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RESEARCH ARTICLE

Evaluation of sour-type pomegranate germplasm for field performance, fruit yield and anardana quality attributes

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Abstract

Thirty-one sour-type pomegranate genotypes have been evaluated for growth, fruit yield, physico-chemical attributes and anardana quality in randomized complete block design under hot arid climate. Germplasm CIAH PG-1 had highest fruit number/plant 46.92 as well as fruit yield 12.40kg/plant, followed by Gul-e-Shah R. Pink (42.74 fruit number/plant and 10.98kg/plant) and Tujetis EC-104347 (42.75 fruit number/plant and 9.96kg/plant). The highest fruit weight 263.84g was also recorded in CIAH PG-1. The highest aril content (67.71%) was observed in CIAH PG-1 which was statistically at par with Khog and Bedana Seedless. The highest juice acidity was recorded in Tujetis EC-104347 (3.57%), statistically alike CIAH PG-1 (3.50%). The lowest dehydration ratio was observed in CIAH PG-A-3 (2.23), comparable to CIAH PG-A-5 (2.31). Maximum anardana recovery was reported in CIAH PG-1 (2.23kg/plant) which was followed by Tujetis EC-104347 (1.93kg/plant) and Gul-e-Shah Rose Pink (1.82kg/plant). The anardana acidity ranged from 4.63 to 7.99% and the promising germplasms with more than 7% acidity were AHPG H-2, Tujetis EC-104347, CIAH PG-1, Khog, Gul-e-Shah, IC-318712 and Tabest. Based on nine points hedonic scale, CIAH PG-1 received the highest overall acceptable sensory score of 8.67, followed by Tujetis EC-104347 and Gul-e-Shah R. Pink at 8.37 and 8.23 respectively. In conclusion, CIAH PG-1 demonstrated exceptional performance across various matrices, including field performance, anardana recovery, quality and sensory attributes, which establishes it as the superior choice for quality anardana production. Tujetis EC-104347 and Gul-e-Shah R. Pink also observed suitable option for processing applications and valuable contributors to future breeding programs.

Keywords

anardana recovery; germplasm; physico-chemical attributes; sour-type pomegranate

Introduction

Pomegranate (*Punica granatum* L.) is a potential fruit crop of arid and semi-arid regions of India. It is mainly classified into 2 groups *i.e.* sweet-type and sour-type. The sweet-type pomegranate fruits are primarily used for table and juice purpose, while sour-type are used for anardana preparation along with other value-added products particularly in ayurveda. Pomegranate offers enormous health benefits and serving as a natural source of antioxidants, particularly anthocyanins, hence, it is often hailed as "Super

food or Food medicine". Anardana is an acidulant spice used in the Indian cuisines for sour-sweet taste (1). It is prepared from the dehydrated seeds of pomegranate fruits wherein the seeds are dried along with adhering pulp. It is also used to add flavour to vegetables and legumes as well as meat dishes. Several formulations of anardana have been used as ayurvedic medicines in the treatment of dysentery, diarrhoea, stomach-ache, inflammations hymenoletidosis, dyspepsia, bronchitis and cardiac problems (2). The sour pomegranate fruit has also got various medicinal properties including laxative, diuretic and used for curing vomiting, sore throat, earache, chest troubles, spleen complaints, bronchitis, liver and kidney disorders (3).

In India, pomegranate cultivation is concentrated in the states of Maharashtra, Gujarat, Karnataka, Andhra Pradesh, Madhya Pradesh, Rajasthan, Telangana and Tamil Nadu. The crop covers an area of over 2.63lakh ha with an annual production of 31.96lakh tonnes and a productivity of 12.15tonnes/ha in India (4). Different parts of pomegranate tree such as leaves, fruits and bark have traditionally been used for medicinal and other properties (5). These beneficial effects may be related to its high antioxidant activity owing to presence of a range of biologically active compounds such as anthocyanins, punicalagin, ellagic acid and gallic acid (6, 7). The edible part of the fruit is rich in essential nutrients, including acids, sugar, vitamins, polysaccharides, polyphenols and minerals (8, 9). The composition of pomegranate fruit is mainly dependent on the genotype, climatic condition, maturity stage and growing practices (10). Analysis of variability exists in the phenols, flavonoids, total antioxidant activity and other physical and chemical properties among different pomegranate genotypes allow researchers to identify genotypes with higher level of bio-active compounds. Traditionally, the sour types of wild pomegranate known as 'daru' type are being used in the preparation of anardana; but their fruit size is very small and yield is very low.

The market demand for anardana has been steadily increasing, necessitating the development of improved cultivars. ICAR-Central Institute for Arid Horticulture (CIAH), Bikaner has collected, generated, evaluated and maintained over 106 diverse pomegranate germplasm in field gene repository to develop cultivars adaptable to hot arid environment with improved yield and quality. Hence, an attempt was made to evaluate the performance of sour -type of pomegranate genotypes under hot arid climate to screen and identify the sour-type pomegranate genotypes with high fruit yield, anardana recovery and superior quality.

Materials and Methods

The present study was conducted at Research Farm and Post-Harvest Laboratory of ICAR-Central Institute for Arid Horticulture, Bikaner. Thirty-one sour type pomegranate germplasm namely Saih Sirin, Uthkal, AHPG H-2, Tujetis EC -104347, CIAH PG-1, Speen Sacarin, Bedana Thin Skin, AK Anar, Bedana Seedless, Gul-e-Shah Red, Patna-5, P-21, Gul -e-Shah R. Pink, Yercaud Local, AHPG H-3, Malta, Khog, Gul -e-Shah, IC-318712, Basin Seedless, EC-62812, Sirin, Tabest, AHPG H-1, Kalisirin, Agah, CIAH PG-A-6, CIAH PG-A-2, CIAH PG-A-5, CIAH PG-A-4 and CIAH PG-A-3 were evaluated under hot arid climatic condition during 2019-2021 (Fig. 1). The age of pomegranate germplasm orchard was 5 years and planted at of 4 m x 6 m spacing in randomized complete block design under drip irrigation system.

The agro-climatic condition of Bikaner is characterized by extremes of temperature (-4°C during winter and as high

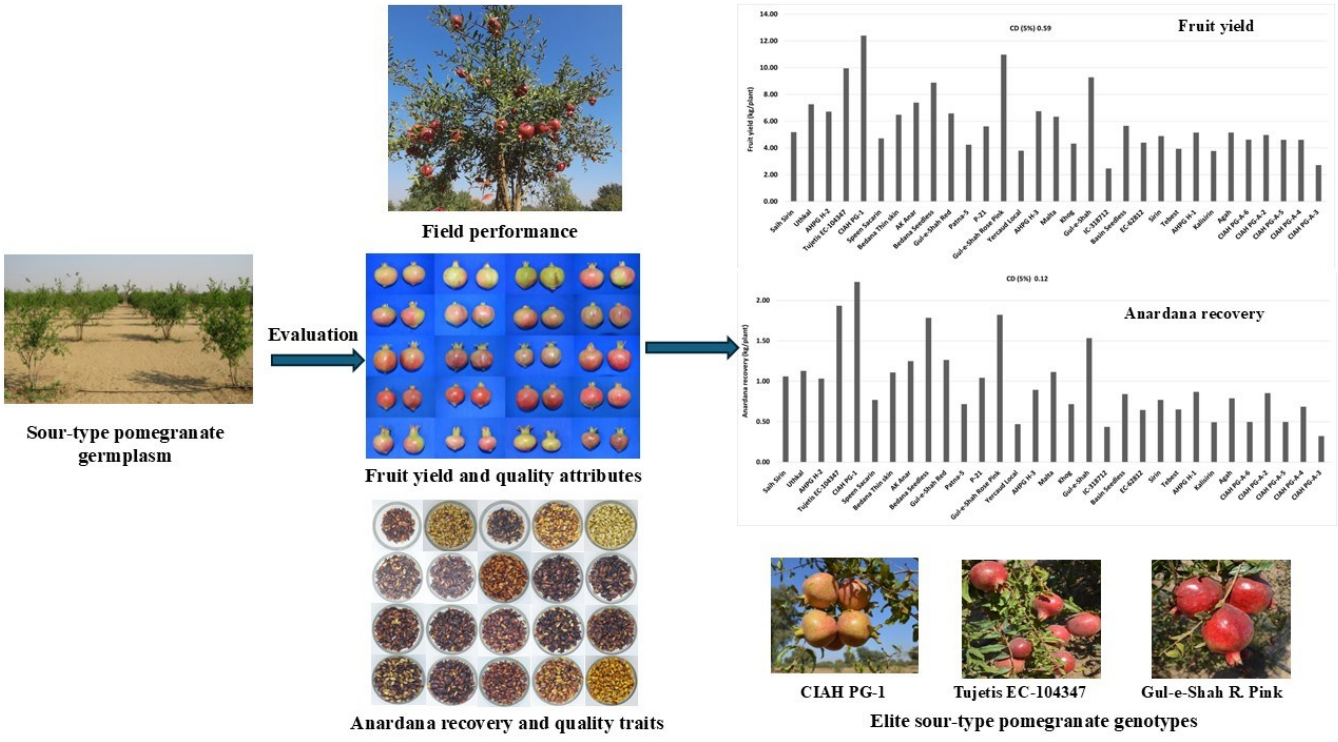

Fig. 1. Graphical representation of the experimentation.

as 50°C in summer), low rainfall (300-400mm) in short spells during July to September, high vapour pressure deficit, intense solar radiation and sandy soils with poor soil fertility and water holding capacity. Plants were trained to a multi-stem system with 3-4 stems per plant and pruning was done after fruit harvesting during winter (January–February) every year. Uniform intercultural operations like desuckering, weeding, irrigation and fertilization were performed to grow the crop. Weeding was done around the plant basin by spade as per requirement, while harrowing was carried out with tractor-driven disc harrow in February, July, September and November. Irrigation was applied to the plants uniformly through a drip irrigation system. Recommended dose of manure and fertilizers (45kg FYM, 625g N, 250g P and 250g K) per plant per year were applied. The micronutrient mixture (2% iron, 5% zinc, 2% manganese, 0.5% copper, 0.05% molybdenum and 0.5% boron, on w/w basis) foliar spray was given twice after 1 and 2 month of fruit set.

Data were recorded on different plant growth, fruit yield, fruit and anardana quality attributes viz., plant height (m), canopy volume (m^3), tree vigour, growth habit, fruit number/plant, fruit weight (g), yield (kg/plant), fruit-cracking (%), TSS (°Brix), juice acidity (%), TSS: acidity ratio, aril colour, aril and peel (%). The extracted arils were dehydrated using cabinet dryer (Model NSW 154, Narang scientific Works Pvt. Ltd., New Delhi) at 55°C for 7h. The tray positions were shuffled inside the drier to ensure uniform heat transmission to all the trays.

In anardana quality attributes, data were recorded on dehydration ratio, phenols (mg GAE/g), flavonoids (mg Cat. E/g), total antioxidant activity (mg AAE/g), anardana acidity (%) and anardana recovery (kg/plant). The aril colour was observed by comparing it with the colour chart of the Royal Horticultural Society, London.

The total soluble solids of the fruit juice were determined with digital refractometer Atago PAL II by putting a few drops of juice on the prism. The refractometer was calibrated with distilled water before use. The acidity of juice was determined by titration with 0.1N sodium hydroxide. Five mL of juice was taken in the conical flask and 10mL of water was added to it and was titrated against standard 0.1N NaOH solution using phenolphthalein as an indicator till it gave pink coloured end-point.

The estimation of total phenolics, flavonoids and total antioxidant activities were carried out in aqueous ethanolic extracts. One g of grounded anardana samples were homogenized in 70% aqueous ethanol (10mL) and centrifuged at 12000rpm at 4°C for 15min by using refrigerated centrifuge (LABY, SP-90BLH). The pallet was re-extracted twice using 5mL of 70% ethanol each time and then extracts were pooled. The final volume was adjusted to 20mL with the extraction solvent and then stored at -20° C until further use.

The total phenolics content was determined with the Folin-Ciocalteu reagent (11). Reaction mixture containing appropriate aliquot of ethanolic extract, 0.5mL of 1 N phenol reagent (Folin- Ciocalteu) and of 6% sodium carbonate solution (2mL) (w/v) was incubated at boiling water bath for 2min. Then, the tubes were kept at room temperature for cooling the solution and the absorbance was recorded at 650nm against reagent blank. The total phenolics content was expressed as mg gallic acids equivalents (mg GAE/g).

The assessment of the total flavonoid content was carried out by the aluminium chloride colorimetric assay (11). One ml of ethanolic extracts was taken to test tubes and added 0.3mL each of 5% sodium nitrite (w/v) and 10% aluminium chloride mixed well and added 3.4mL of 4N sodium hydroxide. Tubes were mixed by vortexing and incubated at room temperature for 10min. The absorbance was recorded at 510nm using the reagent blank as a reference. Catechol served as the positive reference standard and the outcomes were quantified and expressed mg Catechole equivalent (mg Cat. E/g).

Total antioxidant activity (TAA) was determined by *in-vitro* systems cupric ion reducing capacity (CUPRAC) assay (12) using ascorbic acid as reference compound. A volume of suitable aliquot (50-100µL) of ethanolic extract and or fresh juice was added to the reaction mixture containing 1mL each of 10mM cupric chloride, 75mM neocuproine and 1M ammonium acetate (pH 7.0). The tubes were incubated under dark for 30min and measured the absorbance at 450nm against the reagent blank. Whole assays were carried out in triplicate to get mean value and expressed as mg ascorbic acid equivalent (mg AAE/g).

The organoleptic evaluation for the colour, flavour, taste, texture and overall acceptability was conducted using nine points hedonic scale (13, 14) to assess the consumer acceptance based on rating from like extremely (score 9) to dislike extremely (score 1). Sensory evaluation of anardana was conducted at ambient temperature conditions by the panel of 7 judges. The experimental data were subjected to statistical analysis using the standard methods (15).

Results and Discussion

Field performance and fruit yield attributes

The data presented in Table 1, reveals significant variations in the vegetative and yield attributes i.e. plant height, canopy volume, plant vigour, growth habit, fruits number/plant and fruit cracking (%) in pomegranate germplasm. Plant height was recorded as significantly utmost ($p<0.05$) in the germplasm 'Uthkal' (2.63m), followed by Kalisirin (2.50 m), while minimum plant height was recorded in germplasm CIAH PG-A-6 (1.75m). Canopy volume was also significantly highest ($p<0.05$) in germplasm 'Uthkal' (8.92m^3), followed by 'Kalisirin' (7.30m^3) and 'CIAH PG-1' (6.81m^3), while lowest canopy volume was observed in 'CIAH PG-A-6' (2.61m^3) and 'Malta' (3.48m^3). Similar variations in pomegranate germplasm were also reported (16).

Plant vigour was categorized in dwarf, vigorous,

Table 1. Field performance of sour-type pomegranate germplasm under hot arid climate

Germplasm	Plant height (m)	Canopy volume (m^3)	Plant vigour	Growth habit	Fruits no./ plant	Fruit cracking (%)
Saih Sirin	2.33	5.07	Vigorous	Deciduous	28.81	9.78
Uthkal	2.63	8.92	Very vigorous	Deciduous	33.32	12.76
AHPG H-2	2.24	5.58	Vigorous	Evergreen	33.77	16.31
Tujetis EC-104347	2.28	5.69	Vigorous	Deciduous	42.75	9.39
CIAH PG-1	2.47	6.81	Very vigorous	Evergreen	46.92	10.26
Speen Sacarin	2.33	6.10	Vigorous	Deciduous	29.63	16.73
Bedana Thin Skin	2.26	5.75	Very vigorous	Evergreen	37.64	15.05
AK Anar	2.25	5.27	Vigorous	Deciduous	38.46	10.77
Bedana Seedless	2.16	5.04	Semi vigorous	Deciduous	41.38	7.31
Gul-e-Shah Red	2.03	4.12	Dwarf	Deciduous	27.59	6.22
Patna-5	1.91	3.73	Dwarf	Evergreen	22.09	14.48
P-21	2.37	6.71	Very vigorous	Evergreen	32.65	12.48
Gul-e-Shah R. Pink	2.29	5.23	Very vigorous	Deciduous	42.74	3.61
Yercaud Local	2.31	5.87	Vigorous	Evergreen	37.77	9.82
AHPG H-3	2.35	6.14	Very vigorous	Deciduous	31.98	7.30
Malta	1.93	3.48	Dwarf	Deciduous	37.18	10.66
Khog	2.09	4.59	Vigorous	Deciduous	22.50	16.09
Gul-e-Shah	2.39	6.27	Very vigorous	Deciduous	39.83	3.54
IC-318712	2.36	6.46	Very vigorous	Deciduous	23.05	6.03
Basin Seedless	2.22	5.52	Semi vigorous	Evergreen	28.51	14.40
EC-62812	2.25	5.85	Vigorous	Semi deciduous	33.71	5.43
Sirin	2.09	4.49	Semi vigorous	Deciduous	26.00	14.79
Tabest	2.18	5.27	Vigorous	Deciduous	30.50	15.13
AHPG H-1	2.35	6.42	Very vigorous	Deciduous	32.75	16.99
Kalisirin	2.50	7.30	Very vigorous	Deciduous	24.14	14.39
Agah	2.08	4.10	Semi vigorous	Deciduous	31.81	9.64
CIAH PG-A-6	1.75	2.61	Dwarf	Deciduous	31.84	4.47
CIAH PG-A-2	2.31	6.25	Vigorous	Deciduous	31.98	5.25
CIAH PG-A-5	2.13	5.39	Vigorous	Evergreen	33.64	5.46
CIAH PG-A-4	2.19	5.18	Semi vigorous	Evergreen	33.75	4.01
CIAH PG-A-3	2.29	5.44	Vigorous	Deciduous	26.52	5.67
SEm±	0.027	0.17	-	-	1.02	1.44
CD (5%)	0.077	0.50	-	-	2.9	4.08

semi vigorous and very vigorous types. Among 31 pomegranate germplasm, 4 were categorized as dwarf type, 12 as vigorous and 5 as semi vigorous and 10 as very vigorous type. Uthkal, Kalisirin and CIAH PG-1 were classified as very vigorous, while CIAH PG-A-6, Malta and Patna-5 were categorized as dwarf type germplasm. Under hot arid climatic conditions, pomegranate germplasm exhibits 3 behaviours: evergreen, semi-deciduous or deciduous. Most germplasm observed under deciduous category (21Nos.), while one under semi-deciduous and 9 under evergreen category. Germplasm such as AHPG H-2, CIAH PG-1, Bedana Thin Skin, Patna-5, P-21, Yercaud Local, Basin Seedless, CIAH PG-A-4 and CIAH PG-A-5 were found evergreen type. EC-62812 was semi-deciduous and the remaining 21 germplasm performed as deciduous as their leaves turned yellow and dropped during extreme winter months (December-January). The evergreen type is a positive character under hot arid climatic conditions, as the '*mrig bahar*' (flowering in July-August and harvesting in December-January) is recommended in pomegranate under these conditions to get quality fruit harvest (17).

In deciduous type germplasm, fruit growth is adversely impacted due to a reduced photosynthetic area, as leaves are absent and fruits are exposed to frost during December-January. The highest average number of fruits/ plant was recorded in germplasm CIAH PG-1 (46.92), followed by Tujetis EC-104347 (42.75) and Gul-e-Shah R. Pink (42.74). In contrast, the lowest number of fruits/plant was found in Patna-5 (22.09), Khog (22.50), IC-318712 (23.05) and Kalisirin (24.14). Fruit yield was also varied significantly among different germplasm (Fig. 2). The maximum fruit yield was recorded in germplasm CIAH PG-1 (12.40kg/plant), followed by Gul-e-Shah R. Pink (10.98kg/ plant) and Tujetis EC-104347 (9.96kg/plant). Fruit cracking was varied from 3.54 to 16.99% across the pomegranate germplasm, with the lowest fruit cracking observed in 'Gul -e-Shah' (3.54%) which was statistically at par with Gul-e-Shah R. Pink (3.61%) and CIAH PG-A-4 (4.01%). Comparable variations in plant height and fruit yield among pomegranate germplasm have been reported in earlier studies (18-20), validating these findings. Based on field performance, germplasm 'CIAH PG-1' was identified as superior for fruit yield and plant traits particularly its evergreen and very vigorous nature.

Fruit quality attributes

The data divulged significant variations in fruit quality attributes among the pomegranate germplasm including fruit weight, aril and peel content, TSS, acidity and TSS and acidity ratio (Table 2). The fruit weight was ranged

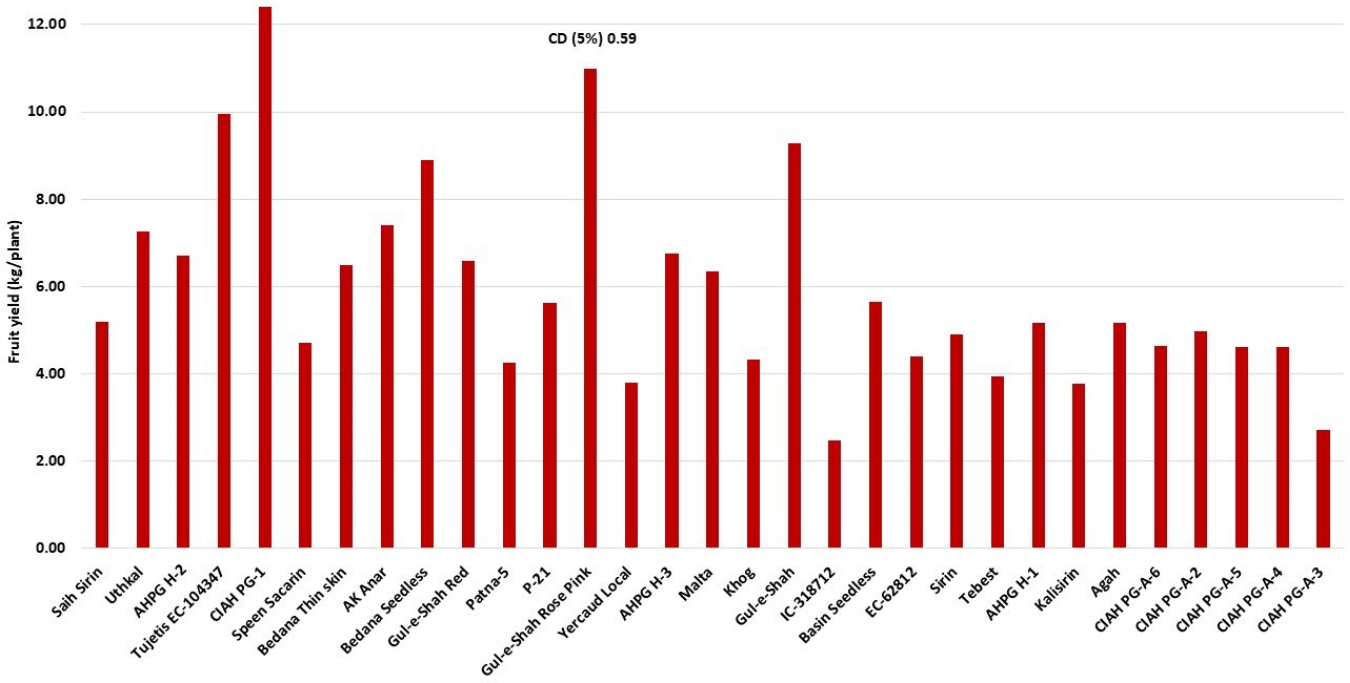

Fig. 2. Fruit yield of sour-type pomegranate germplasm under hot arid climate.

from 103.75 to 263.84 g. The significantly maximum ($p< 0.05$) fruit weight was recorded in germplasm CIAH PG-1 (263.84 g), followed by Gul-e-Shah R. Pink (257.16g) and Gul-e-Shah Red (238.53g), while minimum fruit weight was recorded in germplasm Yercaud Local (100.67g), CIAH PG-A -3 (103.75g) and IC-318712 (106.93g). Aril content, an important fruit quality attribute, was maximum in germplasm CIAH PG-1 (67.71%), which was statistically at par with Khog and Bedana Seedless ($p<0.05$). The minimum aril recovery was recorded in germplasm CIAH PG-A-5 (25.22%) and CIAH PG-A-3 (26.68%). Variation in fruit weight and aril content among pomegranate germplasm were also observed (16). Peel content varied from 32.51 to 74.89% among different pomegranate germplasm and was recorded significantly lowest in CIAH PG-1 (32.51%), statistically similar to Khog (32.90%) and Bedana Seedless (34.19%). The highest peel content was recorded in germplasm CIAH PG-A-5 (74.89%) and CIAH PG -A-3 (73.46%).

The germplasm 'Saih Sirin' exhibited significantly higher juice TSS (19.04°Brix), followed by AHPG H-2 (16.09° Brix) and Khog (16.02°Brix). Juice acidity was significantly varied from 0.77 to 3.57 % across pomegranate germplasm ($p<0.05$). It was observed highest in Tujetis EC-104347 (3.57%), statistically similar to CIAH PG-1 (3.50%). The lowest juice acidity was recorded in germplasm Malta (0.77%), which was statistically at par with P-21 (0.82%) and Bedana Thin Skin (0.84%). The results are in accordance with the previous studies on the variability in juice TSS and acidity (16, 21). The TSS:acidity ratio is a key index to measure the sugar content in relation to acidity which gives fruits characteristic taste and flavour. It is also an indicator of horticultural maturity for fruit harvesting. A significant difference was observed in TSS:acidity ratio and it was found maximum in germplasm Malta (18.54), statistically similar to Bedana Thin Skin (18.36). The minimum TSS:acidity ratio recorded in CIAH PG-A-5 (3.49), which was statistically at par with Tujetis EC-104347 (3.56) and CIAH PG-1 (3.80). Similarly, variability in pomegranate germplasm for fruit weight, TSS and acidity was reported in previous studies (19, 20). In sour-type pomegranate germplasm, higher fruit weight and greater aril content with high acidity are considered positive traits. Based on fruit quality attributes like fruit weight, aril per cent and juice acidity, germplasm CIAH PG-1 and Tujetis EC-104347 were found superior for important fruit quality attributes.

Anardana quality attributes

A significant variation in the anardana quality attributes including aril colour, dehydration ratio, phenols, flavonoids, total antioxidant activity and anardana acidity was observed among the pomegranate germplasm (Table 3). Aril colour varied considerably among the evaluated sour-type germplasm. The darker-coloured aril was observed as Red 46 A in CIAH PG-1, Red 46 B in Gul-e-Shah and AK Anar; Red 46 C in AHPG H-2, Tujetis EC-104347 and Bedana Thin Skin. Similarly, aril colour was also reported darker as Red 42 C in Tabest and Gul-e-Shah Red; and Red 38 C in AHPG H-1 and Kalisirin. The pink colour Red 55 A was observed in Basin Seedless and EC-62812, while Red 55 B noted in Gul-e-Shah R. Pink. The lighter-coloured arils, as Yellow-White 58 B was observed in germplasm CIAH PG-A-2, CIAH PG-A-3, CIAH PG-A-4, CIAH PG-A-5 and CIAH PG-A-6. Dehydration ratio across the germplasm was recorded lowest in CIAH PG-A-1 (2.23) which was statistically at par with CIAH PG-A-5 (2.31), whereas maximum dehydration ratio was recorded in CIAH PG-A-6 (4.18), which was statistically similar to Khog (4.08).

The total phenol content has varied significantly among different sour-type pomegranate germplasm, with the maximum recorded in CIAH PG-A-3 (47.05mg GAE/g), followed by CIAH PG-A-6 (34.42mg GAE/g), whereas minimum phenol content was recorded in Gul-e-Shah (7.85mg GAE/g) and P-21 (9.62mg GAE/g) ($p<0.05$).

Table 2. Fruit quality attributes of sour-type pomegranate germplasm under hot arid climate

Germplasm	Fruit weight (g)	Aril (%)	Peel (%)	TSS (°Brix)	Acidity (%)	TSS: acidity ratio
Saih Sirin	179.80	57.43	43.06	19.04	2.10	9.10
Uthkal	217.78	56.97	43.63	13.37	2.49	5.37
AHPG H-2	199.14	52.82	47.48	16.09	3.40	4.74
Tujetis EC-104347	233.04	61.54	38.59	12.72	3.57	3.56
CIAH PG-1	263.84	67.71	32.51	13.30	3.50	3.80
Speen Sacarin	158.91	59.50	40.56	12.47	2.58	4.83
Bedana Thin Skin	172.24	53.48	46.53	15.32	0.84	18.36
AK Anar	192.23	52.87	47.46	16.02	2.81	5.70
Bedana Seedless	214.62	66.94	34.19	15.37	1.92	8.02
Gul-e-Shah Red	238.53	62.79	37.51	14.66	2.61	5.63
Patna-5	192.54	56.34	44.17	13.82	1.01	13.70
P-21	173.56	61.96	38.08	12.78	0.82	15.62
Gul-e-Shah R. Pink	257.16	53.69	46.56	15.27	2.98	5.13
Yercaud Local	100.67	44.22	56.20	12.51	1.77	7.10
AHPG H-3	211.10	47.71	52.39	12.52	2.34	5.35
Malta	170.73	61.24	39.04	14.27	0.77	18.54
Khog	192.02	67.41	32.90	16.02	3.53	4.54
Gul-e-Shah	233.03	52.79	47.12	12.68	3.31	3.84
IC-318712	106.93	51.05	48.63	13.40	2.57	5.22
Basin Seedless	198.36	51.00	49.00	14.64	1.08	13.57
EC-62812	130.34	51.86	47.99	12.73	2.31	5.51
Sirin	187.94	60.67	39.97	11.19	2.71	4.13
Tabest	129.16	57.16	43.19	13.01	3.39	3.83
AHPG H-1	157.15	59.04	40.99	13.68	2.09	6.54
Kalisirin	156.67	44.73	55.52	13.86	3.20	4.34
Agah	162.08	52.16	48.31	14.67	2.25	6.52
CIAH PG-A-6	150.32	45.08	55.32	12.47	2.00	6.23
CIAH PG-A-2	152.15	56.08	44.18	13.57	1.82	7.47
CIAH PG-A-5	137.91	25.22	74.89	11.19	3.21	3.49
CIAH PG-A-4	137.08	36.58	63.94	14.55	1.40	10.41
CIAH PG-A-3	103.75	26.68	73.46	12.12	1.94	6.47
SEm±	2.25	0.76	0.80	0.10	0.03	0.17
CD (5%)	6.39	2.15	2.29	0.30	0.09	0.48

Similarly, flavonoids content also varied significantly across pomegranate germplasm. The highest flavonoids content was recorded in CIAH PG-A-3 (0.564mg Cat. E/g), followed by CIAH PG-A-6 (0.400mg Cat. E/g), while lowest flavonoids content was observed in germplasm Kalisirin (0.106mg Cat. E/g) and Basin Seedless (0.135mg Cat. E/g) ($p<0.05$). Total antioxidant activity (TAA) was recorded highest (61.41mg AAE/g) in germplasm CIAH PG-A-3, which was statistically at par with CIAH PG-A-6 (60.34mg AAE/g), while lowest TAA was recorded in germplasm Gul-e-Shah (11.69mg AAE/g) and EC-62812 (12.55mg AAE/g) ($p<0.05$). The acidity of the dried arils varied from 4.63 to 7.99% among the sour-type pomegranate germplasm with the presence of higher acidity levels (>7%) in germplasm AHPG H-2, Tujetis EC-104347, CIAH PG-1, Khog, Gul-e-Shah, IC-318712, Tabest, Kalisirin and CIAH PG-A-5, which can be classified as Superior Quality Grade Anardana (1). The genetic makeup of the pomegranate germplasm significantly influences the anardana recovery (Fig. 3). Across the germplasm, highest anardana recovery was recorded in CIAH PG-1 (2.23kg/plant), followed by Tujetis EC-104347 (1.93kg/plant) and Gul-e-Shah Rose Pink (1.82kg/plant), while lowest anardana recovery was recorded in CIAH PG A-3 (0.32kg/plant), IC-318712 (0.44kg/plant) and Yercaud Local (0.47kg/plant). Significant differences in anardana quality attributes like colour, total phenols, flavonoids, acidity and antioxidant activity in pomegranate germplasm collected from different locations were also reported in earlier studies (22).

Sensory evaluation of anardana

The sensory evaluation of anardana on nine-point hedonic scale has revealed a significant variation in attributes such as colour, flavour, taste, texture/mouth feel and overall acceptability (Table 4). The colour score ranged from 5.17 to 8.50, with the highest value in germplasm CIAH PG-1

Table 3. Anardana quality attributes of sour-type pomegranate germplasm under hot arid climate

Germplasm	Aril Colour (RHS Colour Chart)	Dehydration ratio	Phenols (mg GAE/g)	Flavonoids (mg Cat. E/g)	TAA (mg AAE/g)	Anardana acidity (%)
Saih Sirin	Red-Purple N66 B	2.80	14.69	0.169	16.23	6.21
Uthkal	Red-Purple 68 D	3.66	19.57	0.223	18.06	6.69
AHPG H-2	Red 46 C	3.44	19.48	0.229	17.18	7.67
Tujetis EC-104347	Red 46 C	3.17	10.44	0.175	14.57	7.99
CIAH PG-1	Red 46 A	3.76	12.72	0.143	14.61	7.47
Speen Sacarin	Red 50 A	3.65	15.11	0.230	19.36	6.51
Bedana Thin Skin	Red 46 C	3.13	14.03	0.184	15.72	4.63
AK Anar	Red 42 B	3.13	14.08	0.230	16.66	6.94
Bedana Seedless	Red-Purple N57 D	3.33	13.63	0.195	15.12	6.18
Gul-e-Shah Red	Red 42 C	3.27	10.91	0.168	13.94	6.76
Patna-5	Red 50 C	3.34	11.70	0.154	12.60	5.15
P-21	Red 42 D	3.36	9.62	0.155	12.66	4.75
Gul-e-Shah R. Pink	Red 55 B	3.24	19.25	0.172	25.08	6.90
Yercaud Local	Red-Purple N57 D	3.58	14.04	0.233	16.63	5.82
AHPG H-3	Red 50 A	3.61	21.20	0.282	23.83	6.19
Malta	Red 44 A	3.49	14.68	0.257	17.44	4.77
Khog	Red 45 A	4.08	13.12	0.163	12.51	7.72
Gul-e-Shah	Red 46 B	3.21	7.85	0.139	11.69	7.42
IC-318712	Red 46 D	2.89	14.05	0.181	15.86	7.02
Basin Seedless	Red 55 A	3.44	11.64	0.135	14.42	4.76
EC-62812	Red 55 A	3.54	13.53	0.140	12.55	5.74
Sirin	Red 50 B	3.85	13.45	0.205	13.29	6.36
Tabest	Red 42 C	3.46	13.27	0.204	13.31	7.06
AHPG H-1	Red 38 C	3.51	15.08	0.197	14.29	6.14
Kalisirin	Red 38 C	3.42	11.22	0.106	14.46	7.18
Agah	Red 40 A	3.41	11.24	0.207	15.24	6.40
CIAH PG-A-6	Yellow-White 58 B	4.18	34.42	0.400	60.34	6.17
CIAH PG-A-2	Yellow-White 58 B	3.23	13.71	0.212	21.60	6.12
CIAH PG-A-5	Yellow-White 58 B	2.31	19.64	0.279	36.74	7.66
CIAH PG-A-4	Yellow-White 58 B	2.38	19.11	0.314	25.26	6.08
CIAH PG-A-3	Yellow-White 58 B	2.23	47.05	0.564	61.41	6.82
SEm±	-	0.04	0.32	0.004	0.43	0.13
CD (5%)	-	0.12	0.93	0.012	1.22	0.38

(8.50), closely followed by Tabest (8.43). The flavour score ranged from 5.50 to 8.43 with the highest score recorded in germplasm CIAH PG-1 (8.43), followed by Tujetis EC-104347 (8.33). The highest score for taste was recorded in germplasm CIAH PG-1 (8.43) which is statistically at par with Tujetis EC-104347 (8.43), while lowest score recorded in Basin Seedless (5.20) and Bedana Thin Skin (5.23). The highest texture/ mouth feel score was recorded in Gul-e-Shah (7.63), which was at par with Agah (7.57) and CIAH-PG-1 (7.53) and the lowest texture score was observed in CIAH PG-A-2 (5.03) and CIAH PG-A-6 (5.27). The highest value for overall acceptability was observed in germplasm CIAH PG-1 (8.67) followed by Tujetis EC-104347 (8.37) and Gul-e-Shah R. Pink (8.23), while lowest score for overall acceptability was registered in germplasm CIAH PG-A-5 (5.10) and CIAH PG-A-2 (5.20). The variation in anardana sensory attributes among pomegranate germplasm, are in accordance with the previous studies (21). In earlier studies, significant variation in anardana sensory attributes like colour, flavour, taste, texture and overall acceptability across the pomegranate germplasm collected from different locations were reported (22).

Table 4. Anardana sensory attributes of sour-type pomegranate germplasm under hot arid climate

Germplasm	Colour	Flavour	Taste	Texture	Overall acceptability
Saih Sirin	5.67	6.70	7.30	6.07	6.73
Uthkal	8.13	6.33	7.50	6.30	6.40
AHPG H-2	8.20	7.80	8.33	6.40	7.80
Tujetis EC-104347	8.00	8.33	8.43	7.33	8.37
CIAH PG-1	8.50	8.43	8.43	7.53	8.67
Speen Sacarin	8.13	7.27	6.30	6.27	8.00
Bedana Thin Skin	6.40	6.40	5.23	6.30	7.53
AK Anar	8.30	7.27	7.50	7.33	7.20
Bedana Seedless	6.50	7.20	7.27	6.40	7.20
Gul-e-Shah Red	7.93	7.53	7.40	7.17	8.00
Patna-5	8.03	6.30	6.40	6.80	4.33
P-21	8.13	6.17	5.30	7.10	6.87
Gul-e-Shah R. Pink	7.20	7.77	7.60	6.40	8.23
Yercaud Local	8.20	6.33	6.37	7.27	6.70
AHPG H-3	7.77	7.40	7.20	6.40	7.50
Malta	8.33	6.37	5.30	7.30	7.23
Khog	8.30	7.60	8.23	7.50	7.10
Gul-e-Shah	8.40	8.10	8.27	7.63	7.80
IC-318712	8.00	7.23	7.97	6.47	6.57
Basin Seedless	7.53	6.30	5.20	7.27	7.03
EC-62812	6.40	6.40	6.37	6.37	7.03
Sirin	6.40	7.17	7.20	6.40	7.07
Tabest	8.43	7.53	6.80	7.50	8.10
AHPG H-1	7.30	7.20	7.03	7.33	8.10
Kalisirin	8.40	5.50	7.27	7.40	8.10
Agah	8.27	7.13	6.40	7.57	7.40
CIAH PG-A-6	5.60	5.80	6.30	5.27	5.30
CIAH PG-A-2	5.17	5.80	6.30	5.03	5.20
CIAH PG-A-5	5.33	7.10	8.30	5.80	5.10
CIAH PG-A-4	5.23	5.70	6.33	5.70	5.23
CIAH PG-A-3	5.30	5.63	6.50	5.47	5.20
SEm±	0.06	0.48	0.09	0.05	0.37
CD (5%)	0.17	1.36	0.26	0.14	1.06

Conclusion

Pomegranate offers immense health benefits and serving as a natural source of antioxidants, vitamins and minerals. These identified potential sour-type pomegranate genotypes will improve both production and processing application. It offers scope for commercialization and development of pomegranate processing industry for national and international markets. The preparation of anardana, along with other value-added products, will diversify its applications, particularly in Ayurvedic medicines. In the changing climate scenario, conservation of diverse germplasm and strengthening of field gene repositories will help its utilization in future breeding programs to develop improved cultivars adaptable to hot arid and semi-arid environment. This will help in boosting the local economy of the region as well as provide nutritional security to the inhabitants. The evaluation of thirty-one sour-type pomegranate germplasm under hot arid climatic condition exhibited significant variations for their vegetative growth, fruit yield, anardana recovery and quality traits. Among the evaluated germplasm, CIAH PG-1 stood out for its exceptional performance across various matrices, including field productivity, anardana recovery, quality traits and sensory attributes, which establish it as the superior choice for anardana-type pomegranate production. Along with CIAH PG-1, Tujetis EC-104347 and Gul-e-Shah R. Pink also showed promise across various parameters. These identified sour-type pomegranate

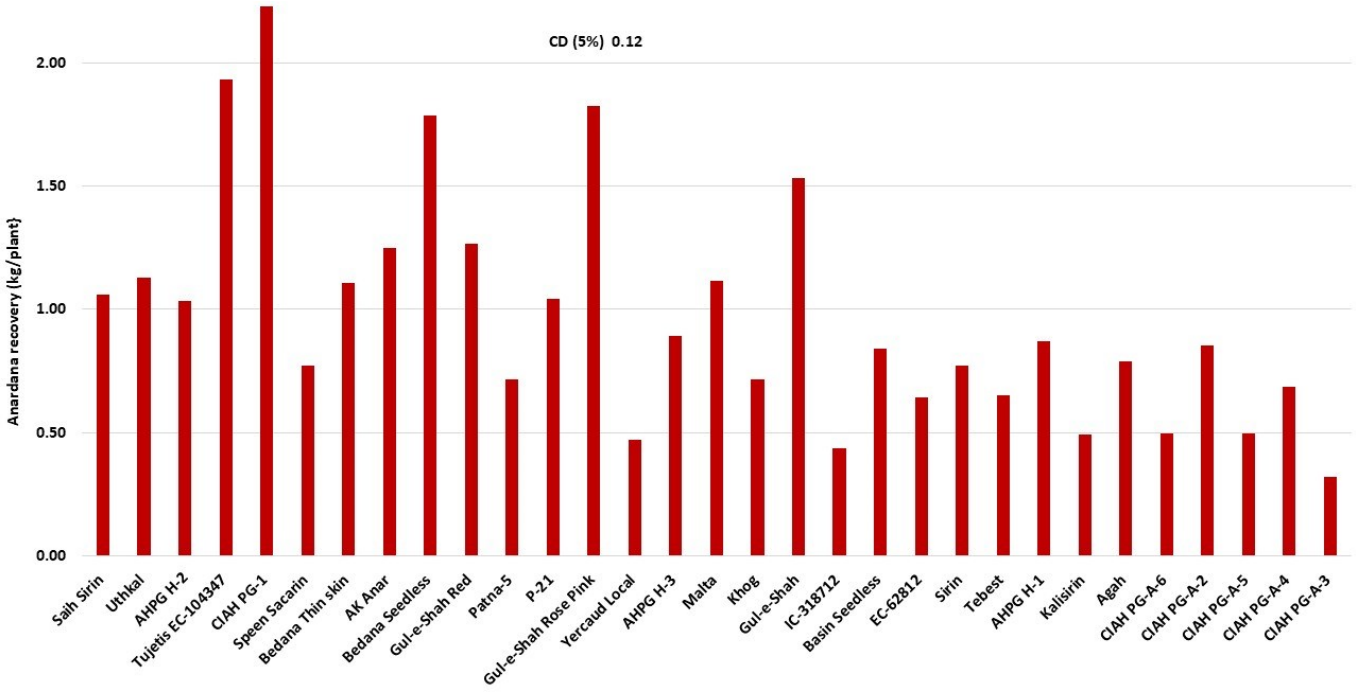

Fig. 3. Anardana recovery of sour-type pomegranate germplasm under hot arid climate.

genotypes hold great potential for enhancing production and processing applications, as well as future breeding programs.

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Authors' Contributions

RK carried out conceptualization, experiment implementation in field, data recording and analysis, writing and review. MKB participated in biochemical analysis and editing. JSG carried out experiment implementation in field, data recording and editing, VRRS involved in anardana quality analysis and editing.

Compliance with Ethical Standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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