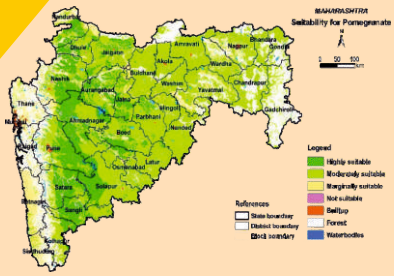
ICAR-NRCP Technological Innovations in Pomegranate Cultivation 2005-2021



ICAR - National Research Center on Pomegranate, Solapur

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Compilation and Editing

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Preface

Pomegranate is an important fruit crop of arid and semi-arid regions of India. In Ayurveda, this ancient fruit has been considered as “Paripurna Aushadhalay” due to its immense medicinal properties. Of late, its importance has increased manifold due to its immense nutritional and medicinal values. By virtue of its potential, today, pomegranate is cultivated globally over 0.58 mha with a production of 7.01 mt. India is leading producer of pomegranate in the world. In India it is cultivated over 2.58 lakh ha with an annual production of 30.97 lakh tonnes and productivity of about 12 MT ha^{-1}. Cultivation of pomegranate has added new dimension in raising the income of farmers. With rapid increase in pomegranate cultivation in India in both traditional and non-traditional areas more and more challenges are being faced by the growers with respect to diseases, pests, flower regulation, nutritional imbalances and overall management. Realizing the importance of this crop in sustainable livelihood and immense export potential, Indian Council of Agricultural Research, New Delhi established National Research Centre on Pomegranate on September 25, 2005 at Solapur, Maharashtra.

The centre, since its inception in 2005 has made noteworthy research to develop farmers' friendly techniques viz., production of quality planting material, development of new varieties, plantation techniques in marginal lands, canopy management; soil, irrigation & nutrition management, integrated disease and pest management schedules, maturity indices, developed adhoc list of chemicals for the export by defining the PHI and MRL etc., which enlightened the way for sustainable and quality production. The centre also developed new varieties and focused on different post-harvest technologies and developed many value added products which help in entrepreneurship developments. It was felt necessary that all these developed technologies should reached to stakeholders in standard form. Hence these technologies have been compiled and put forth in the form of book for user agencies.

As a founder member and Director of NRCP, Solapur I take this privilege to publish this book entitled ICAR-NRCP Technological Innovations in Pomegranate Cultivation 2005-2021 developed by our scientists in the field of pomegranate improvement, production, protection, post-harvest and value addition aspects at ICAR-NRC on pomegranate, Solapur since its inception. These fool proof technologies will pave the way for sustainable pomegranate production at the national and international arena in the days to come.

I, solemnly acknowledge all our scientists and staff for their contribution in developing these technologies.

R. A. Marathe
Director
ICAR-NRCP, Solapur

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Crop Production

Crop Protection

Post Harvest Technology & Value Addition

CROP IMPROVEMENT

Variety: Pomegranate Hybrid NRCP H-6 (Solapur Lal)

Dhinesh Babu, K., Jalikop, S.H., Murthy, B.N.S., Sampathkumar, P. Singh, N. V., Ram Chandra, Maity, A., Jyotsana Sharma, Pal R.K., Jadhav, V.T. and R.A., Marathe

Year: 2016

Solapur Lal is the first bio-fortified pomegranate variety suitable for table and juice purpose. The variety is protected under PPV & FRA, New Delhi with the registration number of REG/ 2016/1747.

Pomegranate variety Solapur Lal :

1. Joints Agresso : 24-30 December, 2021
2. SVRC: 18.08.2022
3. CVRC: 05.08.2024

Compared to ruling Bhagawa variety, it has

Sr. No	Characters	Solapur Lal	Bhagawa (Check variety)
1	Maturity (days)	160-165	180-185
2	Yield	31.68 kg/tree, 23.4 t/ha	25.69 kg/tree ,19.0 t/ha
3	TSS (^{0}Brix)	17.6	15.8
4	Vitamin C (mg/100g)	19.6	14.4
5	Anthocyanin (mg/100g)	390	360
6	Iron content (mg/100g)	1.50	0.90
7	Zinc content (mg/100g)	0.25	0.20




Variety: Pomegranate Hybrid NRCP H-12 (Solapur Anardana)

Dhinesh Babu, K., Jalikop, S.H., Murthy, B.N.S., Sampathkumar, P. Singh, N. V., Ram Chandra, Maity, A., Jyotsana Sharma, Pal R.K., Jadhav, V.T. and R.A., Marathe

Year: 2016

This is the first variety developed by NRCP Suitable for processing (Anardana) purpose and protected under PPV&FRA, New Delhi with the registration number of REG/2016/1750.

Pomegranate variety Solapur Anardana:

1. Joints Agresso: 25-27 May, 2023
2. SVRC: 08.02.2024
3. CVRC: 05.08.2024
4. Dedicated to the Nation by Hon'ble PM of India on 11.08.2024

Compared to ruling variety with Amlidana

Sr. No	Characters	Solapur Anardana	Amlidana (Check variety)
1	Yield (kg/tree)	30.72	14.65
2	Yield (t/ha)	22.73	10
3	Anthocyanin (mg/100g)	456	50
4	Titrable Acidity (%)	4.80	4.2
5	Anardana recovery from Arils (%)	21.7	17.2




Variety: Pomegranate Hybrid NRCP H-14

Dhinesh Babu, K., Singh, N, V., Ram Chandra, Jyotsana Sharma, Maity, A., Jadhav, V.T., Pal R.K., R.A., Marathe, Mallikarjun, Shilpa, P., Roopa Sowjanya, P., Patil, P.G., Jalikop, S.H., Sampathkumar, P. and Murthy, B.N.S.

Year: 2016

This hybrid is pink type variety suitable for table purpose. It has high TSS content (17.8° Brix), pink arils and yellowish fruit surface. It was registered with PPV&FRA with registration number REG/2016/1748 and got registered on 12.12.2023.

Characteristic features of NRCP H-14 compared to ruling Bhagawa variety

Parameter	NRCP H-14	Bhagawa
Maturity (days)	165.0	180.0
No. of fruits/plant	115.0	84.5
Fruit weight (g)	288.2	292.0
Fruit yield (kg/plant)	33.14	24.68
100 aril weight (g)	32.50	35.2
Total Soluble Solids°(Brix)	17.8	15.9
Titrable Acidity (%)	0.45	0.49
Vit-C (mg/100g)	19.2	14.4
Anthocyanin (mg/100g)	121.4	360.0




Variety: Pomegranate Hybrid NRCP H-4

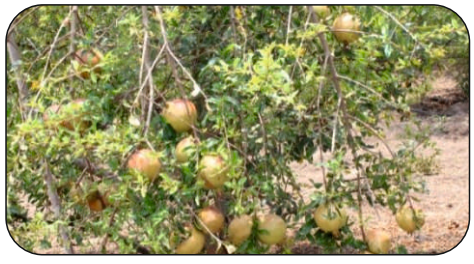
Dhinesh Babu K., Singh, N, V., Ram Chandra, Jyotsana Sharma, Maity, A., Jadhav, V.T., Pal R.K., Marathe, R.A., Mallikarjun, Shilpa P., Roopa Sowjanya P., Patil P.G., Jalikop S.H., Sampathkumar P. and Murthy B.N.S.

Year: 2016

This is the pink type hybrid variety suitable for anardana purpose. It is rich in titrable acidity (5.76%), pink arils and yellowish fruit surface. It is registered with PPV&FRA REG/2016/1749 and got registered on 12.12.2024.

Characteristic features of NRCP H-4 as compared to ruling Amlidana variety

Parameter	NRCP H-4	Amlidana
Maturity (days)	140.0	145.0
No. of fruits / plant	110.0	60.3
Fruit weight (g)	262.2	228.1
Fruit yield (kg / plant)	28.8	13.6
100 aril weight (g)	30.0	36.0
Total Soluble Solids°(Brix)	15.9	15.6
Titrable Acidity (%)	5.76	4.20
Vitamin-C (mg/100g)	18.8	14.2
Anthocyanin (mg/100g)	59.8	60.5

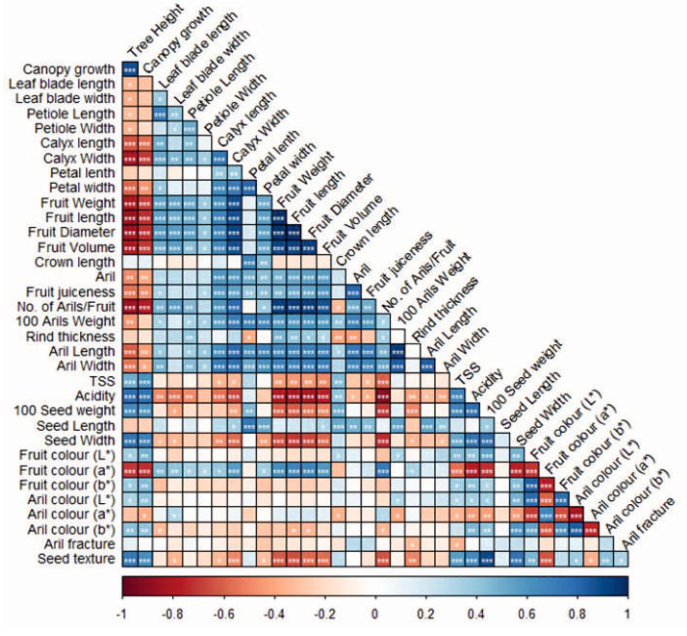



Morphological and physico-chemical markers for selection of economically important traits in pomegranate

Shilpa Parashuram, Babu, K.D. and Roopa Sowjanya, P.

Year: 2016-18

Forty pomegranate germplasms were evaluated for thirty-two various morphological and physico-chemical traits during Mrig bahar 2016-17 and 2017-18. A significant positive correlation was recorded between tree height and canopy growth (r = 0.88); petal length and petal width (r = 0.79); fruit weight and fruit length (r = 0.97); fruit weight and fruit diameter (r = 0.98); fruit weight and fruit volume (r = 0.90); fruit weight and the number of arils/fruit (r = 0.92); fruit volume and number of arils/fruit (r = 0.93); 100 arils weight and aril length (r = 0.94); acidity (%) and TSS (r = 0.66); 100 seed weight and seed texture (r = 0.89); fruit rind color L* and fruit rind color b* value (0.82), and aril color L* value and b* value (r = 0.82). A negative correlation was observed between fruit weight and acidity % (r = −0.80); number of arils per fruit and acidity (%) (r = −0.92); acidity (%) and fruit color a* (r = −0.78); fruit rind color a* value and b* value (r = −0.76); aril color L* value and a* value (r = −0.74). The traits like dimensions of fruits, calyces, petals were highly correlated, with the number and size of the arils these will serve as morphological markers in selection. TSS and acidity will serve as physiochemical markers for fruit quality parameters selection indirectly.



Correlogram of the morphological traits. For each pairwise correlation, the graph displays the correlation coefficient (Pearson) according to the color scale reported at the bottom. Asterisks indicate significantcorrelation(*:p<0.05;:p<0.01;***:p<0.001)**

Discovery of SNP markers associated with bacterial blight disease incidence and severity in pomegranate

Shilpa Parashuram, Singh, N. V., Jyotsana Sharma, Babu, K. D., Roopa Sowjanya, P. and Murthy, B.N.S.

Year: 2017-18

Pomegranate bacterial blight disease (BBD) (*Xanthomonas axonopodis pv. punicae,* Xap) is the major devastating disease in pomegranate prevalent in all major pomegranate growing areas of India. Use of host resistance is the primary method to control this disease. Association analysis and population structure study were conducted for BBD reaction in 171 pomegranate germplasm accessions maintained at ICAR-NRCP, Solapur. Genotyping By Sequencing (GBS) was used for Single Nucleotide Polymorphism (SNP) discovery. In total 948847 SNPs were used for association mapping using R package GAPIT. Three well-differentiated genetic populations and admixtures were postulated in the pomegranate panel by STRUCTURE 2.3.4. Association analysis for BBD was done using compressed mixed linear model (MLM) using the R package GAPIT, that involves EMMA and P3D algorithms to conduct GWAS. 12 SNP markers were strongly associated with BBD severity while 35 SNP markers with disease incidence. These markers can be utilized in pomegranate breeding for BBD resistance through marker-assisted selection.

SNP Markers associated with BBD Incidence						SNP Markers associated with BBD Severity		
	SNP	Position		SNP	Position		SNP	Position
1	MTKT01000422.1	1247	19	MTKT01000329.1	40071	1	MTKT01000422.1	1247
2	MTKT01000169.1	127690	20	MTKT01000329.1	40404	2	MTKT01000676.1	127905
3	MTKT01000121.1	129	21	MTKT01000329.1	43337	3	MTKT01000676.1	127912
4	MTKT01000545.1	13284	22	MTKT01000535.1	542329	4	MTKT01000676.1	127955
5	MTKT01000373.1	16174	23	MTKT01000535.1	611942	5	MTKT01000676.1	127968
6	MTKT01000329.1	166676	24	MTKT01000785.1	669442	6	MTKT01000329.1	179588
7	MTKT01000329.1	169039	25	MTKT01000785.1	669444	7	MTKT01000329.1	180256
8	MTKT01000329.1	173971	26	MTKT01000785.1	669446	8	MTKT01000773.1	185683
9	MTKT01000329.1	174051	27	MTKT01000785.1	669448	9	MTKT01000329.1	202671
10	MTKT01000329.1	179588	28	MTKT01000785.1	669452	10	MTKT01000329.1	255707
11	MTKT01000329.1	180256	29	MTKT01000785.1	669454	11	MTKT01000725.1	40855
12	MTKT01000329.1	202671	30	MTKT01000785.1	669458	12	MTKT01000535.1	542329
13	MTKT01000329.1	255707	31	MTKT01000785.1	669459			
14	MTKT01000329.1	259037	32	MTKT01000535.1	695235			
15	MTKT01006151.1	261	33	MTKT01000329.1	70290			
16	MTKT01000329.1	31189	34	MTKT01000545.1	7376			
17	MTKT01000329.1	33537	35	MTKT01005898.1	96851			
18	MTKT01000329.1	39924						

Clonal Fidelity testing of *in-vitro* propagated plants by ISSR, RAPD & SSR markers

Roopa Sowjanya, P., Singh N.V., Sangnure Vipul, Shilpa, P., Mundewadikar D., Patil, P.G., Babu, K.D. and Jyotsana Sharma

Year: 2017-18

The fidelity testing of Bhagawa plantlets raised through micro propagation were conducted. The plantlets of cv. Bhagawa, (mother plant, micro propagated) plants were considered for screening of Random Amplified Polymorphic DNA (RAPD), Simple Sequence Repeats (SSR) and Inter Simple Sequence Repeat (ISSR) markers for their polymorphism and their subsequent utilization in fidelity testing programme. RAPD, SSR and ISSR were analysed in order to evaluate their genetic stability and/or detect likely existing variations among *in vitro* derived plantlets. A set of RAPD, ISSR and SSR primers was used for PCR. Higher numbers of bands were obtained by ISSR rather than RAPD, but none of the primers showed polymorphism among micro propagated plantlets of Bhagawa. The profiles generated based on the three marker systems were found to be highly uniform and monomorphic among Bhagawa and Super Bhagawa. Cluster analysis further confirmed genetic stability of micro propagated plantlets. By using NTYsys software, SAHN similarity coefficients obtained for 3 markers systems in plants of *In-vitro* regenerates were estimated were 0.66 (RAPD), 0.83 (ISSR) and 0.83(SSR). The molecular analyses precisely proved that production of genetically stable pomegranate plantlets and certified the application of micro propagation protocol. The Major output of present study highlighted that there is no genetic difference between Bhagawa and *in vitro* propagated Bhagawa clones.

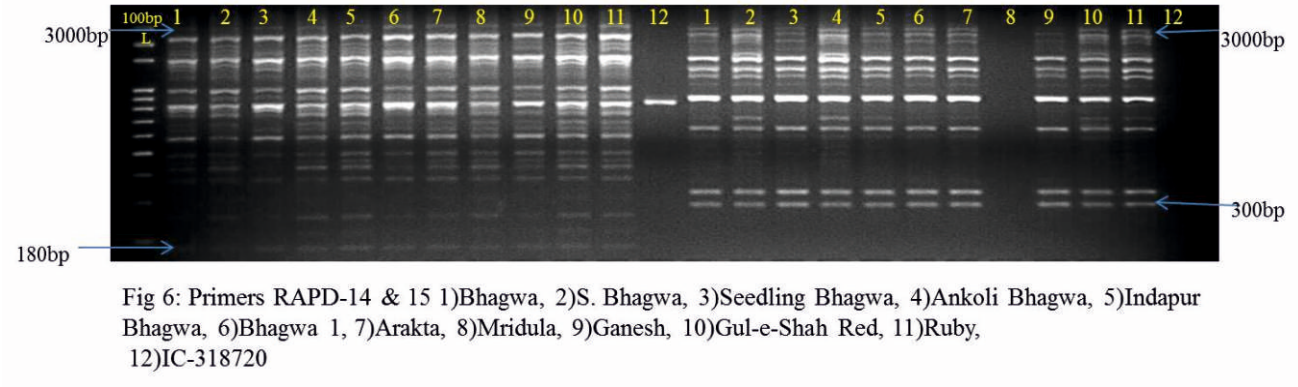


Fig 6: Primers RAPD-14 & 15 1)Bhagwa, 2)S. Bhagwa, 3)Seedling Bhagwa, 4)Ankoli Bhagwa, 5)Indapur Bhagwa, 6)Bhagwa 1, 7)Arakta, 8)Mridula, 9)Ganesh, 10)Gul-e-Shah Red, 11)Ruby, 12)IC-318720

Clonal fidelity testing of *in vitro* propagated plants by ISSR & RAPD

Morphological, biochemical and nutritional markers for selection of bacterial blight disease resistant genotypes in Pomegranate

Shilpa Parashuram, Jyotsana Sharma, Gaikwad, N.G., Maity A., Babu, K.D. and Roopa Sowjanya, P.

Year: 2018-19

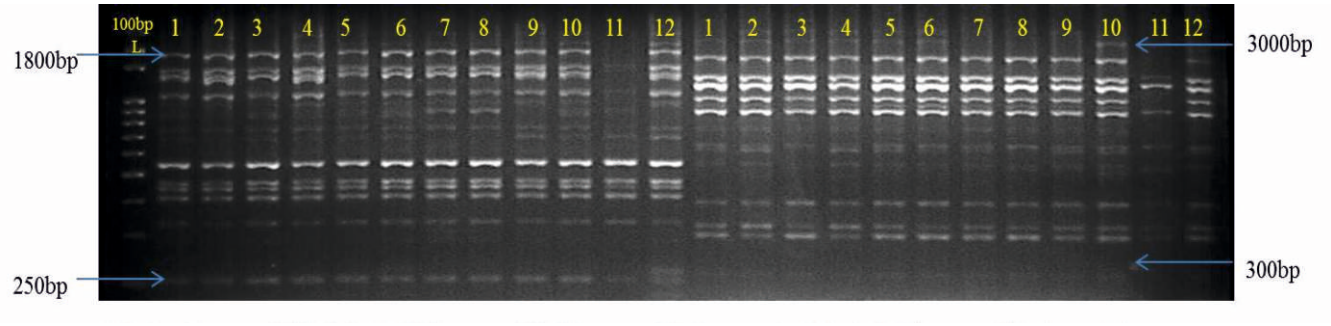
Fruit quantitative characters including morphological, biochemical and nutritional parameters were recorded in 24 pomegranate genotypes which recorded BB disease reaction from moderately resistance to highly susceptible. Statistically significant differences were found between the genotypes for fruit quality parameters under the study except for non-reducing sugar (%). Results revealed that BB incidence and severity were found positively correlated with fruit weight (0.76**, 0.77**), fruit length (0.77**, 0.81**), fruit diameter (0.76**, 0.77**), 100 aril weight (0.50*, 0.53**), aril length (0.53**, 0.59**), aril width (0.56**, 0.59**), antioxidant capacity (0.42*, 0.43*) and pH (0.60**, 0.67**) traits. While a significant negative correlation was found with TSS (-0.65**, -0.67**), acidity (-0.70**, -0.75**), total phenol (-0.45*, -0.51*) and reducing sugar (-0.40*, -0.41*) content. Total sugar content has showed the negative correlation (-0.40*) with the BB severity only. Genotypes studied revealed statistically significant correlation of BB incidence and severity with nutritional content in fruits. Both BB incidence and severity were found to have positive correlation with Fruit P content (0.50*, 0.55*) and K content (0.55**, 0.59**), Zn content (0.42*, 0.49*) and Cu content (0.44*, 0.48*) traits. Fruit N content (0.44*) showed the positive correlation with BB severity only. It is also noted that both BB incidence and severity are positively (0.96**) correlated. While a significant negative correlation was found with the TSS (-0.73**, -0.78**), acidity (-0.88**, -0.91**) and seed texture (-0.73**, -0.76**). Correlation values given in parenthesis, values with single star (*) significant at 5% and with double star (**) significant at 1%. Thus, Total Soluble Solids content, acidity %, total phenol content, reducing sugar, total sugar content and seed texture traits are considered to be the key morphological and biochemical markers for selecting bacterial blight resistant genotypes in pomegranate.

Standardization of SRAP markers for assessing pomegranate (*Punica granatum* L.) genetic diversity

Roopa Sowjanya, P., Kiran K, Vipul Sangnure, Singh, N.V., Shilpa, P., Patil, P.G., Babu, K.D., Sharma Jyotsana and R.A., Marathe

Year: 2020-2021

The SRAP markers are ORF sequences and multi loci oriented marker. The exploitation of SRAP markers was rare in case of pomegranate. Validation and standardization of PCR of SRAP markers, the influence of thermo cyclers on PCR was tested. So in this we standardized PCR components for reaction and thermal cycler program. The DNA was isolated from different pomegranate cultivars namely Ganesh, Bhagawa, Solapur Lal, Maha, Dholka, G-137, IC-318718, Ganesh ornamental, Acc No. 6 and EC-81839. The different proportions of PCR reaction mixtures were used but the DNA amplified with the mixture consists of 40ng DNA, primer (forward and reverse) 1.4 µl, dinucleotides 2 µl, *Taq* polymerase 0.2 µl, $MgCl_2$-Oµl, distilled water- 4µl. Thermal cycler programme consists of at different temperatures at different durations, whereas, the results were obtained at initial denaturation 94°C, followed denaturation at 94°C for 1 min, Annealing 55°C for 1 min, Extension 72°C for 1 min for 5 cycles, continued by second cycle of denaturation 94°C for 1 min, Annealing 55°C for 1 min, Extension 72°C for 1 min for 35 cycles and the final extension at 72°C for 10 min and hold at 4°C. The primer combination of Me5 + Em3 has shown the results at standardized program. The number of bands from SRAP ranged from 1 to 11. Hence we standardized the SRAP program in pomegranate.



SRAP Me 3 + Em 6 used for diversity analysis of 12 genotypes of pomegranate

Chloroplast genome sequence of promising pomegranate genotypes

Roopa Sowjanya, P., Singh, N.V., Shilpa, P., Patil, P.G., Babu, K.D., Sharma Jyotsana and R.A., Marathe

Year: 2020-2021

Comprehensive chloroplast (cp) genome analysis of 16 pomegranate *(Punica granatum* L.) genotypes representing commercial cultivars, ornamental and wild types was made through using next-generation sequencing (NGS) technology. Comparative genome analysis revealed that the size of cp genomes varied from 158,593 bp (in wild, “1201” and “1181”) to 158,662 bp (cultivar, “Gul-e-Shah Red”) amongst the genotypes, with characteristic quadripartite structures separated by a pair of inverted repeats (irs). Interestingly, high variations were observed in sizes of large single copy (LSC, 88,976 to 89,044 bp) and small single copy. Although, the structural organization of newly assembled cp genomes were comparable to that of previously reported cp genomes of pomegranate (“Helow,” “Tunisia,” and “Bhagawa”), the striking differences were observed with the *Lagerstroemia* lines, viz., *Lagerstroemia intermedia* (NC_0346620) and *Lagerstroemia speciosa* (NC_031414), which clearly confirmed previous findings. Furthermore, phylogenetic analysis also revealed that members outside the genus Punica were clubbed into a separate clade. Microsatellite survey across cp genomes resulted in the identification of a total of 233 to 234 SSRs, with majority of them being mono-, followed by di-, tri-, tetra-, and pentanucleotides. Furthermore, the comparative structural variant analyses resulted in the identification of many varietal specific SNP/indel markers. Successful development of large-scale cp genomics resources to leverage genetic, taxonomical, and phylogenetic studies in pomegranate.

The chloroplast genome of cultivar Bhagawa

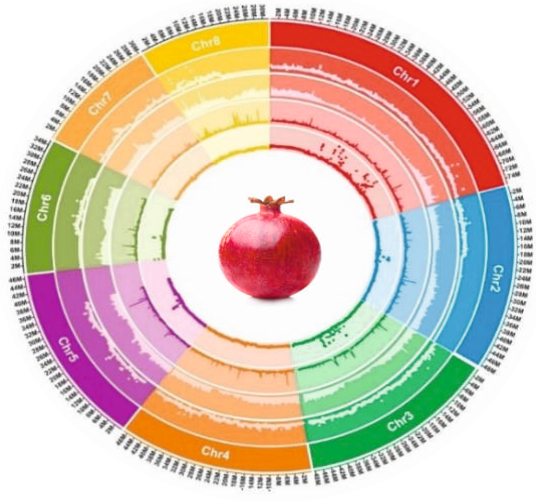
Whole genome sequencing of Indian pomegranate cv. Bhagawa

Roopa Sowjanya, P. Singh, N.V. Shilpa, P. Patil, P.G. Babu, K.D., Sharma Jyotsana and R.A., Marathe

Year: 2020 -2021

To fast-track the pomegranate improvement program, *de novo* whole-genome sequencing of the main Indian cultivar 'Bhagawa' was initiated. We have demonstrated a combination of commercially available technologies from Illumina, PacBio, 10X Genomics, and BioNano Genomics could be used efficiently for sequencing and reference-grade de novo assembly of the pomegranate genome. The research led to a final reference-quality genome assembly for 'Bhagawa' of 346.08 Mb in 342 scaffolds and an average N50 of 16.12 Mb and N90 of 1088.62 Kb. This assembly covered more than 98% of the estimated pomegranate genome size, 352.54 Mb. The LTR assembly index (LAI) value of 10 and 93.68% Benchmarking Universal Single-Copy Orthologs (BUSCO) completeness score over the 1,440 ortholog genes of the completed pomegranate genome indicates the quality of the assembled pomegranate genome. Furthermore, 29,435 gene models were discovered with a mean transcript length of 2,954 bp and a mean coding sequence length 1,090 bp. The 'Bhagawa' genome was compared with the genomes of the pomegranate cultivars 'Dabenzi' and 'Taishanhong.' About 1,573 protein-coding resistance genes identified in the 'Bhagawa' genome was classified into 32 domains. In all, 314 copies of miRNA belonging to 26 different families were identified in the 'Bhagawa' genome.

The whole genome of this fruit, will open up incredible avenues for vastly improving productivity, quality, and resilience of improved varieties against biotic and abiotic stresses at much faster pace," The reference-quality genome assembly of 'Bhagawa' is certainly a significant genomic resource for accelerated pomegranate.



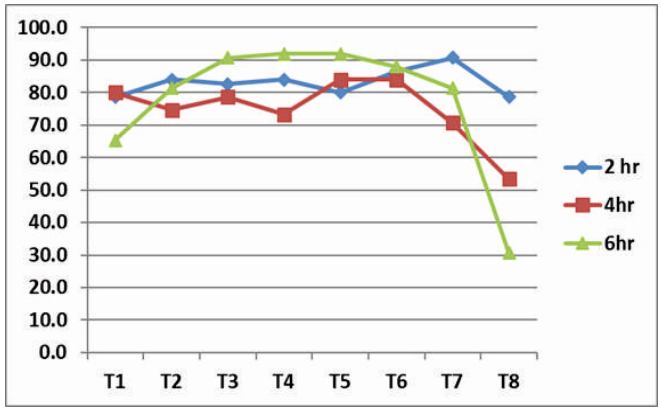
Outer to Inner rings (1) Chromosomes (2) SNPs (3) InDels (4) Genes (5) Repeats

Standardization of protocol for EMS treatment in cv. Bhagawa and fixation of LD_{50} dose for mutagenic treatment in pomegranate

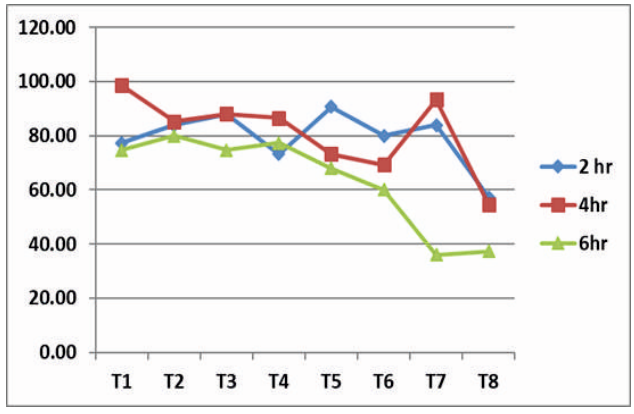
Shilpa Parashuram, Babu, K. D., Singh, N.V., Roopa Sowjanya, P. and R.A., Marathe

Year: 2021-22

To induce resistance to bacterial blight disease in pomegranate, seeds of cv. Bhagawa with and without pre-soaking were treated with 8 different concentrations of EMS (0, 0.2%, 0.4%, 0.6%, 0.8%, 1% and 1.4%) for 2 hrs, 4 hrs, 6 hrs and studied the effect on seed germination under laboratory condition. The results revealed that the lethal dose-50 (LD_{50}) value for developing EMS mutagenic population in pomegranate is to be 1% for 6 hrs in case of without pre-soaked treatment and 1.4% for 4 hrs with pre-soaked treatment. This standard dose will be used in mutation breeding programmes of pomegranate for inducing genetic variability for the traits of interest.



Seed treatment with EMS (0-1.4%) with 24hrs pre-soaking in water



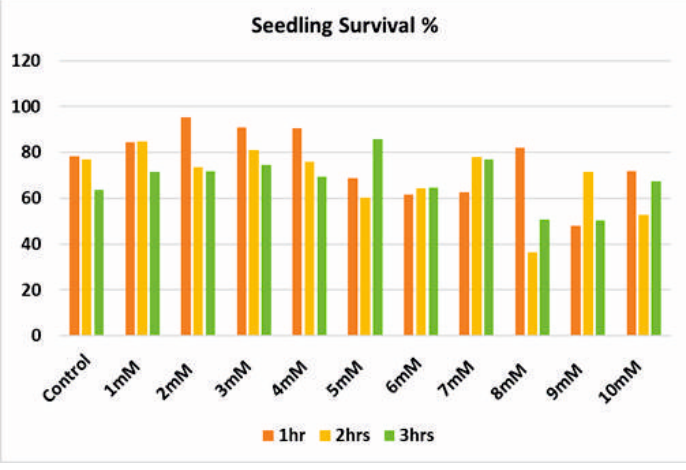
Seed treatment with EMS (0-1.4%) without pre-soaking in water

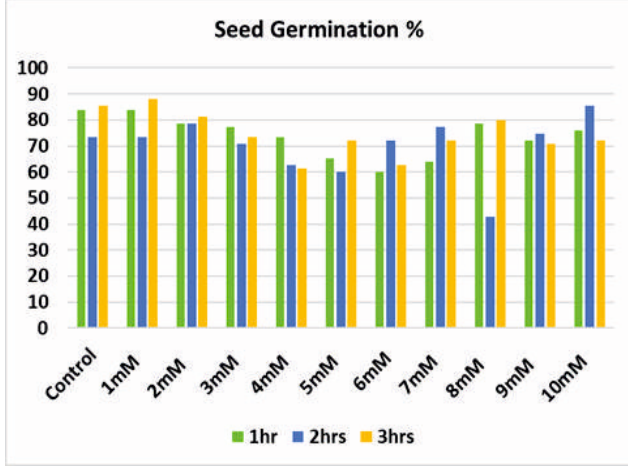
Standardization of protocol for Sodium Azide treatment in cv. Bhagawa and fixation of LD_{50} dose for mutagenic treatment in pomegranate

Shilpa Parashuram, Shankar Bhosale, Singh, N.V., Roopa Sowjanya, P., Babu, K. D. and R.A., Marathe

Year: 2021-22

An experiment was conducted in pomegranate to study the effect of Sodium Azide (SA) mutagen on the seed germination, seedling survival and to determine its optimum dose which can be used in pomegranate mutation breeding programs. Freshly harvested seeds of "Bhagawa" cultivar was treated with 10 different concentrations of SA *i.e.*, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 mM for 1 hr, 2 hrs., 3 hrs and were evaluated by comparing with the untreated control seeds. The results revealed that increase in SA concentration up to 6 mM caused a remarkable decrease in the percentage of seed germination and seedling survival for 1 hr treatment while up to 5 mM and 4 mM treatments in case of 2 hrs and 3 hrs duration treatments. Among different duration treatments, 2 hrs treatment of SA has exhibited maximum Coefficient of Variation (%) for seed germination (16.36%) and seedling survival (20.78%) in comparison to others. Accordingly, 5 mM for 2 hrs is identified as the LD_{50} dose of SA mutagen which can be applied for inducing genetic variability in pomegranate.





PLANT PRODUCTION

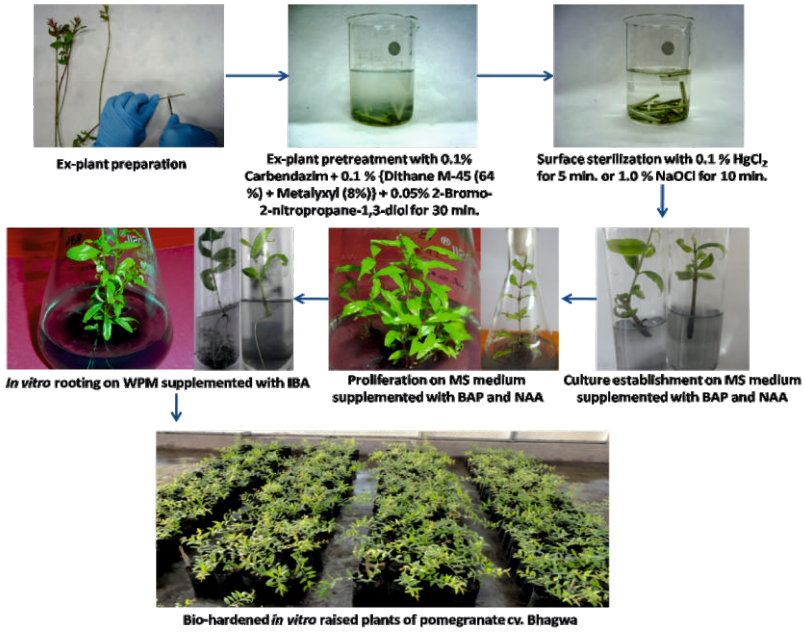
In-vitro propagation of pomegranate cv.Bhagawa including biohardening

Singh, N.V., Pal, R.K., Babu, K.D., Ram Chandra, Sharma, K.K., Maity, A. and D.T., Meshram

Year: 2013

Availability of disease-free planting material particularly with respect to bacterial blight disease on pomegranate is the key issue for sustainable production and productivity of this high value crop in the arid and semi-arid agro ecosystem. *In-vitro* propagation technology would ensure rapid and bulk production of bacterial blight disease free planting materials.

The protocol for large scale multiplication of disease free (bacterial blight / wilt) planting material having systemic resistance to diseases, better establishment and growth of pomegranate plants has been developed. The *in-vitro* propagation protocol in cv. Bhagawa with culture establishment of 80.00 % and rooting success of 72.00 % was achieved using nodal segments and shoot tips. Root colonization, population of beneficial microbes in rhizospheric soil, growth, physiological and biochemical parameters of *in-vitro* raised plants were found to be improved by bio-hardening. The technology significantly improves plant establishment and rooting. The biohardening process enables the better root colonization, population of beneficial microbes in rhizospheric soil, growth, physiological and biochemical parameters of the plants.



Bio-hardening of *In-vitro* raised pomegranate plants

Singh, N.V., Pal, R.K., Jyotsana Sharma and A., Maity

Year: 2014 (further refined during 2016-2021)

Technology deals with bio-hardening of *in-vitro* raised pomegranate plantlets during secondary hardening stage by utilizing plant beneficial *Glomus intraradices*, *Aspergillus niger* AN 27 and *Penicillium pinophilum* for production of micropropagated plants with improved field performance. The main objective of the technology is to improve the field performance of micropropagated pomegranate plantlets by utilizing plant beneficial microbes

After 30-40 days of initial/primary hardening of plantlets in cocopeat or cocopeat + perlite+vermiculite, plants are shifted to polybags/root trainers/netpots pre-sterilized containing planting medium or potting medium (Sand: Soil: FYM, 2:1:1 or peat/ biopeat / cocopeat based potting mixture). Biohardening with Arbuscular Mycorrhizal Fungi Glomus intraradices (*Rhizophagus irregularis*) @ 10g/ kg planting medium should be carried out during secondary hardening stage (potting mixture having infective propagules of Glomus intraradices with freshly sown wheat seeds were given to the licensee. Recently, *Penicillium pinophilum* (pure cultures were given to both the parties) has also been added as bio-hardening agent in pomegranate. *Penicillium pinophilum* is commercially available as SONAR™. The biohardening with plant beneficial microbes was found to improve the performance of plants in terms of growth, physiological and biochemical functioning of plants. The biohardening should be done at least two months before distributing the plants to farmers. Planting mixture should be sterilized prior to addition of bio-hardening agents either through solarization or steam sterilization or pre-sterilized peat/biopeat/cocopeat should be used

Two step Hardwood cutting protocol of pomegranate including bio-hardening

Singh, N.V., Pal, R.K., Babu, K.D., Ram Chandra and Shinde Yuvraj

Year 2019-20

The technology includes a two-stage hardwood cutting and sanitation protocol for high cutting success and production of healthy saplings in pomegranate cv. Bhagawa. The sanitation protocol includes treatment of 20-25 cm long and 8-12 mm thick hard wood cuttings of pomegranate with 15 minutes dip in the lukewarm solution (45 °C) of 2-bromo-2-nitro-1,3-propanediol@ 500mg per litre + Carbendazim (50 % WP) @ 1.0 g per litre followed by 15 minutes dip in the NaOCl (4.0%) solution @ 2.0% for surface sterilization of cuttings. This is followed by quick dip treatment of the basal portion of the cuttings with rooting hormone @ 2500 ppm IBA for 1 min. The cuttings of semi-dormant of rest period should be taken for hard wood cutting preparation. The cuttings are planted in a pre-sterilized cocopeat or mixture of cocopeat, vermiculite and perlite (2:1:1) after rooting of cuttings the cuttings may be shifted to nursery bags and inoculated with plant beneficial microbes like AMF (only multiplies in/on root system), *Aspergillus niger* AN27 and *Penicillium pinophilum.*

Standardization of potting mixture for pomegranate nurseries

Marathe R.A., Ram Chandra, Jadhav V.T., Dhinesh Babu, K. and Jyotsana Sharma

Year: 2010

Healthy planting material is the first step for a successful crop production, and this becomes all the more important in horticultural crops which are perennial. Pomegranate planting material especially air layers and stem cuttings, carry latent infections of threatening diseases like bacterial blight and wilt. Root knot nematode and wilt causing fungi like *Certocyctis fimbriata* spread through untreated / infected potting mixture. In many nurseries. Application of nitrogenous fertilizers to achieve vigorous growth is normal practice thereby creating nutrient imbalance in the seedlings. To address all these issues a pot experiment was conducted for 2 consecutive years during 2006–08 to study the effect of different potting media on biomass production, soil fertility status and nutrient uptake pattern of 'Ganesh' pomegranate (*Punica granatum* L.) seedlings. Different potting materials, like black clayey soil, river sand, farmyard manure, vermi compost, sawdust, sugarcane trash were used in different combinations for raising of the seedlings.

The results revealed that the seedlings could not survive in sawdust and sugarcane trash media or its incorporation with other media. Incorporation of farmyard manure showed complete supremacy in improving nutrient content of leaf, stem and roots of the plants except N. Use of soil and sand alone or mixture of both as potting media was not beneficial to sustain the growth of the seedlings because of their poor fertility status. However, incorporation of sand along with organic manures in soil was rather beneficial that could promote desirable growth of the seedlings by supplementing adequate nutrients and aeration. Thus, soil + sand + vermicompost (1:1:0.5) or soil + sand + farmyard manure (1:1:1) could be used for raising of pomegranate seedlings.

Development of microbial consortium for pomegranate nurseries

Marathe, R.A., Ram Chandra, Jadhav, V.T., Dhinesh Babu, K. and Jyotsana Sharma

Year: 2013

Pomegranate is an economically important fruit crop in arid and semi arid regions of India. The region is characterized by nutrient deficient shallow gravelly soils, high temperature, low and irregular distribution of rainfall and low organic matter. The utility of microbes in maintenance and built up of soil fertility, thereby, enhancing plant growth and yield is indispensable. In addition, such biofertilizers are cheaper, eco-friendly and based on renewable energy sources.

Hence, an attempt has been made to assess the effectiveness of various plant growth-promoting micro-organisms *viz. Gluconaetobacter diazotrophicus, Pseudomonas striata, Trichoderma viride, P. fluorescens, Azospirillum brasilense,* pink pigmented facultative methylotrophs (PPFM) occurring in the region, on growth and nutrient uptake by pomegranate saplings prepared from air layers.

The study demonstrated that the microbial inoculants under study survived well under semi-arid climate and benefited the growth of saplings by improving the soil properties, fertility status, physiological parameters and nutrient uptake. Dual inoculation with N_2-fixing *A. brasilense* and *P-solubilizing*. *P. striata* was most effective in promoting uptake of nutrients, plant height and biomass which may be helpful to produce vigorous plants to survive and thrive under stressed soil condition. Hence using these microbial inoculants in potting mixture for air layers may facilitate their better establishment and growth under field condition.

Root distribution pattern based nutrient and irrigation application in pomegranate grown in different soil types

Marathe, R.A. and D.T., Chaudhary

Year: 2012

Root distribution study is one of the important aspects of perennial fruit trees, which have wide spread root system. Root distribution pattern forms the crux for optimum and economic utilization of irrigation, fertilizers and other inputs. It is also important in exploring new potential areas for commercial cultivation.

Root distribution pattern in terms of root weight and root activity (i.e. root length) was studies in 4-years old pomegranate cv. Bhagawa grown in three different soil types viz. very shallow with gravelly loam texture, medium deep clayey and Deep clayey. Roots were collected from six radial distances (0-30, 30-45, 45-60, 60-75, 75-90 and 90 cm and above) and seven depths (0-15, 15-30, 30-45, 45-60, 60-75, 75-90 and above 90 cm). The roots were graded on the basis of root diameter into six categories, viz. (i) very fine < 0.5 mm (ii) fine 0.5 < to < 2 mm (iii) small 2 < to < 5 mm (iv) medium 5 < to < 10 mm (v) large 10 < to < 20 and (vi) very large > 20 mm. Observations pertaining to root biomass and roots length were recorded.

Total weight of roots (diameter up to 5 mm) under shallow, medium deep and deep soil was 992.7, 1100.0 and 1176.3 g respectively. Cumulative root length (activity) was highest in medium deep soils (2722.8 m) followed by shallow (2332.4 m) and deep soil (2084.0). With the increasing radial distance from the tree trunk dry weight of all categories of roots decreased in shallow and medium deep soil. Similarly with the increasing soil depth from the surface, dry weight of all categories roots decreased in all the studied soil types.

On weight basis, contribution of small roots (2 < to < 5 mm) to the total weight was highest whereas, on the basis of root length, contribution of very fine roots (< 0.5 mm) was exceptionally high compared to other categories of the roots. Root growth or root activity of pomegranate plants was better in shallow, light textured soils compared to deep, clayey soils. In these soils major root activity was confined in 0-60 cm radial distance and 0-45 cm vertical distance. However, in deep, clayey soils more or less uniform distribution of roots was observed up to 90 cm distance. Accordingly fertigation schedules should be planned in these orchards.

Removal of soil with roots from individual circular layers of 15 cm width and depth

Root Distribution of pomegranate cv. Bhagawa grown under different soil types

Shallow light texture Soil **Medium deep** **Deep clayey Soils**

Root distribution under shallow light textured soil

Root distribution under deep clayey textured soil

Innovative soil management technique for sustainable pomegranate cultivation on marginal lands

Marathe, R.A. Jadhav, V.T., Dhinesh Babu, K. and Jyotsana Sharma

Year: 2009

In India, over 32 million ha area is under hot and arid region. Soils of these areas have undulating topographies, shallow depth, sandy texture with low organic matter emanating poor fertility status. Thus, it is restricting the choice of crops for cultivation. But, a drought tolerant pomegranate could be effectively cultivated on these marginal lands. Therefore, an innovative planting technique for pomegranate *(Punica granatum* L.*)* cv. Bhagawa was standardized by adopting different soil management practices.

Pit digging: In this system, trapezoidal pits of 1.5 × 1.5 m top and 1.2× 1.2 m bottom dimensions with 0.60 m should be dug in weather rock (murrum) and refilled with clayey or loamy soil occurring in the low lying areas or ponds. If surface soil available between two rows is of good quality, then it can also be used. Pits filled with clayey soil had the highest macro-nutrient supplying capacity resulted in vigorous plant growth and optimum fruit yield. This method of plantation is followed in very shallow soils on comparatively flat lands.

Trench digging: Generally this method of plantation is practiced on slopy lands where soil depth is very shallow. Sometimes pits filling with machineries may not be economical, then with the help of farm machinery trench of 1 meter wide and 60 cm depth are dug on the contour line at specific (row to row distance) interval or across the slope. The dugout coarse texture earth materials (murrum) should be dumped beside the trench towards sloping side and trenches are refilled with clayey or loamy soils. The trenches may also be filled surface soil from upper side of the trench if it is of good quality.

General instructions for filling the pits

1. The pits should be dug before summer season and exposed to scorching sun so as to have natural solar sterilization of soil. This will help to kill different types of pathogens, insects and their eggs and weed seeds.
2. These pits should be refilled with good quality soil up to 30 cm above the ground surface which subside to ground level after rainy season.

3. Before filling of pits dusting of Carbaryl powder or drenching with 5 litres of solution having (0.25% (2.5ml/l) Chlorpyriphos 20EC and 2.0 g/liter Carbendazim 50%WP) OR (2ml/l Propiconazole 25 EC) followed by 2% Fluensulfone @ 20-40 g/plant or Fluopyrum 34.48% SC @ 2 ml/l may be done while filling the pits.
4. Material to be mixed in top 30 cm soil layer of the pit : well decomposed FYM (10 kg), SSP (1 kg), Neem cake (0.5 kg), *Trichoderma* mixture (25 g), PSB (15 g) and *Azotobacter / Azospirillium* (25 g).

Pit digging

Trench digging

Bedding System: an innovative new method of plantation for pomegranate

Marathe, R.A., Jadhav, V.T., Dhinesh Babu, K. and Jyotsana Sharma

Year: 2011

Pomegranate is the most important crop of arid and semi-arid regions of India. Most of the pomegranate growing areas are characterized by undulating topography with soils having shallow depth, course texture, low water holding capacity and low fertility. While soils of valley or lower basin are very deep, clayey in texture and poor in internal drainage creating waterlogging conditions during the rainy season. The root distribution studied of pomegranate revealed that major portion of the root activity is confined in 0-60 cm radial distance and 0-45 cm vertical distance. So, it is imperative to provide good quality soils at least in this active root-zone for commercial production on sustainable basis.

Bedding system of plantation comprises of digging 0.60 m wide and 0.30 m deep trenches below the soil surface and filling the trenches with good quality soil which may be from the upper soil layer (area between two rows) of the same field or brought from outside. Similarly above the ground level, a bed of 2 m wide and 0.45 m height with sloping sides down on both ends are prepared. Thereby these beds get naturally separated by parallel dead furrows oriented in the direction of land slope. The water drains from the beds into dead furrows, which discharge into a field drain constructed at the lower end of the field and perpendicular to the dead furrows.

While preparing these beds, soil tilth is made friable up to 50 cm depth by undertaking ploughing and harrowing operations using MB plough, cultivator and finally with rotavator. Afterwards, the bunds are prepared by bund former or ridger and final smoothening by manual labour.

In light textured shallow soils, depth is most important. Initially soil profiles are dug in the field to find out depth of good quality soil and underlain murrum (weathered rock) layer. Ploughing and other cultural operations should be carried out only to the cultivated top soil layer. Subsoil or murrum layer contains calcium carbonate deposits or mixed concretions of calcium and iron which may be harmful to the plants during the

initial years. Therefore, soils from only top layer are used for refilling or preparing beds.

In heavy textured soils, soil material lying between two rows from the same field can be used for bed preparation.

- **Benefits of the system in light textured shallow soil**
- In shallow soils, this system provides increased rooting depth (at least 50 cm) for proper growth of active root-zone of the plants.
- During low rainfall periods, these beds, constructed across the slope acts as a water harvesting units and conserve soil as well.

  Enhanced nutrient availability in the soil, nutrient uptake by the plants, vegetative growth, induced more flowering, checking the fruit drop thereby increasing fruit yield of the plants.

- **Benefits of the system in heavy textured deep soil**

  During rainy season also, this system is highly effective in maintaining well-drained
- conditions, at least in upper 0-30 cm soil depth where nearly 80 per cent of root activities are confined.
- During high rainfall periods, it facilitates percolation, draining of water with non-erosive velocity, thereby checking soil erosion losses.

  Very low incidences of disease especially wilt.

Bedding Photo layout

Performance of different planting systems in pomegranate

'Bedding System' of plantation

Luxurious growth of the plants grown on 'Bedding System' of plantation - Very low plant mortality

Very high mortality of the plants grown on 'Continuous Trenches' system of plantation

Heavy fruiting on the plants grown on bedding system of plantation

Soil suitability for the cultivation of Ganesh and Bhagawa varieties of pomegranate

Marathe, R.A., Jadhav, V.T., Babu, K. D. and Jyotsana Sharma

Year: 2012

The soil morphological and physical properties mostly affect the water relations of soil, while, chemical properties predominantly influence the nutritional status of plant. It is imperative to select proper soil to harvest optimum yield on sustainable basis. Hence, the present investigation was conducted to evaluate the performance of pomegranate cv. Ganesh and cv. Bhagawa grown on different types of soils as gravelly, sandy loam, loam and clayey black soil having different depths of 30, 60, 90 and 120 cm.

The results revealed that in general for both the varieties,

- Clayey soils had higher macro-nutrient supplying capacity while loamy soil had higher micro-nutrient supplying capacity. Nutrient uptake by the plants was better in loam textured soil with better leaf chlorophyll contents and vegetative growth of the plants.
- Better quality fruits were produced on the plants grown in light textured soils.
- Incidence and severity of wilt and bacterial blight disease was higher in the plants grown on deep clay textured soils compared to light textured soils.

GANESH

- It is observed that pomegranate cv. Ganesh is comparatively hardy and recorded highest fruit yield in the plants grown on clayey soils having depth of 30 cm. Drastic reduction in fruit yield was recorded with the increase in depth of clayey soil (90 and 120 cm).
- Fruit yield was equally better in the plants grown on loamy soil having 60 cm depth followed by mixture of clayey soil and coarse soil material (sand) (< 25 %) having depth of 60 cm.
- Macro nutrient uptake and chlorophyll content in the leaves was better in the plants grown on heavy texture soil material, which resulted into vigorous plant growth compared to light textured soil.

BHAGWA

- In case of cv. Bhagawa, plants grown in clayey soil up to 60 cm depth produced the highest fruit yield with highest cost benefit ratio.
- In case of clay textured soils, the depth was most important factor for harnessing the fruit yield. Increase in depth above 60 cm resulted in drastic reduction in fruit yield mainly due to very low flowering induction thereby fruit yield.
- Loam textured soil having depth of 60 cm recorded maximum Mn and Zn contents in the leaves, high leaf chlorophyll content, vegetative growth and number of hermaphrodite flowers in the plant.

Performance of pomegranate on different soil types of central India and its management

Marathe, R.A.

Year: 2010

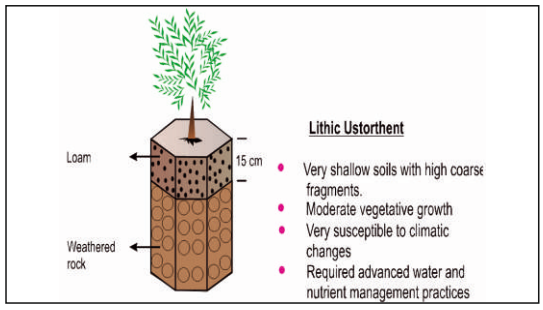
Pomegranate is a perennial fruit crop with the productive life of 15 to 20 years. It takes about 3 to 4 years for a plant to come into bearing. Therefore, one should have proper knowledge about the soil characteristics and its influence on plant performance is so as to make proper planning for the plantation of pomegranate orchard to harvest optimum yield. Extensive surveys in Central India revealed that pomegranate growing soils can be categorised into three broad soil groups on the basis of soil depth, texture and plant performance. The major soil characteristics and their management practices to be followed are given below.

1. Very shallow , coarse textured soils:

The coarse textured or light soils having depth up to 30 cm, high coarse fragments underlain by weathered rock (murrum) are grouped under this category. These soils occurred on undulating topography and have very high hydraulic conductivity, high percolation rates and the water drained out very rapidly. The water and nutrient holding capacity and buffering capacity of these soils are very low. The organic carbon content and soil fertility status is also very poor.

Vegetative growth of the plants is poor owing to shallow rooting depth. For the induction of flowering, plants will get sufficient stress within 15 to 20 days of withholding irrigation. So, one can take fruit yield in Mrig or Hasta bahar with maximum yield and monetary returns. These soils have low buffering capacity and plants may undergo frequently stress condition reducing productive life of the orchards. Due to better drainage the microclimate is dry resulted in low incidence and prevalence of pests and diseases.

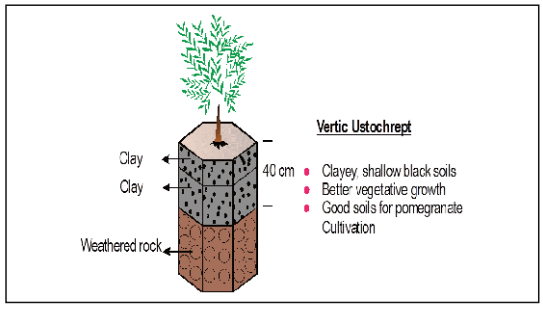
Intensive management practices are required to be followed on these type of soils. Regular application of organic manures or manure slurry (liquid form) is essential. Total quantity of recommended nutrient doses should be split to maximum and applied as fertigation. Drip system of irrigation with two laterals fixed with six online drippers (2 or 4 lph) placed on both side of plants along the row should be used in such soils. Quantity of irrigation water should be very low and should be applied frequently may be on alternate days, percolation losses may occur if applied in heavy doses. During bearing period providing low or irregular irrigation will adversely affect the fruit yield and quality due to low buffering capacity of the soil.



Profile of shallow coarse textured soil

2. Shallow, clayey black soils

The black soils with depth up to 60 cm are categorised under this group. The clay percentage in these soils is high but as it is underlain by weathered rock (murrum), it provides good drainage conditions. The nutrient and water holding capacity and buffering of these soils is good. The organic carbon content and soil fertility status of these soils are comparatively better than in shallow coarse textured soils. The vegetative growth, flowering and fruit yields are also high in these soils. Intensive management practices as mentioned above are required to be followed in these soils as well to harvest higher yields. These are the ideal soils for the plantation of fruit crops like pomegranate.

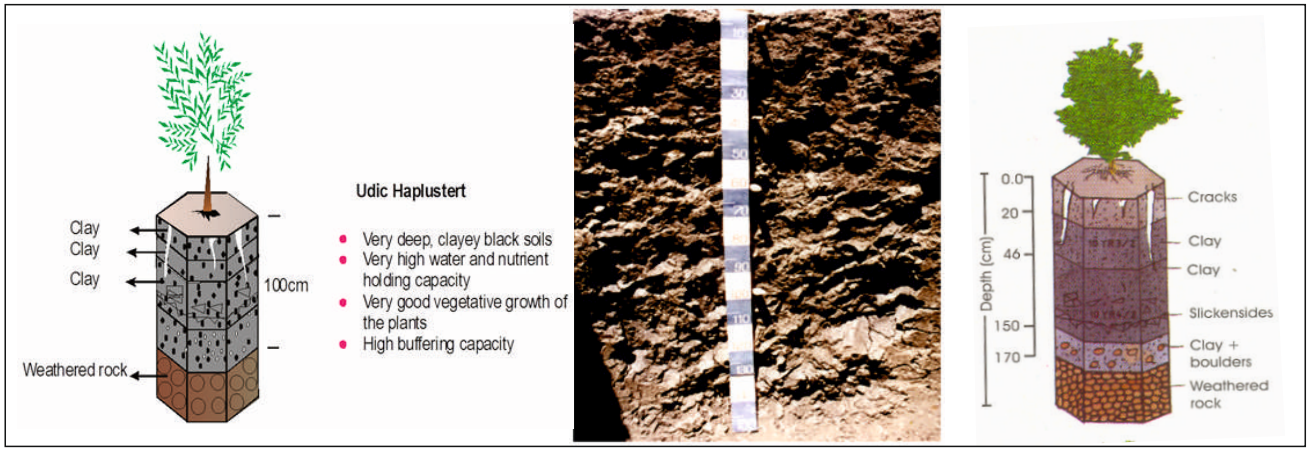


Profile of shallow heavy textured black soil

3. Deep, clayey black soils

The clayey black soils with depth more than 75 cm are categorised under this group. These soils generally occur in low land or inter valley basins. These soils have very high clay content, water and nutrient holding capacity, buffering capacity and sufficient rooting depth. All these factors favour vigorous growth of the plants. However induction of flowering is major problem thereby drastically reducing fruit yield of the plants. In pomegranate flowering induction is directly related or triggered by stress in the plants. In central India, generally stress in the plants is induced by withholding the irrigation. In shallow or light textured soils, stress induction takes place after withholding irrigation for short span. However in these deep, clayey soils, the plants get constant supply of water from the subsurface horizons even after water withholding for several months and plants did not get sufficient stress for the induction of flowering.

Hydraulic conductivity and drainage conditions of these soils are very poor. During rainy season, waterlogging conditions prevails in the orchards, hampering intercultural operations, increased weed infestation, increased humidity thereby favouring the incidence and spread of diseases. These types of soils are not recommended for the plantation of pomegranate orchards.



Profile of deep, heavy textured black soils

Identification of nutrient deficiency symptoms in pomegranate cv. Bhagawa

Marathe, R.A., Jadhav, V.T. and A., Maity

Year: 2010

Balanced and judicious use of nutrients assumes great importance. Short supply of any particular nutrient element lowers its content within the plant and produces characteristic morphological and spectral symptoms particularly on the leaves of the plants. Characterization of these nutrient deficiency symptoms on leaves could be very effectively used by a trained personnel in diagnosing nutrient disorders and provide an immediate evaluation of nutrient status in plant.

Hence, an experiment was conducted in sand culture under green-house conditions on pomegranate cv. Bhagawa. The treatments were imposed using nutrient deficit technique and comprised of -N, -P, -K, -Ca, -Mg, -S, -Fe, -Zn, -Cu, -Mn, -B and -Mo with one full nutrient strength solution as control. The marked deficiency symptoms on leaf were documented in the form of photographs.

DEFICIENCY SYMPTOMS

Nitrogen deficiency : Uniform yellowing of whole leaves appeared initially on lower and mature leaves. Afterwards, these leaves became brittle and get broken into pieces on folding. At advanced stage, young leaves became uniformly chlorotic and light brown followed by drying up from the tip. Plants became pale yellow and growth got stunted. Reduction in growth was apparent by lowest shoot, root biomass and shoot-root dry weight ratio. Early induction of flowering was observed even at nursery stage. Almost all the plants under nitrogen deficiency treatment produced large number of flower-buds and flowers (20-30 flowers / seedling in pots) at early stage and most of them were hermaphrodite.

Phosphorus deficiency : Deficiency symptoms prominently appeared on the young leaves. Yellowing of leaf started from tip while other part remained green. Leaves became slender, elongated and were smaller in size. Leaf margins turned upward and got tunnel like shape. At advanced stage, entire leaves became yellow followed by appearance of chlorotic spots, which later on turned dark brown. In phosphorus deficient plants, concentration of phosphorus was three times lower than that observed in phosphorus sufficient plants.

Potassium deficiency : Deficiency symptoms appeared initially on older leaves. Many brown spots appeared on the dorsal side of leaves along the leaf margin starting from tip. At advanced stage, leaf margin became yellow followed by scorching. Present report on deficiency symptoms of potassium revealed as specks throughout the old leaves irrespective of necrosis.

Calcium deficiency : Interveinal yellowing started from leaf tip and advanced towards midrib from margin. Veins remained green during initial stages and became yellow at later stages. The yellow portion of the leaf tip acquired inverted 'V' shape. Also, pinkish tinge appeared on the lower side of yellow portion of the leaf. At advanced stage, yellow portion of leaves turned dark brown in color and half of the leaves from the tip dried up.

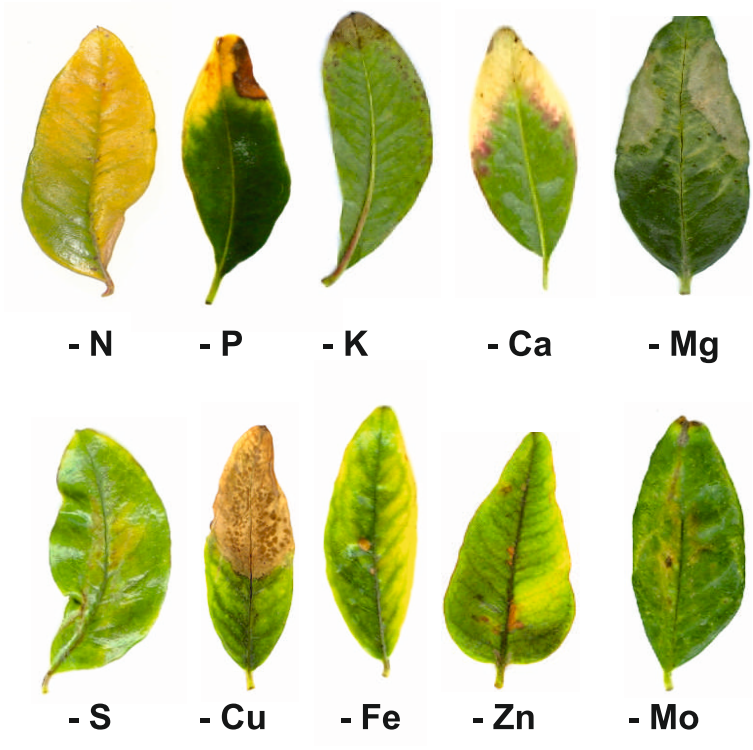
Magnesium deficiency : Leaf margin and veins turned light green in color. Initially grey patches appeared on the side margin of the leaves and subsequently spread on whole leaf. Leaves dried up and the color of dry leaves turned grey, while in case of Ca it was dark brown.

Sulphur deficiency: Light green colored leaf veins first appeared on middle leaf. Yellowing started in the middle of leaf around the mid rib and interveinal areas turned yellow in color and whole leaf become pale yellow. However, the intensity of yellowing was low as compared to that observed with nitrogen deficiency.

Copper deficiency : It caused irregular growth and pale green leaves that withered at leaf margins. Leaf margins became yellow and leaves at top of the plant wilted first followed by chlorotic and necrotic areas on leaves and necrosis of the apical meristem. Leaves on top of the plant showed unusual puckering with veinal chlorosis.

Iron deficiency: The symptomology of iron deficiency is usually manifested as interveinal chlorosis of young leaves while the veins remained green. Such typical symptoms appeared in many fruit crops but even after six months of the experimentation, such symptom were not observed in pomegranate.

Zinc deficiency : Deficiency was first pronounced as interveinal chlorosis in young and mid-shoot leaves. Interveinal yellowish areas started appearing at leaf tip margins, which eventually affected all growing points of the plant. Most common zinc deficiency symptom was rosetting or little leaf, shoot dieback or defoliation, which were not much pronounced in pomegranate.



Nutrient deficiency symptoms in pomegranate

Iron deficiency symptoms in pomegranate

Nutrient antagonism in pomegranate - Plant dry matter portioning and nutrient uptake

Marathe, R.A. and V.T., Jadhav

Year: 2012

Balanced nutrient application is one of the most important factor to harvest optimum yield and NUE. Excess of one nutrient may lead to deficiency of several other nutrients, and conversely content of a specific nutrient may lead to deficiency of several other nutrients. Hence an experiment was conducted in sand culture under green-house conditions on pomegranate cv. Bhagawa. The treatments were imposed using nutrient deficit technique and comprised of -N, -P, -K, -Ca, -Mg, -S, -Fe, -Zn, -Cu, -Mn, -B and -Mo with one full nutrient strength solution as control.

Highly significant variation in dry matter of different portions of the plants viz. leaf (11.1 - 19.1 g), stem (22.2 – 30.9 g) and root (11.9 – 16.9 g) as well as total biomass (47.0 – 66.9 g) of the plants was apparent amongst the different treatments. Plants grew with complete nutrient solution recorded the highest dry weight of shoot, root and total biomass as compared to all other macro and micro-nutrient deficiency treatments. Plants with nitrogen deficiency recorded significantly lowest amount of leaf, stem, shoot and total biomass. The reduction in the plant biomass with nitrogen (-N) and phosphorus (-P) deficient treatments was due to preferential partitioning of photosynthetic carbon to the roots.

Root dry weight reduced significantly under calcium deficiency, which resulted in significant increase in shoot-root dry weight ratio. Much influence on plant biomass content was not observed with the deficiency of various micronutrients. The lowest value of shoot-root ratio was observed with nitrogen deficiency followed by phosphorus, sulphur and manganese deficiency treatments, while it was the highest under calcium deficiency followed by molybdenum and boron deficiency treatments.

Nutrient interaction in stem and leaf

Leaf nutrient content indicated that deficiency of N, P, K, Fe and Cu had significant influence and lowest content of these nutrients were recorded in the leaves. The impact was more prominent with P deficiency, which lowered the content of many nutrients viz. N, K, Ca, Mg and Mn in the leaves. While, K deficiency led to increase in N and Mg content in leaves. Another important nutrient interaction was observed with Fe, which had synergistic effect on the uptake of P, K, Ca, Mg and Zn with their higher content in leaves.

Unlike leaf, in the stem, only -N, -P and -K treatments showed significant decrease in nutrient content, while -Ca, -Mg, -Fe, -Mn, -Cu and -Zn did not show much influence and maintained sufficient quantity of these nutrients. Stem nutrient content data revealed that P deficiency increased Fe, Mn, Cu and Zn contents in stem. Similarly -Mg and -S treatments had marked influence on uptake of other nutrients. Deficiency of B adversely affected the content of Ca, Fe, Mn, Cu and Zn nutrients in the stem of pomegranate plant. Nitrogen deficiency led to increase in content of K, Mg and Cu while K deficiency resulted decrease in content Ca and Mg in stem. With the reduction in K supply, translocation of nitrates, phosphates, calcium, magnesium and amino acids get depressed.

Leaf sampling technique for critical nutrient analysis in pomegranate cv. Bhagawa

Marathe, R.A. and V.T., Jadhav

Year: 2011

In fruit crops, foliar leaf analysis has been recognized as reliable tool for appraisal of nutrient status and application of fertilizers. The success of foliar analysis as diagnostic tool largely depends on sampling of representative index tissue and proper period of sampling. The leaf nutrient content was found to vary with season, leaf age, cultivar and growth of the plant and hence, it is necessary to standardize the sampling of leaves at proper age and form proper position for particular nutrient.

The experimental results revealed very high variation in leaf nutrient content during different seasons (67.0 to 265.5 %) compared to the leaves located at different positions (5.2 to 62.0 %). Seasonal variation of leaf Cu, P, Mn and Fe content was high (145.9 to 265.5 %) compared to N, Ca, Zn, K and Mg (67.0 to 137.0 %) content. Among the different seasons, variation in leaf nutrient content was high and most unstable during rainy season followed by winter and summer season.

On the basis of seasonal variation, it can be concluded that the best time for leaf sampling of pomegranate cv. Bhagawa would be from February to May for most of the nutrients except Mg for which sampling has to be done during the month of March to June. Graphical depiction indicated that stabilization of micronutrient content was observed between 10^{th} to 12^{th} leaf pair. In this stability zone, higher values were recorded at 10^{th} leaf pair position. These findings were also supported by field observation where it was seen that in cv. Bhagawa, the primary branch had maximum 14 to 16 leaf pairs and recommended leaves are fairly mature leaves having green colour and are not rigid and brittle like older leaves.

It is concluded that for leaf sampling in pomegranate cv. Bhagawa, it is ideal to choose 10^{th} to 14^{th} pair of leaves during the period of February – March for determination of most of the nutrients except K for which sampling has to be done during April - June.

Identification of soil and plant nutrient constraints in pomegranate orchards of Maharashtra, Karnataka and Andhra Pradesh States

Marathe, R.A. and Y.R., Shinde

Year: 2010

Pomegranate is the major fruit crop of semi-arid regions of Maharashtra (MS), Karnataka (KA) and Andhra Pradesh (AP) States. In these states, the soil under pomegranate cultivation varied greatly with respect to soil characteristics, plant nutrient contents and required different nutrient management practices to acquire maximum nutrient use efficiency. To find out soil and plant nutrient constraints in these states, large scale surveys were conducted in 347 pomegranate orchards covering an area about 60,000 ha in these states.

In general, it was observed that in these states most of the pomegranate growing soils are grouped under Entisols, Inceptisols and vertic intergrades of Vertisols derived from basaltic montmorillonitic mineralogogy. Majority of these soils have shallow depth, sandy to sandy loam clay texture and substantial coarse fragments. Few orchards in intervalley basin also have deep clayey soils. In Maharashtra, very few orchards have pH below 7.0 while in Karnataka 20 percent orchards have pH less than 7.0. Electrical conductivity of most of the orchards have EC < 1.00 dS/m) while considerable amount of CaCOI (> 15%) was recorded in 20 percent orchards of these states. All these parameters are within the tolerable limits for pomegranate cultivation. Organic carbon content was in sufficiency range. Soil availability of N was in low to medium range while P was found to be most limiting nutrient deficient in 69.4 to 80.0 percent orchards. Potassium availability was in higher range in all these orchards. Amongst micronutrients, Fe was in lower range in majority orchards (53.3-84.4 %), surprisingly Zn was high in majority orchards (60-80 %), Mn in medium range while Cu was in high to very high range in almost all the orchards,

Leaf nutrient status data revealed that N was in sufficient to high range in MS and AP states while low in KA states, leaf P was deficient in more than 90 percent orchards in MS and AP and better in KA state. Leaf K, Ca, Mg was in sufficient in these states. Amongst micronutrients, leaf Fe and Zn was in sufficiency range, Mn in lower range in MS and AP while surprisingly Cu was in lower range in these states. Accordingly, state specific nutrient management schedules are needed to be developed.

Multi-stem training system for pomegranate

Dhinesh Babu K., Marathe R.A., and D.T. Meshram

Year: 2018

Evaluation of pomegranate under different training systems (single, double, triple, four, five and >5 stems / plant) revealed that the fruit set was highest under single training system whereas it was lowest under control (>5 stems / plant). The yield was highest under four stem training system followed by triple stem where as it was lowest under control. Under multi-stem training system, even if any stem gets damaged or lost due to infestation of shot hole borer, bacterial blight, insect pests damage etc, complete plant will not be lost and plant will survive and produce yield. However, it is required to have periodical pruning so that the spray solutions as well as light will penetrate deeply into the canopy of the plant.

Single stem / plant

Double stems / plant

Three stems / plant

Four stems / plant*

Five stems / plant

Control (>5 stems / plant)

Training systems for pomegranate

Pruning technique for crop regulation in pomegranate

K. Dhinesh Babu, Marathe R.A., Singh, N.V. and A. Maity

Year: 2019-20

Pomegranate (*Punica granaum* L.) is an important fruit crop of arid and semiarid regions of the world. It is basically deciduous in nature. However, it behaves as evergreen, partially deciduous and deciduous under tropical, subtropical and temperate climatic conditions respectively. This characteristic feature of pomegranate makes it highly amenable for crop regulation during Ambia, Mrig and Hasth bahar. India is the only country in the world where pomegranate fruits are available throughout the year. Crop regulation becomes possible through pruning of pomegranate. However, it is essential to standardize the pruning technique in pomegranate for crop regulation. To standardize the pruning practice for pomegranate, an experiment was conducted with mature plants of pomegranate variety Bhagawa. There are 7 treatments covering 3 levels of pruning viz., light pruning (removal of 6" shoots from the tip), medium pruning (removal of 12” shoots from the tip) and heavy pruning (removal of 18" shoots from the tip) individually and combined with removal of tertiary shoots which was compared with unpruned trees (control). Light pruning of pomegranate by removing about 6” shoots from the shoot tip resulted in highest fruit set, no. of fruits, yield besides optimum fruit weight. Control (unpruned trees) registered the lowest value for fruitset and yield. The BCR was highest in light pruning (4.52) with about 42% higher yield over the control.

Gibberellic acid mediated fruit size enhancement in pomegranate

Dhinesh Babu, K., Marathe R.A., Singh, N.V., Maity, A., Patil, P.G. and Shilpa, P.

Year: 2018-19

Pomegranate (*Punica granatum* L.) attained the status of 'Dollar fruit' with an export to the tune of about 90,000 tonnes annum, due to its enormous nutritional value and immense medicinal value, in domestic and international market. Grading of fruits based on fruit size and weight is a prerequisite for pomegranate marketing. Better grade fruits fetch higher price and paves the way for better remuneration. With the objective of enhancing the fruit size, an experiment was executed in pomegranate cultivar Bhagawa during mrig bahar 2019-20 and 2020-21. Pomegranate trees selected from mature orchard were foliar sprayed with Gibberellic Acid (GA_3) at 7 different concentrations along with a control (water spray) on 30 days after anthesis and 60 days after anthesis. The treatments include GA_3@ 10 ppm, 20 ppm, 30 ppm, 40 ppm, 50 ppm, 60 ppm & 70 ppm. The results revealed that increase in gibberellic acid concentration from 10 ppm to 50 ppm significantly enhanced the fruit quality in terms of fruit weight, fruit length, fruit diameter, and fruit yield over the control. Foliar spray of GA_3@ 50 ppm recorded the highest mean fruit weight and fruit yield. This might be due to the mighty, phenomenal role of GA_3 in promotion of cell division, elongation. However, GA_3 concentration beyond 50 ppm was not significantly effective in promoting the fruit weight and fruit yield, probably due to supraoptimal concentration. The proportion of export grade fruits (above 250g) was higher in GA_3 treated plants compared to control.

Control

GA_3@50ppm

Control of flower drop in pomegranate

Dhinesh Babu, K., Singh, N.V. and R.A., Marathe

Year: 2021

In pomegranate, the crop regulation helps to produce uniform flowering and fruiting. However, there is fruit drop during different stages of fruit growth, especially after fruit set. Fruit drop due to hormonal imbalance could be managed through extraneous application of suitable auxins. An experiment was conducted in pomegranate variety Bhagawa during hasth bahar.

Foliar spray of the growth regulator: 2,4-D (2,4-Dichlorophenoxy acetic acid) at six concentrations (5,10,15,20,25 and 30ppm) along with a control. The increase in concentration of the growth regulator: 2,4-D significantly reduced the flower drop with minimum number of dropped flowers (21.3 flowers / tree). Hence, 2,4-D @ 20 ppm has been found to be highly beneficial for management of fruit drop.

Control

2,4-D@20ppm

P and K solubilizing bio-formulation

Ashis Maity, Jyotsana Sharma, R.K. Pal, Ramchandra, N.V. Singh, Babu, K.D. and R.A., Marathe

Year: 2018

Most of the pomegranate growing soils of arid and semi-arid region of India have undulating topography, shallow depth, low organic carbon content and poor in nutritional content. From the same area and root zone of pomegranate, a carrier based potassium and phosphate solubilizing bio-formulation of *Penicillium pinophilum* MCC 0114 was isolated It has capacity to supplement 70% requirement of potassic fertilizers in pomegranate. If used with 200 g potassium feldspar per tree, it can totally replace the potassic fertilizer requirement of pomegranate tree and increases K uptake by 47.47% and P uptake by 63.44%. Approximately 24 - 35% increase in economic yield with better fruit quality of pomegranate. Prevent incidence of wilt disease in pomegranate caused by *Ceratocystis fimbriata*. Survive well under semi-arid agro-climatic condition as it is native to this agro-climatic condition. Method of multiplication is very easy and rapid

Bio-formulation inoculated with K-feldspar @ 200 g plant^{-1}

Recommended dose of potassic fertilizer application

Without potassic fertilizer application

Nutrient supplementation in pomegranate using organics sources

Marathe, R.A. and V.T., Jadhav

Year: 2014

Pomegranate is an important fruit crop of arid and semi-arid regions of the world. It has very high export potential owing to its antioxidant and nutraceutical values. With increasing health consciousness, the demand for organically produced pomegranate fruits is growing in the Middle East, America and European countries.

Hence, an experiment was conducted to find out feasibility of organic sources *viz.,* farm yard manure (FYM), vermicompost (VC), poultry manure (PM), *in-situ* green manuring (GM) with sun hemp (*Crotalaria juncea* L.), ex-situ green manuring with Glyricidia (*Gliricidia sepium*) , *ex-situ* green manuring with Karanj (*Pongamia pinnata*), *ex-situ* green manuring with neem, (*Azadirachta indica*) in comparison with recommended dose of nutrients supplied through inorganic fertilizers and control *i.e.* without any fertilization.

It is recommended that the nutritional requirement of pomegranate could be fulfilled with the exclusive use of organic sources without affecting growth performance and yield. The highest fruit yield was obtained with PM which was 110.8% and 25.5 % more than that of control and inorganic fertilizer application respectively. Plants supplied with PM recorded balanced uptake of all the major and micronutrients. FYM which is easily available was also very effective for improving soil organic carbon and thereby increasing soil fertility status with respect to available P, K, Cu, Zn and Mn in the soil. Among the various green manures, sun hemp was very effective in increasing fruit yield. With the use of GM with sun hemp, the microbial load of soil increased 3 to 4 folds, which would translate into higher soil fertility.

It can be concluded that organic sources *viz.* farmyard manure, poultry manure and green manuring with sun hemp could be harnessed for successful organic pomegranate production.

Organic manures slurry – a new method of manure application

Marathe, R.A., Shinde, Y.R. and Jadhav, V.T.

Year: 2013-14

Majority of the pomegranate growing areas are characterized by nutrient deficient, shallow, gravelly soils with low organic matter and fertility status. The improvement of carbon and soil health it is necessary to apply organic manures in sufficient quantity. But it is scarcely available in the region. Many a times farmers are using manures in raw form, un-decomposed and placed on the soil surface in the form of heaps or simply dumped below the plant canopy. It is not incorporated in the root zone of the plants and hence major portion of organics remained unutilized due to lack of moisture and is subjected to loss of N, P and K to the extent of 30-35%, 20-25% and 4-6%, respectively owing to leaching, washing and volatilization.

Hence, an experiment was conducted at ICAR-NRCP, Solapur to develop an effective method of organic manures application. The experiment comprised of application raw and decomposed farmyard manure (FYM) in the form of slurry (liquid form) as sole or in combination with micronutrients and/or microbial inoculants and compared with soil application well decomposed farmyard manure as standard practice.

The experimental results revealed that, the well decomposed organic or FYM should be applied in the form of slurry i.e liquid form of the manure wherein manure is mixed with water in 1:10 ratio in a tank, drum or container and kept for 10 to 15 days with intermittent stirring. It may be applied in plant basin in split doses. Various microbial inoculants [Symbion-VAM/Glomus fasciculatum, Kalisena (*Aspergillus niger*, AN - 27), *Trichoderma viridi, Azotobacter chrococcum*, PSB, Pseudomonas species and Potash Mobilizing Bacteria] can also be mixed with the slurry.

Different micronutrient fertilizers viz. $FeSO_4$, $MnSO_4$ and $ZnSO_4$ can also be added with this slurry (@ 50 g each / plant/ year). In the process inorganic micronutrients get converted to chelated form and are released slowly as per the requirement of plant. As mixing of micronutrient along with microbial inoculants had adverse effect on the soil microbial population, they can be applied separately with FYM slurry. A gap of at least 5 days may be maintained between two applications, so that these microbes can multiply well in the soil.

Application of various organics itself provide considerable amount of available micronutrients in the soil and enhanced microbial population thereby micronutrient availability to the plants owing to production of growth promoting substances and nutrient solubilising enzymes.

Raw organic manure should not be applied. Due to its wide C:N ratio it immobilizes the soil available nutrients thereby temporarily down size the supply of nutrients to the plant. For faster multiplication of microbes, jaggery or flour of coarse cereal may be added as practiced by many farmers.

Application of FYM in slurry form is highly effective in light textured and gravelly soils as it easily reaches to active root-zone of the plant owing to greater porosity in the soil. As a result, it improves soil physical conditions, aeration, microbial activities and nutrient availability in the root-zone. Improvement in soil fertility, physical properties coupled with microbial population might have led to enhanced growth and fruit yield of plants.

1) Unscientific methods of organic manure applications

2) Slurry units

Quantity of irrigation water required for pomegranate orchards on different soil types

Marathe, R.A., Jadhav, V.T., Dhinesh Babu, K., Sharma Jyotsana and D.T., Chaudhary

Year: 2010

For the first time exact quantity of irrigation water in liters per plant is recommended for the easy understanding by the farmers by conducting full-fledged field experiment in pre-bearing and bearing orchard grown in both light and heavy textured soils. The treatments consisted of replenishment of extremely low to very high quantity of irrigation water equivalent to 30, 40, 50, 60, 70, 80 and 90% of cumulative pan evaporation (CPE).

Pomegranate grown in water scarcity areas like Solapur district of Maharashtra, required supplemental irrigation only during middle winter and summer season. Quantity of irrigation water required was highest during the month of May followed by April and was lowest in the month of December. The amount of applied irrigation water increases with the increasing canopy of the plants.

In both the soil types, the irrigation should be provided in such a way that it should confined to root zone of the plant only. It is advisable to give irrigation on the basis of volume of plant canopy instead of age of the plants.

Light textured soils

It is suggested to apply irrigation water equivalent to 60% of CPE in pre-bearing orchards. While in bearing orchards, moderate level of irrigation i.e. 70% of CPE irrigation maintains good aeration and sufficient moisture regime in the root zone which resulted in higher nutrient uptake, vigorous growth, highest fruit yield and water use efficiency as well.

Irrigation water can be provided at the rate of 5.15, 5.84, 6.92, 8.58, 12.01, 13.28 and 6.06 litres of water / day / plant through drip irrigation system during the month of December, January, February, March, April, May and June, respectively to the bearing orchard having plant height and canopy spread of 2.0 m.

Heavy textured soils

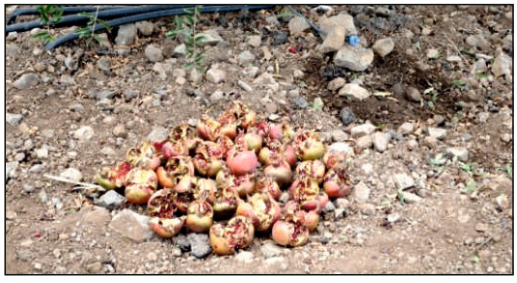
Though it is not advisable, in few pockets pomegranate is being grown in the heavy textured deep soils having very high clay content, high water and nutrient holding capacity due to its smectitic mineralogy. Application of inappropriate amount of irrigation water in these soils creates waterlogging, poor aeration and weed infestation leading to infestation of pests and diseases and problems related to induction of flowering.

In these soils, variation in irrigation water did not show any adverse effect on plant growth during pre-bearing phase. However, during bearing phase irrigation equivalent to 60% of CPE recorded highest plant growth, fruit yield and water use efficiency. Accordingly, it is recommended to apply irrigation water at the rate of 3.86, 4.38, 5.19, 6.43, 9.01, 9.96 and 4.55 litres of water /day/ plant during the month of December, January, February, March, April, May and June respectively to the pomegranate plant having height and canopy spread of 1.75 m.

On the other hand, on both type of soils, moisture stress facilitates accumulation of carbohydrate and transition from vegetative phase to reproductive phase. So flowering intensity increased with decreasing quantity of irrigation water. Application of irrigation water equivalent to 30-40% of CPE did not maintain sufficient moisture at 30-45 cm soil depth resulting in more fruit cracking to the extent of 37.7 - 58.8 %.

Fruits harvested under different treatments

Higher fruit yield under 0.70 ETc treatment



Very high fruit cracking in light textured soil under 0.30 ETc treatment

Very high fruit cracking in heavy textured soil under 0.30 ETc treatment

High fruit cracking under 0.40 ETc treatment

Fruit cracking under 0.50 ETc treatment

Yield of the pomegranate fruit as affected by quantity of irrigation water

"Two laterals" and "Ring" method of irrigation in pomegranate – A new method of micro-irrigation systems

Marathe, R.A., Jadhav, V.T., Dhinesh Babu, K., Sharma Jyotsana and D.T., Chaudhary

Year: 2010

Geometry pattern of lateral or drippers is most important factor in micro-irrigation systems of irrigation. Majority of pomegranate orchards are grown on light textured soils of semi-arid and arid regions having very high infiltration and percolation rates. At present, irrigation is being provided by using drip system through only 2 drippers of 4 to 16 lph capacity placed on both sides of the plant, which resulted in very limited wetting zone and heavy percolation losses. This type of geometry promotes bi-directional root growth disturbing natural root growth pattern of the plant. Hence an experiment was conducted to compare micro irrigation systems having varied number of drippers and their geometry where measured equal quantity of cumulative irrigation equivalent to 0.80 E-Pan was provided on every alternate day through water meters and separate pipeline installed for every treatment.

This newly developed two lateral system of irrigation comprises of six emitters of 2 lph capacity fixed on two laterals placed along the rows on both side of plants at a distance of 50 cm away from the trunk. In this system of irrigation, moisture availability was sufficient up to 60 cm depth which is the effective rooting zone of the pomegranate plant having more than ninety percent root activity. This system of irrigation maintained good balance of air and water in the soil, enhanced nutrient uptake, chlorophyll content, growth and flowering which resulted in producing highest yields amongst all other micro-irrigation systems. This system is very easy for installation and handling and maintenance cost is also low.

Two lateral method

In the same experiment, we also tried another method of irrigation i.e. ring method of irrigation which is equally good and the results are at par with two lateral system of irrigation. This new 'ring method of irrigation system' comprises of 8 inline emitters of 2 lph capacity placed in the form of ring encircling the plant. It is a unique combination of online and inline laterals wherein rings of inline laterals are attached with jointer and 'T' connections with online lateral placed along the rows of the plants. The size and diameter of ring increases with the increasing age of the plant.

Amongst all the micro-irrigation systems, this system provides maximum wetting zone especially in the root zone of the plant. Pomegranate is a crop of arid to semi-arid regions as such the surface soil remains dry for almost 9 months in a year. In any other systems some area of the plant basin remains dry thereby restricting uptake of nutrients from these areas due to unavailability of moisture. But this ring method of irrigation system provides maximum wetting area and uniform distribution of water especially in the active root zone of the plant.

Ring Method

Determination of maturity indices for commercial varieties of pomegranate

Dhinesh Babu, K., Singh, N.V., Gaikwad, N., Maity, A., Pal, R.K. and R.A., Marathe

Year: 2013-14

Pomegranate (*Punica granatum* L.) is an important fruit crop of arid and semiarid regions of the world with immense medicinal and nutritional value. Bhagawa, Ruby, Ganesh, G-137, Jalore Seedless, Arakta and Mridula are some of the popular cultivars of pomegranate which are commercially cultivated in different parts of India. These varieties differ in their maturity period (time taken from full bloom to harvest). Harvesting the fruits of pomegranate too early does not allow fruits to ripen properly while late harvesting limits the market life of fruits. Hence, an experiment was conducted to determine the appropriate maturity indices for harvesting pomegranate during 2011-12 and 2012-13. Days after full bloom (DAFB), fruit weight, fruit length, fruit diameter, 100 arils weight, TSS, titrable acidity and brix-acid ratio (BAR) were recorded at 15 days interval after fruit set. The maturity indices, *viz.* total soluble solids (TSS) and brix-acid ratio determined for harvesting the fruits of pomegranate with better edible quality is as follows. ie. 15.95°Brix TSS and 31.90 BAR at 180 DAFB for Bhagawa, 15.80°Brix TSS and 32.91 BAR at 175 DAFB for Ruby, 16.10°Brix TSS, 37.44 BAR at 150 DAFB for Ganesh, 16.20°Brix TSS, 36.00 BAR at 145 DAFB for Jallor Seedless, 15.40°Brix TSS, 34.22 BAR at 140 DAFB for Arakta and 15.50°Brix TSS, 33.69 BAR at 140 DAFB for Mridula.

Maturity indices of pomegranate cv. Solapur Lal

Dhinesh Babu, K., Singh, N.V., Gaikwad, N., R.A. Marathe

Year: 2018-19

To determine the maturity indices for harvesting of pomegranate var. Solapur Lal, the flowers were tagged on the day of anthesis. The fruit samples were collected after fruit set at an interval of 15 days from 90 to 165 days. Once maturity is approached, the samples were collected at 5 days interval to fix up the appropriate maturity indices for harvesting. Solapur Lal attained maturity at 160 days after anthesis with highest total soluble solids content (17.7°Brix), titrable acidity (0.40%) and TSS/acid ratio (44.25) with the mean fruit weight around 272.0g/fruit.

Frequency of irrigation for pomegranate orchards grown on different soil types

Marathe, R.A., Jadhav, V.T., Dhinesh Babu, K., Sharma Jyotsana and D.T., Chaudhary

Year: 2010

The irrigation frequency, defined by interval between two successive irrigations should be used in a way so as not to compromise the water need of the plants in their different pheonological stages. Application of water in small doses at frequent interval ensures their optimum utilization and higher crop yields and hence it is necessary to determine the most appropriate time to proceed with irrigation without causing hydric stress to the plant.

For the first time full-fledged field experiment was conducted in pre-bearing and bearing orchards to evaluate the influence of very low to very high irrigation interval *i.e.* daily irrigation, cumulative irrigation at 1-day interval, 2-days interval, 3-days interval, 4-days interval and 5-days interval. Irrigation equivalent to 80% CPE was provided using drip irrigation system having four (4 lph) drippers placed on four sides of each plant at a distance of 50 cm away from the trunk.

Light textured soils

It is recommended that in pomegranate orchards grown in light textured soils, irrigation should be provided on every alternate day through drip irrigation system. Because of low water retention capacity of light textured soils, irrigation at and above 3-days interval, induces heavy fruit cracking adversely affecting fruit yield.

Heavy textured soils

It is recommended that on heavy textured soil of semi-arid region of India, irrigation should be provided at 2-days interval through drip irrigation system. With this irrigation frequency, balanced nutrient uptake resulted in better plant growth and higher fruit yield. Irrigation at 3-days interval might not make much harm to pomegranate plants due to high water retention capacity of clayey soils. But during fruiting period, irrigation interval exceeding 3-days causes fruit cracking thereby, adversely affecting the fruit yield.

It is observed that irrigation frequencies did not have much influence on the plant growth during the pre-bearing phase. In both soil types, practice of daily irrigation tends to keep the soil always in wet conditions, increased humidity in microclimate inducing congenial atmosphere for the incidence and severity of pests and diseases adversely affecting crop productivity.

Effect of grafting methods and time on scion sprouting, graft success and subsequent growth of grafted plants of pomegranate cv. 'Bhagawa'

Chandra R, Jadhav VT, Sharma J, Marathe RA, NV Singh, C. Awachare, KD Babu

Year 2018

In pomegranate (Punica granatum L.) fruit crop air layering method is commonly used for multiplication of planting materials till date. Grafting has not been tried in India for propagation of elite saplings. Presently, wilt is an emerging threat to the pomegranate industry and without availability of a standard broom of grafting technique and tolerant rootstock, can be a magnificent at easy to solve the wilt problem. In view of this, an attempt was made to standardize the grafting method and time on suitable rootstock to overcome the wilt problem. Two grafting methods (wedge and tongue grafting) and five dates (15 December, 30 December, 15 January, 30 January and 15 February) were evaluated during 2007-08 at the National Research Centre on Pomegranate, Solapur, Maharashtra, India. One year- old seedlings of 'Phule Arakta' were used as a rootstock for the present study. In general, scion sprouting started between 8 and 12 days after grafting. Significantly higher scion sprouting was recorded with wedge grafting done in the last week of January after 15 (90.00%) and 21 (96.67%) days of grafting. Consequently, maximum graft success (85.00%) was recorded after 90 days of grafting with wedge grafting done on 30 January. Plant height and scion length after 6 months of grafting was higher when wedge grafting was done between 30 December and 30 January. Grafted plants during this period had perfect union as indicated by normal diameter recorded at graft union. This reflected high scion and rootstock compatibility.

Grafted plants of pomegranate of Bhagwa grafted over Phule Arakta

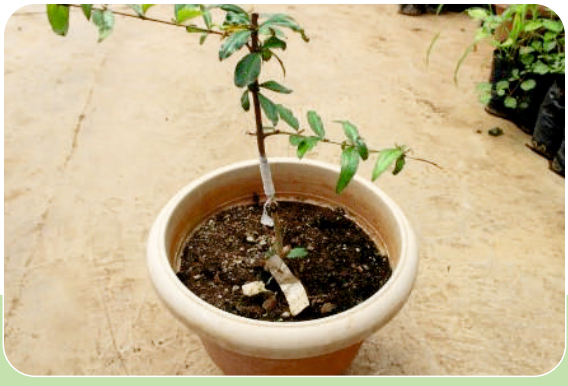
Bhagwa graft showing the graft union

Wedge grafting of Bhagwa over Phule Arakta

Polytube capping of scion

Successful graft union

Grafted plants of pomegranate var. Bhagawa



Pomegranate graft shifted to pot

Pomegranate grafts planted in the field

Determination of maturity indices for pomegranate var. Solapur Anardana used for anardana processing

K. Dhinesh Babu, Singh NV, and Gaikwad NG

Year 2019

To determine the maturity indices for harvesting of pomegranate variety Solapur Anardana. the flowers were tagged on the day of anthesis. The fruit samples were collected after fruit set at 15 days interval from 90 days to 135 days interval. Once the maturity is approached, the fruit samples were collected at 3-5 days interval to fix up the appropriate maturity indices. The fruits of Solapur Anardana attained maturity at 148 days after anthesis with highest TSS (16.6oBrix), anthocyanin (456 mg/100g), anardana recovery from arils (21.6%), lowest acidity with mean fruit weight around 280.0g.

Maturity Indices for pomegranate var. Solapur Anardana

- Time taken for maturity : 148 days
- Average fruit weight : 280 g/fruit
- Titrable Acidity : 4.8%

Mature fruit of pomegranate var. Solapur Anardana

Standardization of protocol for anardana preparation

K. Dhinesh Babu, NV Singh, J. Sharma, RA Marathe

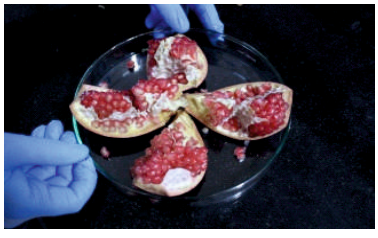
Year 2021

Anardana is the dried form of arils and arils are the edible parts of pomegranate. It is obtained by drying the arils of pomegranate in the hot air oven with air circulation facility. It is useful as souring agent. An attempt was made for preparation of anardana from sour type pomegranate varieties and accordingly, the protocol was standardized. The methodology involves the following important steps.

Select the clean fruits

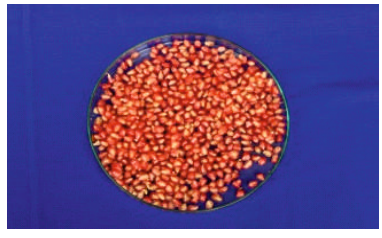
Cut open the fruits

Slice into quarters



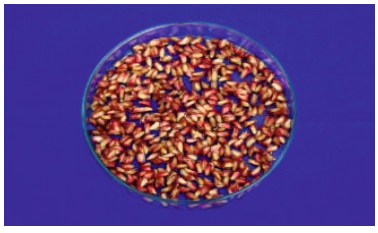
Gently tap the segments

Collect the arils from segments

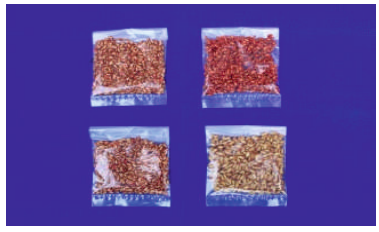


Clean / pre - treat the hygienic arils

Dry at 60°C for 10h in a dryer with raking



Collect the dried arils (anardana)



Pack the anardana in pouch

STEPS IN ANARDANA PREPARATION:

SELECTION OF GOOD QUALITY FRUITS

↓

WASHING AND CLEANING

↓

PEELING
(Incision around crown, Crown removal, Incision along fruit,
Splitting of fruits, Splitting into quarters)

↓

SEPARATION OF ARILS
(Tap the fruits, Extraction of arils,
pre-treatment 1%KMS for 3 minutes)

↓

DRYING OF ARILS
(Loading of arils in dryer; Setting the Temperature 60^{o}C,
Drying for 10 hrs)

↓

COLLECTION OF DRIED ARILS (After 8-10 hrs time period with Approx 9.9% moisture)

↓

PACKING OF ANARDANA
(Polythene Bag, Aluminium Laminated Pouch)

↓

STORAGE OF PACKED ARILS (3, 6 months, etc.)

Determination of anardana recovery from sour type pomegranate

K. Dhinesh Babu, NV Singh, and J. Sharma

Year 2021

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

Anardana recovery from pomegranate hybrids

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

Fresh arils of Solapur Anardana

Dry anardana prepared from Solapur Anardana

Influence of chemical defoliants on defoliation and twig bud sproutingin pomegranate (*Punica granatum* L.) 'Bhagawa'

R. Chandra, V.T. Jadhav, K. Dhinesh Babu, A. Maity and RA Marathe

Year 2009

An experiment was conducted on defoliation in pomegranate (*Punica granatum* L.) using chemical defoliants at the National Research Centre on Pomegranate, Solapur, Maharashtra (India). Defoliation in pomegranate is a very common practice followed in Maharashtra, Karnataka and Andhra Pradesh to induce synchronized flowering and fruiting. Ethrel, Thio-urea and Curacron alone or in combination with nitrogenous or potassic fertilizers are sprayed on pomegranate shrubs by growers during stress periods. Information on defoliation and twig sprouting percent with different chemical defoliants in pomegranate is very meager. In the present study, an attempt was made to test different chemicals for their efficacy towards defoliation and twig sprouting. Two-year-old pomegranate 'Bhagwa' plants were sprayed with Ethrel (0.3, 0.4 and 0.5%), Curacron (0.4, 0.8 and 1.2%), Dormex (0.5, 1.0 and 1.5%) and water (control) to study the effect of the defoliants and further twig sprouting during December 2008. All the treatments caused defoliation significantly over the control at the 7 th day itself. Except lower doses of Curacron (0.4 and 0.8%), all other doses of chemical defoliants caused leaf fall (defoliation) to a tune of 83.33 to 98.33% after 7 days of spraying. In case of Dormex, drying of lamina was noticed on the 2 nd day of spray but petioles were still green. However, after 15 days of spraying except control and lowest dose of Curacron (0.4%), all other treatments were at par to each other with respect to defoliation and their values ranged between 91.67-98.67%. The twig sprouting after 15 days of spraying was significantly better with lower doses of Curacron (0.4 and 0.8%), Ethrel (0.3 and 0.4%) and Dormex (0.5%). The sprouting percent in these treatments was found to be between (66.43-82.22%) and their effect was at par to each other. But the lowest sprouting (20.55%) was recorded in the control. However, the sprouting was more than 82.23% with all the doses of Curacron, Ethrel and Dormex after 21 days of spray and thus they were effective in inducing sprouting. Though Curacron 0.4%, Ethrel 0.3% and Dormex 0.5% were found to be effective for defoliation in pomegranate during the winter season, Ethephon (0.3%) was found to be most effective for defoliation (83.3% defoliation on 7 days after spray) and 91.6 twig sprouting on 15 days after spray.

Defoliation due to Ethrel 0.3%

Standardization ethephon concentration through split application for defoliation in pomegranate

K. Dhinesh Babu, NV Singh, A. Maity and J. Sharma

Year 2019

As pomegranate is basically deciduous in nature. Defoliation of plants through foliar spray of chemicals/growth regulators is useful for crop regulation through ethephon. The growth, regulator, Ethephon was applied through foliar spray to pomegranate variety Bhgawa in mrig bahar. Ethephon was applied in single spray or double spray at one week interval along with a control. The observation revealed that T3 (Ethephon @200 ppm followed by Ethephon @400 ppm at one week after spray) recorded the highest defoliation on 9 DAFS (88%) and 12 DAFS (93%).

Control (Unsprayed)

Ethephon @200ppm followed by Ethephon@ 400ppm at one week later

PLANT PROTECTION

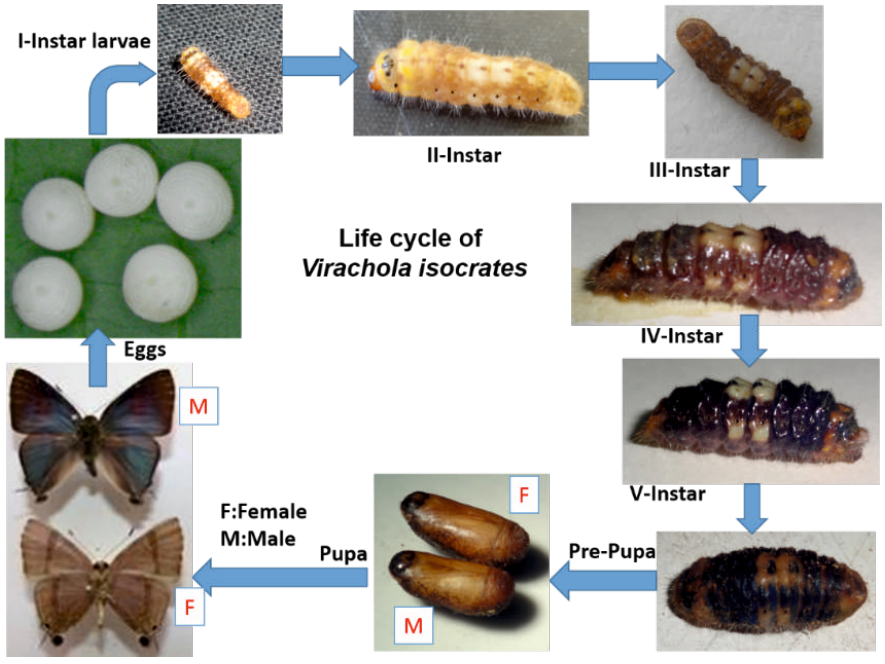
Standardized laboratory-rearing protocol for pomegranate fruit borer on semisynthetic diet

Mallikarjun, M.H., Jyotsana Sharma and U. R. Sangle

Year: 2015-2016

The pomegranate fruit borer, Deudorix (*Virachola isocrates*) Fabricius, is a highly destructive pest, causing over 50% yield losses in pomegranate crops. This pest affects both the quantity and quality of the fruits. The pest is active during the rainy, winter, and summer seasons. Adult females lay white eggs on various parts of the plant, and the hatched caterpillars bore into the fruit, causing visible holes and excreta, which attract fungi, bacteria, and beetles.

Due to a lack of a standardized mass production protocol, there is a poor understanding of the pest's biology, hindering effective pest management. Thus, studies were undertaken to standardize a mass production protocol using a semisynthetic diet. The pomegranate fruit borer was reared in the laboratory on a semisynthetic diet, and its biological parameters were assessed. The larvae completed their development in 35.3 ± 1.88 days on the artificial diet. These findings suggest that the borer can complete its life cycle on a semisynthetic diet, which is economically viable, easy to handle, and environmentally friendly, making it a recommended substrate for mass production under laboratory conditions.



Life cycle of *Virachola isocrates*

Cost-effective monitoring and mass trapping technology for managing pomegranate fruit flies to ensure quality pomegranate production

Mallikarjun, M.H., Jyotsana Sharma and U. R. Sangle

Year: 2017-2018

In India, the Oriental fruit fly, *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae), traditionally considered a non/minor pest of pomegranate, has become a significant threat under changing climatic conditions. This pest now affects 5-10 % of pomegranate fruits, causing quarantine concerns. Damage inspection reveals that ovipositional injuries by B. dorsalis lead to premature ripening and distinct color changes in the fruit. The female's initial injury and subsequent maggot development causes fruit rot, leading to premature ripening and further damage as maggots feed on the rotting fruit before pupating in the soil. Hence, studies were undertaken to develop cost-effective management techniques for fruit flies in pomegranates. Four attractants (Torula yeast, methyl eugenol, Trimedlure, Cue-lure) and three types of traps (McPhail trap, Bucket trap, water bottle trap) were tested during fruit maturity and ripening stages. Three fruit fly species were identified: *Bactrocera dorsalis, Gastrozonini,* and *B. cucurbitae,* with *B. dorsalis* being dominant, comprising 94.04% of captures in pomegranate orchards.

Results indicated that the water bottle trap with methyl eugenol was found to be the most effective and cost-efficient for trapping B. dorsalis compared to the other traps. This method has been standardized for monitoring and mass trapping of fruit flies in pomegranates to ensure effective management and quality production

Bottle trap

Pre-harvest fruit bagging technique for plant protection and improved fruit quality

Mallikarjun, M.H., Jyotsana Sharma and U. R. Sangle

Year: 2018-2019

In India, pomegranates are cultivated year-round and are subject to various biotic and abiotic stresses such as insect pests, diseases, mechanical damage, sunburn of the fruit skin, fruit cracking, agrochemical residues on the fruit, and bird damage. Good agricultural practices (GAP) are gaining popularity worldwide to produce high-quality fruit while reducing reliance on synthetic chemicals. One such practice is pre-harvest fruit bagging, which has emerged as an effective method and is integral to the cultivation of many fruit crops. Therefore, studies were conducted during 2017-18 to assess the benefits of pre-harvest fruit bagging on fruit quality and pest control in pomegranate. After fruit set, the fruits were bagged with various materials *viz*. newspaper, green net, brown paper, white muslin cloth, PPNW bags, and butter paper bags and evaluated against biotic and abiotic factors.

PPNW and butter paper bags effectively protected fruits from pests, diseases, sunburn, cracking, and bird damage. Conversely, control treatments exhibited damage from fruit borers and fruit-piercing moths, with mealybugs observed in newspaper-bagged fruits. Overall, PPNW and butter paper bags proved the most effective against biotic and abiotic factors, yielding high-quality fruits and is economically viable.

News paper

Brown Paper

Green net

Muslin cloth

PPNW bags

Control

Butter paper bags

Cost-effective technology for the management of pomegranate stem borer (*Coelosterna spinator*)

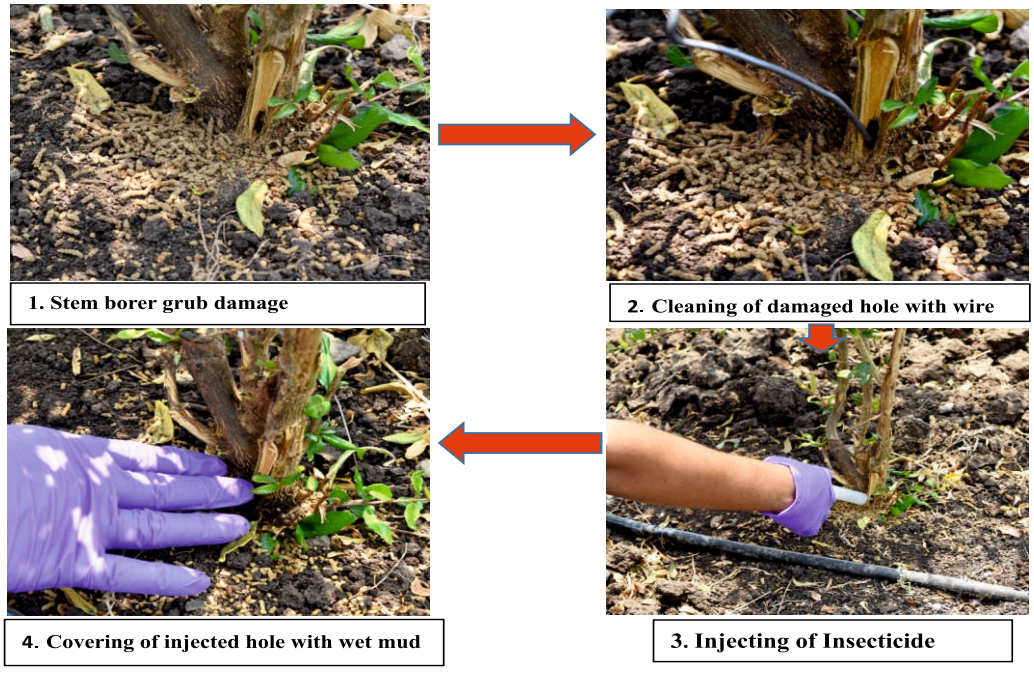
Mallikarjun, M.H., Jyotsana Sharma and U. R. Sangle

Year: 2019-2020

The pomegranate stem borer (*Coelosterna spinator*) is a polyphagous pest, traditionally considered as minor for fruit crop. However, in recent years, changing climatic conditions have turned it into a major and persistent pest. Adult beetles are active during the day, feeding by gnawing the green bark of shoots. After hatching, grubs bore into the trunk and feed on the sapwood, with holes, excreta, and dry powdered material often seen near the base of the plants. Severe infestations can lead to wilting and plant death, with infestation rates ranging from 15-30%.

Due to inadequate management practices, studies were undertaken at NRCP, Solapur to develop cost-effective management techniques for stem borer control in pomegranate. The experiment involved three treatment methods: stem injecting, drenching, and a combination of stem injecting and drenching, using a dosage of 2 ml/g/l water with different insecticides.

Among the three treatment of stem injecting and drenching, showed the 99.0 percent plant recovery from the pomegranate stem borer (*C.spinator*). Thus it is recommended that stem injecting and drenching methods were found promising and economical for the management of pomegranate stem borer with different insecticides.



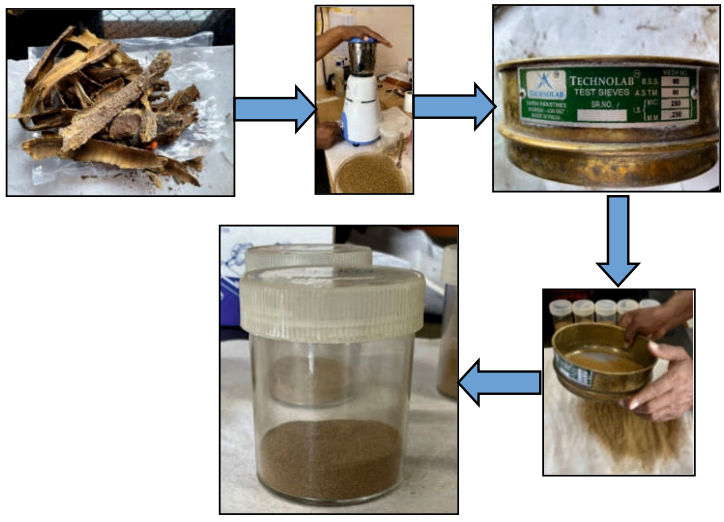
Standardized laboratory-rearing protocol for pomegranate shot hole borer *Euwallacea fornicatus* on Semisynthetic Diet

Mallikarjun, M.H., R.A. Marathe, (Manjunatha, N, Somnath Pokhare) and Fand, D.N.

Year: 2020-2021

Pomegranate shot hole borer (PSHB) is a small beetle that has become a major pest infesting the collar region of the plant by making numerous pin or shot holes causing a discontinuity in the conducting vessels and affecting the conduction of water and nutrients to the upper portion of the plant. Consequently, the drying of the twigs becomes imminent. The drying progressed from the tip towards the base and in severe cases, the entire plant dried up and its infestation varied from 10-80%. Due to a lack of a standardized mass production protocol, there is a poor understanding of the pest's biology, hindering effective pest management. Thus, studies were undertaken at NRCP, Solapur to standardize a mass production protocol using a semisynthetic diet. An experiment aimed to standardize the *In-vitro* rearing protocol for the shot hole borer beetle, *Euwallacea fornicatus,* using three media variants: Media-I (PDA + symbiotic fungi), Media-II (PDA + pomegranate bark dust), and Media-III (semisynthetic medium). The modified semisynthetic medium, containing pomegranate bark sawdust, successfully supported the *in-vitro* rearing of shot hole borer beetles associated with pomegranate wilt, allowing for studies on their biology and aetiology. This study improves our understanding of the beetle's tunneling behavior and biology while demonstrating the feasibility of *in-vitro* rearing. The beetles in semisynthetic Media III, survived for 35 days and completed one life cycle.

These findings suggest that the shot hole borer can complete its life cycle on a semisynthetic diet, which is economically viable, easy to handle, and environmentally friendly, making it a recommended substrate for mass production under laboratory conditions.



Media-III Ingredient	Quantity (g/mg/ml)
Yeast	6
Casein	15
Pomegranate plant bark sawdust	100
Sucrose	10
Agar	15
Wesson's salt mixture	1.5
Sterile distilled water	600
Streptomycin	350 mg

Cost-effective IPM technology for the management of pomegranate shot hole borer (*Euwallacea fornicatus*)

Mallikarjun, M.H., R.A. Marathe, Manjunatha

Year: 2020-2021

Pomegranate Shot Hole Borer (PSHB) is a polyphagous pest, traditionally considered a minor pest. However, in recent years, changing climatic conditions have turned it into a major and persistent pest. It is a small beetle infesting the collar region of the plant by making numerous pin or shot holes causing a discontinuity in the conducting vessels and affecting the conduction of water and nutrients to the upper portion of the plant. Consequently, the drying of the twigs becomes imminent. The drying progressed from the tip towards the base and in severe cases, the entire plant dried up and its infestation varied from 10-80%. Due to inadequate management practices, studies were undertaken at NRCP, Solapur to develop cost-effective management techniques for shot hole borer management in pomegranate. The experiment involved three treatment methods: Stem pasting, stem spray and drenching, using a dosage of 2 ml/g/l water with different pesticides. All three methods were found promising for managing the pomegranate shot hole borer and are recommended for real farm applications as cost-effective management techniques for shot hole borer management.

Stem Pasting

Drenching

Modified IDM/IDIPM (Integrated Disease and Pest Management Schedule) for managing bacterial blight in pomegranate

Jyotsana Sharma, Sharma K.K., K. Dhinesh Babu, Jadhav V.T. and R.A., Marathe

Year: 2008

Bacterial blight caused by *Xanthomonas axonopodis* pv. punicae was the major impediment in successful cultivation of pomegranate, when ICAR-NRC on Pomegranate, Solapur was established in 2005. The disease was causing huge losses (80- 100%) threatening its cultivation. The ICAR-NRCP, Solapur developed a robust integrated disease and pest management schedule (IDIPM) and successfully demonstrated it in the bacterial blight affected farmers' orchards in a network mode in different states. This instilled the confidence among the farmers and resulted in huge expansion of pomegranate area under cultivation, production, productivity and livelihood security of around 2.5 lakh farm families in India.

Year before implementation of IDIPM

After implementation of IDIPM

Effect of ICAR-NRCP developed IDIPM on pomegranate bacterial blight management

Standardized vacuum packaging of *Corcyra cephalonica* eggs to enhance shelf life for mass production of *Trichogramma spp.*

Mallikarjun, M.H, Jyotsana Sharma and U.R. Sangle

Year 2019-2020

The eggs of the rice moth, Corcyra cephalonica, are widely used in the mass production of natural enemies like Trichogramma spp. and green lacewings. However, their short shelf life is a challenge. This study evaluated the impact of vacuum packaging and storage temperatures on the viability of Corcyra eggs. Eggs were vacuum-packed and stored at 5°C, 10°C, and 15°C, with hatching rates assessed after 5, 10, and 15 days. The vacuum packaging caused some damage to the eggs, but vacuum-packed eggs stored at 15°C for 5 days showed promising results, with Trichogramma chilonis parasitizing 32.65% of the eggs and producing 58.42% female progeny. The findings indicate that vacuum packaging, combined with cold storage, could extend the shelf life of Corcyra eggs, making them more viable for mass production of natural enemies like T. chilonis, particularly when stored at 15°C for 5 days.

Parasitization of vacuum-packaged eggs by *T. chilonis*

Standardized laboratory rearing protocol mass production of predatory anthocorid bug *Blaptostethus pallescens* on *Scirtothrips dorsalis*

Mallikarjun, M.H, Jyotsana Sharma and U.R. Sangle

Year 2019-2020

A standardized laboratory rearing protocol for Scirtothrips dorsalis has been developed to facilitate research on the predator-prey dynamics between Scirtothrips dorsalis and natural enemies like the predatory anthocorid bug Blaptostethus pallescens. This technology enables the consistent mass rearing of thrips under controlled conditions.

Procedure:

1. Collection and Initial Setup: Scirtothrips dorsalis are collected from rose plants and reared on fresh red rose flowers in the lab. The rose flowers are placed into glass vials filled with water, with stalks wrapped in cotton to maintain hydration.
2. Containment System: The setup is covered with a glass chimney and sealed with parafilm at the base to prevent thrips escape. The top of the chimney is covered with black muslin cloth secured with a rubber band.
3. Maintenance: Fresh rose flowers are introduced every 2–3 days, encouraging the migration of thrips from old flowers to fresh ones. This ensures a continuous population of thrips for study.

This technology supports the mass rearing of S. dorsalis, aiding in predator studies and biological control development with B. pallescens.

Mass Production of *B.pallescens* on *S.*dorsalis

Standardization of Mass Production Protocol for *Trichogramma spp.* Using *Corcyra cephalonica* Eggs

Mallikarjun, M.H, Jyotsana Sharma and U.R. Sangle

Year 2019-2020

This technology outlines a standardized protocol for the mass production of Corcyra cephalonica eggs, which serve as a host for Trichogramma spp. in biological control programs.

Rearing Box Specifications:

·Box size: 15x30x45 cm

Rearing Medium Composition:

A balanced medium is essential for optimal growth:

·Broken Bajra (Pearl Millet): 2.5 kg

·Groundnut Seed Powder: 70 g

·Yeast Powder: 5 g

·Streptomycin Sulphate: 0.6 g

Egg Inoculation:

·Dosage: 0.125 cc of Corcyra eggs per box The eggs are spread evenly over the medium for uniform larval development.

Rearing Conditions:

·Temperature: 28 ± 2°C

·Relative Humidity: 70–75%

·Photoperiod: 12:12 (light/dark)

Harvesting : After 4–6 weeks, Corcyra moths lay eggs, which are collected and stored for Trichogramma mass rearing. This protocol ensures a consistent supply of viable Corcyra eggs, supporting large-scale mass production of Trichogramma spp. for the management of pomegranate pests.

Mass production *Trichogramma spp.* on *C. cephalonica*

POST HARVEST TECHNOLOGY & VALUE ADDITION

Development of pomegranate juice & RTS beverage

Gaikwad, N.N., Babu, K.D. and Pal, R.K.

Year: 2014-16

Pomegranate is one of the important fruit of tropical and subtropical regions where it enjoys the consumer's patronage for its nutritional and medicinal properties. Pomegranate juice is nutritionally an important beverage since it is consumed frequently for its bioactive compounds (such as anthocyanins, ellagic acid, phytoestrogen flavonoids and tannins). The process protocol for development of pomegranate juice and RTS beverage has been standardized. These products have good acceptability among masses and provide entrepreneurial opportunity due to market demand owing to its health benefits. The fruits affected by biotic stress on peel with low market value can be gainfully utilized for the processing and value addition in to juice and ready-to serve (RTS) beverage. The technology of the pomegranate juice and ready to serve beverage development will include important steps such as selection of fruits, sorting, storage before processing, fruit washing (chlorine water wash followed by the normal water wash), juice extraction, decantation, sterilization of utensils, thermal pasteurization of the juice, filling and sealing of the bottles, storage, quality analysis. The results of storage studies in PP bottles revealed that all the pomegranate juice and RTS beverage stored at low temperature (5˚C). were within safe microbial count of 2 log cfu/ml up to 60 days of storage.

Pomegranate Juice and RTS Beverage

Minimal processing and shelf life extension of minimally processed arils

Gaikwad, N.N. and Pal, R.K.

Year: 2015-16

The minimally processed or "ready-to-eat" pomegranate arils are more popular due to their convenience, high value, unique sensory characteristics and health benefits. However, low shelf life of pomegranate arils due to susceptibility to deterioration has been biggest impediment in popularization of fresh aril consumption. Hygienic processing, passive Modified Atmosphere Packaging (MAP) combined with low temperature storage has been successfully used to prolong the shelf life of pomegranate arils. The fruits has to be cleaned using chlorine water (200 ppm sodium hypochlorite solution) followed by normal water wash. The washed fruits were mopped for the surface moisture removal. The mopped fruits shall be transferred to the high care area with temperature of 16-18°C. The manual aril extraction has been recommended using turning knife for transverse and longitudinal cuts. The arils has to be manually extracted and treated with aloe vera gel solution or alternatively can treated with ascorbic acid and citric acid solution in 1:1 proportion. The treated arils packaged in the punnets with BOPP film on the top. The punnests so packaged in primary packaging has to be packaged in secondary packaging of thermocol box with ice gel for maintaining cold chain. This process will enhance the shelf life up to 14 days on the basis of sensory and microbial quality.

Aloe vera gel treated arils on 14th days after storage

Extraction of the virgin pomegranate seed oil

Gaikwad, N.N. and Pal, R.K.

Year: 2015-16

The present invention is related to process protocol for extraction of virgin pomegranate seed oil. The process involves use of waste /by-product of pomegranate juice industry *i.e.* marc (leftout portion after juice extraction from pomegranates). The seeds are separated from marc manually. The seeds having juice sack over them from which juice is already extracted are soaked in water for different time periods for optimizing seed extraction process. The soaking time of 72-96 hours was finalized for seed extraction. The pulper is operated at 800 rpm for recovery of clean seeds. The oil extraction experiments were conducted to determine optimum moisture content (4%) on dry basis for higher recovery of pomegranate seed oil. The dried seed samples were ground in grinder to size smaller than 700 micron. The recovery and fatty acid profile of the samples extracted at different temperatures were studied. The temperature of 60°C was finalized based on oil recovery and corresponding loss in antioxidant capacity and fatty acid composition with respect to linolenic acid methyl ester, linolic acid methyl ester and eicosanoic acid methyl ester in oil sample at particular temperature.

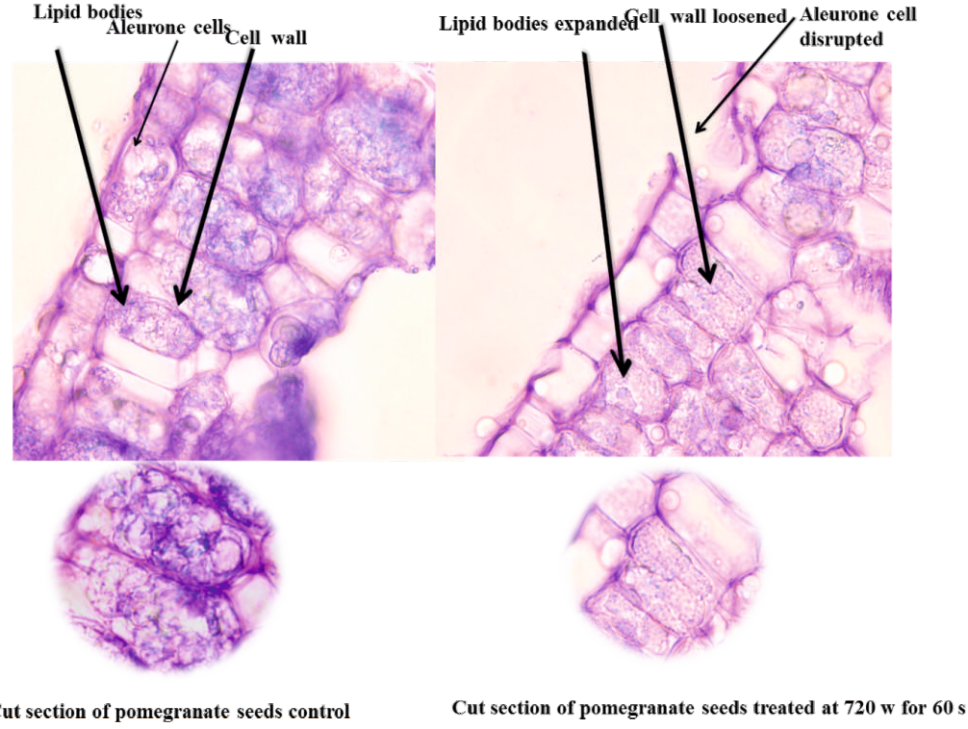
Virgin pomegranate seed oil

Microwave pre-treatment of pomegranate seed oil for improving recovery and quality

Gaikwad, N.N., Babu, K.D. and Pal, R.K.

Year: 2016-17

The studies on microwave pretreatment of pomegranate seed oil were conducted. The seed samples were pretreated in microwave oven at microwave power levels of 360, 540, 720 and 900 watt for pretreatment time of 30, 60, 90, and 120 seconds. The oil was extracted at three levels of extraction time (3, 4 and 5 h). The extraction yield was increased with increase in wattage and pretreatment time. The microwave pretreatment also reduced the extraction time. The microwave pretreatment does not affect the oil quality parameters such as per cent free fatty acid, acid value, saponification value, ester value, per cent glycerin and antioxidant capacity. The thin cut section of pomegranate seed kernel was studied under microscope with camera. Microwave pretreatment on pomegranate seeds show that aleurone cell gets disrupted, cell walls containing lipid body gets loosened and the lipid bodies released. The optimum conditions for microwave pretreatment were 720 watt of microwave power, pretreatment time of 60 s and extraction time of 4 h.



Pomegranate seed cut section under microscope at 1000X magnification

Improvement in storability of the pomegranate fruits with wax coating and packaging

Gaikwad N. N., Babu, K.D. and Pal, R.K.

Year: 2016-17

Improvement in storability of the pomegranate fruits is beneficial for long distance transport through sea for export, and storage to avoid distress sale during glut situation. The fruits were wax (shellac 18 %) pretreated in commercial waxing line followed by packaging in Flexfresh™ liner bags where 3.5 kg fruits were accommodated. The packaged fruits were placed in open top cartons box at 5±0.5℃ at 90± 1% RH. The quality parameters of stored fruits were studied at 15 days interval for storage period of 90 days.

The control fruits were acceptable up to 30 days only followed by the wax pretreated fruits up to 45 days on the basis of sensory score with Physiological Loss in Weight (PLW) of 7.00% and 7.10% respectively. The fruits packaged in liner bag either pretreated or non-treated with wax were found to be acceptable on 90th days of storage with low PLW of 4.30 and 4.36% respectively. The effect of wax pretreatment was found to be non-significant on storability of fruits however effect of liner bag was highly significant. The fruits were removed from cold store and evaluated at every 15 days. The fruits were waxed, packaged and were stored at room temperature, mall condition. The experiment on post cold storage shelf life of fruits stored for 90 days revealed shelf life of 4 and 5 days respectively for storage at room temperature and mall condition (20 °C) respectively.

Control fruits on 0th Day

Shellac wax treated and packaged in liner bag on 90th Day of cold storage

The fruits appearance before and after cold storage

Fruit based carbonated drink from pomegranate and grapes

Gaikwad, N.N. and Pal, R.K.

Year: 2016-17

The present study involved development of carbonated ready to serve beverage from pomegranate and grape juice blend. The blended carbonated RTS is developed with various blending proportions for pomegranate (Bhagawa Cv.): grape (Medica Cv.) and various levels of carbonation. The Ready-to-Serve carbonated drink is prepared with target Brix: Acidity ratio of 30 and TSS of 9 °B and later acidity was adjusted to 0.30 %.

The anthocyanin, ascorbic acid content and total phenols were higher in pomegranate juice as compared to the grape juice. The sensory analysis revealed that the blending of pomegranate: grape juice in 60:40 proportion with carbonation at 9 g/l was found to be most acceptable combination based on sensory score for four parameters with highest score for overall acceptability. The total phenol content 445.00 mg/l of GAE, total anthocyanin 34.02 mg/100ml, Ascorbic acid 2.22 mg/100ml and antioxidant capacity 3.53 mg AAE /100ml. The storability of blended beverage was found to be 3 months at low temperature storage at 5°C and that for ambient conditions was two months.

Carbonation unit and carbonated pomegranate and grape blended RTS beverage

Pomegranate Seed Cake Based Fiber Rich Cookies

Gaikwad, N.N. and Babu, K.D.

Year: 2017-18

Pomegranate seeds are juice processing industry by-product and can also be extracted from unmarketable fruits. Pomegranate seed cake (PSC) is the byproduct of the pomegranate seed oil extraction process. PSC is a good source of proteins, fats and fiber. The pomegranate seed cake recovery in seed oil production is around 80%. The technology has been standardized for development of pomegranate de-oiled seed cake-based cookies. PSC extracted from cold press is safer for consumption as compared to solvent extraction method and is utilized for development of cookies. The optimized conditions for development of cookies were 23.92% PSC, 45.27 g fat and 26 minutes of baking time. The PSC cookies have fiber (8.47 %), protein (5.57 %), hardness (155.81 N) and high overall sensory acceptability. The wheat flour has been replaced to the tune of 23.92% by pomegranate seed cake in cookies. Technology is capable of employment generation as well as waste utilization.

Pomegranate seed cake based cookies

Active modified atmospheric packaging of minimally processed pomegranate arils

Gaikwad, N.N.

Year: 2019

Pomegranate is difficult to eat fruit, minimal processing of pomegranate provide hygiene and convenience. Minimal processing involves fruit reception, temporary storage, fruit washing, surface moisture removal, cutting, aril extraction, weighing, and modified atmospheric packaging in punnet, secondary packaging and transportation through refer van. An experiment was conducted with five different treatment combinations which included T_1-Air, T_2-100% N_2, T_3-20% O_2+ 10% CO_2 + 70% N_2, T_4-30% O_2+ 10% CO_2+ 60% N_2, T_5-40% O_2+10% CO_2+ 50% N_2. The pomegranate fruits are washed, mopped in and arils were extracted at low temperature (18°C), weighed and packed in punnets with peelable polylaminate film over its top. Based on sensorial and microbial quality the best treatments found were T_4 and T_5 after 18 days of storage. The hygenic processing and modified atmospheric packaging (MAP) with super atmospheric O_2 can extend shelf life of pomegranate arils up to 18 days at 5°C.

Active modified atmospheric packaging of pomegranate arils

Development of Probiotic Pomegranate Juice

Gaikwad, N.N., Babu, K.D. and Giri N.A.

Year: 2020

Probiotics are non-digestible food ingredients that stimulate the growth or activity of bacteria in the gastrointestinal tract. The probiotics are being increasingly used as food supplements due to maintenance of healthy gut microflora. The probiotic bacteria's also lose their viability during delivery through the gastro-intestinal tract due to gastric juices present. An experiment was conducted to study the effect of co-encapsulation of prebiotics viz. inulin and GOS (*Galacto oligosachhride*) at various concentrations along with probiotic microorganisms *L. Casei* and *L. acidophilus* in simulated digestive system and pomegranate juice on survivability of probiotic strains. The log reduction is highest in control samples and is low in samples with prebiotic for both microorganism and both prebiotics. The lowest log reduction in probiotic count can be observed for *L. Casei* in prebiotic GOS 1.5%, followed by Inulin 1.5%, GOS 1% and Inulin 1%. The lowest log reduction in case of *L. Acidophilus* was also observed in GOS 1.5% followed by GOS 1%, GOS 0.5% and inulin 1.5%. The survivability of probiotics in pomegranate juice shown that probiotic count on the 90th day of storage in microencapsulated samples with prebiotic (GOS 1.5%) was 9.85 and 9.75 log cfu/ml respectively for *L. Casei* and *L. Acidophilus* which is significantly higher than that of microencapsulated beads and control.

Probiotic pomegranate juice

Pomegranate seed based mouth freshener

Gaikwad, N. N., Maity A., Giri, N.A. and Babu, K.D.

Year: 2021

Pomegranate seeds are by-product of juice processing industry and can also be extracted from unmarketable fruits. Pomegranate seeds are rich in conjugated linolenic acid, protein, fiber etc. A crunchy mouth freshener has been developed from the pomegranate seeds. For the preparation of mouth freshener, pomegranate seeds extracted by cleaning marc (leftover portion of arils after juice extraction) are dried, blended with mix of sugar syrup and spices followed by heat treatment in microwave oven, cooling and vacuum packaging. The mouth freshener has crude fiber (3.89%), total phenols (158.24 mg/L GAE). It is also rich in micronutrients Calcium (2.4 g/kg), Magnesium (1.92 g/kg), Ferrous (222mg/kg), Manganese (14 mg/kg), Zinc (47 mg/kg) and Copper (57 mg/kg). The high value mouth freshener can be replacement for *Gutkha, tobacco, panmasala* etc. owing to good chewability and high sensory acceptability. The pomegranate seed-based mouth freshener development can utilize the seed waste and has considerable employment generation potential as required for building an Atmanirbhar Bharat.

Pomegranate seed based mouth freshener

Foam mat drying of pomegranate juice

Gaikwad, N.N., Giri, N.A. and Marathe, R.A.

Year: 2020

Pomegranate juice is well known for health benefits; however, the seasonality of the fruits, susceptibility of the pomegranate juice for microbial contamination, costly transportation due to higher volume curtails its accessibility to masses. The foam mat drying is an innovative approach for the drying of the juices especially with higher sugars. The experiment was carried to study the effect of different percentages of the whey protein isolate (WPI) as foaming agent and carboxy methyl cellulose (CMC) as stabilizing agent were observed on foam expansion, foam density and foam drainage volume. The 10 % whey protein isolate and 0.25 % of CMC has shown the best results in terms of foam expansion, foam density and foam drainage volume. The drying experiments were conducted up to the moisture content of 4 % (db). at 50, 60 and 70 °C, and foam thickness of 3 and 6 mm. Based on the drying time required and bioactive compound retention the 60°C temperature and 3 mm drying thickness was selected for the drying. At this selected temperature and thickness the drying time of 180 minutes with optimum retention of the bioactive compounds in the reconstituted juice viz. total phenol 2678.87 g/L GAE, antioxidant capacity 41.19 mg/100ml AAE, anthocyanin 24.60 mg/100ml, and ascorbic acid 14.17 mg/100 ml was observed.

Foam mat dried pomegranate juice powder

Pomegranate wine from Cv. Bhagawa, Ganesh and Arakta a comparative evaluation

Gaikwad N. N., Giri, N.A. Babu, K.D. and Marathe, R.A.

Year : 2021

Pomegranate wine from the Cv. Bhagawa, Ganesh and Arakta was developed. The juice of all the cultivars was extracted, clarified and pasturized. The TSS was adjusted to 24°B of the juices of three cultivars. The fermentation was carried out in anaerobic condition using yeast culture of *Saccharomyces cerevisiae* in incubator shaker. TSS (°B) values of different varieties of pomegranate were 16.10, 17.10 and 15.80 for Bhagawa, Ganesh and Arakta respectively. The Arakta juice had high amount of bioactive compounds such as the phenolics, anthocyanins, flavonoids followed by Bhagawa and Ganesh. The fermentation of the wines of the Bhagawa, Ganesh and Arakta completed in the 21 days period with reduction in TSS and sugars during the fermentation process. The yeast cell growth count during fermentation shown the distinctive log, stationary and death phase. The total phenols, anthocyanin content, flavonoid content and consequent antioxidant capacity of pomegranate wine of the Arakta is higher followed by Bhagawa and Ganesh. The developed wines from Bhagawa, Ganesh and Arakta had the ethanol content (13.27 to 13.65%), residual sugar (6.81 to 8.42 %) and can be categorized as natural sweet wines. The presence of large number of volatile compounds viz. (esters, alcohols, acids, alkanes, olefins, diole, aldehydes) in pomegranate wine is due to the yeast metabolism and fermentation. The Arakta wine was found to be the best acceptable wine followed by the Bhagawa and Ganesh in sensory evaluation for parameters such as color, aroma, taste, and style.

Wines from different varieties of the pomegranate

Osmotic assisted convective drying of pomegranate arils

Gaikwad N.N., Giri N.A. and Marathe, R.A.

Year : 2021

The convective drying method is used commercially for pomegranate aril drying. However, its time consuming, energy intensive, and affects the quality. The osmotic pre-treatment has been resorted prior to convective drying for improving drying performance and quality. The quadratic models have adequately explained osmotic pretreatment and the optimum osmotic pre-treatment conditions were temperature (48.52°C), time (209.65 min), and TSS (51.31° B). The osmotic pre-treatment at optimum conditions followed by the convective tray drying reduced the drying time by 9 hours and the mean energy consumption by 0.172 MJ/g. The light microscopy revealed rupture and breakage of the honeycomb-like cellular structure of the pomegranate aril. The quality analysis revealed that the texture (softness) and TSS improved by 11.75 N and 4.2° B likewise sensorial quality such as taste, mouth feel, and overall acceptability of the osmo-assisted tray-dried arils significantly improved over the tray-dried. However, there is a minor loss of 15.48, 12.52, and 15.88% in anthocyanin, phenols and antioxidant capacity in osmo-assisted tray-dried compared to tray-dried. The osmo-assisted tray dried arils were found to be free of microbial growth at refrigerated and room storage conditions even after storage for 6 months with MAP (30% CO_2 :70% N_2).

(a) fresh, (b) tray-dried, and (c) osmo-assisted tray-dried pomegranate arils

Low calorie pomegranate fruit drink

Namrata A. Giri, Gaikwad, N.N. and R. A., Marathe

Year: 2020-2021

Low-calorie drinks are promoted as healthy alternatives to sugar-sweetened beverages. Free or added sugars have been acknowledged as a readily available source of energy, which accounts for a large percentage of daily energy intakes, leading to excess calories, weight gain and obesity. The use of natural and artificial sweeteners has been optimized for the development of low calorie pomegranate fruit drink. It was prepared using natural (stevia) and artificial sweeteners (sucralose and aspartame) by substituting sucrose (refined sugar) at different percentage. The total sugar content of beverage was significantly reduced from 15.03% to 4.5% due to use of non-calorific sweeteners. The energy value was also reduced from 60.12 kcal/100ml to 18 kcal/100ml. The sensory evaluation resulted to higher panel score to the beverage containing 75% stevia and 25% sucrose. The developed low calorie pomegranate fruit drink is unique in terms of reduced calorie content. It is substitute for the individuals who are conscious about their caloric intake or those seeking healthier beverage options. The developed beverage is suitable for the consumers on low calorie diet and also for patient with type-II diabetics.

Low calorie pomegranate fruit drink

Pomegranate juice based blended RTS drink

Namrata A. Giri, Gaikwad, N.N. and R. A., Marathe

Year: 2020-2021

The blended juices are superior to single fruit juice beverage with artificial colour and flavor. The mixing of fruit juices to beverages not only improves the nutrition but also the sensorial characteristics. On the other hand, the present day consumers wish to enjoy the pleasure of sweetness of any fruit drink with reduced calories.

The purpose of blending of lime and ginger juice in pomegranate juice was to improve the flavour and nutritional properties of the drink as single strength pomegranate fruit drink lacks in flavour and other organoleptic properties. The best combination of 85% pomegranate juice along with lime and ginger juice which is nutritious, overall acceptable blended RTS drink and provides total phenols (236.2 mg GAE/l), anthocyanin content (4.61 mg/100 ml), antioxidant activity (7.54 mg/100 ml), ascorbic acid content (1.80 mg/100g) and energy value (53.08 Kcal/100g). When the developed RTS compared nutritionally and organoleptically with RTS drink from pomegranate juice (control) showed 40% increase in antioxidant activity, 20% increase in ascorbic acid, 5% decrease in calorific value and higher hedonic score as well as score for overall acceptability. Furthermore, this blended RTS drink could be safe to consume or stored for the period of 90 days at low temperature (5°C).

Pome lemon ginger blend drink

Pomegranate- karonda mix fruit jam

Namrata Giri, Gaikwad, N.N. and R. A., Marathe

Year: 2020-2021

The pomegranate-karonda mix fruit jam was developed with the purpose of the utilization of nutritional benefits of the highly underutilized karonda fruit along with pomegranate. The processing of pomegranate and karonda fruit into mix fruit jam created distinct and delicious product by combining the natural sweetness of pomegranate with the tartness of karonda fruit.

The best quality of jam with good spreadability and sensory properties was obtained by blending of 50% karonda fruit pulp with 50% pomegranate juice. The obtained pomegranate-karonda mix fruit jam had 65°Bx TSS and provides 260kcal/100g. The combination of pomegranate and karonda fruits in jam creates a unique flavour profile that is both tangy and sweet. Commercial jams often contain high amounts of sugar, artificial colour and flavours. It can attract health-conscious consumers as the product has the health benefits of both the fruits. This may has diverse applications and can be used in various culinary applications, such as spreading on toast, pairing with cheese, topping desserts, or incorporating into savory dishes as a glaze or sauce.

Pome karonda fruit jam

Development of fiber-enriched muffins using pomegranate peel powder

Namrata Giri, Gaikwad, N.N., Manjunatha, N., Pinky Raigond and R. A., Marathe

Year: 2022-2023

Pomegranate peel (50% of fresh fruit weight) is a by-product from pomegranate processing industries and is known as a rich source of bioactive compounds and dietary fibers. It also has good antioxidant and antimicrobial properties. In the present investigation, the potential use of pomegranate peel powder (PPP) in muffins as a natural preservative and fiber rich source was studied. Refined wheat flour was substituted with PPP at different percentage levels. The nutritional value of muffins was improved by a significant increase in the fiber content (4.39 to 10.66%), total phenols (0.443 to 48.53 mg GAE/100g), antioxidant activity (75.94 to 99.36%), calcium (200.33 to 294.33 mg/100g), potassium (227.33 to 425.33 mg/100g) and magnesium (96.33 to 288.33 mg/100g). The PPP added muffins had the fiber content of 10.66 % which was 142.82 % higher than control sample. The muffin samples were organoleptically acceptable up to the level of 8% PPP. The free fatty acid content, peroxide value, and microbial count of the muffin with 8% PPP were significantly lower than the control sample. A muffin with 8% PPP had more oxidative and microbial stability than the control sample for a storage period of 21 and 28 days at ambient and refrigerated temperatures respectively.

Muffins

Pomegranate juice fortified Aonla candy

Namrata Giri, Gaikwad, N.N. and R. A., Marathe

Year: 2020-2021

Aonla candy has considerable demand in domestic as well as international market. Further, to strengthen its demand, retention of quality attributes and its storability are of considerable importance. Aonla candy is usually prepared by dipping in sugar syrup followed by cabinet drying, which results in loss of nutritional quality. Hence, there is need to fortify it with nutrition-rich sweeteners. Therefore, use of pomegranate juice in the preparation of aonla candy will increase its nutritional value as well as colour acceptability. The developed pomegranate juice fortified aonla candy provides 250 kcal/100g calories, 60.75g carbohydrates, 34.31mg GAE/100g total phenols, 228 mg/100g ascorbic acid and 0.60 mg/100g anthocyanin. The developed product is ready to eat confectionary product. It is nutritious and healthy confectionary product, suitable for children. It is also rich in ascorbic acid and bioactive compounds due to fortification of pomegranate juice.

Pomegranate juice fortified Aonla candy

Pomegranate squash blended with muskmelon

Namrata Giri, Gaikwad, N.N. and R. A., Marathe

Year: 2022-2023

Pomegranate squash with enhanced nutritional and sensorial properties was developed by blending it with muskmelon. The pomegranate squash was prepared by blending muskmelon pulp in pomegranate juice at different concentration. The juice of both the fruits was blended as per the formulation and squash were developed with the specification of juice/pulp: 25%, TSS: 40°Bx and acidity: 1.5%. The significant decrease in anthocyanin and total phenols content were found from 13.47 to 3.90 mg cyanidin /100ml and 504.4 to 84.4 mg GAE/L when increase in the percent of muskmelon in blend. Moreover, the ascorbic acid content was recorded significantly higher in squash containing increase in the level of muskmelon juice. Based on the total sensory score received, the sample prepared with 75% pomegranate juice and 25% muskmelon juice was found overall acceptable. It provides 114.96 kcal/100ml calories, 28.74g/ 100ml carbohydrates, 9.5mg/100ml ascorbic acid, 404.4 mg GAE/L total phenols and 3.99 mg/100ml AAE antioxidant capacity. The squash needs dilution in the ratio of 1:3 proportions. This drink is having improved flavour and sensory properties. It is refreshing, nutritious, rich in antioxidant, high ascorbic acid content with no preservatives.

Pome muskmelon squash

Pomegranate based Iron rich RTS drinks

Namrata Giri, Gaikwad, N.N. and R. A., Marathe

Year: 2022-2023

The deficiency of iron is the main cause of Anemia. The single cost effective approach is food fortification using iron that can provide enduring improvement of iron the ready to drink beverage is good vehicle for iron fortification and also a source of utilization of underutilized fruits. An iron rich drink was developed using pomegranate juice, karonda juice and aonla juice. The karonda juice was found rich in iron (20.87mg/L) as compared to pomegranate and aonla juice. However, ascorbic acid content was found highest in aonla juice (185 mg/100ml). The increase in the level of karonda juice in the formulation resulted to increase in the iron content of drink. The nutritional evaluation of the optimized pomegranate iron rich drink showed that, the iron content was increased by 31.91% and ascorbic acid content by 10.66% as compared to control (pomegranate RTS drink without blend of karonda and aonla juice). The prepared drink may fulfill the iron requirement of 32.63% (Men), 21.37% (women) & 22.96% (pregnant women) when consumed 100 ml per day according to RDA.

Iron rich drink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