवा' शाखवृन्त को जंगली अनार जननद्रव्यों के मूलवृन्त पर कलम करने पर 80-100% के बीच कलम सफलता दर्ज़ कि गई तथा भगवा शाखवृन्त की वृध्दि जंगली अनार जननद्रव्यों के ऊपर 'भगवा' मूलवृन्त की तुलना में सार्थक रुप से अधिक पायी गई। पैच के आकार की 'भगवा' कली का चष्मा अनार के जंगली जननद्रव्यों पर लगाने से 90% सफलता जनवरी, 2013 में सोलापुर की परीस्थितियों में दर्ज़ की गई।

एम एस स्थापन माध्ययम + बीएपी+ एनएए+ एडनीन सल्फेट + आर्जिनीन पर कार्तोतक के रुप में पूर्व उपचारित नोडल सीगमेंट्स (कार्बेन्डाझीम+मेटालेग्झील (4%) मेन्कोज़ेब (64%)+स्ट्रेप्टोसाइक्लीन, 30 मीनट के लिए) के इस्तेमाल से 80% कल्चर स्थापन पाया गया। सबसे अधिक औसत शूट लम्बाई (3.56 से.मी.) तथा साइड शूट्स की संख्या(6.03) सायटोकायनीन तथा थायमीन संपन्न माध्ययम पर पाया गया।

ऑक्सिन सम्पन्न तथा पोषक तत्व अल्पतर माध्ययम पर सबसे पहले जड़ (8.99 दिन) तथा सबसे अधिक संख्या में जड़ प्रति शूट (5.33) प्राप्त हुए। सूक्ष्म प्रवर्धित पौधों का जैव कठोरीकरण प्रगति पर है।

अनार में 'भगवा' किस्म काली मिट्टी पर (90 से.मी. गहराई तक) अच्छा विकास करता पाया गया, जबकि 'गणेष' किस्म हल्की तथा काली दोनों प्रकार की मृदाओं पर अच्छे तरीके से वृद्धि करता पया गया है, परन्तु दुर्व्यवस्थित जल निकास के स्थिति में 'गणेष' की तुलना में 'भगवा' ज्यादा अच्छा प्रदर्शन करते हुए पाया गया।

अनार में वानस्पतिक वृद्धि तथा फल उत्पादन भारी (30-60 से.मी) तथा दोमट मिट्टी पर ज्यादा बेहतर पाया गया। भारी मिट्टी की गहराई बढ़ने पर वानस्पतिक वृद्धि तथा फल उत्पादन में भारी गिरावट पायी गई। पौधों के दोनों तरफ दो लेटरल पर छः ड्रीपरों (2.0 ली/घण्टा) की सहायता से सिंचाई का पानी देना पौध वृद्धि की दृष्टि से सबसे उचित पाया गया। दो ड्रीपरों की सहायता से सिंचाई करना पोषक तत्व निष्कर्षण, पौध वृद्धि तथा मृदा प्रोफाइल में नमी वितरण की दृष्टि से उचित नहीं पाया गया। अनार की मौसमानुसार जल आवश्यकता दो वर्ष के पौधों के लिए 3176 ली/वर्ष/पेड़ पायी गई।

सामान्यतः सूक्ष्म पोषक तत्वों की मात्रा फलों में, फल वृध्दि से साथ-साथ तनुकरण प्रभाव (डायलूशन प्रभाव) के कारण घटती जाती है, क्योंकि फलों का विकास पोषक तत्व संचयन दर की तुलना में काफी तेज़ होता है।

फल विकास के शुरुआती दौर में पोषक तत्वों की अधिक माँग रहती है। पोटाश का संचयन फलों में सबसे ज्यादा होता है तथा उसके बाद नत्रजन और फास्फेट का होता है। फल विकास के शुरुआती दौर में ज्यादातर गुरु एवं सूक्ष्म पोशक तत्वों की अधिक मात्रा यह इंगित करती है कि, फलस्थापन तथा वृद्धि से पहले पौधों को उचित मात्रा में गुरु तथा सूक्ष्म पोषक तत्व देना चाहिए।

जैन्थोमोनास एक्ज़ेनोपोडिस पी.वी. *प्यूनकी* के लक्षण प्रारुपी अध्ययन से यह पता चला कि, इसके विभिन्न आइसोलेट्स में ब्लाइट आपतन एवं तीव्रता के लिए भिन्नता है जबकि, कल्चरल लक्षणों के लिए कोई भिन्नता नहीं है। *जैन्थोमोनास एक्ज़ेनोपोडिस* पी.वी. *प्यूनकी* के विभिन्न जगहों तथा समयों पर एकत्रित किये गए आइसोलेट्स के तुलनात्मक जीनोमिक्स से यह ज्ञात हुआ की जिस नस्ल से बैक्टीरीयल ब्लाइट रोग अनार में फैलता है वह एकमात्र उग्र वंशावली की वजह से हो सकता है।

अध्ययन से यह निष्कर्ष निकलता है कि, बैक्टीरीयल ब्लाइट प्रभावित पेड़ों पर तना कोढ़ का बढ़ना *फ्यूज़ेरियम आक्सीस्पोरम* के माध्यमिक संक्रमण से होता है, जो *जैन्थोमोनास एक्ज़ेनोपोडिस* पी.वी. *प्यूनकी* के प्राथमिक संक्रमण के बाद पनपता है। बरसात तथा छिड़काव की बूँदों का जीवाणु के प्रसार में सकारात्मक भूमिका पायी गई है। सहसम्बधन अध्ययन से यह पता चला कि, नत्रजन तथा मैंग्नीज की पत्तों में अधिक मात्रा बैक्टीरीयल ब्लाइट तीव्रता को कम करती है।

9 भिन्न क्रासेस से प्राप्त पहली पिढ़ी के संकरों का बैक्टीरीयल ब्लाइट के लिए व्यापक स्क्रिनिंग कृत्रिम निवेषन द्वारा किया गया। इस अध्ययन में ज्यादातर संकर ब्लाइट के प्रति अतिसंवेदनशील पाये गए है जिनमें 10% से ज्यादा ब्लाइट तीव्रता पायी गई। केवल पाँच संकर ऐसे थे जिनमें कुछ हद तक ब्लाइट सहनशीलता पायी गई तथा इन संकरों पर ब्लाइट तीव्रता 5% से कम थी।

अनार में मर रोग की रोकथाम के लिए 46 मूल परिवेषी (12 जीवाणु 24 कवक तथा 10 एक्टिनोमा-इसीटिज) आइसोलेट्स को *सीरेटोसीस्टीस फिम्ब्रीयाटा* के खिलाफ इस्तेमाल किया गया। समयान्तराल अवलोकन से यह ज्ञात हुआ कि, मर रोग के लक्षण एक मास के बाद दिखने लगते हैं। 0.6 मी. चौड़ी, 0.3 मी. गहरी तथा 0.3 मी. ऊँची क्यारी वाले संप्रयोगों में *सी.फिम्ब्रीयाटा* सबसे कम पाया गया परन्तु *सी.फिम्ब्रीयाटा* की कालरा अवस्था (*सी. एडीपोज़ा*) तथा *फ्यूज़ेरियम आक्सीस्पोरम* इन संप्रयोगों से लिए गए नमूनों में सबसे ज्यादा पाया गये गए। इन संप्रयोगों में सबसे अधिक *फ्यूज़ेरियम* तथा उसके बाद सूत्रकृमि पाये गए। *सी.एडीपोज़ा* की रोगजनकता का विस्तृत अध्ययन जरुरी है।

उत्तर सोलापूर, दक्षिण सोलापूर, पंढ़रपूर और सांगोला तहशीलों में फल भेदक का आपतन नगण्य पाया

गया, जबकि मोहोल में आपतन 10% से कम था । भेदक पीड़कों में से फलभेदक (*ड्यूडोरिक्स अाइसोक्रेट्स*) तापमान से सकारात्मक सहसम्बधन तथा सापेक्षिक आद्रता एवं बारिश से नकारात्मक सहसम्बधन दर्शाता पाया गया। थ्रीप्स संख्या 'गणेष' तथा 'भगवा' किस्मों पर तापमान, सापेक्षिक आद्रता तथा बारिश से नकारात्मक सहसम्बधन दर्शाता पाया गया।

थायमिथोग्ज़ाम 5 ग्राम/पौध की दर से इस्तेमाल करने पर सबसे प्रभावशाली (1.88 प्रति पौध) तथा फिप्रोनिल 5 ग्राम/पौध थ्रीप्स रोकने में सबसे कम प्रभावशाली (3.52/पौध) पाया गया। इस अध्ययन से यह भी ज्ञात हुआ कि, थायमिथोग्ज़ाम की अधिक मात्रा (5 ग्राम/पौध से ज्यादा) थ्रीप्स को रोकने प्रभावशाली नहीं पायी गई।

फल चूशी शलभ (फ्रूट सकिंग मॉथ) पर पाली प्रोपायलीन के बीना बुने हुए बैग के प्रभाव का अध्ययन करने पर यह पाया गया की जिन संप्रयोगों में फलों को बैग से ढ़का गया था, वहाँ नुकसान 17.5% पर ही रुक गया, जबकि कंट्रोल में यह नुकसान पंद्रह दिनों के बाद 23.5% तक पहुँच गया था । पक्वातांक अध्ययन से यह ज्ञात हुआ कि, किस्म 'गणेष', 'रुबी' एवं 'भगवा' में फल परिपक्व पुष्पन के 150, 175 और 180 दिनों के बाद, क्रमशः होता है।

आर.टी.एस. पेय पदार्थ के प्रोटोकाल का मानकीकरण रा.अ.अनु.के द्वारा किया गया है ।

अनार के रस से फरमेंटर का इस्तेमाल करके वाइन बनाया गया तथा उसका संवेदी मूल्यांकन किया गया, यद्यापि वाइन के निर्मलीकरण के लिए शोध जारी है।

EXECUTIVE SUMMARY

Gamma irradiation of seeds of pomegranate cv. Ganesh at BARC, Mumbai paved the way for identification of six promising mutants (No. 320, 348, 375, 388, 391, 528) for various fruit quality parameters under experimental field condition.

Among the commercial varieties evaluated for table purpose, G-137, Ganesh, Jalore Seedless were found to be superior to Bhagwa with respect to fruit yield. The TSS/acid ratio of Jalore Seedless, Ruby, Arakta and Mridula were found to be superior to Bhagwa with respect to their utility for table purpose. Among the NRCP hybrids evaluated physico-chemical parameters, Hybrid -6, 14 were found to be superior to Bhagwa for fruit quality and hence considered suitable for table purpose. NRCP H-6 had highest TSS/acid ratio (39.88) followed by NRCP H-14 (39.53). Six hybrids were found to have acidity more than 3.0% viz., NRCP H-4, H-12,H-11,H-15, H-1 & H-3. These hybrids could be useful for anardana preparation.

Ninety two exotic accessions of pomegranate introduced from California, USA were shifted from NBPGR, Bhowali to NRCP, Solapur during this year. This has enhanced the total collection under Field Gene Banks of National Repository of pomegranate germplasm to two hundred and eighty two. Cuttings of cultivar Wonderful, the leading pomegranate cultivar of USA and Israel were collected and maintained in nursery. Besides, a desirable field variant of pomegranate cv. Bhagwa was collected from farmers field in Patkul, Solapur. This field variant is being evaluated for its further performance with respect to disease incidence & severity.

Among eight promising germplasm multiplied through hardwood cutting, IC 1194, IC 1204 and IC 1205 displayed good cutting success (85.00, 83.33 and 81.67 per cent, respectively) on planting medium consisting of mixture of sand, cocopeat and vermicompost. Different length of hardwood cuttings of 'Bhagwa' on various planting media revealed 20 cm long cuttings on mixture of sand, cocopeat and vermicompost gave 82.50 percent success at 90 days after planting and no significant reduction in cutting success has been observed by reducing the length of cutting from 20 cm to 15 cm.

The graft success ranged from 80-100 per cent at 60 days after grafting when 'Bhagwa' was grafted on seven different wild accessions as rootstocks and the shoot growth of 'Bhagwa' was significant on wild accession as compared to 'Bhagwa' on 'Bhagwa'. Patch budding of 'Bhagwa' on wild germplasm as rootstocks gave more than 90 percent success during Jan, 2013 under Solapur conditions.

Pretreated nodal segments (Carbendazim + Metalaxyl (4%) + Mancozeb (64%) + Streptocycline for 30 min.) as explants resulted in good culture establishment (80.00 %) on MS basal medium + BAP + NAA + Adenine sulphate + Arginine medium. The maximum average shoot length (3.56 cm) and the highest number of side shoots (6.03) were obtained when sprouts were inoculated on cytokinin and thiamine rich media. Shoots on auxin rich and low salt media took minimum days to root (8.99) and produced the maximum number of roots per shoot (5.33). Biohardening of *in vitro* raised plants of pomegranate cv. 'Bhagwa' is under progress.

Bhagwa variety of pomegranate grows well in black clayey soils even up to depth of 90 cm and is more tolerant to poor drainage conditions compared to Ganesh variety. While, Ganesh variety grows equally well in light textured soils but is more susceptible to poor drainage conditions compared to Bhagwa variety.

Vegetative growth and fruit yield of pomegranate plants were better in heavy textured soils having depth of 30-60cm as well as in loamy textured soils. Drastic reduction in growth and yield

was observed with the increasing depth beyond 60cm heavy textured soils. Application of irrigation water through 6 (2 lph) drippers fixed on two laterals placed on both side of the plant was found to be the best method for plant performance. Application of irrigation water through two drippers was not better with regards to nutrient uptake, plant growth as well as moisture distribution in soil profile. Application of irrigation water on daily basis as well as at 4-5 days interval basis was not much effective under both soil types.

The micronutrient concentration in fruit declined throughout the fruit growth period due to dilution effect as the growth of the fruit was much faster than the accumulation rate of nutrients.

There is a high demand for mineral nutrients in the initial period for fruit growth and development. Potassium was the most accumulated nutrient in fruit, followed by N and P. High concentration of most of the macro and micronutrients in fruit of pomegranate in early stage of growth reveals that it is necessary to supplement a good balance of macro and micronutrients before growth and fruit set of pomegranate to satisfy their requirement to mineral nutrients.

Phenotypic studies on *X. axonopodis* pv. *punicae* revealed that although there are variation among isolates for blight incidence and severity, the isolates did not vary in cultural characters. The comparative genomics of *Xanthomonas axonopodis* pv. *punicae* based on isolates obtained, so far, from diverse geographical location and distinct time points revealed that that the strain causing bacterial blight of pomegranate could be a single virulent lineage. It is concluded that the stem cankers in bacterial blight affected orchards enlarge due to secondary infection of fungi like *Fusarium oxysporum*, after initial necrosis by *X. axonopodis pv. Punicae*. Regarding the movement of *X. axonopodis* pv. *punicae* in air it is found that spray/rain water splashes have a positive role in the dissemination of the pathogen. It is inferred from the correlation study that higher N and Mn content in pomegranate foliage would reduce the bacterial blight disease severity.

Extensive screening of F1 hybrid seedling population derived from 10 different crosses for their tolerance to bacterial blight disease was undertaken through artificial inoculation. It revealed that most of the population was moderately to highly susceptible showing more than 10 per cent blight severity, except 5 hybrids which showed some tolerance with less than 10 per cent blight severity.

Regarding the wilt disease of pomegranate, 46 rhizosphere isolates were obtained for screening against *Ceratocystis fimbriata causing wilt of pomegranate.* Periodical observations revealed that wilt symptoms initiated within one month of inoculation. The treatments with bedding system 0.6m width x 0.3m depth x 0.3m ridge, showed lowest wilt and *C. fimbriata* population, however *Chalra* state of another *Ceratocystis* sp. *C. adiposa* and *F. oxysporum* was found in highest number of samples in these treatments. The pathogenicity of *Chalra* state of *C. adiposa* needs to be studied. In addition *Fusarium oxysporum* was found in maximum frequency followed by nematodes in this treatment which is required to be confirmed through further studies.

The incidence of fruit borer (*Deuodrix isocrates) in Mohol taluk was found to be 10 per cent whereas it was nil in* North Solapur, South Solapur, Pandharpur and Sangola *taluks of* Solapur district. Among the borer pests, fruit borer, *Deudorix isocrates* showed positive correlation with temperature and negative correlation with relative humidity and rainfall on both the varieties. Thrips showed negative correlation with temperature, humidity and rainfall on both the var. Ganesh and Bhagwa.

Application of Thiomethoxam @ 5g/plant recorded the lowest population of thrips (1.88 no./plant) while fipronil @ 5g/plant recorded the highest (3.52 no./plant). Effect of bagging of PP Non-woven bags was tested against the fruit sucking moths. In treatments 17.5 per cent of fruits damage remained same whereas in control 17 per cent of fruit damage

increased to 23.5 per cent after 15 days of bagging.

The maturity indices study revealed that pomegranate cultivars Ganesh, Ruby and Bhagwa attain maturity at 150,175 and 180 days after anthesis respectively. Protocol was standardized for preparation of RTS beverage from pomegranate juice. Wine has been prepared from pomegranate juice using the fermentor and sensory evaluation of pomegranate wine was carried out.

RESEARCH ACHIEVEMENTS

1. CROP IMPROVEMENT

1.1. Improvement through induced mutation

1.1.1 Evaluation of gamma irradiated population of pomegranate cv. Bhagwa

In order to create variability, the seeds of cv. Bhagwa and Ganesh were exposed with 3-30 kR gamma irradiation during 2007 and seedlings were raised in big size pots till July 2010 and subsequently planted in the field during 2010 for evaluation. The fruits of Bhagwa mutants were harvested from 4 year old trees and evaluated for their physico-chemical traits. Maximum variation in the population was noted with respect to fruit weight (CV 30.72%), fruit length (CV 11.68%) and calyx length (CV 41.52%) in 30 kR treatment. However, mean fruit weight was maximum (216.57g) with 6 kR. T.S.S, aril% and rind% were maximum in 27 kR population. Fruit weight, 100 aril weight, calyx length, rind thickness, % rind recovery showed high variation irrespective of gamma irradiation treatments. On preliminary screening based on fruit weight, aril and rind colour, TSS and 100 aril weight, some distinct types were identified from the population for further evaluation. Out of selected types, No.4 and102 had bigger fruits (>350g each), No. 717, 816,443 and 636, bold arils (>42g/100 arils), No.123, 821,480, dark red arils and No.448,437 and 394, thick rind with red colour. However, some of the mutants may be useful in crop improvement programme. Very high degree of variability was noted with respect to fruit weight, fruit rind, aril colour and 100 aril weight. Further study is in progress.

Based on 3 consecutive year's data of gamma irradiated population of Ganesh, selection was made considering fruit colour, weight, aril colour and 100 aril weight and TSS. Sixty desirable types were identified out of which six are promising. These promising mutants will be multiplied for further testing and final selection.

Promising mutants of pomegranate cv.Ganesh

S. No	Promising mutant of Ganesh (No.)	Desirable traits
1	320	Reddish yellow rind, medium sized fruit with bold arils
2	348	Red rind, medium sized fruit with bold and red arils
3	375	Yellowish red rind, medium sized fruit with bold arils
4	388	Yellowish rind, large sized fruit with high TSS and bold arils
5	391	Yellowish red rind, large fruit with bold, pink arils
6	528	Red skin, medium fruit size and medium bold arils

Variation in fruit weight, length and diameter of gamma irradiated population of Bhagwa

Irradiation dose	Fruit weight (g)				Fruit length (cm)				Fruit diameter (cm)			
	Range	Mean	SD	CV (%)	Range	Mean	SD	CV (%)	Range	Mean	SD	CV (%)
0 KR (68*)	123.0-354.00	200.38	48.09	24.00	5.03-8.96	7.28	0.68	9.33	5.0-9.35	6.98	0.66	9.42
3 KR (73)	99.50-394.50	199.26	52.26	26.23	5.50-9.35	7.28	0.65	8.95	5.50-8.20	6.92	0.58	8.36
6 KR (70)	129.50-344.0	216.57	48.00	22.16	5.75-8.60	7.48	0.62	8.32	6.10-8.10	7.06	0.53	7.58
9 KR (47)	116.70-324.40	200.85	50.18	24.99	6.0-8.41	7.33	0.62	8.48	6.0-9.75	6.99	0.67	9.63
12 KR (68)	120.0-354.00	211.35	52.88	25.02	5.07-8.60	7.23	0.73	10.11	5.08-8.50	6.95	0.72	10.33
15 KR (59)	108.81-348.00	210.11	51.74	24.63	5.54-9.00	7.37	0.77	10.45	5.52-8.73	7.03	0.70	9.97
18 KR (47)	90.0-320.00	208.68	46.88	22.47	5.50-9.30	7.33	0.64	8.69	5.0-8.50	6.97	0.75	10.75
21 KR (66)	101.50-389.00	204.61	57.57	28.14	5.10-9.25	7.27	0.85	11.64	5.20-9.0	6.90	0.74	10.77
24 KR (28)	117.50-310.50	215.50	49.89	23.15	6.30-8.50	7.48	0.62	8.31	5.45-8.60	7.00	0.69	9.89
27 KR (18)	98.50-294.67	201.90	50.18	24.86	5.60-8.53	7.20	0.73	10.13	5.95-8.10	7.07	0.58	8.25
30 KR (12)	114.67-300.50	195.84	62.12	31.72	5.82-8.50	7.30	0.85	11.68	5.57-7.70	6.83	0.69	10.16

*Values in parenthesis refers to the number of bearing plants

Variation in 100 aril weight, aril length and width of fruit of gamma irradiated population of Bhagwa

Irradiation dose	100 aril weight (g)				Aril length (cm)				Aril width (cm)			
	Range	Mean	SD	CV (%)	Range	Mean	SD	CV (%)	Range	Mean	SD	CV (%)
0 KR (68*)	19.08-43.00	31.19	5.34	17.12	0.91-1.26	1.07	0.05	5.12	0.53-0.77	0.64	0.06	9.46
3 KR (73)	18.97-47.00	31.28	4.89	15.62	0.87-1.29	1.07	0.07	6.45	0.53-0.78	0.63	0.05	8.13
6 KR (70)	21.61-43.50	32.86	5.03	15.32	0.95-1.27	1.07	0.06	5.68	0.53-0.82	0.65	0.07	10.25
9 KR (47)	19.50-45.50	31.52	6.49	20.58	0.94-1.23	1.08	0.06	5.41	0.55-0.73	0.63	0.05	7.48
12 KR (68)	19.20-57.00	32.95	6.49	19.71	0.94-1.35	1.08	0.06	5.88	0.46-0.85	0.63	0.07	10.57
15 KR (59)	20.00-44.50	33.27	4.98	14.95	0.96-1.28	1.07	0.05	5.12	0.55-0.77	0.61	0.04	7.24
18 KR (47)	25.25-47.50	34.42	4.92	14.29	1.02-1.28	1.09	0.05	4.87	0.56-0.82	0.62	0.05	8.36
21 KR (66)	15.63-47.50	32.71	6.94	21.21	0.95-1.18	1.07	0.04	4.17	0.53-0.93	0.62	0.06	10.17
24 KR (28)	15.50-51.00	32.86	6.76	20.56	0.90-1.24	1.07	0.07	6.99	0.53-0.76	0.63	0.06	10.37
27 KR (18)	23.0-48.00	34.99	6.44	18.42	0.92-1.20	1.07	0.06	5.83	0.53-0.73	0.60	0.05	8.57
30 KR (12)	22.0-42.50	34.14	5.32	15.59	1.02-1.20	1.09	0.05	4.75	0.55-0.73	0.62	0.06	10.06

*Values in parenthesis refers to the number of bearing plants

Variation in calyx length, rind thickness and rind % of fruit of gamma irradiated population of Bhagwa

Irradiation dose	Calyx length (cm)				Rind thickness (cm)				Rind %			
	Range	Mean	SD	CV (%)	Range	Mean	SD	CV (%)	Range	Mean	SD	CV (%)
0 KR (68*)	1.00-2.40	1.56	0.34	22.12	0.17-0.53	0.32	0.06	20.00	22.73-48.44	35.78	5.38	15.03
3 KR (73)	1.00-2.46	1.53	0.36	23.88	0.23-0.55	0.34	0.07	20.76	23.27-46.44	37.19	4.69	12.61
6 KR (70)	1.00-2.35	1.56	0.32	20.53	0.15-0.53	0.34	0.08	23.07	22.59-65.64	36.48	6.40	17.55
9 KR (47)	0.90-3.00	1.47	0.38	25.88	0.18-0.62	0.30	0.09	28.91	20.48-51.18	35.66	6.26	17.54
12 KR (68)	0.80-2.93	1.42	0.41	29.12	0.20-0.60	0.33	0.09	27.07	19.81-51.98	36.60	6.05	16.52
15 KR (59)	0.78-2.50	1.41	0.41	29.15	0.19-0.48	0.32	0.07	21.90	21.25-53.96	37.31	7.03	18.83
18 KR (47)	0.88-2.10	1.38	0.30	22.12	0.18-0.49	0.33	0.07	20.98	23.36-46.83	36.88	4.33	11.73
21 KR (66)	0.60-2.55	1.43	0.43	29.93	0.20-0.62	0.34	0.08	24.84	0.00-55.78	37.49	9.80	26.14
24 KR (28)	0.60-1.83	1.23	0.35	28.84	0.22-0.55	0.33	0.08	25.54	19.30-54.69	37.39	8.44	22.58
27 KR (18)	0.65-2.60	1.35	0.55	40.78	0.17-0.45	0.32	0.07	22.16	22.76-88.83	39.01	13.88	35.59
30 KR (12)	0.95-3.10	1.46	0.61	41.52	0.25-0.41	0.32	0.05	16.48	25.75-52.67	37.68	7.83	20.79

*Values in parenthesis refers to the number of bearing plants

Variation in TSS and aril% of fruit in gamma irradiated population of Bhagwa

Irradiation dose	TSS (°Brix)				Aril (%)			
	Range	Mean	SD	CV (%)	Range	Mean	SD	CV (%)
0 KR (68*)	12.57-16.66	14.97	0.93	6.24	51.56-77.27	64.22	5.38	8.38
3 KR (73)	11.88-19.50	15.16	1.24	8.17	53.56-76.63	62.81	4.69	7.46
6 KR (70)	10.78-18.19	15.24	1.19	7.81	34.36-77.41	63.52	6.40	10.08
9 KR (47)	11.29-16.49	14.65	1.23	8.41	48.82-79.52	64.34	6.26	9.72
12 KR (68)	12.69-17.83	15.52	1.01	6.51	48.02-80.19	63.40	6.05	9.54
15 KR (59)	10.54-18.94	15.54	1.35	8.69	29.0-122.0	62.69	7.03	11.21
18 KR (47)	11.75-17.42	15.00	1.17	7.77	53.17-76.64	63.12	4.33	6.86
21 KR (66)	11.54-17.43	14.85	1.16	7.84	0.00-80.90	59.48	12.80	21.51
24 KR (28)	12.11-16.88	15.15	1.07	7.08	45.31-80.70	62.61	8.44	13.48
27 KR (18)	10.41-16.29	15.01	1.36	9.07	11.17-77.24	60.99	13.88	22.76
30 KR (12)	12.21-16.28	15.01	1.09	7.26	47.33-74.25	62.32	7.83	12.57

*Values in parenthesis refers to the number of bearing plants

1.2 Improvement through hybridization

1.2.1 Evaluation of commercial varieties of pomegranate

Seven commercial varieties of pomegranate planted at Hybrid block of Hiraj farm were evaluated for their vegetative growth, quantitative and qualitative traits under field condition during the fourth year of planting. The cultivars differed significantly from each other for most of the traits. Plant height was highest in 'Mridula' (256.19 cm) whereas it was lowest in 'Bhagwa' (191.20 cm).

A view of hybrid block at NRCP, Hiraj

Evaluation of commercial varieties of pomegranate for vegetative growth characters

Variety	Plant height (cm)	Spread E-W (cm)	Spread N-S (cm)	No. of branches	Diameter (mm)	Girth (mm)
Bhagwa	191.20	196.20	170.00	7.00	40.18	139.43
Ganesh	215.35	185.18	177.92	7.05	49.15	169.98
Ruby	214.38	174.17	169.00	6.06	57.62	193.47
Jalore Seedless	228.42	182.53	170.84	8.00	50.76	177.64
G-137	247.40	204.03	195.73	6.93	58.91	183.99
Arakta	238.92	195.89	199.56	7.56	53.41	173.37
Mridula	256.19	218.53	219.28	7.31	59.68	194.27
CD (5%)	18.24	15.12	15.40	0.70	1.80	10.84

The commercial varieties differed significantly with respect to fruit yield. The fruit yield ranged from 9.62 to12.90 kg/tree. G - 137 recorded the highest yield/tree (12.90 kg.) which was on par with 'Ganesh' (12.53 kg.)

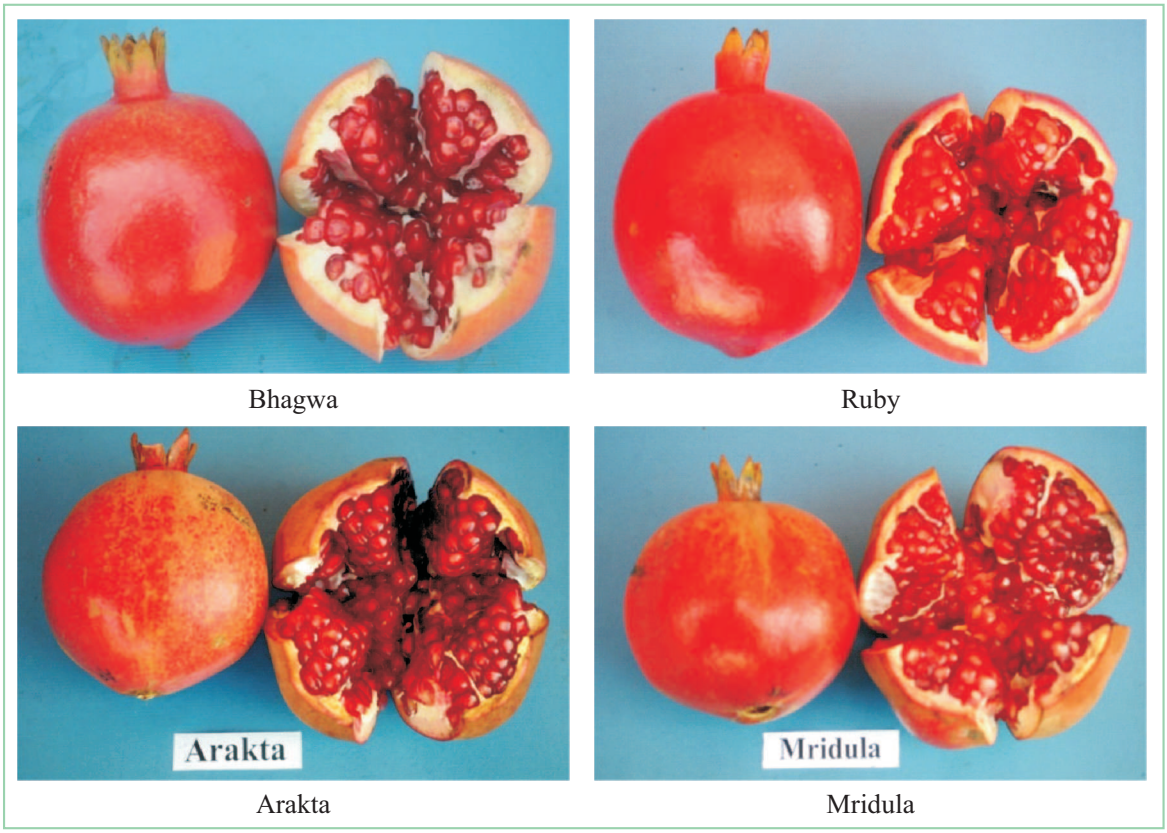
Evaluation of commercial varieties of pomegranate for quantitative traits

Variety	No. fruits/tree	Fruit weight (g)	Yield/tree (kg)	Fruit length (mm)	Fruit diameter (mm)	Rind thickness (mm)	Rind weight (g)
Bhagwa	32.87	310.25	10.20	81.12	80.84	3.20	130.84
Ganesh	39.10	320.50	12.53	83.64	85.12	2.28	109.87
Ruby	30.07	300.12	9.62	77.40	79.28	2.60	80.69
Jalore Seedless	36.12	310.33	11.20	83.16	84.32	2.40	90.82
G-137	40.20	321.00	12.90	85.24	86.48	2.88	111.52
Arakta	36.45	270.16	9.86	75.64	77.08	2.42	69.66
Mridula	35.98	275.10	9.90	74.20	79.40	2.48	72.94
CD (5%)	3.80	22.33	0.68	0.84	1.31	0.31	4.08

The 100 aril weight was highest in Bhagwa (35.12g) followed by Ruby (31.96g). The soluble solids content ranged from 15.50 to 16.25 °B. The TSS/acid ratio was found maximum in Jalore Seedless (36.11) which was found on par with 'Ganesh' (35.77).

Evaluation of commercial varieties of pomegranate for qualitative traits

Variety	100 aril weight (g)	100 aril juice volume (ml)	100 aril juice weight (g)	No. Of arils/ fruit	Aril length (mm)	Aril width (mm)	TSS (°Brix)	Titrable acidity (%)	TSS/ acid ratio
Bhagwa	35.12	23.2	23.5	510.20	10.94	6.88	15.95	0.50	31.90
Ganesh	26.30	22.8	23.6	708.00	10.54	6.62	16.10	0.45	35.77
Ruby	31.96	24.92	25.40	604.10	10.22	6.49	15.90	0.46	34.56
Jalore Seedless	28.90	25.20	25.70	690.00	10.64	6.78	16.25	0.45	36.11
G-137	27.20	25.90	26.36	685.50	10.62	6.84	16.20	0.51	31.76
Arakta	30.50	18.30	18.60	655.00	9.76	6.28	15.50	0.45	34.44
Mridula	30.58	20.75	21.25	660.16	9.72	6.40	15.60	0.45	33.92
CD (5%)	2.40	2.80	2.82	32.10	0.30	0.28	0.26	NS	0.80



Bhagwa | Ruby

Arakta | Mridula

Commercial varieties of Pomegranate

G-137 (12.90 kg), Ganesh (12.53 kg), Jalore Seedless (11.20 kg) were found to be superior to Bhagwa (10.20kg) with respect to fruit yield(kg/tree). For fruit quality based on TSS/acid ratio, Jalore Seedless(36.11), Ganesh (35.77), Arakta (34.44) and Mridula (33.92) were found to be superior to Bhagwa (31.90).

1.2.2 Evaluation of bacterial blight tolerant varieties

Four bacterial blight tolerant varieties of pomegranate were evaluated for their vegetative growth characters, quantitative and qualitative traits during the fourth year of planting. The varieties differed significantly for various traits. Plant height was maximum in Daru (174.17cm) whereas it was minimum in Nana (40.4 cm).

Evaluation of bacterial blight tolerant varieties of pomegranate for vegetative growth

Variety	Plant height (cm)	Spread E-W (cm)	Spread N-S (cm)	No. of branches	Diameter (mm)	Girth (mm)
Nana	40.40	31.10	30.70	5.40	13.31	43.70
Daru	174.17	180.50	164.20	5.89	51.14	180.35
Kalpitiya	134.67	136.33	122.0	3.00	38.88	133.00
Nayana	173.14	164.0	151.7	5.86	46.31	146.29
CD (5%)	32.40	50.25	56.50	0.24	0.78	30.12

The bacterial blight tolerant varieties differed significantly with respect to fruit yield. The fruit yield ranged from 1.60 to 6.69 kg/tree. The yield/tree was highest in Nayana (6.69 kg) which was on par with Kalpitiya (6.33kg). The titrable acidity ranged from 0.45 to 4.72 %. The titrable acidity was found to be highest in Nana (4.72%). Similarly, the TSS/acid ratio was highest in Nayana (36.26).

Evaluation of bacterial blight tolerant varieties of pomegranate for quantitative traits

Variety	No. fruits /tree	Fruit weight (g)	Yield/tree (kg)	Fruit length (mm)	Fruit diameter (mm)	Rind thickness (mm)	Rind weight (g)
Nana	62	35.10	2.18	40.52	40.40	1.12	9.52
Daru	10	160.25	1.60	64.50	61.82	3.50	60.50
Kalpitiya	25.5	248.33	6.33	71.12	71.72	3.20	88.09
Nayana	26.5	252.60	6.69	75.20	75.06	3.00	96.50
CD (5%)	5.60	17.25	0.64	1.20	0.37	0.29	9.76

Evaluation of bacterial blight tolerant varieties of pomegranate for qualitative traits

Variety	100 aril weight (g)	100 aril juice volume (ml)	100 aril juice weight (g)	No. arils/ fruit	Aril length (mm)	Aril width (mm)	TSS (°Brix)	Titrable acidity (%)	TSS/acid ratio
Nana	14.25	11.25	11.75	150	7.00	4.62	12.35	4.72	2.62
Daru	30.04	17	17.5	270	9.89	6.74	17.55	2.19	8.01
Kalpitiya	29.44	14	14.82	450	8.93	5.59	16.00	0.58	27.58
Nayana	32.50	25	26.5	405	10.44	7.55	16.32	0.45	36.26
CD (5%)	1.84	1.95	1.98	23.31	0.20	0.17	0.27	0.24	1.98

1.2.3 Evaluation of other pomegranate varieties

Eleven varieties of pomegranate were evaluated for their vegetative growth characters and physico-chemical parameters of fruits in comparison with Bhagwa during the fourth year of planting. The varieties differed significantly for vegetative and vegetative and other physico-chemical parameters.

The varieties differed significantly with respect to plant height which ranged from 111.00 to 326.00 cm. The plant height was highest in Muskat (326.0 cm) whereas it was lowest in Amlidana (111.00 cm).

Evaluation of pomegranate varieties for vegetative growth characters

Variety	Plant height (cm)	Spread E-W (cm)	Spread N-S (cm)	No. of branches	Diameter (mm)	Girth (mm)
Bhagwa	191.20	196.20	170.00	7.00	40.18	139.43
Amlidana	111.00	89.67	105.00	4.00	44.72	120.33
B.Sedana	237.00	143.60	140.40	10.60	44.72	140.95
Dholka	254.33	170.67	208.33	6.33	60.75	205.72
Jodhpur	278.80	210.00	258.20	11.20	48.53	165.10
Jyothi	251.50	184.50	192.50	8.00	43.38	161.50
Kabul Yellow	277.40	250.20	245.80	9.40	55.95	190.37
Kasuri	258.50	226.00	229.00	8.00	46.81	166.25
Kerala Local	220.50	154.75	177.25	7.00	43.76	154.67
KRS	289.60	260.50	254.20	8.20	79.36	258.33
Muskat	326.00	272.00	280.00	12.00	56.31	205.00
Yercaud-1	307.26	271.00	271.20	9.00	73.51	219.53
CD (5%)	20.20	16.60	16.50	1.32	1.72	15.30

The fruit yield ranged from 4.61 to 11.80 kg /tree and the varieties had significant variation for fruit yield. The yield/tree was highest in KRS (11.80 kg).

Evaluation of pomegranate varieties for quantitative traits

Variety	No. fruits/tree	Fruit weight (g)	Yield/tree (kg)	Fruit length (mm)	Fruit diameter (mm)	Rind thick (mm)	Rind weight (g)
Bhagwa	28.2	313.33	8.84	81.20	80.88	3.12	130.80
Amlidana	28.00	228	6.38	68	70	2.53	73.5
B.Sedana	60.00	110	6.60	40	50	2.6	55
Dholka	33.00	171.75	5.15	66.24	67.42	2.64	77.5
Jodhpur	30.00	153.5	4.61	59.6	65.05	2.51	52
Jyothi	34.00	286.6	9.74	74.73	80.13	4.1	100
Kabul Yellow	28.08	248.66	6.98	74.67	76.88	3.25	88.05
Kasuri	29.00	316.57	9.16	82.53	87.48	4.25	137
Kerala Local	30.20	315.20	9.52	87.68	75.51	3.6	143.5
KRS	36.20	326.22	11.80	81.44	87.86	2.58	113.5
Muskat	22.40	315	7.06	87.26	86.65	2.19	131.5
Yercaud-1	31.00	200	6.20	68.20	69.56	1.71	53.5
CD (5%)	5.90	12.80	0.68	0.92	1.28	0.42	5.12

Kerala Local recorded the highest TSS/acid ratio (31.91). This was on par with Kasuri (31.87), Bhagwa (31.76), Jyoti (31.66), Muskat (31.56) and KRS (31.45).

1.2.4 Evaluation of Ruby hybrids of pomegranate

Four pomegranate hybrids developed at IIHR, Bangalore using Ruby as pollen parent were evaluated for their vegetative growth, physico-chemical parameters in comparison with Bhagwa during the fourth year of planting at NRCP, Solapur.

The hybrids differed significantly for plant height which ranged from 191.20 to 318.90cm. The plant height was highest in Kalpitiya x Ruby (318.90cm) whereas it was lowest in Bhagwa (191.20 cm).

Evaluation of pomegranate varieties for qualitative traits

Variety	100 aril weight (g)	100 aril juice volume (ml)	100 aril juice weight (g)	No. of arils/fruit	Aril length (mm)	Aril width (mm)	TSS (^{0}B)	Acidity (%)	TSS/acid ratio
Bhagwa	35.0	23.0	23.3	519.3	10.94	6.86	15.88	0.50	31.76
Amlidana	36.5	22.0	22.5	320.0	10.28	7.24	16.60	2.11	7.86
B.Sedana	41.5	26.5	27.0	80.0	12.53	8.19	14.18	1.11	12.81
Dholka	30.0	19.5	20.0	375.0	10.41	6.96	15.41	0.53	29.01
Jodhpur	20.0	11.0	11.6	420.0	8.79	5.40	14.78	0.55	26.85
Jyothi	33.5	19.5	20.0	440.0	9.17	6.44	15.20	0.48	31.66
Kabul Yellow	26.0	17.0	18.0	620.0	8.55	590	15.06	0.51	29.41
Kasuri	38.5	27.5	28.0	620.0	10.32	6.05	15.30	0.48	31.87
Kerala Local	45.0	32.5	33.0	335.0	10.63	7.38	15.32	0.48	31.91
KRS	39.5	27.0	27.5	530.0	10.19	6.06	15.10	0.48	31.45
Muskat	40.5	27.0	27.5	710.0	10.42	6.9	15.15	0.48	31.56
Yercaud-1	40.0	20.5	21.0	285.0	10.41	7.09	16.51	0.61	27.06
CD	2.65	2.83	2.80	37.20	0.32	0.28	0.28	0.32	1.36

Evaluation of Ruby hybrids for vegetative growth

Hybrid	Plant height (cm)	Spread E-W (cm)	Spread N-S (cm)	No. of branches	Diameter (mm)	Girth (mm)
Bhagwa	191.20	196.20	170.00	7.00	40.18	139.43
{(GxD)xG}xR*	229.60	203.40	199.80	6.40	46.06	157.28
KxR	318.90	249.40	268.60	6.50	74.72	272.78
NxR	280.60	228.00	201.40	5.40	100.01	342.53
{(Gxn)x(GxD)}xR	226.13	125.38	118.75	5.63	24.54	91.41
CD (5%)	13.30	12.75	17.60	0.38	1.40	12.20

(*G- Ganesh, D- Daru, K- Kalpitiya, n-Nana, N- Nayana, R- Ruby)

The hybrids differed significantly for fruit yield and yield/tree ranged from 7.32 to 14.28 kg. The yield / tree was highest in Nayana x Ruby (14.28kg) followed by {(Gxn)x(GxD)}xR (12.12kg), KxR (10.35kg). The fruit yield of Nayana x Ruby, {(Gxn)x(GxD)}xR were on par with Bhagwa (10.20kg).

The TSS/acid ratio ranged from 31.90 to 40.70 which was highest (40.70°B) in {(Gxn)x(GxD)}xR. The TSS/ acid ratio of all the four Ruby hybrids was superior to Bhagwa (31.90).

1.2.5 Evaluation of other pomegranate hybrids

Eight pomegranate hybrids were assessed for various physico-chemical parameters in comparison with Bhagwa during the fourth year of planting. The plant height was highest in {[(Gxn)xD]x (Gxn) x B (267.60 cm) whereas it was lowest in Sweet 7/10 (170.67cm).

Evaluation of Ruby hybrids for quantitative traits

Hybrid	No. fruits/ tree	Fruit weight (g)	Yield/ tree (kg)	Fruit length (mm)	Fruit diameter (mm)	Rind thickness (mm)	Rind weight (g)
Bhagwa	32.87	310.25	10.20	81.12	80.84	3.20	130.84
{(GxD)xG}xR*	32.50	228.7	7.32	68.81	72.76	2.80	84.5
KxR	33.5	309.0	10.35	78.09	82.65	2.48	91.5
NxR	46	310.5	14.28	79.22	77.01	2.36	92.5
{(Gxn)x(GxD)}xR	48	252.5	12.12	72.11	77.86	2.28	76.5
CD (5%)	3.96	4.34	0.40	2.06	1.08	0.37	9.55

(*G- Ganesh, D- Daru, K- Kalpitiya, n-Nana, N- Nayana, R- Ruby)

Evaluation of Ruby hybrids for qualitative traits

Hybrid	100 aril weight (g)	100 aril juice volume (ml)	100 aril juice weight (g)	No. of arils/ fruit	Aril length (mm)	Aril width (mm)	TSS (°Brix)	Acidity (%)	TSS/ acid ratio
Bhagwa	35.12	23.2	23.5	510.20	10.94	6.88	15.95	0.50	31.90
{(GxD)xG}xR*	33.5	21.5	23	416	9.94	6.87	16.96	0.45	37.86
KxR	35.5	25.0	26	560	10.78	7.02	16.48	0.45	36.79
NxR	36.0	24.5	25.5	556	10.86	7.08	14.85	0.38	38.67
{(Gxn)x(GxD)}xR	34.0	22	23.5	502	10.06	6.83	16.28	0.40	40.70
CD (5%)	NS	1.25	1.29	31.74	0.29	0.12	0.39	NS	0.99

(*G- Ganesh, D- Daru, K- Kalpitiya, n-Nana, N- Nayana, R- Ruby)

Evaluation of bacterial blight tolerant hybrids for vegetative growth

Hybrid	Plant height (cm)	Spread E-W (cm)	Spread N-S (cm)	No. of branches	Diameter (mm)	Girth (mm)
Bhagwa	191.20	196.20	170.00	7.00	40.18	139.43
Bx3/3{(Gxn)xD}-MR*	206.77	174.77	165.69	6.62	53.58	189.07
Bx3/3{(Gxn)xD}	234.70	200.3	206.3	8.7	41.87	154.78
Bx{(Gxn)xD}	252.40	236.20	224.00	7.80	54.54	175.48
{[(Gxn)xD]x(Gxn) x B	267.6	230.4	212.90	6.60	57.88	188.10
Sour 6/4	218.67	204.67	178.67	3.33	71.42	247.33
Sour 6/5	236.60	241.00	212.60	5.20	56.19	173.07
Sweet 6/7	262.80	248.20	236.60	7.20	62.45	203.77
Sweet 7/10	170.67	157.33	163.67	7.33	30.42	100.70
CD (5%)	14.20	12.82	14.10	0.80	1.84	11.36

(*B- Bhagwa, G- Ganesh, D- Daru, n-Nana, R- Ruby, MR- moderately tolerant to bacterial blight)

The hybrids differed significantly for fruit yield. The yield/tree was highest in {[(Gxn)xD]x (Gxn)} x B (13.10 kg). B x{(Gxn)xD} was found on par with Bhagwa (10.20 kg.).

The hybrids differed significantly for soluble solids content which ranged from 14.22 to 16.46 °B. The TSS/acid ratio was highest in Sweet 7/10 (37.02) followed by Sweet 6/7 (36.38) which is superior to Bhagwa (31.90).

Evaluation of bacterial blight tolerant hybrids for quantitative traits

Hybrid	No.fruits /tree	Fruit weight (g)	Yield/tree (kg)	Fruit length (mm)	Fruit diameter (mm)	Rind thickness (mm)	Rind weight (g)
Bhagwa	32.87	310.25	10.20	81.12	80.84	3.20	130.84
Bx3/3 {(Gxn)xD}-MR	12.84	237.1	3.04	71.79	72.28	2.12	99.0
Bx3/3 {(Gxn)xD}	34.96	242.0	8.46	75.84	75.47	2.57	91.5
Bx{(Gxn)xD}	36.10	292.3	10.55	78.94	79.47	3.22	124.0
{[(Gxn)xD]x(Gxn) x B	46.00	284.8	13.10	78.85	78.38	3.07	117.5
Sour 6/4	17.33	202.3	3.51	68.19	70.83	3.28	72.0
Sour 6/5	40.20	202.5	8.14	68.3	69.19	2.33	73.5
Sweet 6/7	39.4	190.5	7.51	63.58	67.05	2.14	89.5
Sweet 7/10	14.9	172.2	2.56	62.1	66.57	2.06	69.0
CD (5%)	1.96	5.24	0.82	1.98	1.60	0.10	7.92

(*B- Bhagwa, G- Ganesh, D- Daru, n-Nana, R- Ruby, MR- moderately tolerant to bacterial blight)

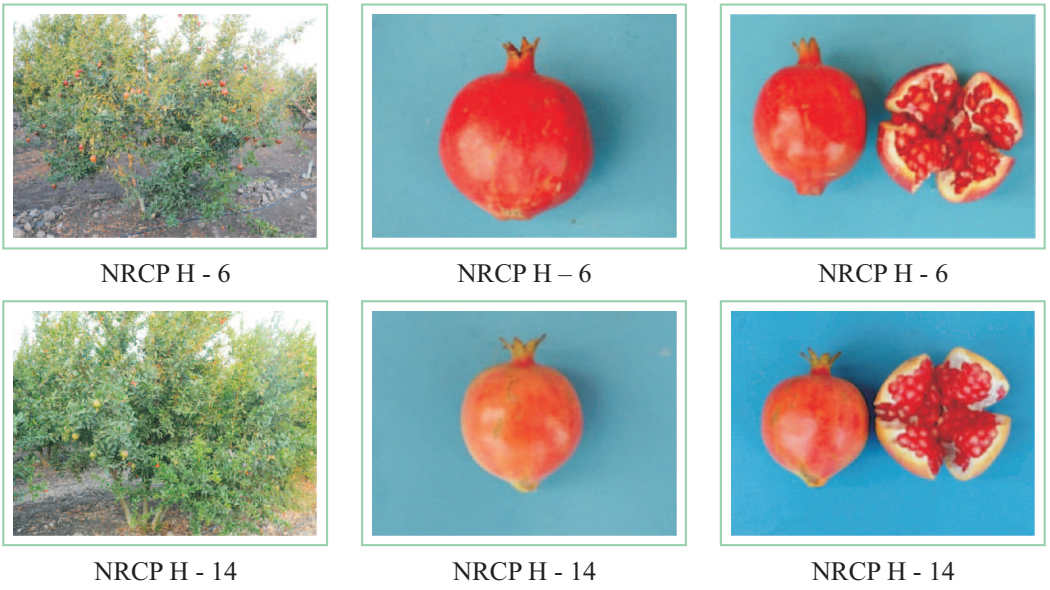
Evaluation of bacterial blight tolerant hybrids for qualitative traits

Hybrid	100 aril weight (g)	100 aril juice volume (ml)	100 aril juice weight (g)	No. arils/ fruit	Aril length (mm)	Aril width (mm)	TSS (°Brix)	Titrable acidity (%)	TSS/ acid ratio
Bhagwa	35.1	23.2	23.5	510.20	10.94	6.88	15.95	0.50	31.90
Bx3/3 {(Gxn)xD, MR	39.0	27.5	28.0	455	11.14	6.94	16.46	3.67	4.49
Bx3/3 {(Gxn)xD}	25.0	16.5	17.0	530	8.82	6.06	14.53	4.43	3.28
Bx{(Gxn)xD	38.1	25.2	26.5	474	10.58	7.25	15.30	3.62	4.23
{[(Gxn)xD]x(Gxn) x B	43.0	25.0	26.0	230	11.31	7.28	16.23	1.83	8.87
Sour 6/4	36.0	23.5	24.0	420	10.05	6.07	14.22	3.62	3.93
Sour 6/5	34.5	22.5	24.0	485	9.95	6.32	15.34	3.49	4.40
Sweet 6/7	45.5	29.0	29.5	347	10.66	6.81	16.3	0.45	36.38
Sweet 7/10	48.5	31.5	32.0	310	10.67	7.5	15.33	0.41	37.02
CD (5%)	1.52	1.71	1.74	20.21	0.31	0.16	0.37	0.14	1.16

(*B- Bhagwa, G- Ganesh, D- Daru, n-Nana, R- Ruby, MR- moderately tolerant to bacterial blight)

1.2.6 Evaluation of hybrids developed by NRCP, Solapur

With the objective of transferring the bacterial blight tolerant characters of nana and Daru in to the commercial variety Bhagwa, hybridization was undertaken between Bhagwa and the three way cross hybrid {(Gxn)xD}. Out of 45 surviving seedling population of the F1 hybrid, 20 offsprings were planted in Hybrid block for assessing their performance in comparison with Bhagwa.



NRCP H - 6 | NRCP H – 6 | NRCP H - 6

NRCP H - 14 | NRCP H - 14 | NRCP H - 14

Promising hybrids developed by NRC Pomegranate

The hybrid population was assessed for vegetative traits and physico-chemical parameters during fourth year of planting. The plant height was significantly different among the hybrids which ranged from 191.20 to 392.0cm. The maximum plant height was recorded by NRCP H-1(392.0cm) and all the hybrids were found to be taller compared to Bhagwa (191.20cm) revealing the vigorous nature of the NRCP hybrids.

The hybrids differed significantly with respect to fruit yield which ranged from 8.12 to 19.54 kg/ tree during fourth year of planting. The highest fruit yield was recorded by NRCP H-13 (19.54 kg). This was followed by NRCP H-15 (17.16 kg) and NRCP H-14 (16.34 kg) for fruit yield (kg/tree) which is higher than Bhagwa (10.20 kg). In total, the fruit yield /tree of eleven hybrids were superior to Bhagwa (10.20 kg).

Evaluation of NRCP hybrids for vegetative growth parameters

Variety	Plant height (cm)	Spread E-W (cm)	Spread N-S (cm)	No. of branches	Diameter (mm)	Girth (mm)
Bhagwa	191.2	196.2	170.0	7.00	40.18	139.4
NRCP H-1	392.0	335.0	315.0	11.00	73.91	247.5
NRCP H-2	280.0	269.0	265.0	12.00	51.37	172.5
NRCP H-3	276.0	265.0	241.0	12.00	64.74	210.5
NRCP H-4	321.0	279.0	255.0	07.00	69.20	177.33
NRCP H-5	325.0	252.0	220.0	09.00	61.16	197.5
NRCP H-6	249.0	245.0	290.0	11.00	52.16	166.0
NRCP H-7	215.0	135.0	173.0	05.00	37.62	125.0
NRCP H-8	335.0	295.0	302.0	09.00	70.12	234.7
NRCP H-9	312.0	281.0	289.0	12.00	54.30	185.3
NRCP H-10	315.0	284.0	311.0	12.00	55.78	161.0
NRCP H-11	245.0	265.0	259.0	10.00	61.90	172.0
NRCP H-12	265.0	262.0	248.0	09.00	67.90	221.3
NRCP H-13	342.0	286.0	289.0	11.00	60.29	198.5
NRCP H-14	325.0	305.0	208.0	10.00	55.52	204.8
NRCP H-15	241.0	255.0	205.0	11.00	57.78	195.0
NRCP H-16	290.0	262.0	290.0	09.00	63.69	193.5
NRCP H-17	275.0	265.0	295.0	07.00	76.11	279.3
NRCP H-18	225.0	209.0	203.0	12.00	54.73	185.5
NRCP H-19	217.5	219.7	206.2	10.0	66.27	230
NRCP H-20	221.0	280.0	265.0	05.00	55.89	213.5
CD (5%)	15.36	13.52	14.90	0.70	1.80	10.64

Evaluation of NRCP hybrids for quantitative traits

NRCP hybrid	No.fruits /tree	Fruit weight (g)	Fruit yield (kg/tree)	Fruit length (mm)	Fruit diameter (mm)	Rind thickness (mm)
Bhagwa	32.9	310.25	10.20	81.12	80.84	3.20
NRCP H-1	52.0	215.00	11.18	74.05	71.93	3.96
NRCP H-2	70.0	224.33	15.70	93.08	85.24	3.11
NRCP H-3	84.0	169.00	14.19	70.15	75.19	3.30
NRCP H-4	64.0	127.00	8.12	66.03	63.92	2.77
NRCP H-5	78.0	108.20	8.44	63.11	63.33	2.13
NRCP H-6	84.0	181.75	15.26	64.9	71.09	3.21
NRCP H-7	54.0	162.33	8.76	69.52	69.16	2.86
NRCP H-8	40.0	239.17	9.56	79.43	80.60	3.81
NRCP H-9	64.0	200.00	12.80	65.48	76.85	3.91
NRCP H-10	60.0	169.25	10.15	73.13	68.95	2.14
NRCP H-11	52.0	224.50	11.67	70.67	76.24	2.99
NRCP H-12	42.0	327.75	13.76	64.99	85.28	2.30
NRCP H-13	62.0	315.25	19.54	86.75	85.31	3.55
NRCP H-14	70.0	233.50	16.34	89.54	75.90	2.36
NRCP H-15	79˙0	217.33	17.16	75.01	72.91	2.73
NRCP H-16	63.0	171.00	10.77	62.42	71.23	3.03
NRCP H-17	60.0	176.75	10.60	72.7	72.64	2.83
NRCP H-18	35.0	354.00	12.39	84.93	91.51	2.48
NRCP H-19	50.0	163.00	8.15	57.27	55.84	1.65
NRCP H-20	40.0	205.25	8.21	69.06	72.42	3.36
CD (5%)	6.2	20.16	1.6	0.96	1.40	0.37

Based on TSS/acid ratio, H-6 & H-14 were found to be superior to Bhagwa for fruit quality and hence considered suitable for table purpose. NRCP H-6 had highest TSS/acid ratio (39.88) followed by NRCP H-14 (39.53). Besides, NRCP H-10 (31.52) NRCP H-5 (31.01), were found to be on par with Bhagwa for TSS/acid ratio based fruit quality. Six hybrids were found to have acidity more than 3.0%. viz., NRCP H-4,12,11,15,1,3 which would be useful for anardana preparation.

1.2.7 Hybridization for bacterial blight tolerance & raising F1hybrid seedlings

Commercial cultivars of pomegranate (Bhagwa, Ruby) were crossed with bacterial blight tolerant varieties (nana, Kalpitiya, Nayana, Daru, Acc-50) during the month of February. Fruitset ranged from 20.0 to 55.5%. The cross 'Bhagwa x Kalpitiya recorded the highest fruitset (55.5%).

Evaluation of NRCP hybrids for qualitative traits

NRCP hybrid	100 Aril weight (g)	100Aril juice volume (ml)	Aril length (mm)	Aril width (mm)	TSS (°B)	Acidity (%)	TSS/ acid ratio
Bhagwa	35.0	23.0	10.94	6.86	15.88	0.50	31.76
NRCP H-1	33.8	16.5	9.20	7.22	17.22	3.58	4.82
NRCP H-2	25.6	8.0	7.37	6.61	16.22	0.70	23.03
NRCP H-3	30.2	14.0	10.15	6.88	17.13	3.04	5.63
NRCP H-4	29.5	17.0	11.17	5.92	15.69	5.76	2.72
NRCP H-5	22.6	10.0	8.70	5.09	15.88	0.51	31.01
NRCP H-6	38.5	22.0	10.33	6.19	17.55	0.44	39.88
NRCP H-7	43.2	23.5	10.35	8.14	16.59	1.15	14.42
NRCP H-8	34.5	19.0	10.57	6.70	18.17	0.83	21.89
NRCP H-9	33.7	16.5	9.93	7.64	15.9	2.62	6.07
NRCP H-10	25.5	8.0	9.28	6.91	16.08	0.51	31.52
NRCP H-11	25.8	14.0	9.92	7.10	14.85	4.28	3.46
NRCP H-12	42.4	24.5	11.18	8.24	16.9	4.80	3.52
NRCP H-13	45.0	24.0	9.92	7.73	18.28	2.04	8.96
NRCP H-14	44.5	21.5	10.25	7.09	17.79	0.45	39.53
NRCP H-15	34.2	18.5	9.28	6.40	15.75	3.58	4.39
NRCP H-16	33.5	16.0	10.42	7.42	15.81	2.36	6.70
NRCP H-17	36.2	22.0	12.50	7.48	16.65	2.30	7.24
NRCP H-18	53.4	26.0	12.10	7.98	17.46	2.88	6.06
NRCP H-19	26.8	12.5	11.13	7.14	13.79	0.70	19.70
NRCP H-20	29.0	12.0	10.15	6.52	16.34	1.60	10.21
CD (5%)	2.8	2.80	0.32	0.24	0.32	0.26	0.84

Fruitset in pomegranate due to hybridization

Name of the crossing	No. of flowers crossed	No. of fruits obtained	Fruitset (%)
Bhagwa x nana	12	4	33.3
Bhagwa x Kalpitiya	36	20	55.5
Bhagwa x Nayana	60	22	36.6
Bhagwa x Acc-50	20	7	35.0
Bhagwa x Daru	21	6	28.5
Bhagwa x (Kalpitiya x Ruby)	15	3	20.0
Bhagwa x (Nayana x Ruby)	15	7	46.6
Kalpitiya x Bhagwa	5	2	40.0
Nayana x Bhagwa	11	6	54.5
Nayana x Ruby	10	3	30.0
CD (p=0.05)			8.52

The F_1 hybrid seeds of 12 crosses involving 4 commercial varieties (Ganesh, Bhagwa, Ruby, Jalore Seedless) and 3 bacterial blight tolerant varieties (nana, Kalpitiya, Nayana) done during last year were sown in pots to raise the F_1 hybrid seedlings. The F_1 hybrid seedlings were transferred to polybags and maintained under shade in the nursery.

Raising F_1 hybrid population in nursery

2. GENETIC RESOURCES

2.1. Genetic resource management

2.1.1 Germplasm collection and maintenance

Ninety two exotic accessions of pomegranate multiplied and maintained at NBPGR Regional Station, Bhowali, Uttarakhand were shifted during February 2013 at NRCP, Solapur. All the accessions have been planted and these accessions are surviving very well. In addition to this, a total number of 190 germplasm were maintained in field gene banks at Hiraj and Kegaon farms. A total number of 282 germplasm of pomegranate were maintained.

Cuttings of pomegranate cv. Wonderful were collected and maintained in nursery for establishment. Besides, a desirable field variant of pomegranate cv. Bhagwa was collected from farmers field at Patkul, Solapur Dt. The variant is an early type, short duration genotype which requires around five months for fruit development with medium sized fruits.

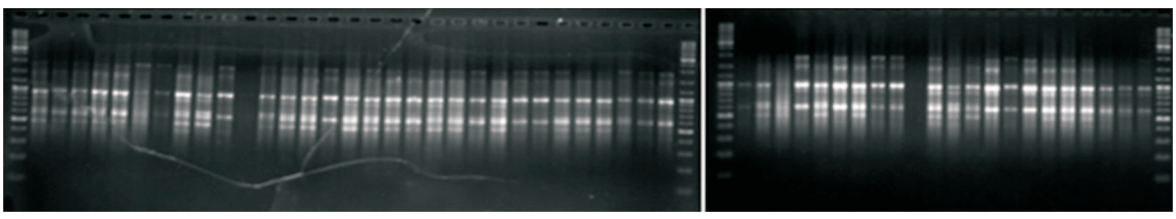
Cuttings of pomegranate cv. Wonderful

A short-duration field variant of Bhagwa

Raising F1 hybrid population in nursery

2.1.2 DNA finger printing of pomegranate germplasm

In collaboration with NBPGR, New Delhi, DNA finger printing of pomegranate collections planted in the Field Gene Banks of the National Respository of Pomegrnate Germplasm was carried out by NRC on Pomegranate, Solapur. ISSR method produced more polymorphic profiles in comparison to SSR and RAPD. The pattern of overall intraspecific polymorphism was found very significant indicating diversity among pomegranate germplasm.



Acc 1-32 and 33-53

ISSR Profiles of Pomegranate Germplasm Collection

Pomegranate germplasm used for DNA finger printing

Pomegranate accession analysed using various DNA markers							
1	Ganesh	17	Coimbatore White	33	Maha	49	IC- 1198
2	Yercaud-1	18	Tabesta	34	P-23	50	IC- 1196
3	Nimali	19	Surat Anar	35	P-13	51	IC- 1194
4	Kalpitiya	20	Bassein Seedless	36	Kasuri	52	Nana
5	Phule Arakta	21	Yercaud	37	Alah	53	IC- 318754
6	17/12	22	Spin Sakaharin	38	Jodhpur Red		
7	Jodhpur Collection	23	Bedana Suri	39	Guleshared		
8	Dholka	24	Muskat	40	P-26		
9	G-137	25	Bosckalincsi	41	P-16		
10	KRS	26	Kabuli Canoor	42	Shirin Nar		
11	Damini	27	Bedana Sedana	43	Mridula		
12	Jallore Seedless	28	Patna-5	44	IC- 1201		
13	Bhagwa	29	Spendanader	45	IC- 1203		
14	Kandhari	30	Dorsata Mallus	46	IC- 1204		
15	Kabuli Yellow	31	A K Anar	47	IC-1205		
16	Jyoti	32	Bedana Thinkskin	48	IC- 1199		

2.1.3 Germplasm evaluation

The germplasm planted, in phased manner since 2007, were evaluated for growth, yield and quality parameters. Two year old, 31 accessions of wild pomegranate collected from Uttarakhand were evaluated for growth and leaf characters. Plant height showed maximum co-efficient of variation (CV) of 24.27% followed by leaf area (20.16%). Similarly, three year old 68 accessions of pomegranate were evaluated for their growth parameters. Plant height (cm), plant spread EW (cm) and NS (cm) ranged from 80-335, 71.70-323, and 136-290 in different accessions. Maximum CV of 30.57% was recorded with respect to plant height followed by plant spread (EW). Besides, sixty five accessions of four year old germplasm were also evaluated for different growth parameters. Plant height, plant spread (EW) and NS ranged from 36.70-370 cm, 33.30-361.70cm and 46.70-328.30 cm, respectively. However, maximum variability (28.33%) was recorded in plant spread (EW) followed by plant height (27.29%). In general, the growth performance of wild accessions collected from Uttarakhand, Himachal Pradesh and Jammu Kashmir were vigorous. Fifty (50) accessions were in bearing condition and thus subjected to fruit analysis for various physico-chemical traits. The physico-chemical characteristics of these germplasm revealed CV range of 7.61 – 41.05 %. Maximum variability was noted with respect to rind weight (41.05%) followed by fruit weight (36.97%) and rind thickness (27.81%).Though least variation was noted in aril recovery (7.61%). Even variation in aril size and color was also recorded in different germplasm. Flower traits of 50 accessions also showed significant variation. Flower length (mm), flower width (mm), flower weight (g), petal length (mm) and petal width (mm) found to range between 18.40-40.40, 5.7-15.6, 0.5-4.3, 10.80-36.60 and 10-25.90, respectively. The maximum variation was noted in flower weight (22.58% CV), followed by petal length and petal width (19.27% CV).High variation was noticed with respect to plant height and spread, rind weight, flower and fruit weight in different germplasm.

Variability study in growth parameters of wild germplasm collected from Uttarakhand

Parameter	Range	Mean	SD	CV(%)
Plant height (cm)	215–334	276.03	30.67	24.27
Plant spread EW (cm)	128– 267	210.50	38.92	18.48
Plant spread NS (cm)	122 - 263	208.68	37.75	18.08
Leaf area (cm)	4.2 – 8.9	6.10	1.23	20.16
Leaf length (cm)	3.3 – 6.2	4.51	0.72	15.96
Average width (cm)	1.0 – 1.6	1.28	0.13	10.15

Variability study of 68 pomegranate accessions

Parameter	Range	Mean	SD	CV (%)
Plant height (cm)	80 - 335	219	66.96	30.57
Plant spread EW (cm)	71.70 - 323	219	64.66	29.93
Plant spread NS (cm)	136 - 290	229.35	36.02	15.70

Variability study in growth parameters of 65 pomegranate accessions

Parameter	Range	Mean	SD	CV (%)
Plant height (cm)	36.70 - 37	226.69	61.85	27.29
Plant spread EW (cm)	33.30 – 361.70	227.69	64.52	28.33
Plant spread NS (cm)	46.70 – 328.30	236.21	44.82	18.97

Variability study in physico-chemical properties of pomegranate germplasm

Parameter	Range	Mean	SD	CV (%)
Fruit weight (g)	10.90 – 314.10	176.19	65.14	36.97
Fruit length (cm)	4 - 10	7.93	1.23	15.51
Fruit width (cm)	2.6 – 8.7	6.69	0.99	14.79
Fruit calyx length (cm)	0.4 – 1.7	1.25	0.33	26.4
Rind weight (g)	3.3 – 112.7	54.22	22.26	41.05
100 Aril weight (g)	12 – 42.90	28.68	5.07	17.68
Aril recovery (%)	54.80 – 78.10	68.59	5.22	7.61
Aril length (cm)	0.90 – 1.5	1.1	0.12	10.90
Aril width (cm)	0.5 -0.8	0.65	0.07	10.76
Rind thickness (cm)	0.1 – 0.6	0.28	0.07	27.81
T.S.S (%)	11.3 - 20	16.10	1.55	9.63

Variability study in flower traits of 50 germplasm collection

Parameter	Range	Mean	SD	CV (%)
Flower length (mm)	18.40 – 40.40	34.29	3.56	10.38
Flower width (mm)	5.7 – 15.6	12.5	1.67	13.36
Flower weight (g)	0.5 – 4.3	3.1	0.70	22.58
Petal length (mm)	10.80 – 36.60	19.25	3.71	19.27
Petal width (mm)	10 – 25.90	16.63	2.50	15.03

2.2 Screening of germplasm against wilt

During the year 2012-13 seven germplasm were screened for wilt resistance by artificially inoculating the rhizosphere soil of one year old potted plants with *Ceratocystis fimbriata* in the month of December, 2012. Periodical observations revealed that wilt symptoms initiated within one month of inoculation and continued to develop further till the end of March, 2013.

S.No.	Germplasm Collection	Plants infected (%)
1.	Jodhpur Collection	40
2.	IC 318705	20
3.	IC 318753	40
4.	IC 318759	40
5.	IC 1182	40
6.	IC 1204	20
7.	Shirin Anar	40

2.3 Screening of germplasm against Thrips

During the year 2012-13 twelve germplasm collection were screened for thrips resistance under shade net. Out of 12 germplasm screened against thrips, none found resistant. The average thrips population per plant ranged between 6.69 and 9.96 among germplasm screened during Oct, 2012 to Jan, 2013.

3. CROP PRODUCTION

3.1 Plant propagation

3.1.1 Propagation of pomegranate through hardwood cutting

3.1.1.1 Evaluation and multiplication of pomegranate germplasm through hard wood cutting for use as rootstocks

An experiment was conducted to evaluate the cutting success of promising germplasm on two different planting media during 2012-13 under green house and observations were recorded at 15, 30, 45 and 60 days after planting (DAP). Eight promising pomegranate germplasm showing less incidence of bacterial blight under field conditions were selected and multiplied through hardwood cutting. Irrespective of planting medium, hardwood cuttings of IC 1194 gave the maximum sprouting (88.33, 85.00 and 86.67 % at 15, 30 and 45 days after planting, respectively) and cutting success (85.00% at 60 days after planting). The sprouting and cutting success of germplasm collection, IC 1204 and 1205 were also at par with IC 1194. Planting medium consisting of mixture of sand, cocopeat and vermicompost (Bed 2) was found significantly better than the mixture of sand, soil and FYM (Bed 1) as far as sprouting and cutting success of germplasm are concerned.

Effect of planting medium on hardwood cutting success of pomegranate germplasm

Germplasm	Planting Medium		Mean[1]	Planting Medium		Mean[2]	Planting Medium		Mean[3]	Planting Medium		Mean[4]
	Bed 1	Bed 2		Bed 1	Bed 2		Bed 1	Bed 2		Bed 1	Bed 2	
IC 1205	83.33 (66.64)*	86.67 (72.74)	85.00 (69.69)	83.33 (66.15)	80.00 (63.93)	81.67 (65.03)	83.33 (66.64)	76.67 (65.81)	80.00 (66.22)	83.33 (66.64)	80.00 (64.64)	81.67 (65.63)
IC 1204	86.67 (68.85)	80.00 (64.64)	83.33 (66.75)	80.00 (63.93)	83.33 (66.15)	81.67 (65.03)	86.67 (72.24)	73.33 (59.22)	80.00 (65.73)	86.67 (72.24)	80.00 (64.64)	83.33 (68.44)
IC 1198	63.33 (52.85)	90.00 (74.95)	76.67 (63.91)	60.00 (50.86)	83.33 (66.15)	71.67 (58.50)	56.67 (48.93)	86.67 (68.85)	71.67 (58.89)	60.00 (50.94)	93.00 (77.66)	76.00 (64.31)
IC 1199	40.00 (39.06)	80.00 (68.81)	60.00 (53.93)	43.33 (41.15)	56.67 (48.85)	50.00 (45.00)	46.67 (43.07)	66.67 (55.08)	56.67 (49.08)	43.00 (41.15)	76.67 (62.71)	60.00 (51.93)
IC 1194	80.00 (63.93)	96.00 (83.77)	88.33 (73.85)	73.33 (59.00)	96.67 (83.77)	85.00 (71.38)	76.67 (61.93)	96.67 (83.77)	86.67 (72.84)	76.67 (61.22)	93.33 (77.66)	85.00 (69.44)
IC 1201	50.00 (45.08)	70.00 (56.78)	60.00 (50.94)	56.67 (48.93)	70.00 (56.78)	63.33 (52.85)	50.00 (45.08)	66.67 (54.78)	58.33 (49.93)	36.67 (37.15)	66.67 (54.78)	51.67 (45.96)
IC 318720	50.00 (45.00)	93.33 (77.66)	71.67 (61.33)	43.33 (41.15)	86.67 (72.24)	65.00 (56.70)	53.33 (46.93)	90.00 (74.95)	71.67 (60.94)	46.67 (43.07)	86.67 (72.24)	66.67 (57.67)
IC 318735	40.00 (39.14)	80.00 (63.93)	60.00 (51.54)	40.00 (39.24)	73.33 (59.00)	56.67 (49.12)	36.67 (37.15)	76.67 (61.71)	56.67 (49.43)	20.00 (21.98)	70.00 (57.29)	45.00 (39.64)
Mean	61.67 (52.57)	84.58 (70.42)		60.00 (51.30)	78.75 (64.60)		61.25 (52.74)	79.17 (65.53)		56.67 (49.30)	80.83 (66.45)	
CD (p=0.05)	G= 12.64			G= 7.73			G= 12.05			G= 13.08		
	B= 6.32			B= 3.87			B= 6.02			B= 6.53		
	GXB= 17.86			GXB= 10.93			GXB= 17.05			GXB= 18.49		

*Transformed value

1, 2, 3 and 4 are mean sprouting/cutting success at 15, 30, 45 and 60 days after planting, respectively

Bed1- mixture of sand, soil and vermicompost; Bed 2 -mixture of sand, cocopeat and vermicompost

Propagation of germplasm through hardwood cutting

3.1.1.2 Effect of hardwood cutting length and planting medium on success rate of propagules

The experiment was set up and treatments were imposed to study the effect of length of hardwood cutting and planting medium on sprouting and cutting success of pomegranate cv. 'Bhagwa'. The objectives behind this study were to produce more number of planting materials using shorter cuttings and to identify the suitable planting medium with high cutting success. The hardwood cuttings were dipped for 10 minutes in the solution of Carbendazim + Streptocycline and allowed to dry for 5 minutes. This treatment ensured production of healthy planting material. The basal portion of cuttings (7-10 cm) was treated with 2000 ppm IBA for 5 minutes before planting. The results depicted that the sprouting success at 15 DAP (96.67 and 86.67 percent with 20 and 15 cm long cuttings, respectively) were significantly influenced by the length of cutting but there were no significant differences in the sprouting and cutting success at 30, 45 and 90 DAP. Thus, stem cuttings of 15 cm length can also be utilized for hardwood cutting without affecting the success rate. Different planting media were tried to compare cutting success on conventional medium (mixture of sand, soil and FYM) vis-à-vis new combinations. Irrespective of the size of cutting, planting medium (mixture of sand, cocpeat and vermicompost) was found to be the best for enhancing the success rate of hardwood cuttings.

3.1.1.3 Trend of cutting success with progressing time period

When a graph was plotted to visualize the trend of cutting success with time period, it was found that the initial sprouting used to be very high which tend to decrease slowly upto 60 DAP and stabilizes thereafter.

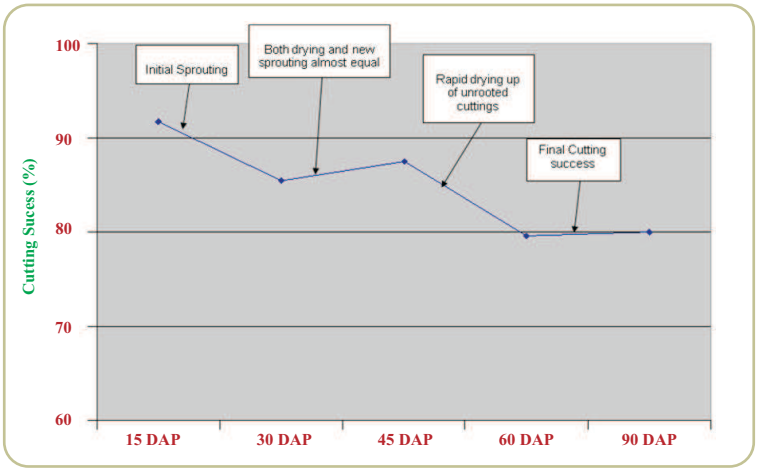
Effect of planting medium and length of hardwood cutting on sprouting and cutting success of pomegranate cv. Bhagwa

Planting Medium	Length of cutting (cm)		Mean[1]	Lengthof cutting (cm)		Mean[2]	Length of cutting (cm)		Mean[3]	Length of cutting (cm)		Mean[4]	Length of cutting (cm)		Mean[5]
	20	15		20	15		20	15		20	15		20	15	
P_0	93.33 (77.64)*	73.33 (59.71)	83.33 (68.68)	90.00 (74.93)	70.00 (57.00)	80.00 (65.97)	90.00 (74.93)	70.00 (57.00)	80.00 (65.97)	76.67 (61.22)	70.00 (60.00)	73.33 (59.11)	80.00 (63.93)	70.00 (57.00)	75.00 (60.47)
P_1	100.00 (89.81)	90.00 (74.93)	95.00 (82.38)	100.00 (89.81)	93.33 (77.64)	96.67 (83.74)	96.67 (83.74)	86.67 (68.85)	91.67 (76.29)	83.33 (66.15)	70.00 (60.00)	76.67 (61.57)	86.67 (68.85)	73.33 (59.00)	80.00 (63.93)
P_2	100.00 (89.81)	93.33 (77.64)	96.67 (83.74)	90.33 (78.80)	93.33 (81.03)	91.67 (79.91)	93.33 (81.03)	93.33 (77.64)	93.33 (79.33)	86.67 (68.85)	83.33 (66.15)	85.00 (67.50)	80.00 (64.64)	90.00 (71.56)	85.00 (68.10)
P_3	93.33 (77.64)	90.00 (74.93)	91.67 (76.29)	83.33 (70.01)	63.33 (53.07)	73.33 (61.54)	83.33 (70.01)	86.67 (72.22)	85.00 (71.13)	83.33 (66.15)	83.33 (66.15)	83.33 (66.15)	83.33 (66.15)	76.67 (61.22)	80.00 (63.68)
Mean	96.67 (83.74)	86.67 (71.80)		90.83 (78.39)	80.00 (67.19)		90.83 (77.42)	84.17 (68.93)		82.50 (65.59)	76.67 (61.57)		82.50 (65.90)	77.50 (62.20)	
CD (p=0.05)	P=12.88 L =9.12 P x L = 18.23			P=16.03 L =11.35 P x L = 22.69			P=15.94 L =11.28 P x L= 22.55			P=6.10 L =4.32 P x L = 8.63			P=7.94 L =5.61 P x L = 11.21		

* Transformed value

1, 2, 3, 4 and 5 are mean sprouting/cutting success at 15, 30, 45, 60 and 90 days after planting, respectively P_0 (Control)- mixture of sand, soil and FYM , P_1- mixture of sand and vermicompost, P_2- mixture of sand, cocopeat and vermicompost, P_3- mixture of sand, FYM and vermicompost

Rooted hard wood cutting of Bhagwa at 45 DAP



Hardwood cutting success in pomegranate cv. Bhagwa with progressing time period

3.1.2 Studies on Grafting

3.1.2.1 Influence of rootstocks on scion cultivars

Two scion cultivars viz. 'Ganesh' and 'Bhagwa' were grafted on seedlings of 'Ganesh',' Bhagwa', 'Mridula' and 'Arakta' as rootstocks to study the stionic influence. A total eight rootstocks and scion graft combinations were tested in the field for evaluation. The growth and fruit quality parameters were recorded on 3 year old trees. Plant height, Plant spread (NS and EW), fruit weight, 100 Aril weight and T.S.S were significantly influenced by the different rootstock and scion combinations.

3.1.2.2 Grafting success in pomegranate

Wedge grafting was tried on 7 rootstocks including wild accessions using Bhagwa as scion. The graft success ranged from 80-100% at 60 (Days after grafting) DAG in different accession. The shoot growth was significantly better when grafted on wild accession as compared to Bhagwa.

3.1.3 Studies on Budding

3.1.3.1 Budding in pomegranate

In a preliminary trial budding success was found to be more than >90%, when budding was done during mid January 2013.This indicated possibility of budding, especially for *in situ* budding.

Budding in pomegranate

3.1.4 *In vitro* propagation studies

3.1.4.1 Effect of different explants pretreatments on culture establishment

Nodal segment explants were given different pretreatments in order to establish contamination free cultures. Among various fungicides and antibiotic combinations, higher contamination free cultures were established when T_1 and T_3 pretreatments were given to the explants.

Though contamination percent was found lowest in cultures treated with T_6 but sprouting was also reduced significantly to 35.00% due to increased duration of treatment with fungicides and antibiotics. The results depicted that an increase in duration and concentration of pretreatments with fungicides and antibiotics beyond optimum level may result into reduced sprouting and increased necrosis.

Effect of different explant pretreatments on *in vitro* culture establishment in pomegranate cv. Bhagwa

Treatment	Days to Sprouting	Sprouting (%)	Contamination (%)	Necrosis (%)
T_0 (Sterile water)	9.00	5.00 (12.93)*	90.00 (71.56)	5.00 (12.93)
T_1 (Carbendazim + [Metalaxyl (4%) + Mancozeb (64%)] + Streptocycline for 30 min.)	15.67	60.00 (50.79)	28.33 (32.15)	11.67 (19.88)
T_2 (Carbendazim + [Metalaxyl (4%) + Mancozeb (64%)] + Streptocycline for 60 min.)	17.67	50.00 (45.00)	23.33 (28.78)	26.67 (30.99)
T_3 (Propiconazole + [Metalaxyl (4%) + Mancozeb (64%)] + Streptocycline for 30 min.)	15.67	55.00 (47.87)	18.33 (25.20)	26.67 (31.07)
T_4 (Propiconazole + [Metalaxyl (4%) + Mancozeb (64%)] + Streptocycline for 60 min.)	16.33	50.00 (45.00)	11.67 (19.88)	38.33 (38.25)
T_5 (Carbendazim + [Metalaxyl (4%) + Mancozeb (64%)] + Cycloheximide + Streptocycline for 30 min.)	12.33	50.00 (45.00)	30.00 (33.00)	20.00 (26.56)
T_6 (Carbendazim + [Metalaxyl (4%) + Mancozeb (64%)] + Cycloheximide + Streptocycline for 60 min.)	15.67	35.00 (36.24)	10.00 (18.44)	55.00 (47.87)
T_7 (Carbendazim + [Metalaxyl (4%) + Mancozeb (64%)] + Cycloheximide + kanamycin acid sulphate for 30 min.)	15.33	30.00 (33.00)	13.33 (21.15)	56.67 (48.93)
T_8 (Carbendazim + [Metalaxyl (4%) + Mancozeb (64%)] + Cycloheximide + kanamycin acid sulphate for 60 min.)	17.67	25.00 (29.92)	10.00 (18.04)	65.00 (53.73)
CD (p=0.05)	1.47	6.86	6.48	6.14

*Transformed value

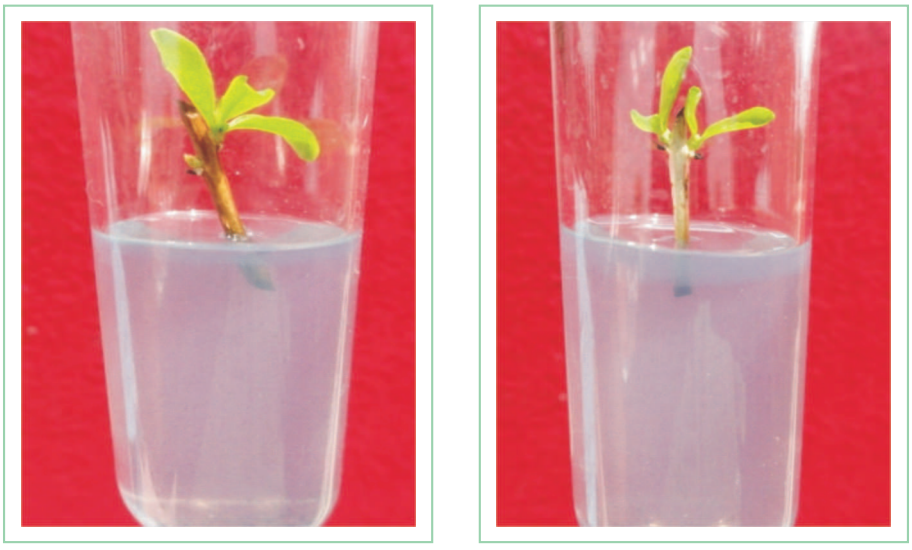
3.1.4.2 Standardization of culture establishment medium

A good culture establishment is very critical for standardization of an effective *in vitro* protocol. Among various media tried for culture establishment, explants on M_2 medium gave the highest sprouting (80.00 %) and M_4 inoculated plants took minimum days to sprout (9.50). All the culture establishment media were having activated charcoal (AC) @ of 200 mg/l.

Effect of different basal medium and growth regulator combinations on *in vitro* culture establishment in pomegranate cv. Bhagwa

Treatments	Sprouting (%)	Necrosis (%)	Days to sprouting
M_0 (MS basal medium)	20.00 (26.47)	70.00 (56.92)	14.25
M_1(MS basal medium + BAP + NAA)	70.00 (56.92)*	20.00 (26.47)	12.00
M_2 (MS basal medium + BAP + NAA + Adenine sulphate + Arginine)	80.00 (63.53)	7.50 (15.68)	10.25
M_3 (MS basal medium + BAP + NAA + Adenine sulphate + Arginine + Cysteine)	62.50 (52.32)	21.25 (27.43)	11.00
M_4 (Basal medium 1 + BAP + NAA)	70.00 (56.94)	17.50 (24.68)	9.50
M_5 (Basal medium 1+ Nutrient supplementation + BAP + NAA)	70.00 (56.83)	11.25 (19.53)	13.00
CD (p=0.05)	6.35	3.77	2.32

*Transformed value



***In vitro* sprouting of nodal segments of pomegranate**

3.1.4.3 Proliferation of established cultures

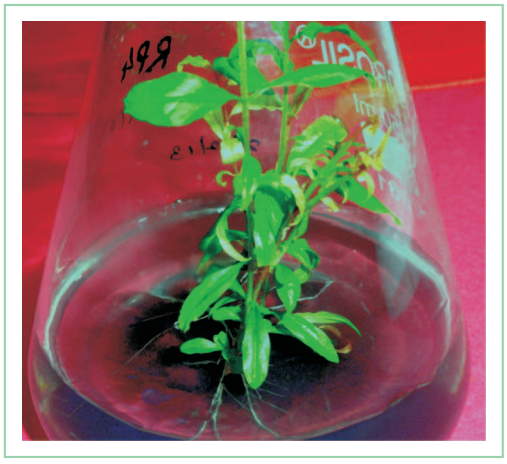
Approximately 2 cm long sprouts were excised and inoculated on proliferation medium. The maximum average shoot length (3.56 cm) was obtained when sprouts were inoculated on medium T_9 and the highest number of side shoots (6.03) were obtained on medium T_6 both these results were significantly superior to the results obtained with control. The results confirmed the pronounced role of cytokinins in shoot proliferation.

Effect of different basal medium and growth regulator combinations on *in vitro* proliferation in pomegranate cv. Bhagwa

Treatment	Average length of shoots at 25 DAI (cm)	No. of side shoots at 25 DAI	Average number of leaves per shoot at 25 DAI
T_0 (Basal medium)	1.80	2.20	3.12
T_1 (Basal Medium 1 + BAP + NAA)	1.88	3.13	3.13
T_2 (Basal Medium 1 + Nutrient supplementation 1 + BAP + NAA)	2.58	3.17	7.70
T_3 (Basal Medium 1 + Nutrient supplementation 2 + BAP + NAA)	2.61	3.13	5.93
T_4 (Basal Medium 2 + Nutrient supplementation 5 + BAP + NAA)	1.64	3.15	3.98
T_5 (Basal Medium 1 + Nutrient supplementation 1+ BAP + GA_3 + NAA)	2.93	3.00	9.37
T_6 [Basal Medium 1 + Nutrient supplimentation2 + Thiamine (x mg/l) + BAP + NAA]	3.07	6.03	10.57
T_7 [Basal Medium 1 + Nutrient supplementation 2 + Thiamine (y mg/l) + BAP + NAA]	2.34	3.05	8.70
T_8 (Basal Medium 1 + Nutrient supplementation 1 + BAP + IAA)	2.62	3.17	5.07
T_9 (Basal Medium 1 + Nutrient supplementation 3 + Zeatin + NAA)	3.56	3.19	11.25
T_{10} (Basal Medium 1 + Nutrient supplementation 4 + Zeatin + NAA)	2.24	3.25	6.37
CD (p=0.05)	0.49	0.89	2.39

Single node segment proliferated into multinodal shoot

***In vitro* multiplication**



***In vitro* rooting**

3.1.4.4 *In vitro* rooting of micro shoots

After 3-4 cycles of multiplication shoots were inoculated into the rooting medium containing 400 mg/l activated charcoal**.** Shoots on R_1 medium took minimum days to root **(**8.99) and shoots on R_7 medium produced the maximum number of roots per shoot (5.33). Root length (4.33 cm) was found maximum when shoots were inoculated on R_6. The performance of microshoots on best performing treatments (R1, R6 and R7 for days to root, root length and number of roots, respectively) were significantly superior to control. Auxins along with activated charcoal and low salt basal medium play critical role in rooting of microshoots.

Effect of different basal medium and growth regulator combinations on *in vitro* rooting of microshoots in pomegranate cv. Bhagwa

Treatment	Days to rooting	Number of primary/ main roots at 25 DAI	Average root length at 25 DAI (cm)
R_0 (Basal Medium)	15.67	2.00	3.00
R_1 [Basal Medium + IAA(x mg/l)]	8.99	4.33	3.53
R_2 [Basal Medium + IBA(x mg/l)]	11.66	3.33	2.17
R_3 [Basal Medium + NAA(x mg/l)]	11.17	3.00	3.02
R_4 [Basal Medium + BAP (a mg/l) + IAA (b mg/l) + NAA (c mg/l)]	10.11	3.00	3.20
R_5[Basal Medium + BAP (a mg/l) + IAA (d mg/l) + NAA (e mg/l)]	9.89	4.00	3.29
R_6 [Basal Medium + IAA (y mg/l)]	9.22	3.67	4.33
R_7 [Basal Medium + IBA (y mg/l)]	10.67	5.33	3.23
CD (p=0.05)	1.69	1.21	1.12

3.1.4.5 Biohardening of tissue culture raised plants using beneficial microbes

An experiment was set up during 2012-13 to study the effect of inoculation of plant beneficial microbes during *ex vitro* hardening on morphological, physiological, biochemical attributes of tissue culture raised plants. Two beneficial microbes namely, *Glomus intraradices* and *Aspergillus niger* were used for biohardening of tissue culture raised plants.

Biohardening of tissue culture raised plants using beneficial microbes

3.2 Soil Management

3.2.1 Identification of suitable soils for sustained productivity of pomegranate

3.2.1.1 Performance of pomegranate orchards on different mixtures used for pit filling.

Performance of two cultivated varieties of pomegranate viz. Ganesh and Bhagwa were studied on different pit filling medium comprising of murrum, sandy soil with high gravels content, loamy and black soils having varied depth.

Vegetative growth parameters

Plant height and spread were recorded as vegetative growth parameters. The results revealed that significant variation in N-S and average spread was observed in Ganesh. Plants on black clayey soil produced highest vegetative growth (in terms of height and spread of plant) followed by black soil filled up to a depth of 30 cm and loamy soil. There was drastic reduction in growth with the increase in depth of black clayed soil. Good vegetative growth was also observed when pits in black soil filled with murrum and with the mixture of black soil and sand. This clearly indicates the importance of well drained condition to have good vegetative growth of pomegranate cv. Ganesh. Pit filled with only murrum recorded lowest vegetative growth during fourth year of study.

Significant variation in plant spread of 'Bhagwa' variety was also observed on different types of pit filling medium Here, plant growth was highest when pits were filled with black clayey soil up to a depth of 90 cm but drastic reduction in vegetative was noticed when filled with black clayey soil up to a depth of 120 cm. In light textured soils plant growth was poor.

Bhagwa variety of pomegranate grows well in black clayey soils even up to depth of 90 cm and is more tolerant to poor drainage conditions compared to Ganesh variety. While, Ganesh variety grows equally well in light textured soils but is more susceptible to poor drainage conditions compared to Bhagwa variety.

Vegetative growth of pomegranate plants cv. Ganesh grown under different soil

Treatments	Plant Height (cm)	Plant spread (cm)		
		E–W	N – S	Average
Light Gravely soil 30 cm depth	162.5	143.8	141.3	142.5
Light Gravely soil 60 cm depth	161.7	141.7	138.3	140.0
Sandy loam soil 60 cm depth	165.8	148.3	139.2	143.8
Loamy soil 60 cm depth	164.2	149.2	160.0	154.6
Black clayey soil 30 cm depth	174.2	154.2	151.7	152.9
Black clayey soil 60 cm depth	178.3	159.2	165.8	162.5
Black clayey soil 90 cm depth	158.3	134.2	130.8	132.5
Black clayey soil 120 cm depth	157.1	136.3	131.3	133.8
Black clayey soil (50%) + Sand (50%)	168.5	144.2	150.0	147.1
Black clayey soil (75%) + Sand (25%)	162.5	150.0	151.7	150.8
Weathered murrum	160.0	134.2	120.0	127.1
CD (p=0.05)	NS	NS	22.3	19.4

Vegetative growth of pomegranate plants cv. Bhagwa grown under different soil

Treatments	Plant Height (cm)	Plant spread (cm)		
		East-West	North-South	Average
Light Gravely soil 30 cm depth	141.7	118.3	135.0	126.7
Light Gravely soil 60 cm depth	126.7	99.2	121.7	110.4
Sandy loam soil 60 cm depth	145.8	137.5	138.3	137.9
Loamy soil 60 cm depth	140.8	117.5	127.5	122.5
Black clayey soil 30 cm depth	145.0	141.3	152.9	145.0
Black clayey soil 60 cm depth	148.3	138.3	143.3	140.8
Black clayey soil 90 cm depth	148.3	138.3	141.7	140.0
Black clayey soil 120 cm depth	147.7	137.3	131.7	134.5
Black clayey soil (50%) + Sand (50%)	144.0	141.3	132.5	136.9
Black clayey soil (75%) + Sand (25%)	147.8	127.5	132.5	130.0
Weathered murrum	137.5	133.3	130.8	132.1
CD (p=0.05)	NS	19.0	16.0	16.0

Fruit yield

Significant variations in yield attributes of Ganesh variety were also noted in plants grown on different types of pit filling medium. Total number of fruits per plant varied from 12.0 to 27.7 and it was highest in the plants grown on black clayey soils filled up to a depth of 30 cm followed by black soil mixed with sand (in 1:1 proportion) and black soil filled up to a depth of 60 cm and loamy soil. There was reduction in fruit yield when plants were grown on pits filled with black clayey soils up to a depth of 60 and 90 cm. The poor drainage conditions prevailed under these treatments might have resulted lower production of fruit. Fruit weight also showed more or less same trend. However, average weight of fruit was highest in the plants grown on pits filled with black clayey soil up to a depth of 90 cm owing to lesser number of fruits with higher plant canopy volume. Fruit weight was lowest in plants grown on light gravelly soils followed sandy loam soils.

Fruit yield attributes of Ganesh variety as affected by different pit filling medium

Treatments	No. of fruits/plant	Wt. of fruits / plant (kg)	Average wt of each fruit (g)	Fruit length (mm)	Fruit diameter (mm)
Light Gravely soil 30 cm depth	17.0	3.785	222.9	72.4	75.0
Light Gravely soil 60 cm depth	18.0	4.185	232.2	72.5	74.4
Sandy loam soil 60 cm depth	17.3	3.980	230.1	72.0	75.1
Loamy soil 60 cm depth	20.0	4.787	240.0	74.7	75.0
Black clayey soil 30 cm depth	27.7	6.788	245.5	76.3	77.6
Black clayey soil 60 cm depth	20.7	5.242	254.1	74.7	77.4
Black clayey soil 90 cm depth	12.0	3.158	263.2	70.4	73.6
Black clayey soil 120 cm depth	16.0	3.888	243.2	72.9	74.0
Black clayey soil (50%) + Sand (50%)	22.7	5.343	236.1	72.5	76.0
Black clayey soil (75%) + Sand (25%)	16.7	3.855	231.5	74.0	76.6
Weathered murrum	15.3	3.596	234.9	70.4	72.3
CD (p=0.05)	6.63*	1.53	4.24*	NS	NS

Fruit quality

Significant variations were noted in percent fruit juice, total soluble solids (TSS), TSS/ acid ratio when grown on different types of pit filling medium. While fruit height and diameter, rind thickness and percent rind, fruit aril percentage and juice acidity showed non-significant variation. Highest juice percent in the fruit was noted on sandy soil followed by light gravelly soil and only murrum. While, it was low on black soils filled up to a depth of 30 cm and other treatments comprising of black soil. However these treatments had fruits with thicker rind. Highest TSS values were recorded in fruits produced on loamy soil followed by light gravelly soil and it was lowest on black soils filled up to a depth of 30 cm. Similarly TSS / acidity ratio was also highest in light gravelly soils and loamy soils. In general it was observed that better quality fruits were produced on light textured soils treatments.

3.2.1.2 Performance of pomegranate under different planting systems

The performance of pomegranate plants under different planting system comprising of continuous trenches of different depth and shape, broad bed and furrow systems of different height and pits of different sizes were evaluated. The beds have 0.3-0.5m height in the middle and tapers gently on both sides to a length of 0.5m from the elevated point. The plants were evaluated for foliar nutrient content, vegetative growth, incidence of diseases and fruit yield.

Nutrient content in the leaves

Significant variation in the foliar content of N, K, Fe, Mn and Zn content was noted under different planting systems, while it was non-significant in case of P, Ca, Mg and Cu content. Bedding system of plantation was found very effective in enhancing foliar content of most of the nutrients. Sufficient rooting depth coupled with good drainage and aeration provided congenial condition for the uptake of most of the nutrients by the roots. On the basis of foliar nutrient content, this system was followed by continuous trench system where rooting depth is quiet high compared to pits of both the sizes. Moreover availability of moisture for longer duration under this system resulted in better root growth and hence, more areas were exploited by the roots for nutrient absorption.

Fruit quality of 'Ganesh' variety as affected by different pit filling medium

Treatments	Rind thickness (mm)	Rind fruit (%)	Fruit Arils (%)	Fruit Juice (%)	Juice acidity (%)	TSS (^{O}Brix)	TSS/acid ratio
Light Gravely soil 30 cm depth	1.97	26.6	73.4	50.5	0.40	16.87	42.29
Light Gravely soil 60 cm depth	1.90	24.8	75.2	53.1	0.40	16.00	40.01
Sandy loam soil 60 cm depth	1.93	26.3	73.7	53.8	0.42	15.87	37.89
Loamy soil 60 cm depth	1.77	26.5	73.5	51.2	0.44	17.20	39.09
Black clayey soil 30 cm depth	1.90	25.4	74.6	50.6	0.48	15.47	32.51
Black clayey soil 60 cm depth	2.10	30.0	70.0	46.4	0.43	15.93	37.09
Black clayey soil 90 cm depth	2.34	27.2	72.8	49.1	0.47	16.47	35.34
Black clayey soil 120 cm depth	2.12	28.3	71.7	49.6	0.44	16.13	36.50
Black clayey soil (50%) + Sand (50%)	2.02	29.0	71.0	48.4	0.43	16.80	39.14
Black clayey soil (75%) + Sand (25%)	1.86	25.9	74.1	51.7	0.44	16.13	36.42
Weathered murrum	1.75	26.4	73.6	52.2	0.46	16.13	34.86
CD (p=0.05)	NS	NS	NS	3.19	NS	0.88	3.80

Nutrient content in the leaves of pomegranate plants grown under different treatments

Treatments	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn
	(%)					(ppm)			
T 1	2.18	0.146	0.78	1.90	0.41	107.5	60.1	72.8	26.0
T 2	2.01	0.141	0.67	2.03	0.45	105.2	52.3	75.8	27.0
T 3	2.24	0.151	0.89	1.87	0.39	110.0	61.8	85.3	32.5
T 4	2.14	0.146	1.05	1.59	0.36	91.7	54.4	64.8	26.2
T 5	2.07	0.143	0.83	2.01	0.37	110.0	62.4	69.2	29.5
T 6	2.15	0.149	0.86	2.05	0.41	112.1	57.3	67.3	26.5
T 7	2.46	0.148	1.05	1.85	0.42	122.2	53.6	67.2	25.7
CD (p=0.05)	0.23	NS	0.21	NS	NS	16.5	7.5	NS	4.5

T 1 - Pits of 1 x 1 x 1 m size**, T 2-** Pits of 0.60 x 0.60 x 0.60 m size**, T 3 -** Continuous trenches 1 x 1 m size**, T4 -** Continuous trenches 0.60 x 0.60 m size**, T5-** Trapezoidal trenches 0.60 m deep, 1.5 m top width**, T6-** Bedding system 0.60 m width x 0.30 m deep x 0.30 m above ground**, T 7 -** Bedding system 0.60 m width x 0.60 m deep x 0.30 m above ground

Vegetative growth parameters

Plant vegetative growth parameters in terms of height and spread were recorded during January 2013. Significant variation in plant spread was observed under different planting system. Bedding system (0.60 m width x 0.60 m deep x 0.30 m above ground) of planting with different bed size resulted higher vegetative growth compared to other systems of planting. This system provided better drainage conditions in upper 30 cm soil depth where maximum root activities take place and this resulted in to least incidence of soil borne diseases. There was significant reduction in plant growth under other systems of planting specially in continuous trenches mainly due to incidence of diseases namely wilt.

Vegetative growth of pomegranate plants grown under different planting systems

Treatments	Plant Height (m)	Plant spread (m)		
		E– W	N – S	Average
Pits of 1 x 1 x 1 m size	116.4	87.5	104.6	96.1
Pits of 0.60 x 0.60 x 0.60 m size	132.5	127.5	116.3	121.9
Continuous trenches 1 x 1 m size	131.3	80.0	77.5	78.8
Continuous trenches 0.60 x 0.60 m size	116.9	116.9	113.1	115.0
Trapezoidal trenches 0.60 m deep, 1.5 m top width	136.3	107.5	108.8	108.1
Bedding system 0.60 m width x 0.30 m deep x 0.30 m above ground	153.8	146.3	156.3	151.3
Bedding system 0.60 m width x 0.60 m deep x 0.30 m above ground	165.6	171.9	165.0	168.4
CD (p = 0.05)	NS	40.0	50.1	43.6

Incidence of diseases

Disease especially wilt incidence might have occurred during 2012, which increased during rainy season and become severe during 2013. Most of the plants grown under bedding system of plantation remained healthy (75.0 to 87.5 %) while under continuous trench system of plantation all the plants got infected with disease leading to highest plant mortality (50%). Remaining plants were also severely infected with wilt disease and are on the verge of decline. The prevalence of prolonged moisture saturation condition during rainy season in continuous trench system might have created congenial atmosphere for the spread and growth of diseases resulting in high plant mortality. In the same plot bedding system of plantation provided good drainage and aeration at least in upper 30 to 50 cm soil surface having highest root activities which retarded the spread of wilt diseases.

Soil moisture content

To study the soil moisture movement pattern under different planting systems, the tree basins were flooded with irrigation water in order to simulate the water saturated conditions as prevails during rainy season. The moisture content in three soil depths (0-15, 15-30 and 30-45 cm) was measured at 2 to 3 days interval by gravimetric method. The results revealed that in surface 0-15 cm soil layer, moisture content was more in different trench systems followed by pits of 1 m^3 size. In bedding systems it decreased immediately 2 to 3 days after flooding and always remained at low throughout the observation period which created well drained conditions in surface layers throughout the rainy season. Similar situations also prevailed in 15-30 cm soil depth. But at 30-45 cm soil depth much variation in soil moisture content was not observed under different planting systems. Throughout the observation period, soil moisture content was high under continuous trench system at all the depths which maintained sufficient moist condition even during the dry period.

Similar study was made under normal drip system of irrigation and soil moisture content at three depths (0-15, 15-30 and 30-45 cm) was measured under different planting systems. Higher moisture content at lower soil depth was observed under all the planting systems compared to surface layer. Much variation was not observed under different planting system.

Incidence of wilt disease in pomegranate plants grown under different planting systems

Treatments	Healthy plants (%)	Severely infected live plants (%)	Plant mortality (%)
Pits of 1 x 1 x 1 m size	25.0	50.0	25.0
Pits of 0.60 x 0.60 x 0.60 m size	12.5	62.5	25.0
Continuous trenches 1 x 1 m size	0.0	50.0	50.0
Continuous trenches 0.60 x 0.60 m size	37.5	50.0	12.5
Trapezoidal trenches 0.60 m deep, 1.5 m top	37.5	50.0	37.5
Bedding system 0.60x0.30x0.30 m above ground	87.5	0.0	12.5
Bedding system 0.60x0.60x0.30 m above ground	75.0	0.0	25.0

Periodical (saturation to nearly dry condition) soil moisture content (%) at different depth under different treatments of planting system

Vertical depth (cm)	T 1	T 2	T 3	T 4	T 5	T 6	T 7
Date of sampling - 17.12.2012							
0 - 15	18.6	18.3	19.8	19.6	20.0	17.5	18.0
15 - 30	19.5	19.2	20.1	20.1	19.8	18.8	17.8
30 - 45	20.1	19.0	20.5	18.5	19.9	18.5	19.0
Date of sampling - 20.12.2012							
0 - 15	18.0	17.8	19.3	18.3	19.0	16.3	16.5
15 - 30	19.0	18.3	20.5	19.3	19.6	16.8	15.9
30 - 45	19.5	17.0	20.8	19.1	19.1	18.0	18.6
Date of sampling - 22.12.2012							
0 - 15	17.0	16.8	18.0	17.6	18.1	15.0	15.7
15 - 30	17.8	17.0	18.7	18.5	18.0	16.3	15.9
30 _ 45	17.8	16.0	19.1	18.0	17.5	16.2	16.5
Date of sampling - 25.12.2012							
0 - 15	15.3	15.0	16.2	16.0	15.5	14.4	14.8
15 - 30	16.2	16.0	17.0	16.5	16.2	15.2	15.0
30 - 45	16.2	14.5	17.2	17.0	15.5	15.1	14.6
Date of sampling - 28.12.2012							
0 - 15	14.5	14.2	14.8	14.3	14.9	13.0	13.2
15 - 30	14.6	15.1	15.6	15.1	15.6	14.8	14.0
30 - 45	15.0	14.0	15.5	15.2	15.5	15.0	14.6
Date of sampling - 31.12.2012							
0 - 15	11.6	11.0	12.2	12.0	12.2	10.5	10.0
15 - 30	12.2	12.1	12.5	12.6	13.0	11.6	11.0
30 - 45	13.0	11.2	13.6	13.0	12.5	13.3	12.9
Date of sampling – 04.01.2012							
0 - 15	8.1	7.8	9.5	9.2	8.7	8.0	7.6
15 - 30	11.0	11.2	10.8	11.2	12.1	10.1	10.7
30 - 45	12.5	10.0	11.6	11.2	11.5	12.2	12.5

(First flood irrigation on 15.12.2012 till saturation)

T 1 - Pits of 1 x 1 x 1 m size**, T 2-** Pits of 0.60 x 0.60 x 0.60 m size**, T 3 -** Continuous trenches 1 x 1 m size**, T4 -** Continuous trenches 0.60 x 0.60 m size**, T5-** Trapezoidal trenches 0.60 m deep, 1.5 m top width**, T6-** Bedding system 0.60 m width x 0.30 m deep x 0.30 m above ground**, T 7 -** Bedding system 0.60 m width x 0.60 m deep x 0.30 m above ground

Periodical soil moisture content (%) under alternate day drip irrigation system under different treatments of planting system

Vertical depth (cm)	T 1	T 2	T 3	T 4	T 5	T 6	T 7
Date of sampling – 26.01.2013							
0 - 15	18.2	18.0	18.7	18.3	19.0	17.7	17.5
15 - 30	18.8	18.3	19.5	19.3	19.6	18.8	18.9
30 - 45	19.5	18.7	19.8	20.0	20.0	18.0	18.6
Date of sampling - 28.01.2012							
0 - 15	18.6	17.9	18.2	19.0	19.0	17.8	18.0
15 - 30	19.0	18.4	19.8	19.2	19.6	18.2	19.0
30 - 45	19.8	18.7	20.0	19.7	19.3	18.5	18.2
Date of sampling - 31.01.2012							
0 - 15	19.0	18.4	17.9	18.5	18.4	17.5	18.3
15 - 30	19.5	19.0	20.0	19.0	20.0	18.0	19.0
30 - 45	20.0	19.0	20.2	19.7	18.7	19.0	18.9
Date of sampling - 03.02.2012							
0 - 15	18.0	18.1	17.5	18.0	18.0	17.1	17.7
15 - 30	19.0	19.0	19.5	19.0	19.0	18.5	19.2
30 - 45	19.5	18.8	19.6	19.2	18.5	19.3	19.5

First drip irrigation on 25.01.2012

Fruit yield

Fruit yield data revealed highly significant variation under different planting systems which might be due plant mortality and severe infection with wilt disease. There was large variation in number of fruit per plant ranging from 16.25 to 36.38 fruits per plant and it was highest in the plants grown under bedding system of plantation. The plants grown under this system were healthy with good vigor which led to production of higher yield. This was followed by trench system of plantation where plants were also with good vigor in spite of disease infection. Fruit yield in terms of weight also followed similar trend.

Fruit yield and quality of pomegranate plants as affected by different system of plantation

Treatments	No. of fruits/plant	Total fruit weight / plant (kg)	Average weight of each fruit (g)	Fruit height (mm)	Fruit diameter (mm)
Pits of 1 x 1 x 1 m size	18.13	4.310	241.3	65.2	67.0
Pits of 0.60 x 0.60 x 0.60 m size	16.38	3.885	237.5	63.2	67.0
Continuous trenches 1 x 1 m size	16.25	3.698	228.8	61.5	64.5
Continuous trenches 0.60 x 0.60 m size	29.88	7.509	250.2	65.7	67.9
Trapezoidal trenches 0.60 m deep, 1.5 m top	24.25	6.261	252.0	66.2	68.5
Bedding system 0.60 x 0.30 x 0.30 m above ground	30.88	8.936	290.4	67.7	68.1
Bedding system 0.60 x 0.60 x 0.30 m above ground	36.38	9.373	257.5	63.8	66.9
CD (p=0.05)	9.27*	2.54*	24.0*	NS	NS

Fruit quality

Fruits of live plants grown under different planting system were harvested three times during the month of January 2013 and analysed for different quality parameters. Almost all the parameters showed non-significant variation amongst the treatments except juice percentage. Highest juice content was recorded in the fruits grown under bedding system and was lowest under pits of 60 x 60 x 60 cm^3 dimension. It was also observed that fruits produced under bedding system of plantation were of good quality.

Fruit quality parameters as affected by different planting systems

Treatments	Rind thickness (mm)	Rind fruit (%)	Fruit Arils (%)	Fruit Juice (%)	Juice acidity (%)	TSS (^{O}Brix)	TSS/acid ratio
Pits of 1 x 1 x 1 m size	2.43	36.6	63.4	43.5	0.46	15.40	33.5
Pits of 0.60 x 0.60 x 0.60 m size	2.73	37.1	63.0	41.7	0.48	15.60	33.2
Continuous trenches 1 x 1 m size	2.56	37.9	62.1	43.4	0.44	15.05	34.1
Continuous trenches 0.60 x 0.60 m size	2.56	36.9	63.1	43.5	0.44	14.95	34.1
Trapezoidal trenches 0.60 m deep, 1.5 m top	2.52	36.4	63.6	42.9	0.47	15.50	33.5
Bedding system 0.60 x 0.30 x 0.30 m above ground	2.14	35.3	64.7	44.0	0.43	15.30	35.9
Bedding system 0.60 x 0.60 x 0.30 m above ground	2.42	35.2	64.8	44.7	0.44	15.30	35.1
CD (p=0.05)	NS	NS	NS	1.42	NS	NS	NS

3.3 Nutrient management in pomegranate

3.3.1 Response of various organic sources of nutrients on growth, yield and quality of pomegranate

The plant performance in terms of growth, fruit yield and quality was studied in response to use of various organic sources of nutrients comprising of farmyard manure, vermicompost, poultry manure, and various green manures such as sunnhemp, glyricidia, karanj and neem leaves. Application of inorganic fertilizers at recommended dose served as a check along with control. Organic sources of nutrients were applied on nitrogen equivalent basis.

Nutrient content in the leaves

The leaf samples collected during October 2010 were analyzed for different macro- and micro-nutrient contents. Significant variation was noted in foliar content of N, K, Fe and Zn while, it was non-significant in case of P, Ca, Mg, Mn and Cu. Highest N content was recorded with inorganic fertilizer application at recommended dose followed by green manuring with sunhemp. While, foliar content of P, Ca and Cu was highest with farmyard manure application. Green manuring with sunhemp was found most effective in enhancing foliar content of K, Fe and Zn.

Nutrient content in the leaves of pomegranate plants grown under different treatments

Treatments	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn
	(%)					(ppm)			
T 1	2.07	0.162	0.82	2.00	0.45	126.7	24.3	52.9	30.3
T 2	2.05	0.149	0.73	1.56	0.50	117.2	19.7	41.1	25.6
T 3	1.97	0.150	0.85	1.76	0.50	130.1	21.0	40.0	28.1
T 4	2.08	0.128	0.97	1.82	0.48	141.9	25.4	35.1	35.6
T 5	2.00	0.134	0.84	1.70	0.50	128.5	23.1	45.5	26.5
T 6	2.05	0.132	0.88	1.82	0.50	123.9	23.0	34.9	25.7
T 7	2.06	0.138	0.87	1.97	0.51	127.1	21.5	42.3	27.5
T 8	2.24	0.159	0.94	2.00	0.48	117.1	23.5	41.0	27.3
T 9	1.77	0.125	0.76	1.82	0.46	113.3	20.8	40.2	26.0
CD (p=0.05)	0.21	NS	0.026	NS	NS	15.9	NS	NS	5.77

T1 – Farmyard manure, T2 – Vermicompost, T3 – Poultry manure, T4 – Sunhemp Green manuring *in situ,* T5 – Glyricidia Green manuring *ex situ,* T6 – Karanj Green manuring *ex situ,* T7 –Neem leaves Green manuring *ex situ,* T8 – Inorganic fertilizers, T9 – Control

Chlorophyll content

Significant variation was observed in chlorophyll content of leaves with the application of various organic sources of nutrients. Highest SPAD values were recorded with inorganic fertilizer application at recommended dose while, it was lowest in control plots. Among the organic sources of nutrients, higher chlorophyll content was recorded with plants received nutrients through vermin-compost, *in situ* green manuring with sunnhemp and farmyard manure.

Chlorophyll content in the leaves of pomegranate plants supplied with different organic manaures

Treatments	Chlorophyll content (SPAD)
Farmyard manure	60.8
Vermicompost	61.4
Poultry manure	56.4
Sunnhemp Green manuring *in situ*	60.7
Glyricidia Green manuring *ex situ*	59.2
Karanj Green manuring *ex situ*	59.4
Neem leaves Green manuring *ex situ*	59.8
Inorganic fertilizers	61.1
Control	51.2
CD (p=0.05)	2.44

Vegetative growth parameters

Significant variation was noted in plant height, N-S spread and average spread with different organic sources of nutrients. Plant height and N-S spread was highest when the plants were supplied nutrients through vermicompost while average spread was highest with farmyard manure application. After four years, these organic treatments were found superior to inorganic fertilizer application in enhancing plant height.

Fruit yield

Fruit yield data revealed highly significant variation among the various organic sources of nutrients. There was large variation in number of fruit per plant ranging from 13.0 to 29.7 fruits per plant and it was highest in the plants where nutrients were supplied through poultry manure followed by farmyard manure. This implies that poultry manure application might have some beneficial effects on flowering and fruiting setting of pomegranate. Although, plant growth and foliar nutrient content was higher with inorganic fertilizer application and green manuring with sunhemp, it was not reflected in fruit yield. Fruit yield in terms of weight followed similar trend. Weight of individual fruit was highest in the plants supplied with inorganic fertilizers while it was lowest with the application of poultry manure. Fruit length and diameter showed non-significant variation.

Vegetative growth of pomegranate plants as affected by different treatments of organic manuring

Treatments	Plant height (cm)	Plant spread (cm) (East-West)	Plant spread (cm) (North-South)	Plant spread (cm) (Average)
Farmyard manure	133.6	130.8	125.0	127.9
Vermicompost	140.0	123.3	128.8	126.1
Poultry manure	125.0	121.7	120.6	121.1
Sunnhemp Green manuring *in situ*	127.3	122.8	123.6	123.2
Glyricidia Green manuring *ex situ*	126.7	116.7	121.7	119.2
Karanj Green manuring *ex situ*	124.2	119.4	113.9	116.7
Neem leaves Green manuring *ex situ*	125.6	124.4	117.8	121.1
Inorganic fertilizers	129.0	126.7	121.1	123.9
Control	115.8	108.3	105.0	106.7
CD (p=0.05)	11.3	NS	12.4	9.25*

Fruit yield as affected by different treatments of organic manuring

Treatments	No. of fruits/plant	Wt. of fruits / plant (kg)	Average wt of each fruit (g)	Fruit length (mm)	Fruit diameter (mm)
Farmyard manure	26.3	3.857	146.8	59.6	64.6
Vermicompost	15.0	2.176	145.0	63.5	67.0
Poultry manure	29.7	3.958	133.8	62.7	65.5
Sunnhemp Green manuring *in situ*	19.7	2.972	150.9	62.3	66.8
Glyricidia Green manuring *ex situ*	15.3	2.380	155.1	62.4	66.0
Karanj Green manuring *ex situ*	14.7	2.028	137.7	60.4	65.3
Neem leaves Green manuring *ex situ*	17.7	2.754	155.9	63.7	68.4
Inorganic fertilizers	18.3	3.153	172.0	66.6	71.4
Control	13.0	1.878	144.1	62.8	68.2
CD (p=0.05)	5.49*	0.839*	11.04*	NS	NS

Fruit quality

Except rind thickness, significant variation was observed in all other fruit quality parameters under study with different organic sources of nutrients. Highest percentage of fruit arils with lowest rind content was recorded under control plots. Fruits grown under green manuring with sunhemp had highest juice percentage which was also at per with that obtained through poultry manure application. Lowest values of fruit juice acidity and highest TSS / acid rations were observed with vermin-compost application. Fruits produced with the application of organic manures had better quality compared to inorganic fertilizers.

Fruit and juice quality parameters as affected by different treatments of organic manuring

Treatments	Rind thickness (mm)	Rind fruit (%)	Fruit Arils (%)	Fruit Juice (%)	Juice acidity (%)	TSS (^{O}Brix)	TSS/acid ratio
Farmyard manure	2.54	39.9	60.1	41.5	0.43	15.1	35.0
Vermicompost	2.51	39.4	60.6	40.8	0.37	15.1	40.6
Poultry manure	2.50	37.1	62.9	43.8	0.41	15.5	38.3
Sunnhemp Green manuring *in situ*	2.37	36.4	63.6	44.0	0.44	15.8	36.2
Glyricidia Green manuring *ex situ*	2.43	36.9	63.1	43.3	0.42	15.3	36.6
Karanj Green manuring *ex situ*	2.60	41.5	58.5	41.3	0.45	15.2	33.6
Neem leaves Green manuring *ex situ*	2.59	38.2	61.8	43.7	0.46	15.4	33.5
Inorganic fertilizers	2.63	38.3	61.7	43.0	0.42	14.6	35.2
Control	2.35	35.4	64.7	43.6	0.39	14.8	38.2
CD (p=0.05)	NS	2.57*	2.57*	1.58*	0.04	0.65	3.93

3.3.2 Micronutrient management for sustainable growth, yield and quality of pomegranate

3.3.2.1 Seasonality of nutrients in leaves and fruits of pomegranate

Fruit growth

Fruit fresh and dry mass accumulation of pomegranate was small until 4th fortnight after full bloom representing 12.29% and 17.48% of final harvestable fruit respectively. From this period onwards, more expressive increments in both fresh and dry mass took place, so that in 9th fortnights, the fresh and dry weight attained 71.62% and 80.85% of final harvestable fruit mass. After 9th fortnight onwards, the fresh and dry mass accumulation of fruit was very small and fruit growth attained plateau until harvesting.

Primary nutrient concentration in leaf and fruit

The seasonality of nitrogen (N) concentration in leaves exhibited somewhat different trend than phosphorus (P) and potassium (K). The N concentration in leaves of non-bearing flushes initially increased upto 45 days after full bloom, thereafter it decreased gradually during rest of the growth period of fruits. While its concentration in leaves of bearing flushes decreased slightly during first phase of fruit growth (i.e. upto 75 days after full bloom) and in the second phase of fruit growth period its concentration started building up, attained a peak at 105 days after full bloom and then declined gradually towards maturity of the fruit. As in the first phase, the growth of fruit was small, only little amount of N from leaves redistributed to the sink (developing fruit) which resulted slight dip in N concentration during this phase. However in second phase, the growth of fruit was very rapid, N from leaves of both bearing and non-bearing flushes (as N is very mobile within the plant) redistributed towards fruit resulting in declining concentration of N in leaves. In fruit N concentration declined gradually during the entire period of fruit growth and development.

Phosphorus (P) concentration in leaves decreased gradually throughout the growing cycle of the fruit. There were no significant differences of P concentration in leaves of non-bearing and bearing flushes. The pattern of changes of P concentration in fruit was also similar to N, but here P concentration in fruit decreased sharply in first phase of fruit growth which might be due to its involvement in cell division that take place during this period. Thereafter its concentration remained more or less stable as the fruit grew.

Potassium concentration in leaves initially increased during the first fortnight, then sharply decreased at 45 days after full bloom and again its concentration built up to 105 days after full bloom, thereafter its concentration declined towards maturity of the fruit. Overall the potassium concentration in leaves showed a declining trend throughout the growing cycle of fruit owing to redistribution to other plant organs (sink). As the growers used to apply K through fertigation during the second phase of fruit growth for improving fruit quality which might have led to building up of K concentration in leaves. Further it was observed that K concentration in leaves of non-bearing flush was higher during most of the time of fruit growth cycle than bearing flushes. Like P and N, potassium concentration in fruit also showed declining trend throughout the growth of fruit with sharp fall at 45 and 90 days after full bloom which may be explained as dilution effect. At harvest, the relative order of concentration of primary nutrients in fruit was K>N>P. And it was estimated that 625.31 mg K, 465.97 mg N and 57.25 mg P were removed with the harvest of single fruit.

Secondary nutrient concentration

Among the secondary nutrients (Ca, Mg & S), calcium (Ca) and magnesium (Mg) concentration in leaves showed increasing trend during the growth cycle of the fruit. There was no significant difference of Ca concentration in leaves of non-bearing flushes and bearing flushes. However Mg concentration in leaves of non-bearing flushes was higher than bearing flushes during the later part of fruit growth (i.e. 90 days after full bloom onwards). The increase in leaf Ca concentration along the fruit growth and developmental stages can be explained by limited mobility of Ca in the plant tissue and hence very little redistribution to other plant parts took place during the fruit growth period. In fruit, Ca concentration increased in first phase of fruit growth, thereafter its concentration declined sharply in the second and subsequent phases. As the growth of fruit in the first phase was small, Ca accumulation during this phase led to increase in its concentration and the declining trend of Ca concentration in fruit during later part of fruit growth may be attributed to the low mobility of Ca in phloem, although the concentration in leaves continued to increase during the growth cycle of the fruit. However Mg concentration in fruit continued to increase throughout the growth period of fruit. This increase in Mg concentration in leaf and fruit during the later part of fruit growth period is probably due to lowering of K concentration and hence better chance of getting into the plant and its redistribution to other plant organs.

Sulphur concentration in leaves decreased gradually upto second phase of fruit growth (i.e. upto 120 days after full bloom) and then increased towards maturity of the fruit. During the fruit growth period S concentration in leaves of non-bearing flushes were higher in most of the time than of bearing flushes. In fruit, S concentration remained almost stable during first phase of fruit growth but sharply declined afterwards in the second phase of fruit growth. And then its concentration remained more or less constant in the third phase of fruit growth period. The declining trend of S concentration in leaves indicated its redistribution to the major sink (fruit) and other plant organs. As major growth of fruit took place during 75-135 days after full bloom and further S has important role in growth process which led to dilution of nutrient in fruit and hence its concentration declined sharply. Lower nutrient

concentration particularly of K and S in leaves of bearing flushes than non-bearing flushes indicate that major amount of those nutrients in the bearing flushes were consumed in terminal fruit setting and development. At harvest the relative order of concentration of secondary nutrients in fruit was Ca>Mg>S. It was further observed the Ca concentration in leaves were much higher than in fruits throughout the growth of the fruit which may be the reason for higher susceptibility of fruits to bacterial blight disease infection than leaves as Ca is major constituent of plant cell wall which provides primary defense barrier against pathogenic infection.

Primary and secondary nutrients accumulation in fruit

The quantity of a nutrient present in fruit was calculated as the product of the element concentration by dry weight yield. The relationships between time and nutrient accumulation in fruit were fitted according to regression equations shown in each figure. For each nutrient, the quantity accumulated at successive harvest increased throughout the season. The magnitude of increase diminished after 135 days after full bloom for N, P, K and Ca while accumulation of Mg continued at same pace throughout the growth period. The accumulation of S in fruit was most rapid upto 105 days after full bloom while major accumulation of P and K took place between 75 and 135 days after full bloom. During the season, considerable accumulation of nutrient occurred during early fruit development stage and continued until harvest for most of the primary nutrients. For a number of elements including Ca, N, P and K, there was good linear relationship between elements accumulation in dry matter and time period after full bloom. This usually implied to be indicative of nutrient supply via phloem. Considerable amount of Ca requirement by fruit may be taken up during the initial stages of fruit growth and development, when supply by xylem is likely to predominate. Significant accumulation during early fruit growth indicate this as a period when adequate supply of nutrient particularly Ca to the plant is crucial and when Ca nutrition of fruit might most easily influence those properties where fruit quality is known to suffer because of Ca imbalance later in the season.

Micronutrient concentration

The seasonal trend of micronutrient cations (Fe, Mn, Zn and Cu) in leaves varied greatly from one another. Iron (Fe) concentration in leaves of pomegranate decreased from a maximum at full bloom to a minimum at 45 days after full bloom and then remained stabilized with few ups and downs. Its concentration in leaves of bearing flushes was significantly higher at full bloom and during maturity i.e. 165 and 180 days after full bloom than non-bearing flushes. In fruit, the concentration of Fe declined from a maximum at full bloom to a minimum at fruit harvest. On the contrary, the concentration of manganese in leaves increased with time during fruit growth period and most of the times Mn concentration in leaves of bearing flushes was higher than non-bearing flushes. But in fruit, Mn concentration declined rapidly during initial period of fruit growth i.e. at 30 days after full bloom followed by more gradual decrease to a minimum at fruit harvest.

Zinc concentration in leaves of non-bearing flushes decreased more rapidly at 45 days after full bloom thereafter it decreased regularly to a minimum at fruit harvest but in bearing flushes its concentration initially decreased , again increased to a maximum at 90 days after full bloom followed by gradual declining towards maturity of the fruit. However, its concentration in bearing flushes was significantly higher than non-bearing flushes from 60 days after full bloom to the maturity of the fruit. Like Mn, zinc concentration in fruit also declined rapidly during initial growth period followed by gradual decrease during later period of fruit growth.

Unlike other micronutrient cations, copper concentration in leaves initially increased, then declined followed by again rising up towards maturity of the fruit. Copper concentration was higher in leaves of non-bearing flushes than bearing flushes

during initial growth period i.e. 45 and 75 days after full bloom, while leaves of bearing flushes had higher Cu concentration than non-bearing flushes at late growth period of fruit (i.e. 105, 120, 165 & 180 days after full bloom). Like other micronutrient cations, Cu concentration in fruit also decreased initially at rapid pace from a maximum at full bloom to a minimum at 105 days after full bloom and then its concentration get stabilized as fruit grew faster than the accumulation of nutrient in fruit.

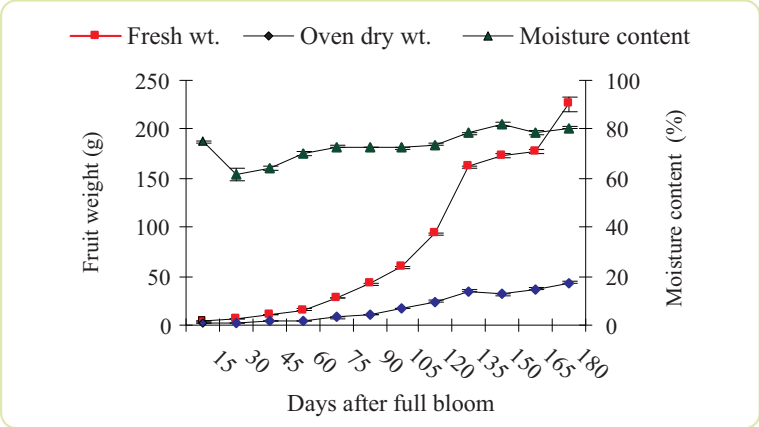
Boron (B) concentration in leaves initially increased to a maximum, followed by more rapid declination to a minimum at 75 days after full bloom and then gets stabilized during later growth period of fruit. There were not much significant differences of B concentration in leaves of bearing flushes and non-bearing flushes except at 45 days after full bloom. Like other micronutrients, B concentration in fruits decreased gradually from a maximum at full bloom throughout the growth period of fruit. By harvest, micronutrient present at highest concentration in fruit was Fe (130.93 mg kg^{-1}), followed by Mn (32.87 mg kg^{-1}), B (24.07 mg kg^{-1}), Zn (17.47 mg kg^{-1}) and Cu (3.17 mg kg^{-1}) respectively.

The decrease in Fe and Zn concentration in leaves during 1st and 2nd phase of fruit growth period may be attributed to the redistribution of nutrients to other plant organs particularly fruit which were at active growing stage. As during initial growth period the fruit growth was very slow, B concentration in leaves built up to a maximum at 45 days after full bloom thereafter it concentration declined owing redistribution of B to the fruits which were at faster growing stage and other organs. The variability of Mn and Cu in leaves observed during the fruit growth period might be attributed to leaf contamination with chemicals sprayed in the orchard for pest and disease control. Although this contamination has impaired a clear trend definition of these micronutrient concentrations in pomegranate leaves, it might be considered that this is a frequent and usual occurrence in pomegranate orchards as a function of crop management procedures. In general micronutrient concentration in fruit declined throughout the fruit growth period due dilution effect as the growth of fruit was much faster than the accumulation rate of nutrients.

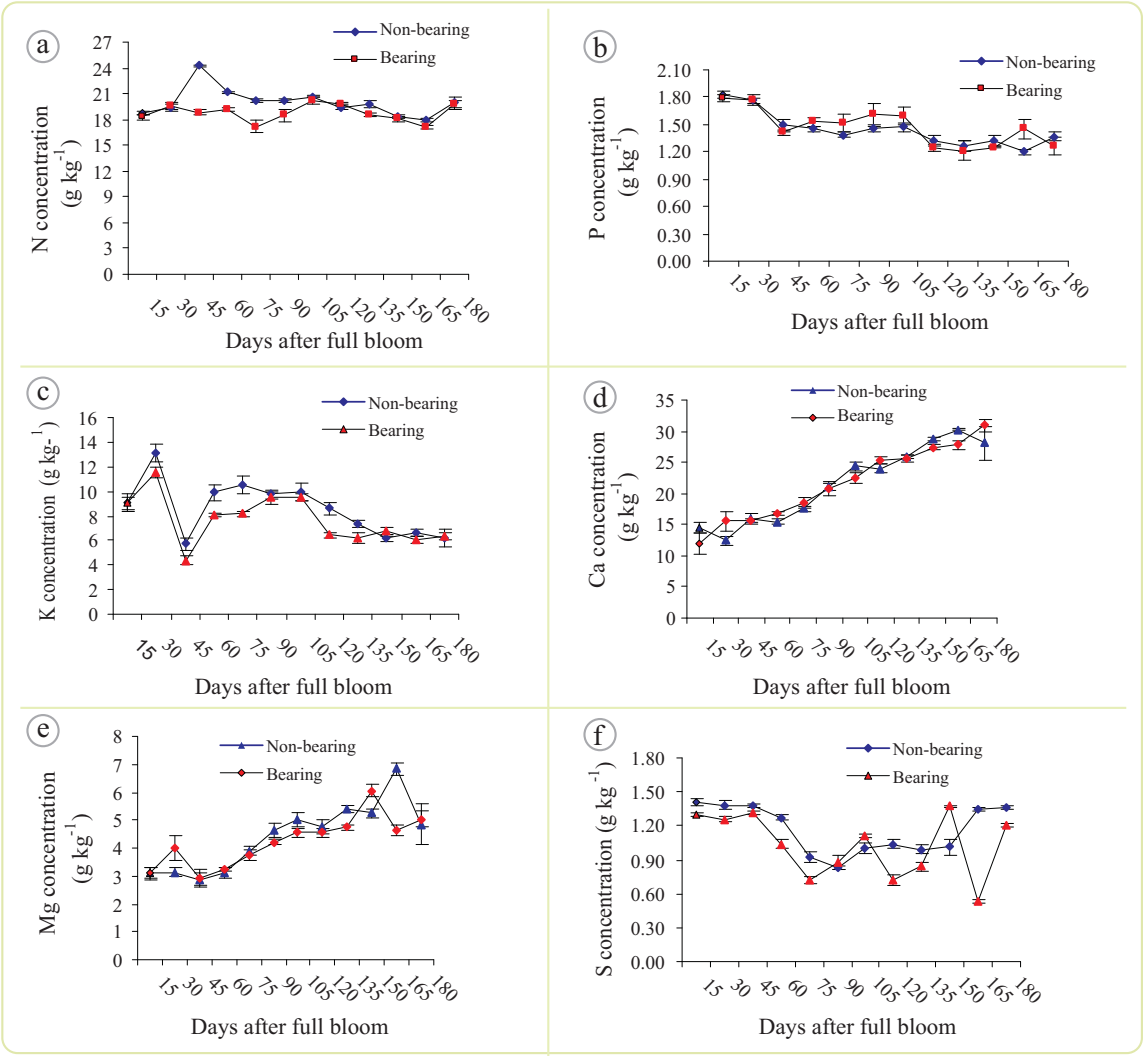
Micronutrient accumulation

The accumulation of all the micronutrients within the fruit also increased during the fruit growth and development. There was very good linear correlation between dry weight yield and the amount of micronutrient accumulated in the fruit. The observed pattern suggested three different phases for fruit nutrients accumulation: (a) in the four fortnights after full bloom, there was a fast decrease in nutrient concentration with fruit growth; (b) from the 4th to 9th fortnights after full bloom, slow and continuous decrease of nutrients concentration in the fruit was observed and (c) from 9th fortnight after full bloom until the end of fruit maturation, nutrient concentration remained almost stable. The first phase occurs during the cellular division period, while the other phases are associated with the period of cellular expansion. This is so called the effect of chemical dilution i.e. reduction in nutrient concentration as a result of increase in fruit dry matter.

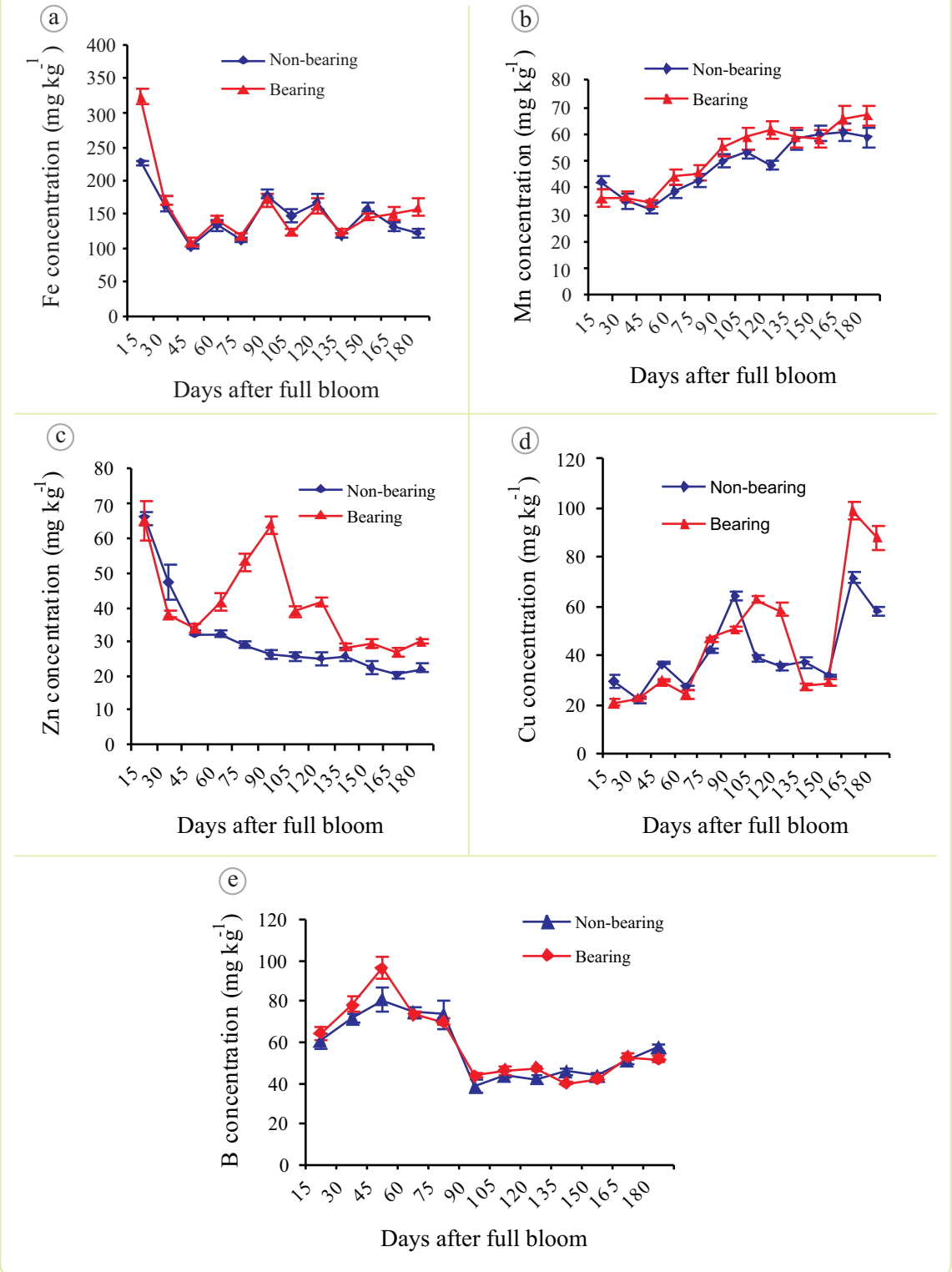
From the observations, it seems that there is a high demand for mineral nutrients in the initial period for fruit growth and development. Potassium was the most accumulated nutrient in fruit, followed by N and P. High concentration of most of the macro and micronutrients in fruit of pomegranate in early stage of growth shows that it is necessary to supplement a good balance of macro and micro nutrients before growth and fruit set of pomegranate to satisfy their requirement to mineral nutrients.



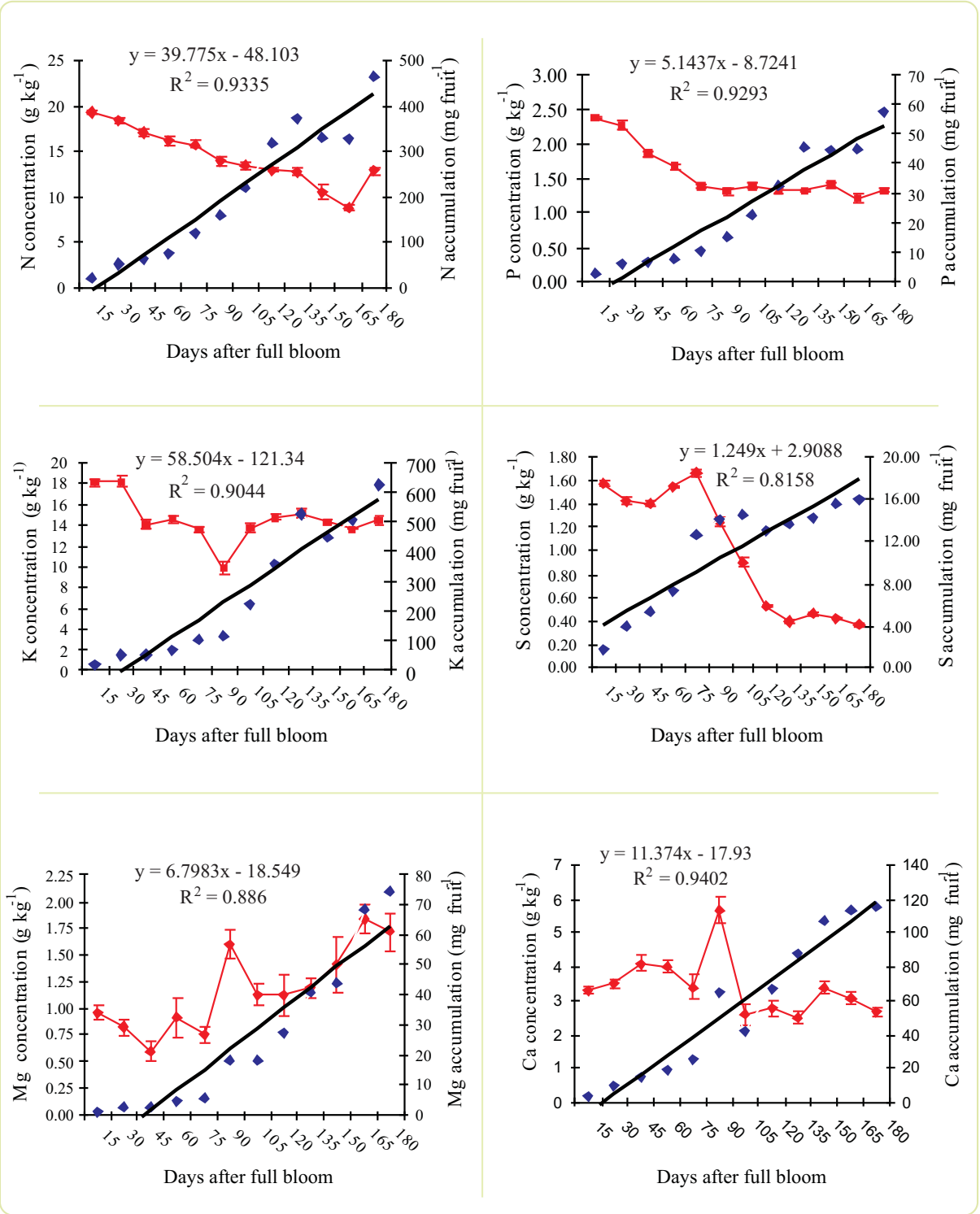
Seasonal changes in fresh and dry weight and moisture content of pomegranate fruit during growth and development. Vertical bar represent ± S.E.



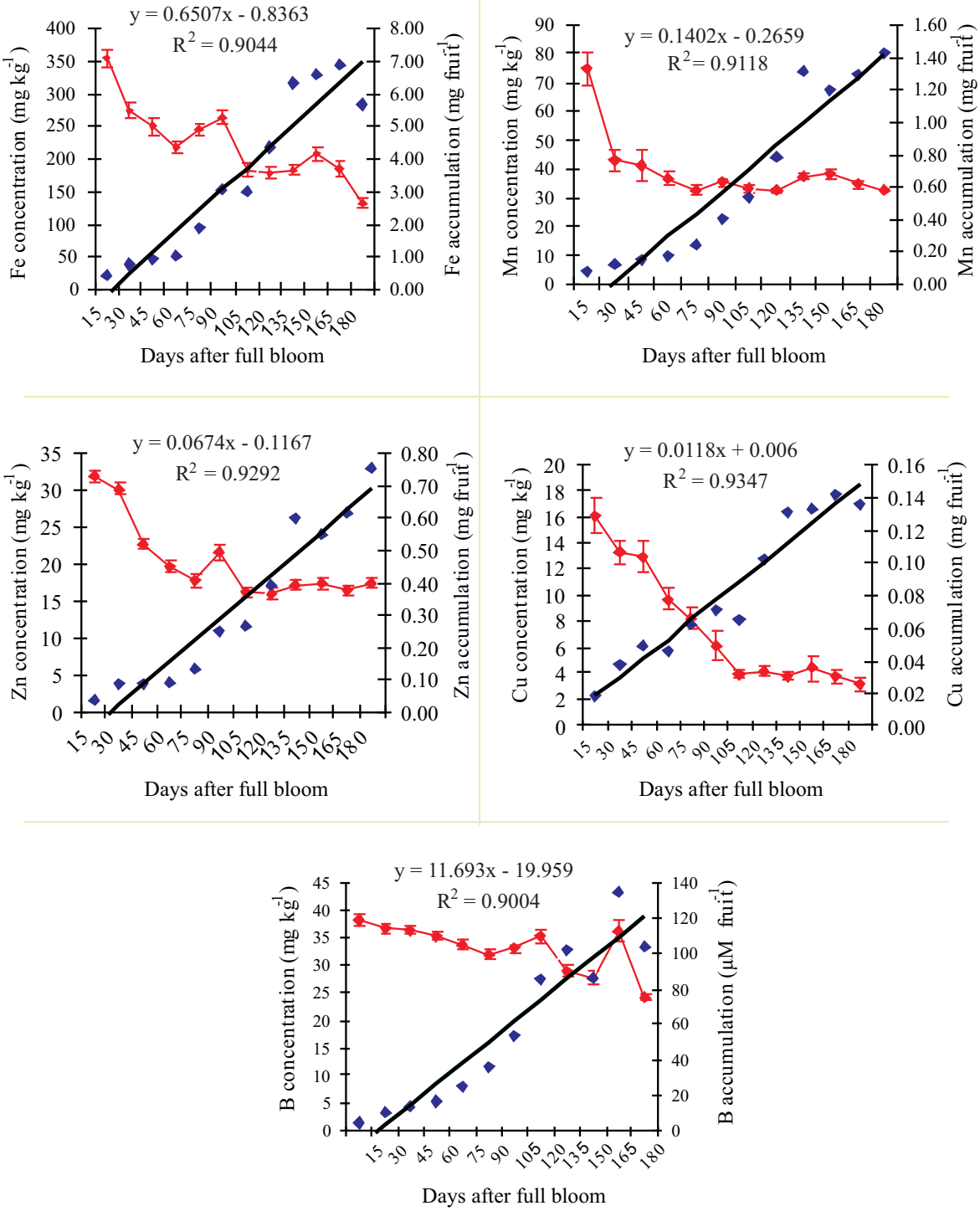
Seasonal changes of primary (a-c) and secondary (d-f) nutrient in leaves of pomegranate tree. Vertical bar represents ± E.E.



Seasonal changes of micronutrient (a-c) in leaves of pomegranate tree. Vertical bar represent ± E.E.



Seasonal changes of primary (a-c) and secondary (d-f) nutrients in fruit of pomegranate. Vertical bar represent ± S.E.



Seasonal changes of micronutrient (a-e) in fruit of pomegranate.
Vertical bar represent ± E.E.

3.4 Water management in pomegranate

3.4.1 Irrigation in pomegranate orchards using varied number of drippers

Various treatments were imposed from December 2011. Same amount of irrigation water equivalent to 80 percent Pan Evaporation was applied on every alternate day through varying number of drippers.

Water applied during the period

Equal quantity of irrigation water was applied to all the treatments during the experimental period. Highest quantity of water was applied during the month of May while it was lowest in December month. It was more or less same in the month of March and April. As few rains were received during the month of June which reduced the requirement of water through irrigation.

Vegetative growth performance

In light textured soil, significant variation in E-W and average spread of the plant was observed with varying number of drippers. Highest increase in E-W spread was obtained in the treatment where irrigation was applied through inline drippers lateral in the form of ring encircling the plant while highest increase in average spread was noted with 6 (2 lph) drippers fixed on two laterals placed on both side of the plant.

In heavy textures soil irrigation applied through 6 (2 lph) drippers fixed on two laterals placed on both side of the plant resulted in better vegetative growth performance.

Quantity of water applied through varied number of drippers

Months	Water applied under all the treatments (litres/plant)	
	Per month	Per day
December - 11	116.5	3.76
January - 12	144.3	4.66
February - 12	176.9	6.10
March - 12	240.5	7.76
April - 12	240.9	8.03
May - 12	278.0	8.97
June - 12	210.8	7.03
Total	1407.8	

Vegetative growth performance of pomegranate plant as affected by varied number of drippers under light textured soil

Treatments Irrigation through	Plant height (cm)			Plant spread in E-W direction (cm)			Plant spread in N-S direction (cm)			Average plant spread (cm)		
	Initial	Final	% increase	Initial	Final	% increase	Initial	Final	% increase	Initial	Final	% increase
2 drippers	110.1	127.3	15.7	111.3	127.1	14.6	101.5	115.8	14.2	106.4	121.4	14.3
3 drippers	109.8	126.3	15.6	100.5	118.1	18.5	95.1	112.5	18.6	97.8	115.3	18.3
4 drippers	114.1	133.1	16.8	110.3	129.4	17.6	102.4	121.9	19.2	106.3	125.6	18.2
6 drippers fixed on 2 laterals	117.6	139.4	19.0	118.0	138.8	17.7	102.8	123.8	20.8	110.4	131.3	19.2
8 inline drippers paced in the form of ring encircling the plant	122.5	141.9	16.0	107.3	129.4	21.0	112.0	128.1	14.9	109.6	128.8	17.8
CD (p=0.05)			NS			3.4			NS			2.33*

Vegetative growth performance of pomegranate plant as affected by varied number of drippers under heavy textured soil

Treatments Irrigation through	Plant height (cm)			Plant spread in E-W direction (cm)			Plant spread in N-S direction (cm)			Average plant spread (cm)		
	Initial	Final	% increase	Initial	Final	% increase	Initial	Final	% increase	Initial	Final	% increase
2 drippers	100.6	115.6	15.0	92.9	106.1	14.5	88.3	101.9	15.8	90.6	104.0	15.2
3 drippers	103.4	120.0	16.0	121.8	139.4	15.1	92.9	110.6	16.6	107.4	125.0	15.7
4 drippers	111.8	130.0	16.9	124.8	142.5	14.6	112.8	130.0	15.7	118.8	136.3	15.0
6 drippers fixed on 2 laterals	116.9	135.0	15.7	108.8	129.4	19.1	108.3	127.5	17.9	108.5	128.4	18.5
8 inline drippers placed as ring encircling the plant	106.1	121.9	14.9	108.9	126.9	16.8	105.6	126.9	20.2	107.3	126.9	18.4
CD (p=0.05)			NS			2.93			NS			2.43

Horizontal movement of soil moisture as affected by irrigation applied through varied number of drippers

Treatments	Horizontal spread / moisture content (%) away from the dripper at the distance of				
	10 cm	20 cm	30 cm	40 cm	50 cm
Heavy textured soil					
Irrigation through 2 drippers (8 lph)	29.1	27.0	25.0	19.2	16.0
Irrigation through 3 drippers (4 lph)	28.0	26.2	23.4	23.4	21.9
Irrigation through 4 drippers (4 lph)	26.9	25.8	23.5	21.2	20.3
Irrigation through 6 drippers (2 lph) fixed on two laterals	25.4	23.3	21.6	16.7	16.2
Irrigation through 6 inline drippers (2 lph) fixed on the lateral encircling the plant	25.8	22.3	21.6	16.0	15.7
Light textured soil					
Irrigation through 2 drippers (8 lph)	20.0	19.6	16.9	14.9	14.8
Irrigation through 3 drippers (4 lph)	19.0	18.5	18.2	17.0	16.6
Irrigation through 4 drippers (4 lph)	19.6	17.8	16.8	15.1	14.0
Irrigation through 6 drippers (2 lph) fixed on two laterals	18.5	17.9	15.3	11.3	10.5
Irrigation through 6 inline drippers (2 lph) fixed on the lateral encircling the plant	18.9	18.1	16.5	15.1	11.9

Moisture distribution in soil profile

Soil samples were drawn at a distance of 10, 20, 30, 40 and 50 cm away from the dripper in horizontal direction as well as 0-30, 31-45, 46-60, 61-75 and 75-90 cm below the dripper in vertical direction.

In heavy textured soils moisture moved in horizontal direction up to 40 cm distance in irrigation through 2 drippers, 6 drippers on 2 laterals and 8 inline drippers in the form of ring while it was up to the distance of 50 cm in 3 and 4 drippers system of irrigation. In light textured soils, moisture moved up to 40 cm distance in 2, 3 and 4 dripper system while it was up to 30 cm in 2 lateral and ring system of applying irrigation.

The soil moisture content data in vertical direction at various depth in heavy as well as light textured soil revealed that moisture availability was sufficient even up to the depth of 90 cm in 2, 3 and 4 dripper system while it was up to 75 cm depth in ring system and up to 60 cm in two lateral system of applying irrigation.

Vertical movement of moisture in soil profile as affected by irrigation applied through varied number of drippers

Soil depth (cm)	Treatments				
	Irrigation through 2 drippers (8 lph)	Irrigation through 3 drippers (4 lph)	Irrigation through 4 drippers (4 lph)	Irrigation through 6 drippers (2 lph) fixed on two laterals	Irrigation through 8 inline drippers (2 lph) fixed on the lateral encircling the plant in the form of ring
Heavy textured soil					
0 - 30	28.7	26.7	24.4	23.5	24.3
31 – 45	27.5	27.3	23.3	21.0	23.5
46 – 60	27.1	27.6	21.3	20.0	22.5
61 – 75	22.2	25.4	18.7	16.5	20.9
76 – 90	21.5	25.7	12.6	14.6	15.2
Light textured soil					
0 - 30	18.5	16.8	17.9	17.1	18.6
31 – 45	18.0	17.0	17.6	16.4	19.8
46 – 60	19.0	17.1	16.1	15.1	18.4
61 – 75	18.5	16.5	16.5	13.2	18.6
76 – 90	17.5	16.7	16.5	12.2	14.4

3.4.2 Frequency of irrigation in pomegranate orchards grown on different soil types

Treatments were imposed from December 2011. Irrigation water equivalent to 80 percent Pan Evaporation was applied to pomegranate plants at different intervals as daily, cumulative water after 1, 2, 3, 4 and 5 days.

Vegetative growth performance

Plant vegetative growth parameters in terms of height and spread were recorded before imposing different treatment (December 2011) and at the end of the experiment (July 2012). Significant variation in plant height and spread was observed under different irrigation frequencies in light textured soil.

Application of irrigation water on every alternate day resulted maximum increase in plant height, N-S and average spread of the plant. While maximum increase in E-W plant spread was recorded with the application of irrigation water after two days interval.

In heavy textures soil, there was not much variation in vegetative growth parameters except plant height under different irrigation frequencies. Application of irrigation water after 2 days interval recorded maximum increase in plant height. Higher water holding capacity as well as better horizontal movement of applied irrigation water in heavy textured soils might have led to less variation in vegetative growth parameters under different irrigation frequencies.

Application of irrigation water on daily basis was found not much effective under both the soil types. Very less quantity of water is needed to be applied on daily basis, out of which major amount get lost through evaporation. So, lesser amount of water is available for plant uptake.

Vegetative growth performance of pomegranate plant as affected by frequency of irrigation in light textured soil

Treatments Irrigation frequency	Plant height (cm)			Plant spread in E-W direction (cm)			Plant spread in N-S direction (cm)			Average plant spread (cm)		
	Initial	Final	% increase	Initial	Final	% increase	Initial	Final	% increase	Initial	Final	% increase
Daily	125.3	143.1	14.4	128.1	146.6	14.7	122.3	141.6	16.1	125.2	144.1	15.3
After 1 day	106.5	125.8	18.1	123.0	143.9	17.1	111.3	131.3	18.2	117.1	137.6	17.6
After 2 day	122.8	141.3	15.2	120.9	142.6	18.1	118.9	137.5	15.7	119.9	140.1	16.9
After 3 day	133.4	153.4	15.2	136.1	156.3	15.4	135.3	155.6	15.5	135.7	155.9	15.4
After 4 day	128.9	146.9	14.0	124.0	142.1	14.9	124.6	142.1	14.2	124.3	142.1	14.6
After 5 day	121.3	138.5	14.5	119.5	135.4	14.0	109.8	126.4	15.3	114.6	130.9	14.5
CD (p=0.05)			1.81*			1.86*			2.11			1.69*

Vegetative growth performance of pomegranate plant as affected by frequency of irrigation in heavy textured soil

Treatments Irrigation frequency	Plant height (cm)			Plant spread in E-W direction (cm)			Plant spread in N-S direction (cm)			Average plant spread (cm)		
	Initial	Final	% increase	Initial	Final	% increase	Initial	Final	% increase	Initial	Final	% increase
Daily	119.9	138.1	15.4	119.5	137.3	15.4	109.1	127.5	17.0	114.3	132.4	16.2
After 1 day	112.0	130.1	16.2	103.5	121.5	17.6	102.4	120.0	17.4	102.9	120.8	17.5
After 2 day	115.3	137.0	19.0	108.4	128.1	18.1	106.0	123.5	16.8	107.2	125.8	17.3
After 3 day	125.1	144.0	15.5	122.9	142.3	15.9	112.3	132.5	18.2	117.6	137.4	17.0
After 4 day	128.6	148.8	15.9	132.3	153.8	16.5	121.4	141.8	16.8	126.8	147.8	16.6
After 5 day	133.6	151.3	13.3	123.6	142.5	15.6	123.5	143.3	16.3	123.6	142.9	15.9
CD (p=0.05)			2.50*			NS			NS			NS

Moisture distribution in soil profile

Moisture distribution in soil profile was studied by taking samples on the next day of applying irrigation at a distance of 10, 20, 30, 40 and 50 cm away from the dripper in horizontal direction as well as 0-30, 31-45, 46-60, 61-75 and 75-90 cm below the dripper in vertical direction and soil moisture content was measured following gravimetric method during May 2012.

The study revealed that moisture moved in horizontal direction up to 30 cm distance from the dripper under daily irrigation treatment and up to 40

cm when irrigation was applied after1 and 2 days interval while it was up to the distance of 50 cm from the dripper when irrigation was applied after 3, 4 and 5 days interval in both the soils. The moisture content data in vertical direction at various depth in heavy and light textured soil revealed that moisture availability was sufficient up to the depth of 60 cm under daily irrigation and 75 cm when irrigation was applied at 1 day interval while in all other treatments sufficient moisture was available up 90 cm depth.

Horizontal moisture spread in soil profile as affected by frequency of irrigation

Treatments	Horizontal spread / moisture content (%) away from the dripper at the distance of				
	10 cm	20 cm	30 cm	40 cm	50 cm
Heavy textured soil					
Daily irrigation	24.2	22.0	21.4	17.2	14.7
Irrigation after 1 day	25.1	23.8	21.9	19.2	14.0
Irrigation after 2 days	24.5	22.1	20.2	20.2	14.0
Irrigation after 3 days	26.5	24.0	22.0	20.0	17.9
Irrigation after 4 days	25.6	24.1	24.1	23.6	21.2
Irrigation after 5 days	26.1	24.7	25.7	21.9	20.5
Light textured soil					
Daily irrigation	18.9	18.2	16.6	13.2	12.4
Irrigation after 1 day	18.8	19.2	17.9	16.9	12.2
Irrigation after 2 days	19.0	19.6	17.4	17.7	11.0
Irrigation after 3 days	19.5	19.6	16.1	15.0	11.3
Irrigation after 4 days	20.6	19.2	17.6	16.2	14.6
Irrigation after 5 days	21.0	20.0	19.9	18.6	14.6

Vertical moisture spread (%) in soil profile as affected by frequency of irrigation

Soil depth (cm)	Treatments					
	Daily irrigation	Irrigation after 1 day	Irrigation after 2 days	Irrigation after 3 days	Irrigation after 4 days	Irrigation after 5 days
Heavy textured soil						
0 - 30	22.4	23.7	23.6	21.4	22.4	25.4
31 – 45	20.2	23.7	20.0	23.7	21.1	24.1
46 – 60	19.1	21.4	20.8	22.1	21.1	24.2
61 – 75	18.5	18.8	18.8	19.8	23.4	23.1
76 – 90	14.6	15.5	16.5	21.0	25.4	22.8
Light textured soil						
0 - 30	17.4	17.0	18.2	16.0	18.4	17.8
31 _ 45	16.8	17.5	18.2	18.1	19.8	18.4
46 – 60	14.1	16.9	16.9	18.6	18.8	18.6
61 – 75	13.4	16.9	16.9	18.0	20.2	17.6
76 – 90	12.1	12.7	15.1	17.5	19.0	18.6

Irrigation requirement of pomegranate orchards under different soil types

The experiment is in progress at research farm of NRC on Pomegranate. This year various treatments were imposed from December 2011. Irrigation water equivalent to 30, 40, 50, 60, 70, 80, and 90 % of Pan Evaporation (E.Tc.) has been applied to pomegranate plants. The chlorophyll content in the leaves and moisture content in the soil under different treatments were measured during the period.

Water applied during the period

Quantity of irrigation water applied under different treatments was as low as 527.6 litres /plant in 0.30 E Tc to as high as 1582.7 liters / plant in 0.90 E Tc during the experimental period. In all the treatments, quantity of applied irrigation water was highest during the month of May while it was lowest in December month. It was more or less same in the month of March and April. Few rains received during the month of June resulted in to lowering of irrigation water.

Quantity of water applied under various treatments

Treatments Irrigation applied equivalent to	December 2011	January 2012	February 2012	March 2012	April 2012	May 2012	June 2012	Total
	(liters per plant)							
0.30 ETc	43.7 (1.41)	54.2 (1.75)	66.4 (2.29)	90.1 (2.90)	90.2 (3.01)	104.1 (3.36)	78.9 (2.63)	527.6
0.40 ETc	58.3 (1.88)	72.2 (2.33)	88.5 (3.05)	120.1 (3.87)	120.3 (4.01)	138.8 (4.48)	105.2 (3.51)	703.4
0.50 ETc	72.8 (2.35)	90.3 (2.91)	110.7 (3.82)	150.1 (4.84)	150.4 (5.01)	173.5 (5.60)	131.6 (4.39)	879.3
0.60 ETc	87.4 (2.82)	108.3 (3.49)	132.8 (4.58)	180.1 (5.81)	180.4 (6.01)	208.3 (6.72)	157.9 (5.26)	1055.2
0.70 ETc	102.0 (3.29)	126.4 (4.08)	154.9 (5.34)	210.1 (6.78)	210.5 (7.02)	243.0 (7.84)	184.2 (6.14)	1231.0
0.80 ETc	116.5 (3.76)	144.4 (4.66)	176.9 (6.10)	240.5 (7.76)	240.9 (8.03)	278.0 (8.97)	210.8 (7.03)	1407.0
0.90 ETc	131.1 (4.23)	162.5 (5.24)	199.2 (6.87)	270.2 (8.71)	270.6 (9.02)	312.4 (10.08)	236.8 (7.89)	1582.7

*Figures in parenthesis indicates water applied per plant per day

Vegetative growth performance

Significant variation in all the growth parameters of the plant was observed in light textured soil under different moisture regimes. Application of irrigation water equivalent to 0.80 ETc resulted in maximum increase in N-S and average spread of the plant. While increase in plant height and E-W plant spread was maximum with 0.90 ETc moisture regimes. It was interesting to note that application of irrigation water equivalent to 0.60 E Tc and 0.70 ETc resulted similar increase in plant growth parameters which were at par with each other. This implies that in light textured soil, good plant growth can also be obtained with the application of lesser amount of irrigation water at 0.60 E Tc.

In heavy textures soil, plant height and average plant spread showed significant variation under different moisture regimes. In heavy textured soil water requirement is more as compared to light textures soils. Increase in plant height and average spread was at par in 0.70 ETc, 0.80 ETc and 0.90 ETc moisture regimes. This implies that in heavy textured soil good plant growth can be obtained with the application of irrigation water equivalent to 0.70 ETc.

Vegetative growth performance of pomegranate plant as affected by quantity of irrigation water applied under light textured soil

Treatments Irrigation water equivalent to	Plant height (cm)			Plant spread in E-W direction (cm)			Plant spread in N-S direction (cm)			Average plant spread (cm)		
	Initial	Final	% increase	Initial	Final	% increase	Initial	Final	% increase	Initial	Final	% increase
0.30 ETc	126.0	143.8	14.2	120.5	139.1	15.6	123.5	140.6	13.9	122.0	139.9	14.7
0.40 ETc	148.1	168.8	13.9	128.1	147.5	15.0	141.9	161.3	13.7	135.0	154.4	14.3
0.50 ETc	116.3	136.0	17.1	98.4	115.0	17.0	109.6	127.1	16.3	104.0	121.1	16.7
0.60 ETc	123.3	145.1	17.8	95.3	112.6	18.4	101.6	118.9	17.8	98.4	115.8	18.0
0.70 ETc	132.0	155.4	17.8	122.6	145.4	18.8	121.8	143.5	18.1	122.2	144.4	18.4
0.80 ETc	124.5	145.6	17.2	96.9	114.4	18.3	93.6	113.1	20.8	95.3	113.8	19.4
0.90 ETc	91.8	108.0	18.0	84.0	99.5	18.8	80.5	96.0	19.0	82.3	97.8	19.0
CD (p=0.05)			1.86*			2.31			2.63*			1.66

Vegetative growth performance of pomegranate plant as affected by quantity of irrigation water applied under heavy textured soil

Treatments Irrigation water equivalent to	Plant height (cm)			Plant spread in E-W direction (cm)			Plant spread in N-S direction (cm)			Average plant spread (cm)		
	Initial	Final	% increase	Initial	Final	% increase	Initial	Final	% increase	Initial	Final	% increase
0.30 ETc	125.0	143.8	15.1	102.4	120.6	17.8	106.8	124.1	16.2	104.6	122.4	17.0
0.40 ETc	117.4	136.9	16.8	106.8	123.8	16.1	104.0	121.3	16.9	105.4	122.5	16.5
0.50 ETc	118.6	138.1	16.5	109.8	128.1	16.8	111.0	131.6	18.5	110.4	129.9	17.6
0.60 ETc	108.9	126.9	16.5	100.4	117.5	17.3	102.8	120.0	16.8	101.6	118.8	17.0
0.70 ETc	128.8	151.0	17.4	115.8	139.4	20.6	125.9	147.9	17.9	120.8	143.6	19.1
0.80 ETc	120.0	142.5	18.8	101.9	121.5	19.4	103.1	121.9	18.5	102.5	121.7	18.9
0.90 ETc	99.3	118.6	18.4	91.9	109.4	19.2	97.8	117.1	19.1	94.8	113.3	19.1
CD (p=0.05)			1.66*			NS			NS			1.87

Moisture distribution in soil profile

Soil moisture distribution in profile was studied by taking samples on next day of irrigation at a distance of 10, 20, 30, 40 and 50 cm away from the dripper in horizontal direction as well as 0-30, 31-45, 46-60, 61-75 and 75-90 cm below the dripper in vertical direction and soil moisture content was measured following gravimetric method during May 2012.

In heavy textured soils moisture moved in horizontal direction up to 30 cm distance from the dripper when irrigation was given at equivalent to 0.30 & 0.40 ETc and up to 40 cm. under 0.50 ETc equivalent moisture regimes. While under 0.60 to 0.90 ETc equivalent moisture regimes, water moved up to 50 cm distance from the dripper. In light textured soil, moisture moved in horizontal direction up to 30 cm under 0.30 & 0.50 ETc equivalent moisture regimes, up to 40 cm under 0. 60 ETc and up to 50 cm from the dripper under 0.60 to 0.90 ETc equivalent moisture regimes.

The moisture content data in vertical direction at various depths revealed that uniform moisture content was maintained up to depth of 60 cm soil in heavy textured soil and up to depth of 75 cm in light textured soil when irrigation water was applied at equivalent to 0.30 and 0.40 ETc., while it was maintained up to 75 cm under 0.60 ETc treatment and up to 90 cm depth in 0.70 to 0.90 ETc treatments.

Horizontal spread of moisture as affected by quantity of irrigation water

Treatments	Horizontal spread / moisture content (%) away from the dripper at the distance of				
	10 cm	20 cm	30 cm	40 cm	50 cm
Heavy textured soil					
0.30 E Tc.	23.4	20.5	19.5	17.4	15.6
0.40 E Tc .	23.2	23.0	21.2	18.0	14.7
0.50 E Tc.	24.4	21.5	20.6	17.4	15.5
0.60 E Tc.	23.7	20.6	21.3	19.2	16.8
0.70 E Tc.	24.7	23.7	23.8	20.9	16.3
0.80 E Tc.	25.1	22.3	22.0	20.3	16.8
0.90 E Tc.	26.0	23.0	21.6	21.6	17.8
Heavy textured soil					
0.30 E Tc.	17.3	16.4	16.2	11.9	11.8
0.40 E Tc.	17.5	15.0	15.8	11.4	7.3
0.50 E Tc.	17.2	13.8	16.9	10.3	7.3
0.60 E Tc.	17.4	17.9	16.9	15.3	10.9
0.70 E Tc.	18.5	18.7	17.7	15.9	9.5
0.80 E Tc.	18.3	18.0	17.9	16.8	11.1
0.90 E Tc.	18.3	17.8	18.5	18.3	13.3

Vertical moisture spread (%) in soil profile as affected by quantity of irrigation water

Soil depth (cm)	Treatments						
	0.30 E Tc	0.40 E Tc	0.50 E Tc	0.60 E Tc.	0.70 E Tc	0.80 E Tc	0.90 E Tc
Heavy textured soil							
0 - 30	22.8	22.6	25.1	24.3	25.7	24.8	26.3
31 – 45	23.6	22.5	22.4	21.5	23.0	24.5	25.6
46 – 60	20.0	22.7	20.1	20.7	23.6	22.0	24.3
61 – 75	15.3	16.5	17.5	19.2	20.6	19.3	22.1
76 – 90	12.4	14.7	14.9	18.0	17.5	16.5	19.2
Light textured soil							
0 - 30	16.6	15.5	17.6	18.3	18.0	18.0	18.8
31 – 45	16.7	15.5	17.1	17.0	17.0	19.5	18.7
46 – 60	14.9	14.5	17.3	18.0	19.8	19.2	18.0
61 – 75	15.0	14.8	16.3	16.9	19.4	18.0	18.1
76 – 90	12.0	11.8	12.5	14.8	15.0	16.9	19.9

3.4.3 Performance of different microsprinklers in pomegranate

Various treatments were imposed from December 2011. Irrigation water was applied through microsprinklers, four drippers and compared with surface application of irrigation water.

Water applied during the period

Quantity of irrigation water applied under different irrigation systems showed large variation ranging from 1407.0 to 3357.0 ltr./plant. Quantity of water required to keep soil moist in the root zone was very high under microsprinklers as compared to drip irrigation system and even surface irrigation system. In micro-sprinkler system, water get lost through evaporation and most importantly it covers larger area (4.62 & 7.50 sq m.) as compared to surface (2.43 sq m) and drip (0.50 sq m) system of irrigation.

Vegetative growth parameters

Significant variation was observed in plant spread in light textured soil under different irrigation systems. Maximum increase in plant spread was recorded with double ring surface irrigation system followed by drip system of irrigation which may be attributed to better root growth and enhanced nutrient uptake under optimum soil moisture regimes. In case of micro-sprinklers, moisture movement in horizontal direction was very large but it was very shallow in vertical direction. This might have created deficit moisture condition in the root zone of the plant within few days after application thereby adversely affecting the plant growth.

In heavy textures soil, significant variation only observed in E-W spread under different irrigation system. Maximum increase in E-W spread was observed in the plants where irrigation was given through double ring surface system.

Water applied to pomegranate plants under different irrigation systems

Treatments Irrigation applied through	Wetting area on soil surface (sq. m.)	December 2011	January 2012	February 2012	March 2012	April 2012	May 2012	June 2012	Total
		(liters per plant)							
4 drippers	0.50	116.5 (3.76)	144.3 (4.66)	176.9 (6.10)	240.5 (7.76)	240.9 (8.03)	278.0 (8.97)	210.8 (7.03)	1407.0
Microjet -180^0	4.62	360.0 (11.61)	420.0 (13.55)	489.0 (16.86)	501.0 (16.16)	507.0 (16.90)	588.0 (18.97)	492.0 (16.40)	3357.0
Microjet -360^0	7.50	332.5 (10.73)	390.0 (12.58)	440.0 (15.17)	455.0 (14.68)	447.0 (14.90)	535.0 (17.26)	450.0 (15.0)	3049.0
Double ring surface irrigation	2.43	257.9 (8.32)	260.8 (8.41)	289.2 (9.97)	299.2 (9.65)	301.0 (10.03)	327.6 (10.57)	295.0 (9.83)	2030.7

*Figures in parenthesis indicates water applied per plant per day

Vegetative growth performance of pomegranate plant as affected by different irrigation system under light textured soils

Treatments Irrigation through	Plant height (cm)			Plant spread in E-W direction (cm)			Plant spread in N-S direction (cm)			Average plant spread (cm)		
	Initial	Final	% increase	Initial	Final	% increase	Initial	Final	% increase	Initial	Final	% increase
4 drippers	96.0	111.4	17.0	112.7	127.6	13.4	111.1	127.8	15.1	111.9	127.7	14.2
Microjet 180	117.4	133.0	13.2	128.0	142.9	11.8	123.6	137.0	11.2	125.8	140.0	11.5
Microjet 360	103.0	117.7	14.7	89.7	101.9	15.0	98.6	111.0	13.5	94.2	106.5	14.2
Double ring surface irrign.	101.8	118.9	18.4	95.4	113.3	21.0	99.4	118.2	19.9	97.4	115.8	20.4
CD (p=0.05)			NS			3.80*			4.3*			3.12

Vegetative growth performance of pomegranate plant as affected by different irrigation systems under heavy textured soils

Treatments Irrigation through	Plant height (cm)			Plant spread in E-W direction (cm)			Plant spread in N-S direction (cm)			Average plant spread (cm)		
	Initial	Final	% increase	Initial	Final	% increase	Initial	Final	% increase	Initial	Final	% increase
4 drippers	109.6	127.0	15.8	114.5	131.3	14.6	114.8	133.5	16.7	114.7	132.4	15.6
Microjet 180	90.1	104.1	16.1	91.2	103.6	14.1	98.3	113.5	15.9	94.8	108.6	15.0
Microjet 360	93.7	108.5	16.1	100.7	115.5	14.8	84.4	97.5	16.0	92.6	106.5	15.4
Double ring surface irrigation	108.8	126.0	16.2	105.9	123.8	17.3	106.2	124.5	17.8	106.1	124.2	17.6
CD (p=0.05)			NS			2.19			NS			NS

Moisture distribution in soil profile

Soil moisture distribution in profile was studied by taking samples on next day of irrigation at a distance of 10, 20, 30, 40 and 50 cm away from the dripper in horizontal direction as well as 0-30, 31-45, 46-60, 61-75 and 75-90 cm below the dripper in vertical direction and soil moisture content was measured by following gravimetric method during May 2012.

The study revealed that under micro-sprinkler system of irrigation, moisture spread in horizontal direction was large even beyond 50 cm away from the emitter while, it was only up to 30 cm under irrigation through drip and double ring surface irrigation system.

The moisture content data in vertical direction at various depths revealed that soil moisture content drastically decreased after 60 cm soil depth under micro-sprinkler irrigation system while in other systems soil moisture content decreased gradually across the depth in both the soils. This implies that very little water moves vertically beyond 60 cm soil depth under micro-sprinkler irrigation system.

Horizontal movement of water in soil as affected by different irrigation systems

Treatments	Horizontal spread / moisture content (%) away from the dripper at the distance of				
	10 cm	20 cm	30 cm	40 cm	50 cm
Heavy textured soil					
Drip irrigation through 4 Drippers	24.2	25.5	24.7	20.1	14.6
Microjet 180^0	27.7	26.2	25.3	25.1	21.8
Microjet 360^0	25.0	27.3	23.4	24.5	25.4
Double Ring surface irrigation	29.9	28.4	22.1	18.0	14.3
Light textured soil					
Drip irrigation through 4 Drippers	19.1	20.6	18.1	15.5	12.5
Microjet 180^0	20.5	19.3	21.1	18.8	20.0
Microjet 360^0	17.1	19.1	18.9	20.0	19.1
Double Ring surface irrigation	22.0	17.6	16.9	14.5	13.6

Vertical moisture spread in soil profile as affected by microsprinkler system of irrigation

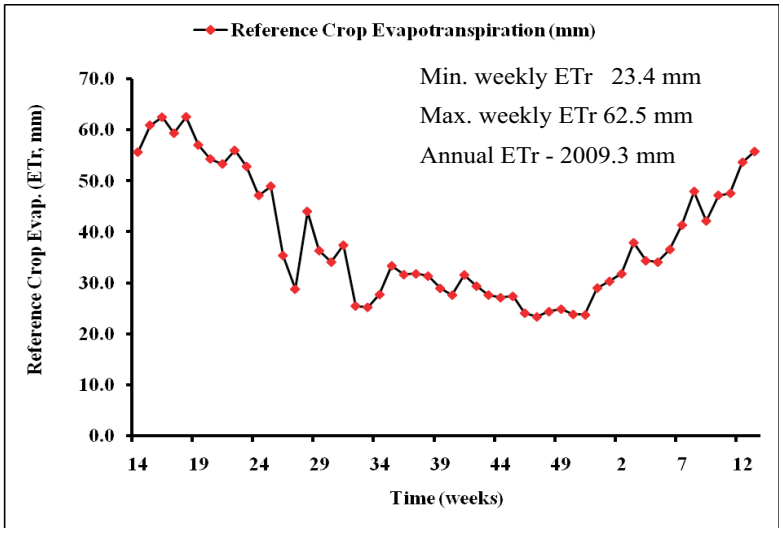
Soil depth (cm)	Treatments			
	Drip irrigation through 4 Drippers	Microjet 180^0	Microjet 360^0	Double Ring surface irrigation
Heavy textured soil				
0 - 30	23.5	22.3	21.3	29.4
31 – 45	22.9	23.3	23.0	26.4
46 – 60	23.5	18.8	16.9	25.0
61 – 75	19.8	14.6	13.9	21.7
76 – 90	17.5	12.1	13.2	22.9
Light textured soil				
0 - 30	20.7	18.9	17.1	21.3
31 – 45	19.4	19.1	19.1	20.4
46 – 60	20.7	17.7	16.9	19.8
61 – 75	17.7	14.5	12.0	18.5
76 – 90	13.9	12.0	11.1	19.4

3.4.4 Estimation of Reference Crop Evapotranspiration (ET_r, mm)

The daily climatic data for the period of April, 2012 to March, 2013 were used to determine daily and weekly reference crop evapotranspiration (ET_r) by using Penman-Monteith Method. The weekly ET_r values are presented in showing the trend of variation of average ET_r values over the period. The yearly reference crop evapotranspiration (ET_r) obtained was 2009.3 mm. The ET_r was maximum in May (19-21 SMW) and minimum in December (49-52 SMW). The weekly minimum and maximum ET_r ranged from 23.4 to 62.5 mm.

Climatic parameters at experimental site

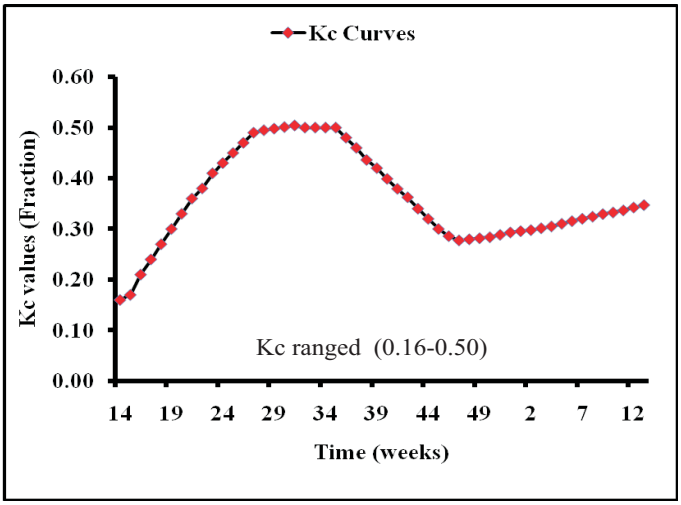
Months	T_{max} (^{0}C)	T_{min} (^{0}C)	R_m (%)	R_x (%)	WS (Km/hr)	SS (Hours)	Epan (mm)	R (mm)
April,2012	39.3	24.0	57.0	27.5	8.6	8.8	13.0	32.2
May	39.4	24.4	60.2	27.5	12.5	9.4	14.6	27.8
June	36.4	23.4	74.7	38.0	13.6	8.5	11.4	10.6
July	31.8	22.6	83.4	55.8	12.0	4.2	6.4	96.1
August	32.3	21.9	83.0	53.4	11.6	5.9	6.4	66.0
September	31.6	21.7	87.4	56.6	8.6	5.9	5.2	66.4
October	31.3	20.1	75.9	45.2	7.1	6.7	5.4	190.8
November	31.3	18.4	72.8	39.1	6.7	7.9	5.8	5.7
December	31.7	16.5	66.7	34.7	6.5	9.2	6.2	0.0
January	32.3	17.3	67.5	44.5	6.6	8.8	6.4	0.0
February	33.6	19.0	70.1	47.6	7.7	9.3	7.6	0.0
March,2013	37.2	21.5	61.3	47.9	7.3	8.2	11.0	0.0
Range	10.0-39	6.9-24	57-87	27-56	6.5-13.6	2.8-9.4	5.2-14.6	0-190.8
SD	9.7	10.0	3.2	2.6	2.6	1.7	3.3	56.61
CV (%)	94.66	99.80	10.01	6.89	6.83	2.82	10.78	103.8



Weekly ETr (mm) values from April, 2012 to March, 2013 at Experimental site

Development of crop coefficient (Kc) values

Five representative plants were randomly selected from experimental plot. Plywood board of 2.5 x 2.5 m^2 sizes with grid marking of 10 x 10 cm^2 was prepared for the estimation of shaded area. Shaded area was measured at solar noon hour (12.00AM). The shaded area was then calculated as the total number of grids times the area of each grid. The weekly crop coefficient value was then computed by using equation (Kc=0.014x+0.08) where, x = shaded area at solar noon hour. The crop coefficient curve for 2nd year pomegranate tree was worked out. The values of crop coefficient increases from 0.16 to 0.50 due to the development, maturation of the leaf surface, increased number of foliage and water sprout of the tree during first year. The Kc values increased linearly from 14th to 35th weeks due to increases in number of leaves and water sprout, as observed from the representative trees and decreased from 36th to 50th weeks due to reduction of foliage through pruning. The crop coefficient (0.28-0.25) increased during 51th to 13th weeks of next year due to increased flowering, excessive water sprout, foliage and management practices.



Crop coefficient curve for 2nd year pomegranate tree

Determination of monthly shaded area (SA), wetted area (WA) and leaf area index (LAI)

The monthly variation of shaded area, wetted area and leaf area index of 2nd year pomegranate tree was recorded. Shaded area, wetted area and leaf area index increased rapidly from April to October months owing to increase in foliage, number of leaves and their area. After November shaded area, wetted area and LAI decreased due to removal of water sprout, leaves, foliage crumbling as a result of management practices. Later shaded area, wetted area and LAI slowly increased because of emergence of new leaves as a result of application of inputs including irrigation water.

Monthly shaded area, wetted area and leaf area index

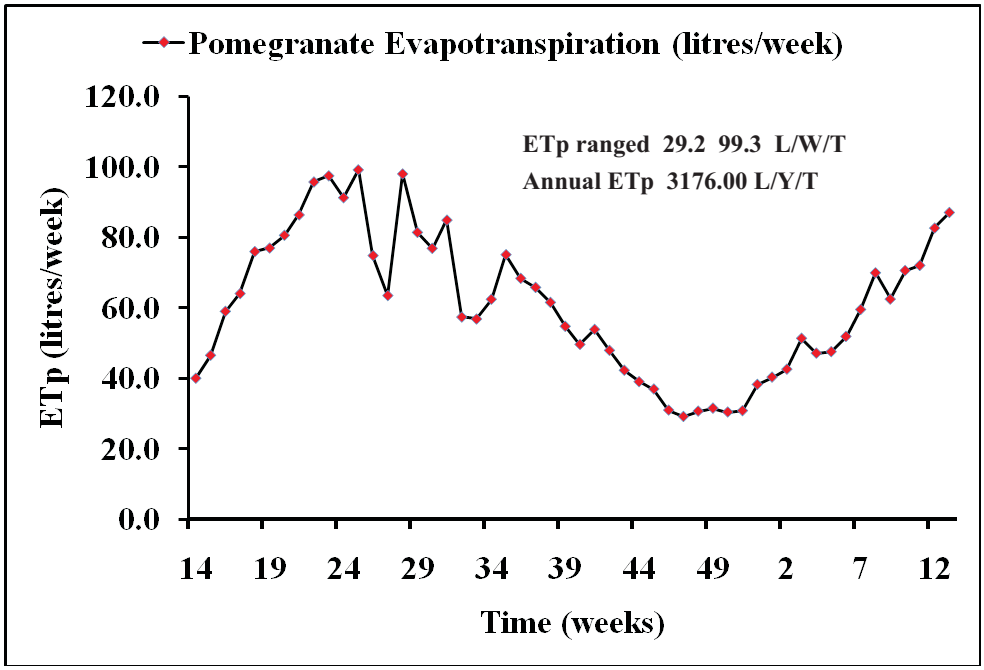
Months	APP(m^2)	SA (m^2)	WA (%)	NL	TA (m^2)	LAI_{APP}
April,2012	18.0	1.68	12.44	10156	4.45	0.25
May	18.0	2.43	18.03	15739	7.35	0.41
June	18.0	3.18	23.55	19184	10.11	0.56
July	18.0	3.99	29.59	21630	13.76	0.76
August	18.0	4.13	30.56	22676	15.64	0.87
September	18.0	3.53	26.11	21075	14.08	0.78
October	18.0	2.74	20.27	20646	13.88	0.77
November	18.0	2.01	14.91	21400	15.15	0.84
December	18.0	1.99	14.77	21331	14.11	0.78
January	18.0	2.14	15.86	22191	15.25	0.85
February	18.0	2.34	17.31	22994	14.95	0.83
March,2013	18.0	2.50	18.55	24015	15.80	0.88

(Spacing-4.5 x 4 m)

Note: (APP-Area per plant (m^2), SA Shaded area (m^2), PSA - Percentage of shaded area (m^2), NL-Number of leaves (Nos.), TA-Total area of leaves (m^2), Kc Crop coefficient (Fraction) and LAI_{SA}- Leaf area index at Solar noon hour (m^2/m^2)

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

The weekly water requirement of 2nd year pomegranate tree was worked out assuming efficiency of drip irrigation system at 90 % and it ranged from 29.2 to 99.3 liters/week/tree during April, 2012 to March, 2013. It shows variations during different development stages of pomegranate tree owing to the variation in reference crop evapotranspiration, pan coefficient, wetted area and crop coefficient values. Lower Kc values represent slower plant growth and lesser plant canopy cover, resulting in lower ETp. The seasonal water requirement of pomegranate tree was worked out to be 3176.0 liters/year/tree.



Weekly pomegranate evapotranspiration (liters/week) of 2nd old age tree

3.5 Exploitation of bio-inoculants in pomegranate productivity

3.5.1 Effect of microorganisms and their consortium on nutrient uptake by pomegranate plant

Five micro-organisms viz. *Azospirillum brasilense*, *Pseudomonas fluorescens*, PPFM, *Pseudomonas striata* and *Penicillium pinophilum* and their consortium were evaluated for their effect on major nutrient uptake by pomegranate plant. It was observed that inoculation of microorganisms singly or in consortium with pomegranate plant significantly increased N, P and K uptake by the plant. The maximum increase in N-uptake was noted when microbial consortium was inoculated along with insoluble source of P (rock phosphate) and K (potassium feldspar) followed by only inoculation with microbial consortium. Application of microbial consortium with insoluble sources of P and K supplemented about 56% of N uptake obtained from the application of recommended dose of fertilizer. While application of *P. striata* along with rock phosphate, *P. pinophilum*, *P. pinophilum* along with potassium feldspar and microbial consortium along with insoluble source of P and K led to maximum phosphorus uptake by plant which was even significantly higher than that obtained from the application of recommended fertilizer dose. Unlike phosphorus, application of microbial consortium along with insoluble source of P and K resulted in maximum potassium uptake by plant which was at par with that obtained from the application of recommended dose of fertilizer. This was followed by application of only microbial consortium and *P. pinophilum* along with potassium feldspar.

In nutshell, inoculation of microbial consortium (comprising of *Azospirillum brasilense*, *Pseudomonas striata*, PPFM, *Pseudomonas fluorescens* and *Penicillium pinophilum*) along with insoluble source of P and K with pomegranate sapling could supplement 100% of P and K and 56% of N uptake obtained from the application of recommended dose of fertilizer at nursery stage.

Effect of microorganisms and their consortium on major nutrient uptake by shoot

Treatment	N-uptake	P-uptake	K-uptake
		mg plant^{-1}	
Control	519.17^{f}	175.04^{e}	456.86^{g}
Azospirillum brasilense	624.93^{de}	215.41^{d}	576.46^{f}
Pseudomonas fluorescens	612.96^{de}	214.58^{d}	717.39^{c}
PPFM	587.45^{e}	210.90^{d}	648.48^{d}
Pseudomonas striata	609.80^{de}	217.01^{d}	605.78^{e}
Penicillium pinophilum	643.75^{d}	248.50^{ab}	731.30^{c}
Rock phosphate @ 200 mg P $_2O_5$ kg^{-1} soil	509.07^{f}	164.32^{e}	460.19^{g}
Potassium feldspar @ 200 mg K_2O kg^{-1} soil	502.49^{f}	172.94^{e}	451.22^{g}
Pseudomonas striata + Rock phosphate @ 200 mg P_2O_5 kg^{-1} soil	633.98^{d}	249.48^{a}	658.44^{d}
Penicillium pinophilum + Potassium feldspar @ 200 mg K_2O kg^{-1} soil	643.69^{d}	243.85^{ab}	784.78^{b}
Microbial consortium	746.25^{c}	237.38^{bc}	786.06^{b}
Microbial consortium + Rock phosphate @ 200 mg P_2O_5 kg^{-1} soil + Potassium feldspar @ 200 mg K_2O kg^{-1} soil	812.49^{b}	247.12^{ab}	813.31^{a}
Recommended fertilizer dose	1186.64^{a}	230.45^{c}	826.41^{a}
CD (P = 0.05)	42.18	11.26	25.40

3.5.2 Screening of phyllosphere microflora against bacterial blight

During survey of pomegranate orchards leaf samples of apparently healthy plants in vicinity of blight affected plants were collected for isolation of phyllosphere microflora. Selective media for isolation of fungal and bacterial flora was used for isolation. 10 gm of leaves were shaken in 90 ml sterile water and serially diluted to 10^{-3} for fungal flora isolation and 10^{-5} for bacterial isolates. In all 22 phyllosphere microflora (8 bacterial, 14 fungal) isolates were obtained and are being screened against *Xanthomonas axonopodis* pv *punicae* causing bacterial blight of pomegranate.

4. CROP PROTECTION

4.1 Bacterial Blight

4.1.1. Phenotypic studies

During the year seven *Xanthomonas axonopodis* pv. *punicae* isolates were collected from Solapur, Maharashtra. Isolates were obtained through isolations from bacterial blight affected plant parts collected during surveys or brought by farmers for identification. The isolates were confirmed to be *Xanthomonas axonopodis* pv. *punicae* on the basis of growth after 72 hours at 30°C, Fuscan production and pathogenicity tests and stored.

Isolates varied in causing bacterial blight (BB) incidence and severity in pot culture studies, with highest incidence from 19.67-70% and severity 30-59% in different isolates.

All *X. axonopodis* pv. *punicae* isolates produced typical yellow mucoid raised colonies on nutrient glucose agar after 8 days though they started appearing after 3-4 days of incubation at 30°C. Fuscan production was seen after 20 days. All isolates were slow growing with visible colony growth after 72 hrs, absence of growth at or below pH 5 and above 7.5. No growth was observed in salt concentration of 2% and above, growth was better in the absence of NaCl.

Hence, it was observed that though *X. axonopodis* pv. *punicae* isolates showed differences in blight incidence and severity did not vary in cultural characters.

4.1.2 Genomics of *Xanthomonas axonopodis* pv. *punicae*

In all, 19 isolates from Karnataka, Andhara Pradesh and Maharashtra were sent to IARI New Delhi after conducting pathogenicity tests in previous year, for genotypic studies. As per the report sent by IARI the type stain of *X. axonopodis* pv. *punicae* (NCPPB466) along with selected isolates from different states were subjected to Multilocus Sequence Typing (MLST) based analysis; eight of the alleles among nine alleles analysed were novel for *Xanthomonas axonopodis.* A total length of 5713bp concatenated sequence comparison revealed that the strain causing pomegranate bacterial blight is genetically close to *Xanthomonas citri* pv. *malvacearum* and *Xanthomonas citri* pv. *citri.*

Therefore comparative genomics of isolates obtained, so far, from diverse geographical location and distinct time points indicated that the strain causing bacterial blight of pomegranate could be a single virulent lineage.

4.1.3 Association of fungi in bacterial blight stem cankers

Role of fungi in bacterial blight cankers was established through a net house experiment as per procedure given in previous year report. Isolation from BB stem cankers of different ages did not produce any *X. axonopodis* pv. *punicae* colonies, although ooze was produced. However, 10 fungi were found in high frequency. Probably the bacteria in ooze were not viable. Five fungal isolates which produced stem cankers in previous year, when inoculated with and without *X. axonopodis* pv. *punicae* isolate, produced cankers, however, where only *X. axonopodis pv. punicae* was inoculated only necrosis was observed and no canker was produced after one month.

It is concluded that the stem cankers in bacterial blight affected orchards enlarge due to secondary infection of fungi like *Fusarium oxysporum*, after initial necrosis by *X. axonopodis* pv. *punicae.*

4.1.4 Movement of *X. axonopodis* pv. *punicae* in air

Movement of *X. axonopodis* pv. *punicae* in air was recorded using air sampler and Modified Nutrient Glucose Agar Medium. 100 l of air was passed through the sampler head onto the agar plate fixed in it. The studies were done twice in rainy season just after rains once in July and once in August 2012, at 2 time intervals (at sunrise and at sunset), at various distances (7.5 and 10 ft, from infected plant and 10 and 15 ft from the last row of plants in the orchard) and heights (3 ft from ground, 1 ft above infected plant/ 6ft

above ground) in heavily bacterial blight affected orchard. The plates were incubated and observed third day onwards up to 15 days. No *X. axonopodis* pv. *punicae* colonies could be detected in air. But in water collected under an infected tree after spraying with plain water on the tree and streaking 10µl/ NGA Petri plate, 1000 colonies/ml of *X. axonopodis* pv. *punicae* were detected.

Though the results indicate that spray/rain water splashes have a positive role in the dissemination of the pathogen, yet the studies need to be repeated for conclusive inference.

4.1.5 Other Diseases

Typical virus like symptoms- vein yellowing, yellowing of leaf lamina, leaf rolling, and necrosis were detected in farmers orchard at Shailgaon, Solapur. Transmission test through grafting and leaf inoculation have been attempted, results are awaited. Samples have been sent to IARI regional station Pune for confirmation.

Virulence of different isolates of *X. axonopodis* pv. *punicae* in pathogenicity tests

Isolate No	Source	Incidence (%)	Disease Index (Severity)
XAP 83	Boramani (S. Solapur)	19.67	2.76 (44)
XAP 84	Wadgaon (S.Solapur)	22.33	2.21 (30.25)
XAP 85	Parmeshwar Pimpri (Mohol)	59.33	2.55 (38.75)
XAP 86	Sangdari Shrisail (S. Solapur)	70.0	2.71 (42.75)
XAP 87	Papri (Mohol)	63.0	2.59 (39.75)
Note: Pathogenicity tests of two isolates XAP 88 and 89 are in progress			

XAP 83

XAP 84

XAP 85

XAP 86

XAP 87

Disease producing ability of selected X. axonopodis pv. punicae isolates

Only XAP | XAP+canker fungi | Only canker fungi

Stem infection due to *X. axonopodis* pv. *punicae* and fungi from bacterial blight cankers alone and in combination

Virus like symptoms in pomegranate orchard at Shailgaon, Solapur (confirmation awaited)

4.1.6 Correlation between foliage nutrient content and bacterial blight disease infection

Leaf samples were collected from pomegranate orchards with varying degree of bacterial blight disease infection. The disease incidence and severity in foliage of those orchards were assessed and the nutrients content of leaves were estimated after wet digestion. The correlation study between leaf nutrient content and bacterial blight disease incidence and severity indicated that nitrogen and manganese content of leaves had significant negative correlation with bacterial blight disease severity with correlation coefficient of r = -0.550* and r = -0.480* respectively. Besides, N inleaves was positively correlated with Mg (r = 0.569*), Mn (r = 0.480*) and Cu (r = 0.695*) and was negatively correlated with K (r = -0.488*). Further K in leaves was negatively correlated with Ca (r = -0.464*), while Ca content in leaves was positively correlated with Mg (r = 0.483*) and Cu (r = 0.488*) and was negatively correlated with Fe (r = -0.442*). Manganese content in leaves was positively correlated with Cu (r = 0.444*) and Zn (r = 0.798*).

It may be inferred from the correlation study that higher N and Mn content in pomegranate foliage would reduce the bacterial blight disease severity.

Correlation between foliar nutrient content and bacterial blight disease index

Foliar nutrient content	Disease index	Disease incidence (%)
N (%)	-0.550*	-0.214
Mn (ppm)	-0.459*	-0.166

4.1.7 Screening of rhizosphere microflora against wilt pathogens

During survey of pomegranate orchards soil samples from rhizosphere of apparently healthy plant/s in severely wilt affected orchards were collected for isolation of microflora. Selective media for isolation of fungal, bacterial and actinomycete flora was used for isolation. 10 gm of soil was shaken in 90 ml sterile water and serially diluted to 10^{-3} for fungal flora isolation and 10^{-4} for actinomycetes and 10^{-5} for bacterial isolates. In all 46 rhizosphere (12 bacterial, 24 fungal and 10 actinomycete) isolates were obtained and are being screened against *Ceratocystis* fimbriata causing wilt of pomegranate.

4.1.8 Screening of Field Tolerant Bacterial Blight Accessions through Challenge Inoculation

Four field tolerant IC Accessions showing less than 5% severity of bacterial blight in field were screened through challenge inoculation with *Xanthomonas axonopodis* pv. *punicae* isolate XAP 80 from January 06- April 05, 2013. XAP 80 was grown for 72 hour in nutrient glucose broth at 30°C and diluted 1:5 before spray. Two month old foliage growth of hard wood cuttings was sprayed with the culture and observations recorded from 3rd day onwards till March 30. None of the field tolerant accessions showed tolerance under challenge inoculations.

Accessions	Bacterial Blight	
	Incidence %	Severity %
IC- 1205	75	50
IC-1199	10	26
IC - 1198	34.67	35
IC- 1182	58.00	21.7
Bhagwa (Control)	30.20	46.15

IC 1205

IC 1182

IC 1198

Bhagwa (Check)

Blight reaction of field tolerant IC accessions to challenge inoculation with *X. axonopodis* pv. *punicae* isolate XAP 80

4.1.9 Screening of Seedling Population of Pomegranate Hybrids

Seedling population of nine pomegranate hybrids, were screened for bacterial blight resistance through challenge inoculation in net house. The screening was started in 2008-09 and done in batches as and when the material was received. The seedling plants which tested negative in earlier screening were retested with a different strain of *Xanthomonas axonopodis* pv. *punicae* (XAP). During the year under report thirty one plants of hybrid 'Bhagwa x {(Ganesh x Nana)] x Daru}' and 9 of 3 other hybrids were found free in earlier screening and 53 (third set) of seedling plants of hybrid Bhagwa x 3/3 [(Ganesh x Nana) x Daru] were tested with a new strain of XAP, none was found free, however, 5 plants of hybrid 'Bhagwa x {(Ganesh x Nana)] x Daru}' showed some degree of tolerance with less than 10 % bacterial blight severity. The final results for the entire screening done since 2008-09 till March 2013 have been summarized.

Screening results show that most of the population was moderately to highly susceptible showing > 10% blight severity, except 5 plants of hybrid 'Bhagwa x {(Ganesh x Nana)] x Daru}', one plant each of [(Ganesh x Daru) x Ganesh] x Ruby and Nayana x Ruby which showed some tolerance with less than 10 % blight severity.

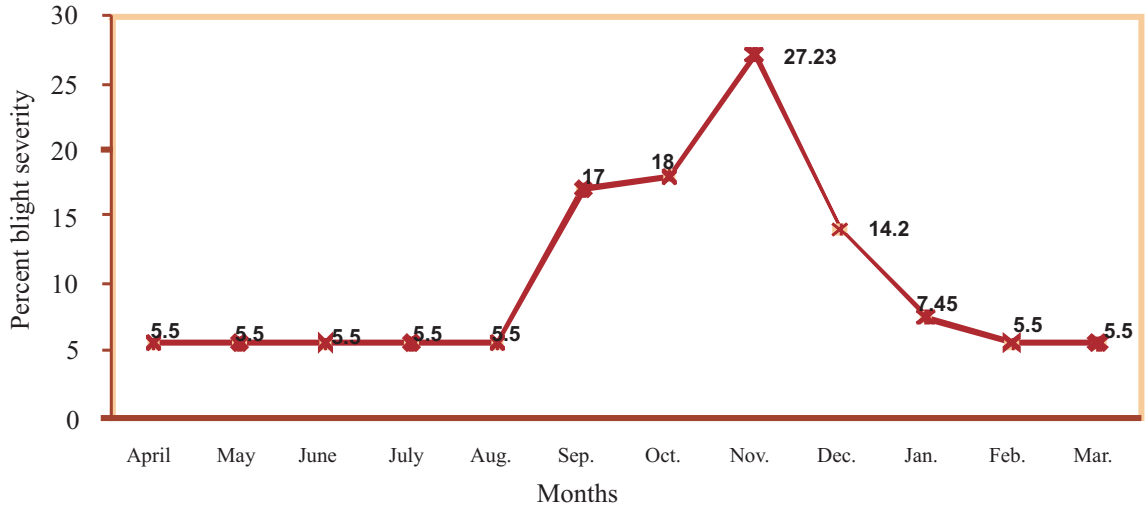
Comprehensive report on screening of seedling population of different pomegranate hybrids for bacterial blight resistance

S. No	Variety	Total received	Screened*	Bacterial Blight Free	SS	MS	HS
1.	[(Ganesh x Nana) x (Ganesh x Daru)] xRuby	55	55	0	0	36	19
2.	[(Ganesh x Daru) x Ganesh]x Ruby	70	70	0	1	27	42
3.	Kalpitya x Ruby	81	81	0	0	31	50
4.	Nayana x Ruby	80	80	0	1	5	74
5.	Bhagwa x 3/3 [(Ganesh x Nana) x Daru]	249	238	0	0	146	92
6.	Bhagwa x {(Ganesh x Nana)] x Daru} ----HA	130	80	0	5	24	51
7.	{[Ganesh x Nana) x Daru] x [(Ganesh x Nana)] } x Bhagwa----HB	125	74	0	0	54	20
8.	Bhagwa x 3/5 [(Ganesh x Nana) x Daru)]	35	17	0	0	13	4
9.	NRCP-HYBRID	20	15	0	0	11	4
	*Plants wilted have been subtracted, 90% wilting was due to stem borer; Susceptibility grades Slightly Susceptible (SS)= Severity <10%; Moderately susceptible (MS) severity ≥10-25%; Highly Susceptible (HS)= severity >25%						

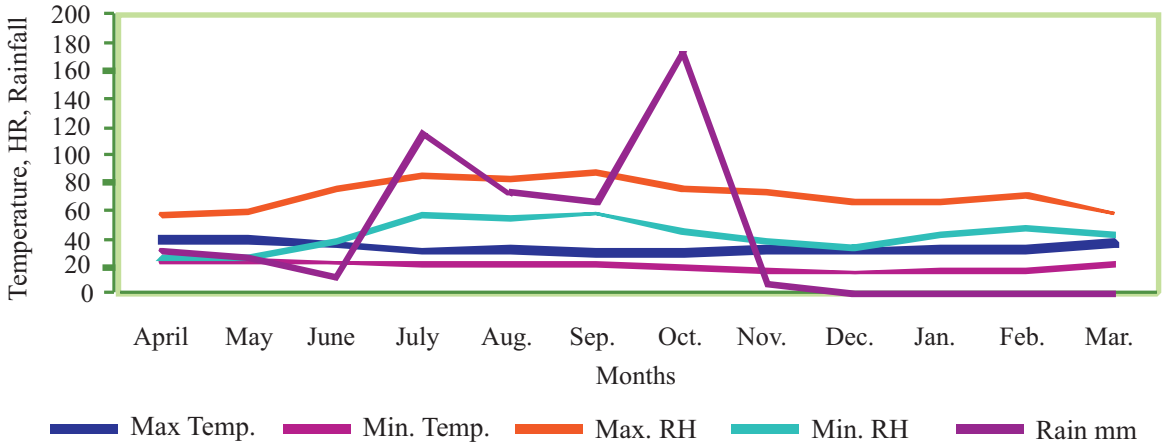
Hybrid ,Bhagwa x 3/3 [(Ganesh x Nana) x Daru]' showing highly susceptible reaction to bacterial blight pathogen *Xanthomonas axonopodis* pv. *punicae* in challenge inoculation

Bacterial blight development

Periodical monitoring of the bacterial blight at the farm revealed that disease was prevalent in mild to moderate proportion during the year. Bacterial blight was observed only in some of the blocks and most of the blocks were free from the disease. Disease severity was quite low (5.5%) in April month and remained so till August and thereafter blight developed at rapid rate. Blight severity was maximum (27.23%) in November month thereafter it again started declining (5.5%) in March 2013.



Bacterial blight progress during different months of 2012-13



Monthly Av. temperatures, relative humidity and rainfall at NRCP Farm.

Influence of Meteorological factors on blight development

Meteorological parameters (Monthly av. Temperature ° C, Relative humidity %, and total rainfall mm, prevalent during April 2012-March 2012-13). Blight buildup was increasing from September onwards and reached its peak in the month of November when disease severity was maximum (27.23%). Prevalence of Moderate temperatures (32.1 20.0°C), high Relative humidity (> 75%) and more rains (172.5mm in October) during August to October months could be attributed to escalation of blight during the period.

Blight developed at a rapid infection rate (r) of 0.08/unit/day from October to November.

Correlation and regression analysis of meteorological factors (monthly hours) with bacterial blight development

Correlation analysis

Monthly hours of different temperature and RH ranges were correlated with blight progress in order to ascertain the influence of critical meteorological factors favoring blight development in the region.

Correlation between Blight severity and Temperature and RH monthly hours

Bacterial blight Severity (%)	Monthly hours at Temperature (°C) and RH (%)	Correlation matrix (r)
	25.0-35.0 and ≥ 80.0	0.67
	25.0-35.0 and ≥ 50.0	0.12
	25.0-35.0 and ≥ 30.0	0.10
	20.0-35.0 and ≥ 80.0	0.62*
	20.0-35.0 and ≥ 50.0	0.42
	20.0-35.0 and ≥ 30.0	0.33
	15.0-40.0 and ≥ 80.0	0.62*
	15.0-40.0 and ≥ 50.0	0.46
	15.0-40.0 and ≥ 30.0	0.32

Correlation analysis of blight severity with meteorological parameters clearly revealed that monthly hours at temperature 25.0-35.0 °C and RH ≥80.0% had maximum, positive and significant correlation (0.67*). Study also revealed that high humidity (≥80.0%) was positively and significantly correlated with blight development at all the three temperature ranges.

Regression analysis

Regression analysis of different independent variables *viz*. Monthly hours at temperatures 25.0-35.0 °C, RH > 80.0% (also at RH ≥ 50.0%, RH ≥30.0%) and rain was carried out to predict the disease severity. On the basis of regression analysis best fit was obtained involving temperatures 25.0-35.0 °C at RH ≥. 80.0% and rainfall on the basis of coefficient of determination value (R^2=0.55).

Regression analysis of meteorological parameters with blight severity to predict blight severity.

Blight severity (%) (Av. blight severity 10.1%)	Meteorological parameters (Monthly hours at temperature °C and RH % and monthly total rain mm)	Average value of variables	Coefficient of determination (R^2)
	V1:Temperatures at 25.0-35.0 °C, RH ≥ 80.0 and V2: rain	V1:2.86 V2: 41.85	0.59*
	V1:Temperatures at 25.0-35.0 °C , RH ≥ 50.0 and V2: rain	V1:28.85 V2:41.85	0.02
	V1:Temperatures at 25.0-35.0 °C , RH ≥ 30.0 and V2:rain	V1:50.92 V2:41.85	0.04

Regression model

On the basis of regression analysis best fit for disease prediction was observed to be as follows:

Blight severity (Y) = 5.49 + (2.59) x var 1 + (-0.06) x var 2 + 5.07

(var1: monthly temperature hours at 25.0-35.0°C and RH ≥ 80.0% and var.2: Total monthly rainfall).

Bacterial blight severity at growers' orchards

Blight was quite severe in the Pimpari village of Mohol taluka at the time of harvest with incidence of 60.0% and severity 38.0% in July 2012. In Capari village of Mohol blight severity was about 35.0%.

Screening of germplasm at gene field bank

Screening of germplasm at field gene bank at Kegaon (162 accessions) against bacterial blight in the month of October, 2012 did not reveal any bacterial blight severity on foliage and fruits.

4.2 Wilt

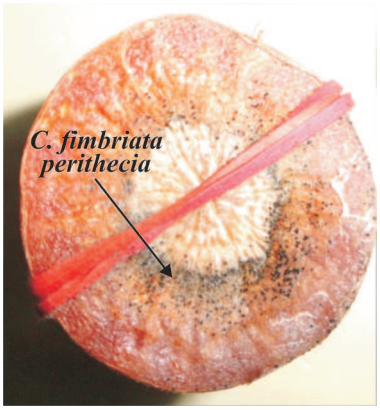
4.2.1 Wilt Distribution in Different Planting Systems

Wilt pathogen, *Ceratocystis fimbriata* was monitored in wilt affected plot (C 4) with different planting method. Pooled soil samples were collected from root zone and 1.5 ft from plant stem at 6 inches in January. Another set of soil samples were collected 1 ft away from stem at 6 inch depth between two plants having at least one wilted plant except in T6 and T7. Ten soil samples were collected between 2 plants and 4 such sets were collected per treatment. Carrot pieces cut into 1 inch size were used for baiting after treating with suitable antibacterial agent. About 1 gram of soil from each sample was kept in a cavity of the pair of carrot pieces, secured tightly with rubber bands and placed in a petriplate which was kept in a glass dessiccator with high humidity at room temperature. Fungal growth was seen in 10-15 days after incubation. The growth was observed under the microscope and observations recorded on the presence of various wilt pathogens.

The bedding system, 0.6m width x 0.3m depth x 0.3m ridge of planting showed lowest wilt incidence and *C. fimbriata* population, however *Chalra* state of another *Ceratocystis* sp. *C. adiposa* and *F. oxysporum* was found in highest number of samples in these treatments. The pathogenicity of *Chalra* state of *C. adiposa* needs to be studied. In addition *Fusarium oxysporum* was found in highest frequency followed by nematodes in this treatment. However, more detailed systemic studies are required to arrive at proper conclusion.

Technique used to see distribution of wilt pathogen/s in soil of different bedding systems

Carrot pieces with soil samples kept under high humidity at room temperature



Growth of *C.fimbriata*

Growth of both *C. fimbriata* and *Fusarium* sp.

Frequency of distribution of wilt pathogens in different bedding system

Treatment	Treatment details	Wilted plants out of 8		Per cent baits showing			
		No.	Per cent	*Ceratocystis fimbriata*	Chalara State of *Ceratocytis adiposa*	*Fusarium oxysporum*	nematode infestation
T1	Pits 1mx1mx1 m	3	37.5	27.5	22.5	5	2.5
T2	Pits 0.6mx0.6mx0.6m	4	50	37.5	17.5	2.5	2.5
T3	Continuous trenches 2mx1m	4	50	30	55	10	5
T4	Continuous trenches 060mx0.60m	3	37.5	22.5	52.5	7.5	22.5
T5	Trapezoidal trenches 1.5m top,0.60m deep Bedding 0.60m wide,0.30 m deep	4	50	25	40	10	20
T6	Bedding 0.60m wide 0.30m deep 0 30m above ground	1	12.5	10	65	32.5	17.5
T7	Bedding 0.60m wide 0.60m deep 0 30m above ground	1	12.5	20	37.5	7.5	10

Wilt Prevalence

During 2012-13 wilt incidence was 3.3% in Mohol (Solapur), 18.1% in Malsirus (Solapur), 13.1% in Karjat (Ahmednagar) and 5.4% in Bagalkot (Karnataka). At Kegaon farm wilt incidence upto 10% was observed in two plots and the infections were observed to be mainly caused by *C.fimbriata,* root knot nematode (*Meloidogyne incognita*) and some samples also revealed association of *Fusarium spp.*

Etiology

Out of 11 samples examined for the detection of the wilt pathogen, 9 samples (81.8%) revealed association of Ceratocystis fimbriata. One sample each revealed presence of shot hole borer (*Xyleborus sp.*) and *Fusarium sp.* Root-knot nematode (*Meloidogyne incognita*) infestations were also observed in four wilt affected samples.

Screening of germplasm for wilt resistance

Out of 5 germplasm accessions (Alah,EC-62812, Tabesta, Bedana and GR Pink) screened for wilt reaction through artificial inoculation of *C.fimbriata,* all but one revealed wilt symptoms. Accessions GR Pink did not succumb to wilt till the last observations were made. Another set of 7 germplasm is being screened include accessions viz. Jodhpur selection, IC-318705, IC- 1182, IC-318759, IC-318753, Sirin Anar, and IC- 1204.

Leaf and fruit spot severity

At the research farm, leaf and fruit spot severity was less than 10.0% and most of the spots were observed to be due to *Cercospora punicae*, *Sphaceloma punicae and Colletotrichum gloeosporioides.* Diseased fruit rot samples (6.0% severity) brought from Warshi orchard (2 year old) revealed association of *Phytophthora* sp. and *Colletotrichum gloeosporioides* on isolations.

4.3 Borer Pests

Survey of fruit borer

Incidence of fruit borer (*Deuodrix isocrates)* in taluks of Solapur district i. e. North Solapur, South

Solapur, Pandharpur and Sangola was found to be nil but Mohol showed less than 10 per cent incidence.

Survey of shot hole borer

During the year 2012-13, in all 11 wilt affected samples from different locations were examined for the association of shot hole borer (*Xyleborus fornicatus*) infestations. The samples examined were from Rajasthan (1), Pimpari, Mohol (2), Bagalkot, Karnataka (1) and NRCP Kegaon farm (7). Some samples revealed the shot hole borer infestations along with root-knot nematode (*Meloidogyne incognita*) and *Ceratocystis fimbrita.*

Population dynamics of borer pests on Pomegranate

Coefficient of correlation for fruit borer on pomegranate was worked out. Among the borer pests, fruit borer, *Deudorix isocrates* showed positive correlation with temperature and negative correlation with relative humidity and rainfall on both the varieties.

Correlation coefficient between fruit borer, *Deudorix isocrates* and weather parameters.

Sl.No.	Fruit Borer Incidence	Correlation Coefficient		
		Mean of Min. & Max. Temp.	Mean of Min. & Max. R.H.	Rainfall
1	Ganesh	0.79	-0.48	-0.10
2	Bhagwa	0.87	-0.53	-0.13

Efficacy of Nematomophagous fungus (*Paecilomyces*) against the root knot nematode

Efficacy of *Paecilomyces* along with *Trichoderma* solution prepared @ 250 ml each in 16 liters of water was studied under field conditions. Control recorded the maximum (70.56) numbers of galls/gm of roots, whereas treatment recorded the lowest (15.59) numbers of galls/gm of roots. An average of 44.85 galls/gm of roots was recorded from control and an average of 24.90 galls was recorded from treatments.

Paecilomyces, solution being prepared

Galls on roots (control)

4.4 Sucking Pests

Survey of sucking insect pests

Incidence of Thrips (*Scirtothrips dorsalis),* in taluks of Solapur district i. e. North Solapur, South Solapur, Mohol, Pandharpur and Sangola is found to be < 10%, > 10%, > 10%, < 10%, and <10%, respectively.

Population dynamics of sucking pests of Pomegranate

Coefficient of correlation for thrips on pomegranate was worked out. Thrips showed negative correlation with temperature, humidity and rainfall on both the var. Ganesh and Bhagwa.

Correlation coefficient between sucking pests and weather parameters.

Sl.No.	Incidence of Thrips	Correlation Coefficient		
		Mean of Min. & Max. Temp.	Mean of Min. & Max. R.H	Rainfall
1	Ganesh	- 0.11	- 0.72	- 0.47
2	Bhagwa	- 0.14	- 0.66	- 0.43

Efficacy of insecticide granule application in field

Thiomethoxam and fipronil granules @ 5 gm, 10 gm and 15 gm each were tested for their efficacy against the sucking pests. Thiomethoxam (5 gm) recorded the lowest (1.88) while fipronil (5gm) recorded the highest (3.52) population of thrips. It was also noticed that increase in dose of thiomethoxam could not control the thrips population.

Efficacy of insecticide granule application in nursery

Thiomethoxam and fipronil granules @ 3.5 gm and 4.5 gm each were tested for their efficacy against the sucking pests in cemented pots under net house. Thiomethoxam (3.5 gm) recorded the lowest (3.6) population while fipronil (3.5gm) recorded the highest (5.4) population of thrips.

Efficacy of Poly Propylene Non Woven bags against Fruit sucking Moths

An experiment was carried out in farmer field to test the suitability of bagging of PP Non Woven bags against the fruit sucking moths. In treatments 17.5 per cent of fruits damage remained same whereas in control 17 per cent of fruit damage increased to 23.5 per cent after 15 days of bagging. Forced feeding of bagged fruits did not yield damage while un-bagged fruits kept in cage were pierced by the fruit sucking moths.

Fruit bagging

Fruit bagging deter moth from piercing

Unbagged fruits pierced by the moth

Effect of graded dose of sulphur on Thrips

Sulphur @ 0, 2.5, 5 and 10 g. each was tested for its effect on sucking pests under light and heavy soil. All the treatment were found non significant with respect their effect on thrips population build up. However, mean thrips population was found more in treatments comprising of heavy soil.

Effect of graded dose of nitrogen on Thrips

Nitrogen @ 0, 2.72, 5.43 and 10.85 g was tested for its effect on sucking pests in cemented pots under net house. Month wise population build up of thrips was found non significant for Oct. 2012 and Jan. 2013, but significantly differ for the other months. Increase in dose of nitrogen did influence the population build up positively for the last month i.e. March 2013.

5. POST HARVEST TECHNOLOGY

5.1 Maturity indices for harvesting of pomegranate

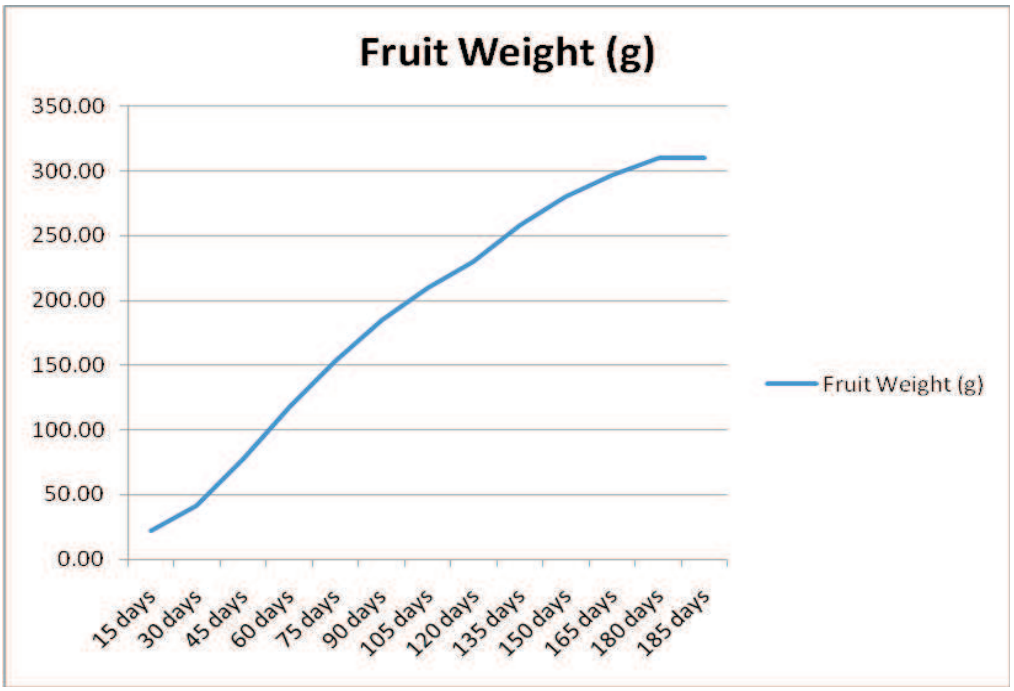
For harvesting the pomegranate fruits at appropriate maturity, it is required to determine the maturity indices viz., days after anthesis, fruit weight, Total soluble solids (TSS), acidity etc. For this purpose, the hermaphrodite flowers in the pomegranate tree were tagged on the day of anthesis (DAA). The fruit samples were drawn after fruitset at an interval of 15 days from the day of anthesis to the fruit maturity. Once maturity is attained, the sampling was done at narrow interval of 2-4 days so as to fix up the appropriate maturity indices under Solapur conditions.

Bhagwa

The fruits of pomegranate cultivar Bhagwa can be harvested when the fruits are about 180 days or TSS , acidity and TSS / acid ratio reaches 15.95 °B, 0.48% and 33.23, respectively under Solapur conditions.

Determination of quantitative maturity indices for pomegranate cv. Bhagwa

Fruit development (days)	Fruit weight (g)	Fruit length (mm)	Fruit dia (mm)	100 aril weight (g)	100 aril juice volume (ml)
15 days	22.50	33.60	32.80	3.90	1.35
30 days	42.25	51.30	50.00	5.90	1.90
45 days	78.20	55.20	51.40	10.50	3.60
60 days	118.40	63.50	64.20	16.80	9.20
75 days	154.00	67.20	67.12	18.40	11.90
90 days	185.50	68.25	67.75	20.60	13.25
105 days	210.00	71.80	70.25	22.10	14.90
120 days	230.50	72.80	72.80	24.50	16.30
135 days	258.25	74.50	74.00	28.40	18.25
150 days	280.50	78.10	77.00	31.60	20.00
165 days	297.00	80.00	80.50	32.80	21.50
180 days	310.25	81.12	80.84	34.03	23.2
185 days	310.30	81.12	80.82	33.90	23.0
CD(p=0.05)	9.90	3.70	1.04	0.52	0.76



Relationship between fruit development period (days) and fruit weight (g)

Determination of qualitative maturity indices for pomegranate cv. Bhagwa

Fruit development (days)	Aril length (mm)	Aril width (mm)	TSS (°B)	Acidity (%)	TSS/acid ratio
15 days	5.80	3.15	8.20	0.64	12.81
30 days	6.10	3.95	8.50	0.63	13.49
45 days	7.50	4.60	8.70	0.63	13.80
60 days	8.30	5.40	9.80	0.62	15.81
75 days	8.75	5.76	10.60	0.61	16.39
90 days	9.00	6.00	11.50	0.60	19.16
105 days	9.40	6.10	12.40	0.58	21.37
120 days	9.80	6.20	13.90	0.56	24.82
135 days	10.00	6.30	15.20	0.54	28.15
150 days	10.30	6.40	15.50	0.52	29.80
165 days	10.60	6.40	15.80	0.50	31.60
180 days	10.94	6.88	15.95	0.48	33.23
185 days	10.94	6.86	16.00	0.48	33.33
CD(p=0.05)	0.24	0.13	0.62	0.22	1.20

The fruits of Bhagwa attains maturity for harvesting on 180 days after anthesis.

Ganesh

The fruits of pomegranate cultivar Ganesh can be harvested when the fruits are about 150 days or TSS , acidity and TSS / acid ratio reaches 16.1°B, 0.45% and 35.77, respectively under Solapur conditions.

Determination of quantitative maturity indices for pomegranate cv. Ganesh

Fruit development (days)	Fruit weight (g)	Fruit length (mm)	Fruit dia (mm)	100 aril weight (g)	100 aril juice volume (ml)
15 days	24.80	27.75	25.90	3.20	1.85
30 days	48.40	43.20	38.70	5.20	2.40
45 days	91.50	61.10	58.40	8.30	3.15
60 days	150.25	64.50	65.10	11.20	10.25
75 days	193.50	69.50	69.25	13.40	11.75
90 days	225.25	75.00	74.50	15.20	13.10
105 days	258.50	77.50	78.30	17.25	16.10
120 days	285.20	79.50	81.00	19.50	19.30
135 days	310.25	81.00	83.25	21.30	21.10
150 days	320.50	83.64	85.12	26.30	22.80
155 days	322.0	83.62	85.10	26.30	22.60
CD(p=0.05)	13.10	3.80	1.12	0.60	0.86

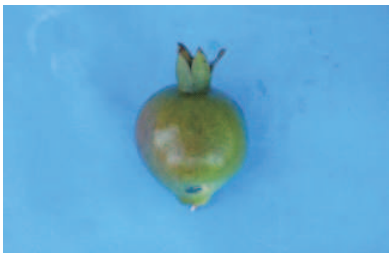
Determination of qualitative maturity indices for pomegranate cv. Ganesh

Fruit development (days)	Aril length (mm)	Aril width (mm)	TSS (°B)	Acidity (%)	TSS/acid ratio
15 days	5.25	2.25	7.5	0.75	10.00
30 days	5.30	2.6	7.60	0.69	11.01
45 days	7.10	3.50	8.00	0.66	12.12
60 days	8.68	4.70	10.8	0.63	17.14
75 days	8.75	5.15	11.35	0.60	18.91
90 days	9.25	5.5	12.00	0.57	21.05
105 days	9.91	6.00	13.3	0.54	24.63
120 days	10.25	6.25	14.8	0.51	29.02
135 days	10.36	6.48	15.60	0.48	32.50
150 days	10.54	6.62	16.1	0.45	35.77
155 days	10.54	6.62	16.2	0.45	36.00
CD(p=0.05)	0.22	0.12	0.60	0.22	1.30

The fruits of Ganesh attains maturity for harvesting on 150 days after anthesis.

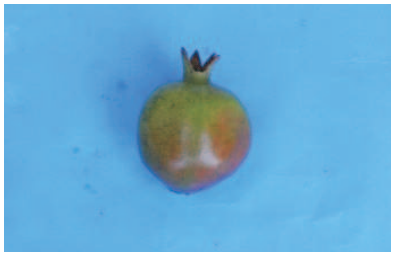
15 days

30 days



45 days

60 days



75 days

90 days

105 days

120 days

135 days

150 days

Maturity Indices of Pomegranate cv. Ganesh at different stages of fruit development

Ruby

The fruits of pomegranate cultivar Ruby can be harvested when the fruits are about 175 days or TSS , acidity and TSS / acid ratio reaches 15.90 °B, 0.46% and 34.56 respectively under Solapur conditions.

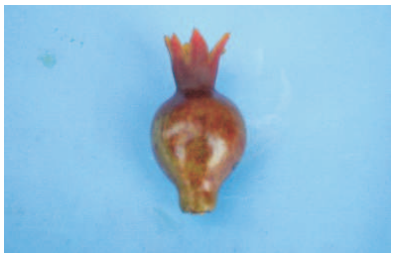
Determination of quantitative maturity indices for pomegranate cv. Ruby

Fruit development (days)	Fruit weight (g)	Fruit length (mm)	Fruit dia (mm)	100 aril weight (g)	100 aril juice volume (ml)
15 days	18.61	24.11	21.89	3.75	1.60
30 days	35.20	45.60	39.50	4.70	2.00
45 days	80.50	50.25	49.80	10.60	4.60
60 days	115.50	56.75	58.50	16.50	9.25
75 days	148.75	63.80	63.10	21.10	13.00
90 days	175.50	66.25	65.50	23.00	14.00
105 days	201.50	68.00	67.25	25.50	18.10
120 days	225.00	70.00	69.50	26.25	20.25
135 days	242.50	71.50	70.75	28.50	20.25
150 days	260.25	74.00	75.50	30.25	20.40
165 days	280.15	76.20	78.00	31.50	22.75
175 days	300.12	77.40	79.28	31.96	24.92
180 days	300.00	77.30	79.28	31.95	24.80
CD(p=0.05)	10.16	3.72	1.12	0.56	0.80

Determination of qualitative maturity indices for pomegranate cv. Ruby

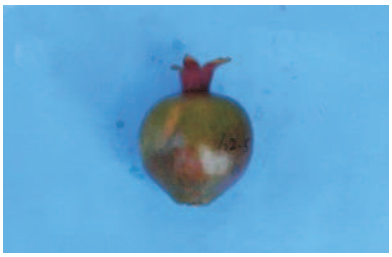
Fruit development (days)	Aril length (mm)	Aril width (mm)	TSS (°B)	Acidity (%)	TSS/acid ratio
15 days	5.25	3.00	8.10	0.77	10.50
30 days	6.00	3.00	8.90	0.74	12.00
45 days	7.06	3.30	9.80	0.70	14.00
60 days	8.60	5.04	10.50	0.67	15.60
75 days	8.80	5.30	11.95	0.64	18.67
90 days	9.05	5.55	13.40	0.60	22.33
105 days	9.15	5.90	13.95	0.58	24.05
120 days	9.35	6.10	14.15	0.54	26.20
135 days	9.60	6.30	14.50	0.51	28.40
150 days	9.80	6.40	15.00	0.50	30.00
165 days	10.10	6.45	15.50	0.48	32.20
175 days	10.22	6.49	15.90	0.46	34.56
180 days	10.24	6.48	15.92	0.46	34.60
CD(p=0.05)	0.22	0.13	0.60	0.23	1.22

The fruits of Ruby attains maturity for harvesting on 175 days after anthesis.



15 days

30 days



45 days

60 days

75 days

90 days

105 days

120 days

135 days

150 days

165 days

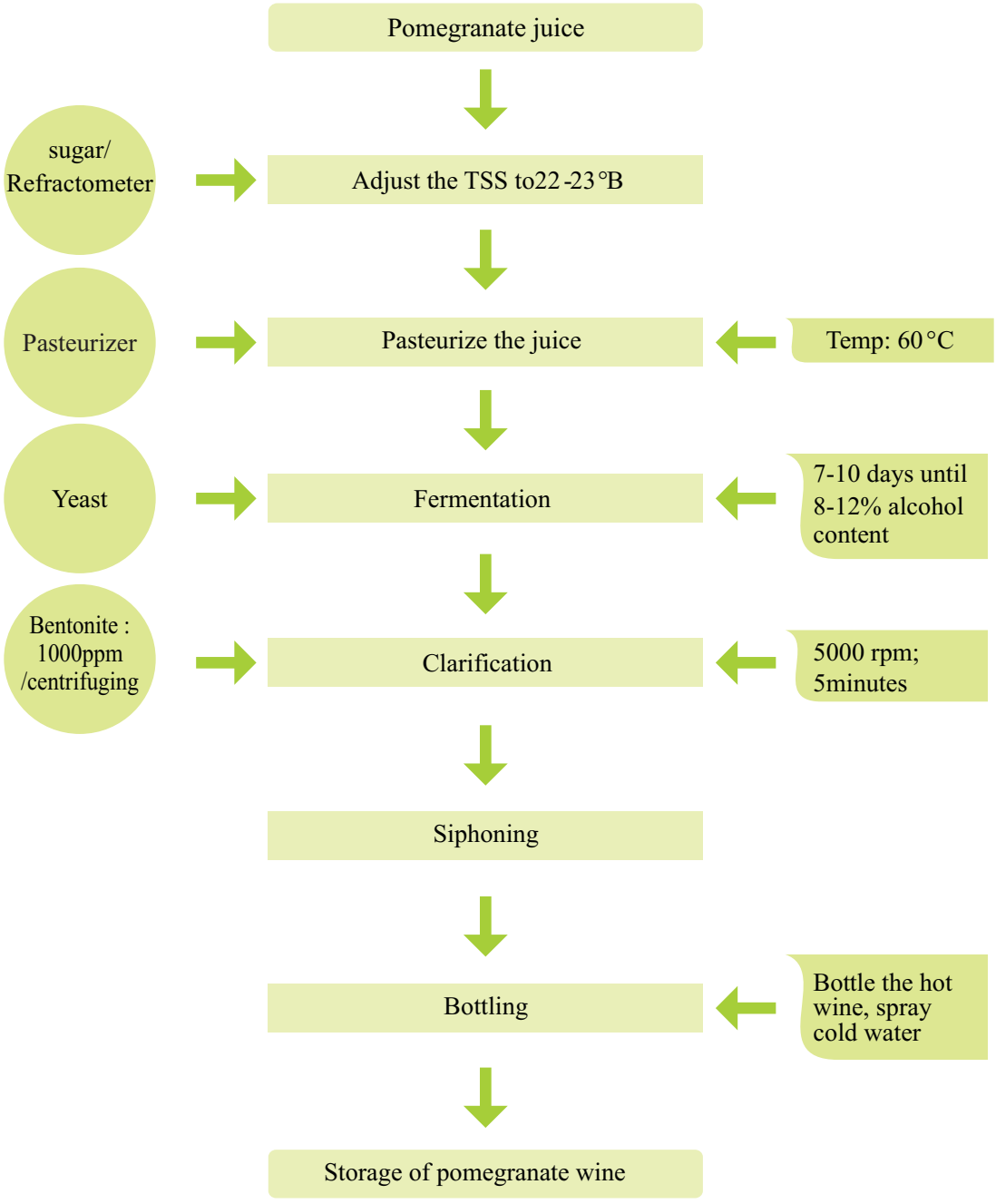
175 days

Maturity Indices of Pomegranate cv. Ruby at different stages of fruit development

5.2 Preparation of processed products

5.2.1 Standardization of protocol for preparation of pomegranate wine

Pomegranate wine contains about 8 - 11.9% alcohol, 0.85g/100g total acidity and 11.5°B soluble solids content. Wine has been prepared through fermentation of pomegranate juice by adopting the following steps.



Flow-chart for preparation of pomegranate wine

Juice Extraction

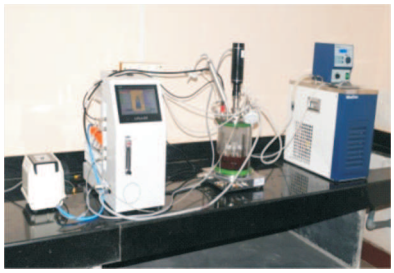
TSS determination

TSS adjustment with sucrose

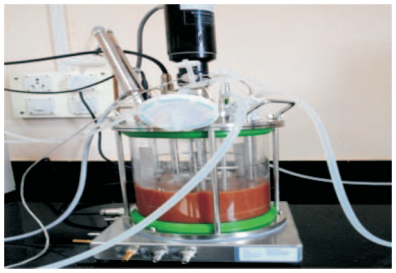
Autoclaving

Starter culture preparation

Inoculation of juice with yeast



Run the Fermentor



Allow the fermentation process

Clarify the wine

Steps in wine making from pomegranate juice

Sensory evaluation of pomegranate wine

A preliminary evaluation on the organoleptic scoring of pomegranate wine by a team of experts revealed the following score on hedonic scale 1-9.

Organoleptic scoring for pomegranate wine

S. No.	Colour	Texture	Flavour	Taste	Overall acceptability
1	9	9	9	9	9
2	8	8	9	9	8.5
3	8	9	8	10	10
4	9	8	8	9	8.5
5	8	8	7	7	7.5
6	9	8	10	7	8.5
7	8	8	8	7	8
8	7	8	9	8	7.5
9	8	7	8	7.5	8
10	3	3	7	4	4
Mean	7.8	7.6	8.4	7.85	7.95

5.2.2 Juice

Pomegranate juice was extracted from 'hand operated juicer' and stored under refrigerated condition with preservative. The juicer consists of the following parts:

- Vertical SS rod connected to the base of the stand
- Height adjustable juice platform with perforated conical filter

The stainless steel rod vertically connects the bottom upon which the platform for juice extraction can be fixed.

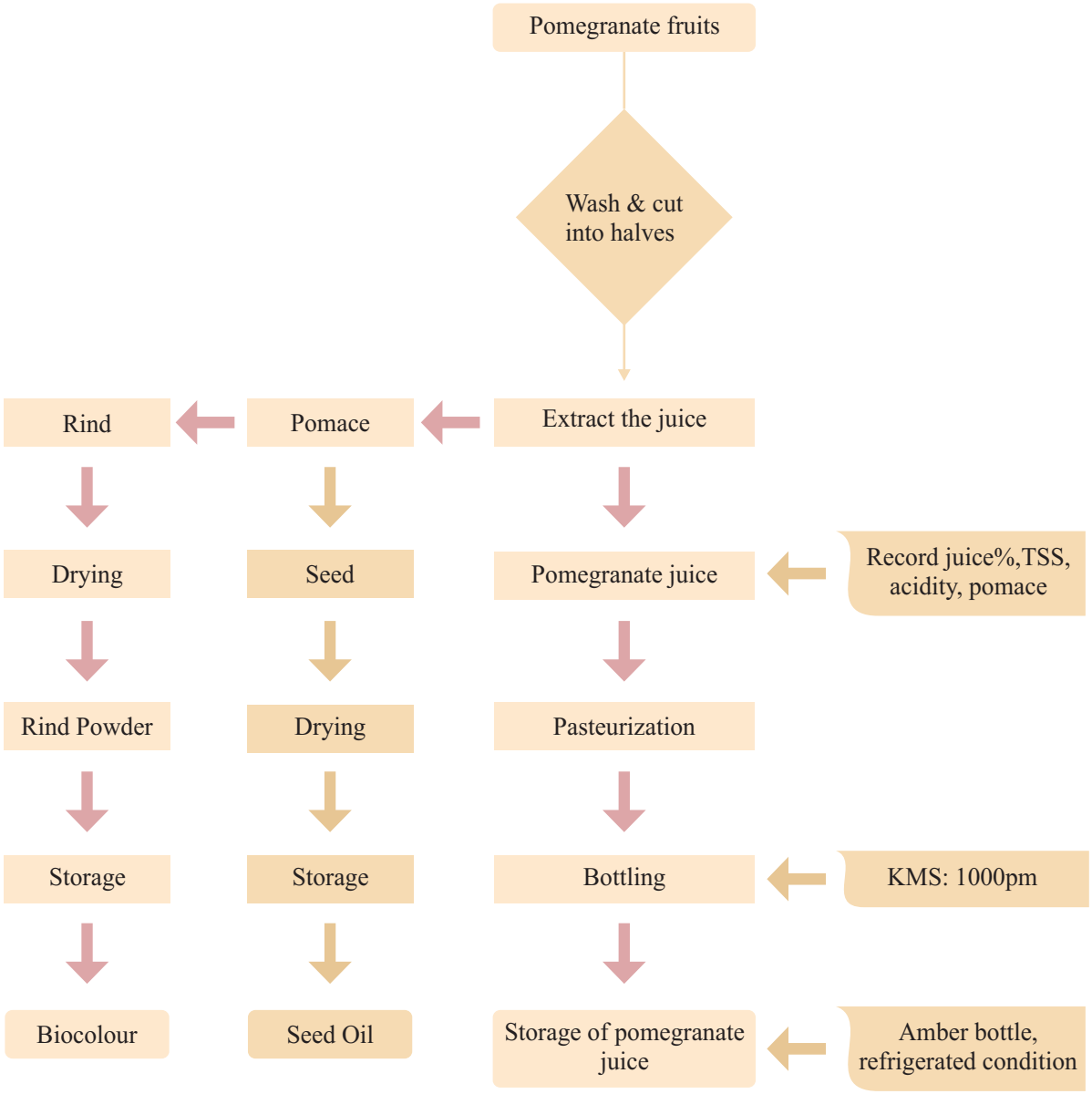
Cut the fruits into halves

Press the handle to squeeze the fruit

Collect the juice

Pomegranate Juice

Steps in juice extraction from pomegranate



Flow-chart for preparation of pomegranate juice

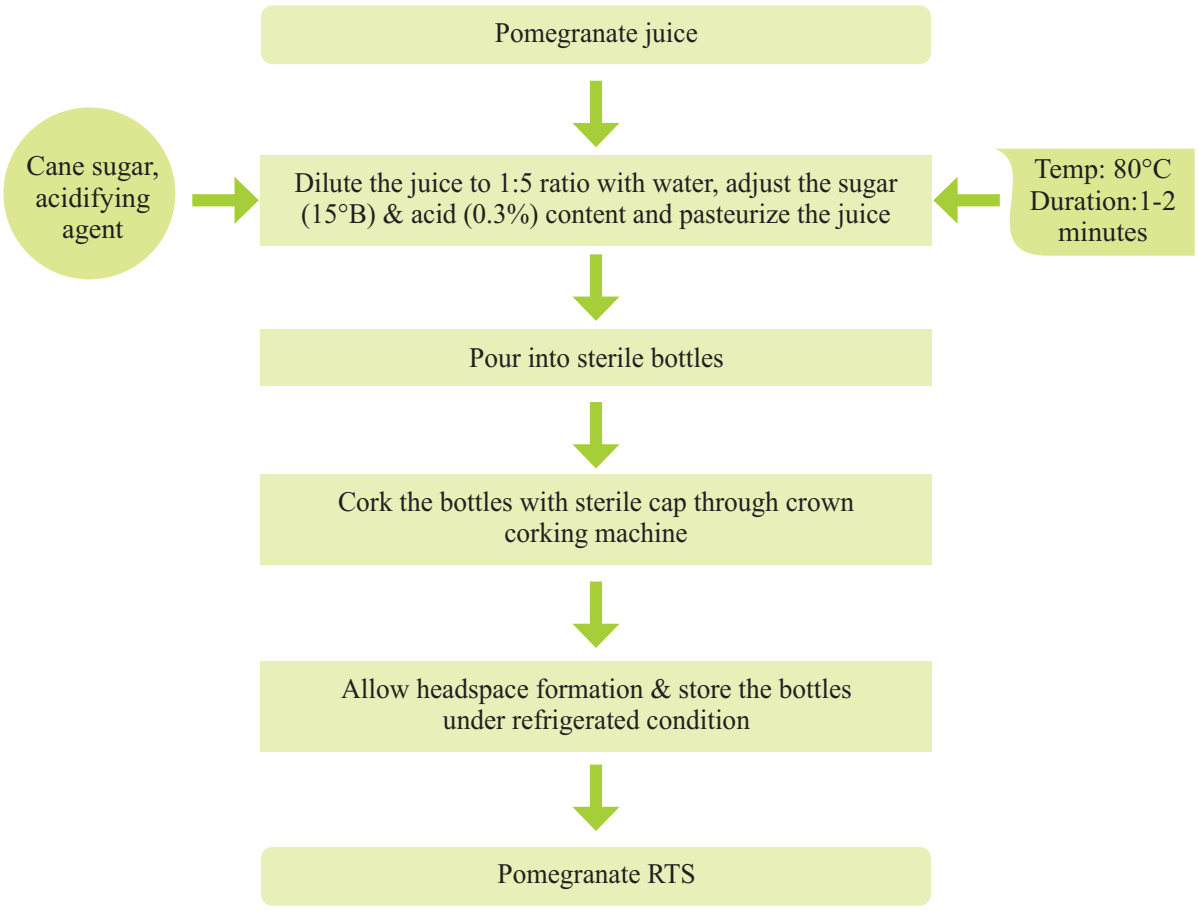
5.2.3 RTS

Protocol was standardized for preparation of ready-to-serve beverage from the pomegranate juice For the first time, RTS beverage was prepared from both Ganesh and Bhagwa cultivars of pomegranate.

RTS beverage from pomegranate cv. Ganesh

RTS beverage from pomegranate cv. Bhagwa

Pomegranate RTS



Flow-chart for preparation of Pomegranate RTS

6. EXTERNALLY FUNDED PROJECTS

6.1 Network Project on Mitigating the Bacterial Blight Disease of Pomegranate in Maharashtra, Karnataka and Andhra Pradesh

Effect of Environmental factors on Bacterial blight and Disease Forecasting

Among the various weather parameters studied, three most important factors for bacterial blight development were - hours when temperatures were between 25-35°C + RH >50%, total rainfall in a week and wind speed. These 3 factors explained 66.9% variation in incidence with 81.9% reliability and 56.5% variation in severity with 75.6% confidence. Three other factors which influenced disease development to some extend were sunshine hours, hours with minimum temperature <20°C and hours with minimum RH<30%, these were negatively correlated with the bacterial blight development.

Maximum bacterial blight incidence and severity was in the months of JuneAugust when minimum temperatures remained at least 20°C and day temperatures remained between 25-35°C for almost 14-15 hrs coupled with minimum RH above 30% for 22-24 hrs and RH >50% for 16-24 hrs. The disease remained almost nil from January to April, started increasing from May, increased till July remained high till August, then started decreasing to almost nil in November and December.

Validation of Integrated Disease and Insect Pest Management (IDIPM) Schedule

Five growers orchards at different locations in Solapur district (Wangi, Kamti, Pimpri, Boramani and Wadgaon) were adopted and demonstrations for Integrated Disease and Insect Pest Management (IDIPM) schedule were taken. The losses due to bacterial blight were reduced by 54.5-100 %, in demonstration plots in comparison to previous crop season when it was not adopted. In comparison to non adopted orchards during the demonstration period > 50% less disease was observed in adopted orchards except in one. All the other diseases and pests were at lower level in adopted orchards except at Kamti where it was almost same.

At Kamti 45.5% fruits were lost due to bacterial blight; however the unsatisfactory yield in other 3 orchards was the result of poor flowering and fruit set, due to various reasons but not due to bacterial blight. The cost of cultivation varied from Rs. 0.77-1.57 lakh per ha and net profits were Rs.0.52 to 2.19 lakh rupees per ha.

6.2 Intellectual Property Management and Transfer/Commercialization of Agricultural Technology Scheme

The Intellectual Property Rights (IPR) provide right to the innovations /inventors for their novel technology and also facilitate to transfer IPR enabled technologies for commercialization through commercial, cooperative and public routes. The Intellectual Technology Management Unit (ITMU) at NRCP was established in June 2008 and implemented w.e.f 2009-10 under the scheme entitled "Intellectual Property Management and Transfer / Commercialization of Agricultural Technology Scheme".

The constitution of ITMU at NRCP is as follows:

Dr R.K.Pal
Director, NRCP Solapur, Chairman
Dr.K.K.Sharma
Pr.Scientist, In-charge/Nodal Officer
Dr. Ram Chandra
Pr. Scientist, Member
Dr S.S. Suroshe
Scientist, Member
Besides, there is one Research Associate working under the Project.

Although, NRCP was established in September 2005, it has since its inception formulated more than 14 Research projects under major programmes involving: i) Pomegranate Improvement ii) Production iii) Protection and iv) Post harvest technology.

Technologies developed/being developed at NRCP Solapur

- The Integrated Disease and Insect Pest Management (IDIPM) schedule has been developed by the Research Centre for mitigating bacterial blight in particular and wilt and other important fruit spot and insect-pests of pomegranate in general. The IDIPM schedule has resulted in successful management of bacterial blight and other important diseases and insect-pests of pomegranate in adopted orchards in Maharashtra, Karnataka and Andhra Pradesh.
- Wedge grafting and Patch budding, novel techniques for pomegranate propagation have been standardized and found successful for the first time in Pomegranate.
- For the first time, *Penicillium pinophilum* has been observed and reported to solubilize phosphorus and potassium and breakthrough may save enormous foreign exchange as the country imports bulk of its potassium fertilizers from abroad. Bioinoculant's performance, however, in field remains to be validated.
- Modified rooting medium has been developed for *in vitro* production of planting material through tissue culture.
- Protocol has been developed for the production of planting material through the use of hardwood cuttings and the technique has revealed 85.0% success in establishment of the plants with profuse rooting. The technology is easy to use and more economical than the existing practice of using air-layers as planting material.
- Preliminary standardization of value added products from pomegranate as wine and RTS has been done.

NRCP received a budget of Rs 4.60 lac from ICAR under the IPR Project during 2012-13. The Research centre has purchased about 62 IPR related books for its library, besides other infrastructural facilities like computer, printer etc. have also been procured.

6.3 Establishment of Distinctness, Uniformity and stability (DUS) test centre on Pomegranate

Protection of plant varieties and farmers' rights authority (PPV & FRA) has provided fund for establishment of pomegranate DUS centers at NRCP, Solapur and CAZRI, Jodhpur. Under this programme, guidelines for the conduct of test for Distinctiveness, Uniformity and Stability (DUS) in pomegranate (*Punica granatum* L.) were prepared. The guidelines included plant material required, procedure to conduct test, methods and observations, grouping of varieties, characteristics and symbols etc. Thirty six essential characteristics like Tree height, tree growth habit, precocity, shoot thorniness, tree foliage density, leaf blade size, leaf apex shape, petiole size, petiole anthocyanin colouration, calyx size, calyx color, Corolla color, corolla type, petal size, fruit size, fruit shape, fruit colour, rind thickness, nipple or fin, crown size, crown neck, aril colour, aril size, seed hardiness, seed size, fruit maturity period, TSS, acidity, fruit juiciness etc. and two special test characteristics (Tolerance against abiotic and biotic stresses) were incorporated in the descriptor of pomegranate under the test guidelines. Besides, various morphological characters of genotypes/ varieties of pomegranate were recorded and data base has been created. Photographs for preparation of photo library for various morphological characters of pomegranate were taken.

6.4 Crop pest surveillance, advisory and Management Project (CROPSAP) for Mango, Pomegranate & Banana

Disease and Insect Pests

Surveys were conducted in selected orchards of Satara, Sangli and Solapur, district during

September October 2012 by NRCP.

In Satara about 49 orchards in 39 villages of 5 talukas *viz*. Phaltan, Khandala, Koregoon, Vaduj and Dahivadi were surveyed covering 155 acres of pomegranate growing area. Koregaon was the only taluka to be free from bacterial blight, in other talukas bacterial blight incidence ranged from 2.67% in Khandala to 35.56 % in Dahivadi, severity was however, less than 5% in all the orchards. In all 42.89% orchards were affected, Dahivadi being most affected with 70% affected orchards followed closely by Vaduj. Wilt incidence ranged from 0.25% to 3.13%. Among insect pests thrips and fruit borer were important pests. Average incidence of thrips was 18.63% on twigs and 6.20% on fruits and fruit borer was 0.53%.

In Sangli 51 orchards in 31 villages of 5 talukas *viz*. Jat, Kawatemahakal, Tasgaon, Vita and Atpadi were surveyed covering 150 acres of pomegranate growing area. None of the talukas surveyed were free from bacterial blight. In different talukas 60-93.75% (average 78.05%) orchards were affected with bacterial blight. The bacterial blight incidence ranged from 9.6% in Tasgaon to 58.75% in Atpadi, severity was however, less than 5% in all the orchards. Wilt incidence ranged from 0.0% in Kawatemahakal and Tasgaonto 2.46% in Vita. Among insect pests -thrips and fruit borer were important pests. Average incidence of thrips was 10.56% on twigs and 3.28% on fruits and fruit borer was 0.40%.

In Solapur 107 orchards were surveyed in 84 villages of 11 Taluks, covering 508.75 acres area. Bacterial blight was present in all the talukas of Solapur. On an average 50.4% orchards (range12.5-100%) were affected with bacterial blight having 44.07% incidence (range 9.5-73.43%) on trees. Average severity of blight on different units (leaves, fruit, stem and tree) was below 5% (max. 11.3 % on leaves). Wilt incidence was 1.57% on an average, with maximum 6.78% in Sangola and no wilt in Malshiras. Among insect pests thrips affected 14.02% twigs and 5.21% fruits. Fruit borer infestation was only 1.01%.

Flowering and Fruiting Status

In Satara, 61% orchards were with moderate to heavy fruit/flower bearing and 34.69% orchards were in rest. The respective figures for Sangli were 67% and 28% and for Solapur 61% and 37%.

7. TRANSFER OF TECHNOLOGY

7.1 Trainings imparted to Govt. officials/Farmers

7.1.1 Number of Farmers trained at NRCP, Solapur

Date	Number of farmers trained/Place belong to	Sponsored by	Officials present
30/04/12	10 farmers from Jalna	State Govt.	State Dept. officials
01/05/12	50 farmers from Keij Taluka (Bid)	State Govt.	State Dept. officials
16/08/12	120 from Solapur	Coromandel Pvt. Ltd.	Farmers and dealers of Coromandel Pvt. Ltd.
07/12/12	25 farmers from Atapadi (Sangli)	Bank of Maharashtra	State agricultural and Bank of Maharashtra officials
12/12/12	41 farmers from Latur	ATMA	State agricultural officials
18/12/12	30 farmers from Washim	ATMA	State agricultural officials
17/01/13	50 farmers from Phaltan (Satara)	ATMA	State agricultural officials
23/01/13	30 farmers from Akola	MACP	State agricultural officials
06/02/13	53 farmers from Srigonda	ATMA	State agricultural officials
08/02/13	40 farmers from Bagalkot	NHM	State agricultural officials
26/02/13	18 farmers from Atpadi (Sangli)	ATMA	State agricultural officials
26/02/13	83 farmers from Ausa (Latur)	ATMA	State agricultural officials
02/03/13	50 farmers from Patan (Gujrat)	Gujrat Govt.	State agricultural officials
23/03/13	100 farmers from Kavathe Mahakal	ATMA	State agricultural officials

7.1.2 Number of Farmers/State Govt. Officials trained at other places.

Date	Place where trained	Number of farmers/ officials trained	Sponsored by	Officials present
20/04/12	Village Hoal, Taluka Keij, District Beed, Maharashtra	250	Network project of Ministry of Agri. GOI, New Delhi .	State dept. of Agriculture officials
25/04/12	Jat, Sangli, Maharashtra	150	CROPSAP, project RKVY. Maharashtra Govt.	State dept. of Agriculture officials
18/06/12	Bhopal, Madhya Pradesh	700	Madhya Pradesh State Horticulture Mission.	State dept. of Agriculture officials
28/07/12	Indapur, Pune.	500	Taluka Krishi Officer and Mahatama Phule Krishi Vigyan Kendra, Indapur, Dist Pune.	State dept. of Agriculture officials
07/08/12	Papri, Solapur	150	Network project of Ministry of Agri. GOI, New Delhi.	State dept. of Agriculture officials
24/08/12	Nimkheda, Zhafrabad, Dist Jalna	300	Network project of Ministry of Agri. GOI, New Delhi.	State dept. of Agriculture officials
13/10/12	College of Agri Osmanabad	100	Network project of Ministry of Agri. GOI, New Delhi.	State dept. of Agriculture officials
14/10/12	Bhandi-Shegaon, Taluka Pandharpur, Dist. Solapur	400	Network project of Ministry of Agri. GOI, New Delhi.	State dept. of Agriculture officials
17/10/12	Jalana road, Beed	400	Dept of Agriculture, Govt of Maharashtra under National Horticulture Mission.	Central and State agri officials
25/11/12	Parite, Taluka Madha (Solapur)	150	Maharashtra Pomegranate Growers Research Association, Pune	Officials from Pomegranate Growers Research Association
14/01/13	SDAO office, Jat, Sangli	150	Dept. of Agriculture under RKVY.	Officials from state agriculture dept.
22/01/13	Experimental farm of KVK, Hiraj, Solapur	550	KVK, K hed, Solapur	Officials from MPKV, Rahuri and State agricultural dept.
25/01/13	Reshimbagh, Nagpur	1200	AGROVISION, Nagpur	Officials from MPKV, Rahuri and State agricultural dept
28/01/13	Sadashivnagar, Malshiras (Solapur)	1500	Maharashtra Pomegranate Association, Pune	Officials from state agriculture dept.
07/02/13	Phaltan (Satara)	1200	Maharashtra Pomegranate Association, Pune.	Local MLA, MP and officials from state agriculture dept.
15/03/13	Vitthalwadi, Indapur (Pune)	300	Farmers club	Officials from state agriculture dept and Pomegranate association.

7.2 Television Talk

Name of the Scientist	Topic	Date/Month of telecast
R. A. Marathe	Management of pomegranate orchards during rainy season with special reference to drainage and water management	E-TV (Marathi) in July, 2012
Jyotsana Sharma, K. Dhinesh Babu, Sachin S. Suroshe and N.V. Singh	Pest Management in Pomegranate	SAM-TV (Marathi) in Sept. 2012
Sachin S. Suroshe	Bacterial blight of pomegranate and its management	E-TV (Marathi) in January, 2013
Sachin S. Suroshe	Wilt of pomegranate and its management	E-TV (Marathi) in February, 2013

7.3 Surveys of Tribal areas under TSP project

7.3.1 Visit to Nagaland state under Tribal Support Project

- Dr. R.A. Marathe, Pr. Scientist surveyed backward areas of North- Eastern states of India during 1 to 6th February 2013 to explore prospectus of high value fruit crop like pomegranate. Saplings of different varieties viz. Bhagwa (10), Ganesh (4), Aarakta (4), Mridula (4) and Ruby (3) were planted in nursery of ICAR research complex for NEH region, Jharnapani, Nagaland.
- Similarly, surveys were conducted by Dr. R.A. Marathe, Pr. Scientist in Medziphema and Mebong areas to find out soil types and other aspect of pomegranate cultivation. Meeting and discussion was also held with Mr. L.S. Reddy, Acting Director and other officials of Central Institute of Horticulture, Medziphema, Nagaland. Lecture was delivered on pomegranate cultivation and related aspects with respect to Nagaland state.

7.3.2 Visit to Rayagada and Kashipur district of Odisha state under fruit diversification programme

- A tour was conducted during 31st February to 5th March 2013 in Mandibishi, Sarambai-bandal, Sindurghatti, Kathibhads areas of Kashipur and Rayagada district of Odisha to explore prospects of introduction of new high value fruit crops like pomegranate under fruit diversification programme for the welfare and betterment of tribal population residing in most remote and backward areas of Odisha state.

Scientist of NRCP imparting training to farmers of Papari (Solapur) on 07/08/12

Scientist of NRCP imparting training to farmers of Bhandi-Shegaon (Pandharpur) on 14/10/12

Members of Maharashtra Pomegranate Association at NRCP, Solapur on 11/12/12

Scientist of NRCP imparting training to farmers of Phaltan (Satara) on 16/01/13 at NRCP, Solapur

Congregation of farmers for training programme at Phaltan, (Satara) on 07/02/13

Discussion on mulching with the farmers of Srigonda (A. Nagar) on 06/02/13 at NRCP

Dr. RK Pal, Director, NRCP addressing the farmers along with MLA and MLC of Sangola on 12/01/13

Dr. Sachin Suroshe, Scientist, NRCP, addressing farmers of Vidharbha at Nagpur on 25/01/13

Dr. RK Pal, Director and Scientists of NRCP discussing the prospect of tissue culture plants with officials of Jain Irrigation on 05.01.2013 at Jalgaon (M.S)

Dr. RK. Pal, Director and Scientists of NRCP along with the Dr. P.S. Minhas, Director and staff of NIASM, during visit to Baramati on 07.02.2013

Dr. RK Pal, Director, NRCP showing the farm facilities of NRCP to members of Maharashtra Pomegranate Growers and Research Association on 11.12.12

Dr. RK Pal, Director, NRCP interacts with farmers of Pandharpur on 28.11.2012

8. INSTITUTIONAL ACTIVITIES

The following events concerned with Research and Development activities of the NRCP were held during the year.

8.1 Research Advisory Committee Meeting

The VIth meeting of the Research Advisory Committee of NRC on Pomegranate was convened on 18th and 19th May, 2012 at NRCP, Solapur under the Chairmanship of Dr. S. D. Shikhamany, Ex-Vice Chancellor, Andhra Pradesh Horticultural University, West Godavari District, Andhra Pradesh. The constitution of the VIth RAC of NRCP was as follows:

Sl.No.	Name	Designation/Address
1	Dr. S.D. Shikhamany - Chairman	Former VC, A.P. Horticulture University, A.P.
2	Dr. P.L. Saroj - Member	ADG In - charge (Hort.), ICAR, New Delhi
3	Dr. H. Shivanna –Member	Director of Research, University of Agricultural Sciences, Bangalore.
4.	Dr. V. Nachegowda -Member	Professor of Pomology, Special officer, College of Horticulture, Kolar, University of Horticultural Sciences, Karnataka.
5	Dr. V.T. Jadhav - Member	Director, NRCP, Solapur.
6	Dr. S.N. Pandey -Member	Ex-ADG (Hort.), ICAR, New Delhi.
7	Dr. Srikant Kulkarni - Member	Former Professor &Head, Plant Pathology, UAS Dharwad, Karnataka
8	Dr. B.M.C. Reddy -Member	National Project Coordinator, UNAP -GEF-TFT Project & former Director, CISH, Lucknow
9	Shri. Arun Nimba Deore - Member	Progessive farmer, Nashik
10	Shri. Jaysingrao Manikrao Deshmukh–Member	Progressive farmer, Pandharpur, Solapur
11	Dr. Ram Chandra - Member-Secretary	Principal Scientist (Horticulture)

NRCP Scientists with Members of Research Advisory Committee

Based on the discussions held in the committee meeting under various projects, the following recommendations have emerged.

i. The scientists should survey pomegranate growing areas and note farmers' practices and their problems/constraints so as to prioritise research activities.
ii. There is a need to develop Orchard health management (OHM) schedule for *mrig bahar* also.
iii. Relationship of bacterial blight disease incidence and severity with foliar nutrient content and soil moisture needs to be worked out.
iv. Conducive changes taking place in the soil for wilt development should be studied.
v. PCR based quick diagnostic kit for identification of wilt should be developed.
vi. Integrated package for managing wilt, nematode and shot hole borer should be developed.
vii. IPM model for fruit borer and thrips should be developed.
viii. DNA fingerprinting of pomegranate germplasm should be taken up.
ix. Efforts should be made to survey pomegranate growing areas and collect better types from Bhagawa and Ganesh.
x. Emphasis should be given on propagation of planting material through tissue culture.
xi. Work on screening of rootstock against biotic and abiotic stresses should be intensified.
xii. Crop stage-wise water requirement and fertigation schedule for pomegranate need to be developed.
xiii. In order to enhance water use efficiency in pomegranate, subsurface drip irrigation should be evaluated.
xiv. Development of technology for wine production

8.2 Institute Management Committee Meeting

The VIIIth IMC meeting of NRCP was held on May 25, 2012 and was attended by the following members.

S. No.	Name	Designation
1.	Dr V.T. Jadhav - Chairman	Director, NRCP Solapur
2.	Dr. A.K. Mishra	Project Co-ordinator (STF), CISH, Lucknow
3.	Dr B.R. Ulmek - Member	Associate Dean and Principal, College of Agriculture, Pune
4.	Dr. Ram Chandra	Principal Scientist, NRCP, Solapur
5.	Dr. R. A. Marathe	Principal Scientist, NRCP, Solapur
6.	Shri A.A. Goswami - Member - Secretary	Administrative Officer, NRCP, Solapur.

The following issues pertaining to development of the centre were discussed.

i) Development of diagnostic kit for against bacterial blight in collaboration with IARI ii) Procurement of essential equipments approved during XI plant bur not yet purchased iii) Standardization of tissue culture protocol for pomegranate iv) Installation of lift irrigation system.

8.3 Institute Research Committee Meeting

The VIIth IRC of NRCP was held on 6th March, 2013. The research achievements of ongoing projects and new research project proposal were presented by the concerned PIs or CoPIs. The following Scientists were present in the meeting.

S.No.	Name	Designation
1.	Dr. R.K. Pal, Director, NRCP	Chairman
2.	Dr. (Mrs.) Jyotsana Sharma, Pr. Scientist (Plant Pathology), NRCP	Member
3.	Dr. K. K . Sharma, Pr. Scientist (Plant Pathology), NRCP	Member
4.	Dr. R. A. Marathe, Pr. Scientist (Soil Science), NRCP	Member
5.	Dr. K. Dhinesh Babu, Sr. Scientist (Hort. - Fruit Science), NRCP	Member
6.	Dr. D. T. Meshram, Scientist, (SWCE), NRCP	Member
7.	Dr. Sachin Suroshe, Scientist (Entomology), NRCP	Member
8.	Dr. Ashis Maity, Scientist (Soil Science), NRCP	Member
9.	Dr. N. V. Singh, Scientist, (Hort. - Fruit Science), NRCP	Member
10.	Dr. D. P. Waskar, Associate Dean & Principal, Colleg of Agriculture Latur, Marathwada Agricultural Universitye	Invited member
11	Dr. Ram Chandra, Pr. Scientist (Hort.), NRCP	Member Secretary

A brief account of ongoing projects and action taken report on VIth IRC held on 19th August, 2011 was presented by Dr. Ram Chandra. Dr. D.P. Waskar, Resource Person, College of Agriculture Latur, MAU, was invited to the meeting and he offered valuable suggestions in each project for improving the research programme.

The progress reports of 15 Projects were presented by PIs/Co-PIs of different projects. Out of 15 ongoing projects, PIs of 7 respective projects were asked to submit RPF III at the earliest and two PIs were requested to submit revised RPF I. Three new projects were approved with necessary modifications.

VIIth Institute Research Committee meeting of NRC on Pomegranate

8.4 Republic Day Celebrations

NRCP celebrated the 64th Republic day of the Nation on 26th January 2012. On the occasion Dr. R. K. Pal, Director NRCP conducted the Flag Hoisting Ceremony and addressed the staff of the Centre.

Flag Hoisting Ceremony at NRCP on the eve of Republic Day

8.5 Hindi Activities

During this year, NRC on Pomegranate has celebrated 'Hindi Fortnight' from 14th Sept to 29th Sept, 2012. Different competitions were organized in Hindi during the fortnight period and all the members of this centre participated in these events. At the end of these competitions prize distribution ceremony was organized and the chief guest of the event was Police Superintendent of Soalpur Shri. Rajesh Pradhan. In his speech honourable chief guest emphasized the promotion of Hindi as common medium of instruction and urged everybody to strive towards promotion of Hindi. Honorable Director, National Research Centre on Pomegranate also highlighted the importance of Hindi in bringing unity in diversity. The event was coordinated by Hindi officer of the centre in cooperation with all the scientists and staff of National Research Centre on Pomegranate.

Besides this, various farmer's training day and scientists-farmers interactions were also organized and the medium of instruction in these events was Hindi.

Participants of Essay writing competition during Hindi fortnight celebration

Prize distribution ceremony for various competitions organized during Hindi fortnight at NRC on Pomegranate

8.6 New Year Celebration

Director and staff of NRCP have celebrated the new year on 1st January, 2013.

Dr. K.K. Sharma greets Director, NRCP on the eve of New Year

Staff of NRCP with the Director during New Year Celebration

9. HUMAN RESOURCE DEVELOPMENT

Participation of Scientists / Staff in Conferences / Refresher Courses / Meetings / Symposia / Workshops / Trainings

Sl No.	Title	Date & Venue	Participant (s)
1.	1st International Conference on 'Bio-resource and stress management'	6th -9th Feb., 2013, Kolkata, India	Dr. Ashis Maity
2.	3rd International Agronomy Congress on 'Agriculture Diversification, Climate change management and Livelihoods'	Nov. 26 -30, 2012, New Delhi, India	Dr. Ashis Maity
3.	5th Indian Horticulture Congress: Horticulture for Food and Environment Security - An International Meet	6-9th Nov, 2012 at PAU, Ludhiana, Punjab, India	Dr. K. Dhinesh Babu Dr. S.S Suroshe Dr. N.V.Singh
4.	Meeting of the Horticulture division of ICAR regarding XII th plan EFC document and various Challenge and Platform programmes	May 5 - 7, 2012 at NASC Complex, Pusa, New Delhi	Dr K. K. Sharma
5.	Meeting of the Horticulture division (ICAR) to discuss issues related to XII th plan EFC document, works and equipments for 20 12-13, submission of RFD for 2012-13 and Six monthly report	July 23, 2012 at NASC Complex, New Delhi	Dr K. K. Sharma
6.	22nd Meeting of ICAR Regional Committee VII to discuss and review the current status of agricultural research in the region.	November 9-10, 2012, International Centre, Goa	Dr. R.K.Pal Dr K. K. Sharma
7.	Meeting of the RFD Nodal officers of the responsibility sub centres to discuss the midterm achievements	23rd November, 2012, KAB-II , ICAR, New Delhi	Dr K. K. Sharma
8.	Meeting on draft RFD, 2013 -14 & its finalization	16th January, 2013, NASC Complex, New Delhi	Dr. R.K.Pal Dr K.K. Sharma
9.	Meeting with Suzlon Pvt. Ltd.	11th April, 2012, Ghatnandre, Sangli Maharashtra	Dr S.S Suroshe Dr. D.T. Meshram
10.	Meeting with Satara Steel Plant Pvt. Ltd.	12th April, 2012, Satara, Maharashtra	Dr S.S Suroshe Dr. D.T. Meshram
11.	Meeting with Hon'ble Guardian minister Solapur	21st July, 2012, Circuit House, Soalpur, Maharashtra	Dr S.S Suroshe
12.	ICAR Hub meeting along with Director, NRCP at NRC Grapes, Pune on 04/01/13.	4th January, 2013, NRC Grapes, Pune	Dr. R.K.Pal Dr. S.S. Suroshe Dr. N.V. Singh
13.	Meeting with officials of Jain Irrigation Pvt. Ltd.	5 and 6th Jan. 2013, Jalgaon, Maharashtra	Dr. R.K.Pal Dr. S.S. Suroshe Dr. N.V. Singh
14.	Meeting with members of Maharashtra Pomegranate Growers Research Association	12th and 28th January, 2013, Solapur, Maharashtra	Dr. R.K.Pal Dr. S.S. Suroshe

Sl No.	Title	Date & Venue	Participant(s)
15.	Global conference on Horticulture for Food, Nutrition and Livelihood Options organized by Lt. Amit Singh Memorial Foundation, N. Delhi and Orissa University of Agriculture and Technology (OUAT)	28th to 31st May, 2012, Bhubaneshwar Odisha	Dr. Jyotsana Sharma Dr. S.S. Suroshe
16.	AGROVISION Workshop, National Expo and Conference on "Building sustainable livelihood and increasing farmers income".	24th to 29th January, 2013,	Dr. S.S. Suroshe
17.	Annual workshop of AICRP on Nematodes on 'Plant parasitic nematodes and their management'	8-9th March, 2013. MPKV, Rahuri, Maharashtra	Dr. S.S. Suroshe
18.	AGROVISION Workshop, National Expo & Conference on "Building sustainable livelihood & increasing farmers income".	Nagpur January 27-30, 2012	Dr S.S. Suroshe
19.	Workshop on 'Technology & machine for hygienically extracting pomegranate arils' by Juran Technology, Israel	17th December, 2012 APEDA,Vashi, Mumbai	Dr. K. Dhinesh Babu
20.	Training Program on 'Project Formulation and Appraisal'	4th -5th February, 2013, ISTM, New Delhi	Dr. N.V. Singh
21.	Pre-distribution meeting on benefits of tissue culture raised pomegranate plants	25th October, 2012 Office of Agriculture Commissioner, Pune, Maharashtra	Dr. N.V. Singh
22.	Meeting on "Protection of horticulture fruit crops due to water scarcity in various districts of Maharashtra	27th April, 2012, Sakar Shankul, Pune	Dr. D.T. Meshram
23.	Meeting on "Pomegranate Insurance based on Weather Parameters"	04th July, 2012, Sakar Shankul, Pune	Dr. D.T. Meshram
24.	Meeting as a member of Scientific Advisory Committee (SAC) at Krishi Vigyan Kendra	24th July, 2012, KVK, Solapur	Dr. D.T. Meshram
25.	ICAR sponsored winter school on "Recent Advances in Microirrigation and Fertigation"	5th-25th November, 2012 , WTC, IARI, New Delhi	Dr. D.T. Meshram
26.	Meeting as a member of Scientific Advisory Committee (SAC), MPKV	18th February, 2013, MPKV, Rahuri, Maharashtra	Dr. D.T. Meshram
27.	RRC meeting	2nd April, 2012, MPKV, Rahuri, Maharashtra	Dr. Ram Chandra
28.	Task Force 6/2011 meeting of pomegranate	29th-30th May 2012, PPV & FRA, New Delhi	Dr. Ram Chand ra
29.	Selection board member as ICAR representative for selection of various posts of KVK	8th –9th June 2012, at Sanaroli, Nanded	Dr. Ram Chandra
30.	Task force 6/2011 meeting of pomegranate	18th – 19th November 2012, PPV & FRA, New Delhi.	Dr. Ram Chandra

Sl No.	Title	Date & Venue	Participant (s)
31	National Consultation Meeting on PGR Management of horticultural crops	18th – 19th December 2012, NBPGR, New Delhi	Dr. Ram Chandra
32.	Meeting called by new body of Maharashtra Pomegranate Growers Research Association	28th October 2012, at Nimbhore, Karmala, Dist. Solapur	Dr. Sachin Suroshe
33.	Meeting with members of Maharashtra Pomegranate Growers Research Association	07th February 2013, at Phaltan, Dist. Satara	Dr. Sachin Suroshe
34.	Technical committee meeting of Maharashtra Pomegranate Growers Research Association chaired by Vice Chancellor, MPKV, Rahuri	08th March 2013, at University Campus	Dr. Sachin Suroshe

10. PUBLICATIONS

10.1 Research Articles

International

1. Chandra, R., Lohkare, A. S., Dhinesh Babu, K., Maity, A. and Singh, N. V. and Jadhav, V. T. Variability studies of physico-chemical properties of pomegranate (Punica granatum L.) using a scoring technique. Fruits 68 (2): 135-146.
2. Mondal, K.K., Rajendran, T.P., Phaneendra, C., Mani, C., Sharma, J., Sukhla, R., Pooja, Verma, G, Kumar, R., Singh, D., Kumar, A., Saxena, A.K., and Jain, R.K. (2012). The reliable and rapid polymerase chain reaction (PCR) diagnosis for X*anthomonas axonopodis* pv. *punicae* in pomegranate. *African Journal of Microbiology Research* 6(30):5950-56.
3. Singh, R. K., Sharma, J., Jha, S.K. and Singh, A. K. (2012). Solarization technique: its use in the multiplication of *in vitro* planting materials. *Current Science* 102 (10): 1433-36.

National

1. Chandra, R. and Jadhav, V. T. (2012). Effect of various grafting methods and time in pomegranate (*Punica granatum* L.) under semi-arid agro-climatic condition of Maharashtra. Indian Journal of Agricultural Sciences 82 (11) : 990-992.
2. Fand, B. B., Gautam, R. D., Kamra, A., Suroshe, S. S. and Mohan, S. (2012). Bioefficacy of Aqueous Garlic Extract and a Symbiotic Bacterium, *Photorhabdus luminescens* against *Phenacoccus solenopsis* Tinsley (Homoptera: Pseudococcidae). Biopestic. Int. 8(1): 38-48.
3. Maity, A., Sharma, J., Jadhav, V. T., Babu, K. D. and Chandra, R. (2012) Effect of solarization on nutrient availability, enzyme activity and growth of pomegranate (*Punica granatum* L) air-layered plants on various potting mixtures. *Indian Journal of Agricultural Sciences 82 (9): 775-782.*
4. Marathe, R. A., Bharambe, P. R., Sharma, Rajvir and Sharma, U.C. (2012). Leaf nutrient composition, its correlation with yield and quality of sweet orange and soil microbial population as influenced by INM in Vertisol of central India. Indian Journal of Horticulture, 69 (3): 317-321.
5. Meshram, D. T., Gorantiwar, S. D., Mittal, H. K. and Singh, N. V. (2013). Computation of reference crop evapotranspiration of Nashik Station of Maharashtra, India. *Mausam* 64(2) : 357-362
6. Meshram, D. T., Gorantiwar, S. D., Mittal, H. K., Singh, N. V. and Lohakare, A. S. (2012). Water requirement of pomegranate (*Punica granatum* L.) plants upto five year age. *Journal of Applied Horticulture* 14(1):47-50.
7. Meshram, D. T., Gorantiwar, S. D., Singh, N. V. and Suroshe, S. S. (2012). Non-destructive leaf area estimation in Pomegranate cv. Bhagwa (*Punica granatum* L.). *Indian Journal of Horticulture* 69(2):163-167.

8. Meshram, D. T., Jadhav, V. T., Gorantiwar, S. D., Singh, N. V. and Suroshe, S. S. (2012). Stochastic Modeling of Pomegranate (*Punica granatum* L.) Evapotranspiration Using Class A Pan for Ahmednagar Station of Maharashtra. *Journal of Agro-Meteorology* 169-179.

10.2 Review Article

1. Ashis Maity, V. T. Jadhav and Chandra, R. (2012) Exploration of microbial wealth for sustainable horticultural production *International Journal of Bio-resource and Stress Management* 3(4):489-500.

10.3 Books

1. K. Dhinesh Babu, R. A. Marathe and V.T. Jadhav. (2012). Post harvest management of pomegranate. National Research Centre on Pomegranate (ICAR), 116 p.

10.4 Book Chapters

1. Jadhav, V.T., Chandra, R. and Singh, N.V. (2012). National Research Centre on Pomegranate, Solapur *In:* (Chadha, K.L., Singh, S.K. and Singh, A.K. (Eds.) Farmer Friendly Technologies in Horticulture. 5th Indian Horticulture Congress, November 6-9, 2012, pp. 142-148.
2. Sharma, J., Sharma, K.K., Jadhav, V.T. (2012). Diseases of Pomegranate. *In: Diseases of Fruit Crops* (Eds. Misra AK, Chowdappa P and Sharma Pratibha, Khetrapal, RK.) pp 181-224, Indian Phytopathological Society, New Delhi (ISBN:81-7019-474-1 India; ISBN:1-55528-331-4 USA), India: 343p

10.5 Technical Bulletin

1. Jadhav, V.T, Ram Chandra, Anshul Lokhare, K.K. Sharma and Sachin Suroshe. 2012. Management of Intellectual Property Rights. *Tech. Bulletin* No.3, NRCP, Solapur, 39p.

10.6 Popular Articles

1. Jadhav VT and Sharma, J. (2012). Pomegranate: A food for health and livelihood. Shodh Chintan. 4th Swadesh Prem Jagriti Sangosthi-2012, organised by Lt. Amit Singh Memorial Foundation, New Delhi and Orissa University of Agriculture and Technology (OUAT) at OUAT Bhubaneshwar, (Odisha) from May 28-31, 2012: p89-95
2. Maity, A., Shinde, Y., Suroshe, S.S., Singh, N.V., Meshram, D.T., and R.K. Pal, "Dalimbachya Swaswat Utpandanasatti Chunkhadiukta jaminitil anadravye vevasthapan" Dalimbvruth 2, pp. 37-40.
3. Marathe, R.A., Jadhav, V.T and Chaudhary, D.T. (May 2012). Dalimb Khat Vyavasthapan. *Lokmangal Shetipatrika*, Solapur
4. Marathe, R.A., Jadhav, V.T and Chaudhary, D.T. (May 2012). Dalimb Bagamadhye Annadravye Parikshan Tantradhyan. *Lokmangal Shetipatrika*, Solapur
5. Marathe, R.A., Jadhav, V.T and Dhineah Babu (May 2012). Dalimb Bagamadhil Hasta Bahar Vyavasthapan. *Lokmangal Shetipatrika*, Solapur

6. Meshram, D.T., Jadhav, V. T. and Gorantiwar, S. D. (2012). "Dalimb Bagechya vay wa Mirg baharanusar Panyache Vevasthapan". *Krushidutt* pp. 86-90. June, 2012.
7. Meshram, D.T., Jadhav, V. T., Gorantiwar, S. D., and Singh, N. V. "Dalimb Bagela Panni Denyachya Sinchan Paddati". *Dalimbvruth* pp.28-36. June, 2012.
8. Meshram, D.T., Lohkare, L. S., Jadhav, V. T. and Gorantiwar, S. D. (2012). "Dalimb Bagechya vay wa Baharanusar Panyache Vevasthapan". *Krusibhusan* pp.34-37. April, 2012.
9. Meshram, D.T., V.T. Jadhav and Gorantiwar, S. D. (2011). *Hasta bahar* Madhe Dalimb Bagela Panyachi Garaj. *Agrowon* pp. 8. 18 September, 2011.
10. Sharma, J., Suroshe, S.S. and Pal, R.K. (2012). *Dalimbvaril telkat dag arthat bacterial blight niyantharan* (Marathi). *Agrowon* 5th Nov.
11. Sharma, J., Suroshe, S.S. and Pal, R.K. (2012). *Dalimbvaril telkat dag arthat bacterial blight niyantharan* (Marathi). *Agrowon* 4thNov.pp9&11
12. Sharma, J., Suroshe, S.S. and Pal, R.K. (2012). *Falanvaril burshijanak thipke ani falkuj (Marathi). Agrowon 8th Nov.*
13. Sharma, J., Suroshe, S.S. and Pal, R.K. (2012). Incidence of thrips and fruit borer on pomegranate (Marathi). *Agrowon* 9thNov.
14. Sharma, J., Suroshe, S.S. and Pal, R.K. (2012). Measures on management of other insects and diseases on pomegranate (Marathi). *Agrowon* 7th Nov.
15. Sharma, J., Suroshe, S.S., Singh, N.V., Maity, A., and Singh, A. (2012) Jivanoo jhulsa rog se prabhavit chetron me anar ke bagon ki dekhbhal. *Vindhya Krishi* 6 (3), pp. 34-44.
16. Singh, N.V., Chandra, R., Meshram, D.T., Maity, A. and Pal, R.K. (2013) Pomegranate: planting material for better quality. *Indian Horticulture* (Accepted).
17. Singh, N.V., Chandra, R., Sharma, J., Singh, A. and Mesharam, D.T. (2012). Anar Me Pravardhan ki pramukh vidhiyaan aur podh utpadan ka dhang. *Vindhya Krishi* 6 (1-2): 30-33.
18. Singh, N.V., Sharma, J., Maity, A., Suroshe, S.S. and Singh, A. (2012) Anar ke pramukh rog avam keet peedak tatha unka prabandhan. *Vindhya Krishi.* 7(1), pp. 6-14.
19. Singh, N.V., Sharma, J., Maity, A., Suroshe, S.S. and Singh, A. (2012). Jeevanu jhulsa rog se prabhavit kshetron mein anar ke bagon ki dekhbhal (Hindi). *Vindhya Krishi* pp 34-44.
20. Sachin S. Suroshe, (2012). An attack of fruit sucking moth on pomegranate (Marathi). *Sakal*. 28th Oct.
21. Sachin S. Suroshe, (2012). Fruit sucking moth infestation on pomegranate (Marathi). *Adhunik Kisan*. 37: 18-24 October.

10.7 Presentation of research papers/ abstracts in Conferences/ Symposia / Seminars/ Workshop / Other fora:

1. Babu, K.D., Jadhav, V.T., Singh, N. V. and Sarkar, P.C. (2012). Effect of post harvest dip of lac formulations on the quality of pomegranate. 5th Indian Horticulture Congress: Horticulture for Food and Environment Security. 6-9th Nov, 2012 at PAU, Ludhiana, Punjab, Abstract p. 497.

2. Maity, A. and Jadhav, V.T. (2013) *Penicillium pinophilum*-an unique potassium and phosphate solubilizer and its potential in plant growth promotion and nutrient uptake in pomegranate. In Proceedings of 1st International Conference on 'Bio-resource and stress management' held on 6th -9th Feb., 2013, Kolkata, Abstract p.5.34.
3. Maity, A., Datta, S.C., Pathak, H. and Jadhav, V.T. (2012) Development of N-supply pedo-transfer function to wheat crop through simulation modeling. In proceedings of 3rd International Agronomy Congress on 'Agriculture Diversification, Climate change management and Livelihoods, Nov. 26-30, 2012, New Delhi, India, vol. 2, Abstract p.239-240.
4. Meshram, D. T., Jadhav, V.T., Chandra, R. Gorantiwar, S. D. and Singh, N. V. (2012). Comparison of indirect and direct method for measuring leaf area index of pomegranate (*Punica granatum* L.) 5th Indian Horticulture Congress: Horticulture for Food and Environment Security. 6-9th Nov, 2012 at PAU, Ludhiana, Punjab, Abstract p. 189.
5. Singh, N. V. and Jadhav, V.T. (2012). Seed germination studies in pomegranate (*Punica granatum* L.) 5th Indian Horticulture Congress: Horticulture for Food and Environment Security. 6-9th Nov, 2012 at PAU, Ludhiana, Punjab, Abstract p. 193.
6. Suroshe, S. S., Jadhav, V.T., Sharma, J., Sharma, K.K. and Singh, N. V. (2012). Population dynamics studies on key insects pests of pomegranate (*Punica granatum* L.) in Solapur, Magarashtra. 5th Indian Horticulture Congress: Horticulture for Food and Environment Security. 6-9th Nov, 2012 at PAU, Ludhiana, Punjab, Abstract p. 562.

10.8 Contributions made in compilation/ documentation

1. Sharma, J. and Jadhav, V.T. (2012). Progress Report (April 2011 to October 2012) of Network Project on 'Mitigating Bacterial Blight of Pomegranate in Maharashtra, Karnataka and Andhra Pradesh' Funded by Ministry of Agriculture, GOI, New Delhi 100p
2. Sharma, K.K., Marathe, R.A. and Dhinesh Babu, K. (2012). NRCP Annual Report 2010-11. NRC on Pomegranate, Solapur, 130p

11. DISTINGUISHED VISITORS

Dr. C.D. Mayee, Ex-Chairman, ASRB, New Delhi with Director NRC on Pomegranate during his visit to the Centre for Pre-RAC meeting on 12th February, 2013

Dr. C.D. Mayee, Ex-Chairman, ASRB, visiting the research laboratories of NRCP during the Pre-RAC meeting on 12th February, 2013


Members of All India and Maharashtra Pomegranate Growers Research Association and In-Charge ZARS, MPKV, Solapur along with Director, NRCP on 11th Nov, 2012


Director, NRCP along with pomegranate growers of Maharashtra during farmers visit on 11th Nov, 2012

12. RECRUITMENT / PROMOTION / RELIEVING

Joining

- Dr. R.K. Pal, Head, Division of Post Harvest Technology, Indian Agricultural Research Institute (IARI), New Delhi joined as Director, NRC on Pomegranate, Solapur on 01.11.2012

Recruitment

- Shri. V. A. Shinde recruited as Assistant Finance and Accounts Officer w.e.f. 02.07.2012
- Shri. A.S. Babar recruited as L.D.C w.e.f. 29.09.2012

Promotion

- Dr. R.A. Marathe, Senior Scientist promoted as Principal Scientist w.e.f. 01.08.2012
- Dr. Ashis Maity, Scientist promoted from RGP ` 6000/-to RGP 7000/-w.e.f 07. 01.2012
- Mr. D.T. Chaudhari, promoted from Technical Assistant T-3 to Technical Assistant T-4 w.e.f. 11.06.2012

Relieving

- Dr. V. T. Jadhav, Director, NRC on Pomegranate, retired from the service on 31.10.2012
- Shri. Sunil More, Assistant, relieved on 24.11.2012 upon selection as Assistant, Office of Commissioner of Income Tax at Pune.
- Smt. S. D. Karale, LDC relieved on 04.12.2012 upon transfer to NBPGR Regional Station, Akola

Recognition

Dr. R.K. Pal, Director, National Research Centre on Pomegranate, Elected as Executive Councilor of Horticulture Society of India, NASC Complex, New Delhi - 110012

13. BUDGET ESTIMATE

Financial Outlay : 2012-13

Head of Account	Rupees in lakhs			
	Plan		Non-Plan	
	RE	Expenditure	RE	Expenditure
A. Recurring				
Estt. Charges	0.00	0.00	159.67	159.64
T.A	5.50	5.50	3.25	3.24
Other Charges	175.00	175.00	89.11	89.11
Total A	180.50	180.50	252.03	251.99
B. Non-Recurring				
Equipment	79.50	79.48	9.00	9.00
Major Works	0.00	0.00	0.00	0.00
Library	0.00	0.00	4.00	4.00
Furniture	20.00	20.00	4.00	4.00
Total B	99.50	99.48	17.00	17.00
C. P. Loans & Advances	0.00	0.00	2.00	2.00
D. Pension	0.00	0.00	3.97	3.25
Grand Total (A+B+C+D)	280.00	279.98	275.00	274.24

Revenue Receipt : 2012-13

	Items	Achievements Amount (Rs.)
1	Income from Farm Produce	1,75,930/-
2	Income from Royalty and Publications	1,37,165/-
3	Income from other sources	70,498/-
4	Interest on loans and advances	98,925/-
5	Interest earned on short-term deposits	8,09,763/-
6	Recovery of loans and advances	5,800/-
7	Application fees from candidate	6,200/-
	Total Revenue Receipt	13,04,281/-

14. STAFF POSITION
(As on 31.03.2013)

Category	Sanctioned during XIth Plan	Staff in position	Vacant
RMP	1	1	0
Scientific	10	9	1
Technical	6	5	1
Administrative	11	6	5
Supporting	2	2	0
Total	30	23	7

Appendix 1

Institute Management Committee of NRCP

(As on 31.03.2013)

Chairman

1. Dr. R.K. Pal
   Director, NRCP, Solapur

Members

2. Dr. Ram Chandra
   Principal Scientist,
   NRCP, Solapur
3. Dr. A.K. Srivastava
   Principal Scientist,
   NRC Citrus, Nagpur
4. Dr. Abraham Verghese
   Principal Scientist,
   IIHR, Bangalore
5. Dr. A.K. Mishra
   Project Co-ordinator (STF)
   CISH, Lucknow
6. ADG (H-1)
   ICAR, New Delhi

Member - Secretary

7. Shri A.A. Goswami
   Administrative Officer,
   NRCP, Solapur

Appendix 2

Research Advisory Committee of NRCP

(Upto 08.09.2012)

Chairman

1. Dr. S.D. Shikhamany
   Former VC,
   Andhra Pradesh Horticulture
   University, Andhra Pradesh

Members

2. Dr. S.N. Pandey
   Ex-ADG (Hort.), ICAR, New Delhi
3. Dr. Srikant Kulkarni
   Former Professor & Head,
   Department of Plant Pathology,
   UAS Dharwad, Karnataka
4. Dr. V. Nachegowda
   Professor of Pomology,
   College of Horticulture, Kolar,
   University of Horticultural Sciences,
   Bagalkot, Karnataka
5. Dr. B.M.C. Reddy
   National Project Coordinator,
   UNAP-GEF-TFT Project &
   Ex- Director, CISH, Lucknow
6. Dr. H. Shivanna
   Director of Research,
   University of Agricultural Sciences,
   Bangalore
7. Dr. V.T. Jadhav
   Director, NRC on Pomegranate,
   Solapur
8. Dr. P.L. Saroj,
   ADG In-charge (Hort.),
   ICAR, New Delhi

Two Non official members

9. Shri. Arun Nimba Deore
   Progressive farmer, Nashik
10. Shri. Jaysingrao Manikrao
    Deshmukh, Progressive farmer,
    Pandharpur, Solapur

Member - Secretary

11. Dr. Ram Chandra
    Principal Scientist, NRCP, Solapur

(09.09.2012 onwards)

Chairman

1. Dr. C.D. Mayee
   Chairman, Former Chairman,
   ASRB,
   New Delhi

Members

2. Dr. O.P. Pareek
   Bikaner
3. Dr. B.B. Vashistha
   Former Director,-NRCSS,
   Jaipur
4. Dr. V. Rajagopal
   Former Director,
   CPCRI, Thirupathi
5. Dr. R.K. Jain
   Plant Pathology &
   Biotechnology Head,
   IARI, New Delhi
6. Director,
   Ex. Officio Member
   NRCP, Solapur
7. ADG (Hort. I),
   Ex. Officio Member,
   ICAR, New Delhi

Member - Secretary

8. Dr. R.A. Marathe
   Pr. Scientist,
   NRCP, Solapur

Appendix 3

Institute Research Council of NRCP

(As on 31.03.2013)

Chairman

1. Dr. R.K. Pal
   Director,
   NRCP, Solapur

Members

2. Dr. (Mrs.) Jyotsana Sharma,
   Pr. Scientist (Plant Pathology),
   NRCP, Solapur

3. Dr. K. K. Sharma,
   Pr. Scientist (Plant Pathology),
   NRCP, Solapur

4. Dr. R. A. Marathe,
   Pr. Scientist
   (Soil Physics-Soil Water Conservation),
   NRCP, Solapur

5. Dr. K. Dhinesh Babu,
   Sr. Scientist
   (Hort.-Fruit Science),
   NRCP, Solapur

6. Dr. D. T. Meshram,
   Scientist (SWCE),
   NRCP, Solapur

7. Dr. Sachin Suroshe,
   Scientist (Entomology),
   NRCP, Solapur

8. Dr. Ashis Maity,
   Scientist (Soil Science),
   NRCP, Solapur

9. Dr. N. V. Singh,
   Scientist,
   (Hort.-Fruit Science),
   NRCP, Solapur

Invited Member

10. Dr. D. P. Waskar,
    Associate Dean. & Principal,
    College of Agriculture Latur,
    Marathawada Agricultural University

Member - Secretary

11. Dr. Ram Chandra
    Pr. Scientist,
    NRCP, Solapur

Appendix 4

Institute Joint Staff Council of NRCP

(As on 31.03.2013)

Chairman

1. Dr. R.K. Pal
   Director,
   NRCP, Solapur

Members (Official Side)

2. Dr. K. Dhinesh Babu
   Sr. Scientist,
   NRCP, Solapur

3. Dr. Ashis Maity
   Scientist,
   NRCP, Solapur

4. Dr. N.V. Singh
   Scientist,
   NRCP, Solapur

5. Shri. V.A. Shinde
   Assist. Fin. & Acctts. Officer,
   NRCP, Solapur

Member - Secretary (Official Side)

6. Sh. A.A. Goswami
   Admn. Officer,
   NRCP, Solapur

Member - Secretary (Official Side)

7. Sh. A.A. Goswami
   Admn. Officer,
   NRCP, Solapur

Member (Staff Side)

8. Shri. D.T. Chaudhari
   Technical Assistant (T-4),
   NRCP, Solapur

Member (CJSC)

9. Shri. R.B. Rai,
   Assistant,
   NRCP, Solapur

Member - Secretary (Staff Side)

10. Shri. Y.R. Shinde,
    Technical Assistant (T-3),
    NRCP, Solapur

Appendix 5

PERSONNEL

(As on 31.03.2013)

RMP

Dr. R. K. Pal
Director

Scientific Staff

Dr. Ram Chandra
Principal Scientist
(Horticulture)

Dr. (Mrs) Jyotsana Sharma
Principal Scientist
(Plant Pathology)

Dr. K.K. Sharma
Principal Scientist
(Plant Pathology)

Dr. R.A. Marathe
Principal Scientist
(Soil Physics)

Dr. K. Dhinesh Babu
Senior Scientist
(Hort.-Fruit Science)

Dr. D.T. Meshram
Scientist
(Soil & Water Conservation Engg.)

Dr. Sachin S. Suroshe
Scientist (Entomology)

Dr. Ashis Maity
Scientist (Soil Science-Pedology)

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

Technical Staff

Shri. D. T. Chaudhari
T - 4 Technical Assistant

Shri Yuvraj Shinde
T - 3 Technical Assistant

Shri. M. S. Gogaon
T - 2 Technical Assistant

Shri. G. A. Salunke
T - 1 Technical Assistant

Shri. V. U. Lokhande
T - 1 Technical Assistant

Administrative Staff

Shri A.A. Goswami
Administrative Officer

Shri. K.S. Sharma
Assistant Administrative Officer

Shri. V. A. Shinde
Assistant Fin. and Acc. Officer

Shri. R.B. Rai
Assistant

Shri. K. B. Khatmode
Lower Division Clerk

Shri. A.S. Babar
Lower Division Clerk

Supporting Staff

Shri. S. S. Bayas
Skilled Supporting Staff

Shri. V. S. Gangane
Skilled Supporting Staff

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

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