

Plant growth and yield performance of pomegranate varieties under hot arid eco-system

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Summary

Five pomegranate varieties were evaluated for vegetative growth and yield for five years during 2017-2021 under a hot arid eco-system. No significant difference was observed among varieties with respect to vegetative characters except canopy volume. The maximum canopy volume was observed in cultivar Jalore seedless (1.73 m³) followed by Bhagwa (0.78 m³) and minimum in variety Ganesh (0.40 m³). The physical fruit parameters and yield attributing characters were recorded as superior in Jalore Seedless exhibited maximum fruit weight (189.8 g), fruit volume (127.2 cc), test weight (282.2 g), total aril weight/fruit (123.8 g), number of fruits/plant (66.6) and yield/plant (12.63 kg) followed by Ganesh and minimum was recorded in Phule Arakta with fruit weight (128.2 g), fruit volume (89.2 cc), test weight (174.0 g), number of fruits/plant (46.2) and yield/plant (5.00 kg). Aril weight (0.28 g), aril length and width (9.99 x 7.22 mm) were also observed to be significantly high in Jalore Seedless. A non-significant difference in juice per cent was observed among Mridula, Jalore Seedless and Bhagwa, with a maximum in cultivar Mridula (58), followed by Jalore Seedless and Bhagwa (50.4) and a minimum in Ganesh (37.4). The highest juice TSS was found in Jalore Seedless (17.02 °Brix) followed by Ganesh (16.52 °Brix) and Bhagwa (15.18 °Brix), while it was significantly lower in Mridula (13.26 °Brix). Based on vegetative growth, fruit physical parameters and fruit yield the performance of Jalore Seedless was superior over the other four varieties under a hot arid environment.

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Keywords: Pomegranate, canopy volume, fruit yield, juice per cent

Introduction

Pomegranate (*Punica granatum* L.) is an important fruit crop of arid and semi-arid region of India. It belongs to the family Lytharaceae. India is one of the largest producers of pomegranate in the world. It is grown in 282 thousand ha area with an annual production of 3215.96 thousand tonnes and a 12.14 MT/ha productivity in India (APEDA, 2021). Among the different pomegranate-growing states in India, Maharashtra is the largest producer occupying two-third of the total area in the country, followed by Gujarat, Karnataka, Andhra Pradesh, Tamil Nadu and Madhya Pradesh. Rajasthan coverage of this crop is about 10.60 thousand ha, production 70.31 thousand tonnes and productivity 6.2 tonnes per hectare (APEDA 2021) cultivated mainly in Bhilwara, Barmer, Jalore, Pali, Jodhpur and Nagaur districts. The area under pomegranate cultivation in India is increasing with time due to its high demand, hardy nature, high yield, therapeutic values, better storage and remunerative price. Pomegranate fruits are highly rich in antioxidants, phenols, flavonoids and minerals. Its juice is highly nutritious and is recommended for patients suffering from gastric troubles. It contains 67.95 kcal energy, 1.41 g protein, 1.60 g fiber, 2.50 mg calcium, 10.22 mg

magnesium, 34.3 mg phosphorus, 0.39 mg iron, 0.26 mg zinc, 0.09 mg thymine, 0.22 mg niacin, 23.38 mg ascorbic acid and 26.00 mg total carotenoids per 100 g fresh weight of fruit (Debjit et al. 2013; Meena et al. 2018). Several processed products such as juices, squash, jelly, anardana and mouth freshener are prepared by processing pomegranate fruit.

Arid region is characterized by high temperature, low and erratic rainfalls with frequent drought; soils are poor in nutrients and water holding capacity. The environmental conditions of arid region are very harsh for the sustainability of plants, hence; selection of a fruit crops and its varieties for such region is important for economic production. Pomegranate has ability to withstand harsh climate and tolerate heat, drought and moisture deficit at great extent. Apart from this, crop growth and fruiting season can be adjusted according to the moisture availability period. At present over 70 cultivars, both from indigenous or exotic sources are available in India (Kumar et al. 2021). The first named pomegranate variety "Ganesh" was released in 1954 from college of Agriculture, Pune. This variety was very popular until the last decade of 20th century. After development of the Bhagwa variety in 2003 by Mahatma Phule krishi Vidyapeeth (MPKV) Rahuri, the major cultivated area of pomegranate was occupied by this variety and cultivable area under Ganesh variety reduced considerably in India. The varieties Mridula, Bhagwa, Jyothi, Kandhari, Phule Arakta, Bhagwa Super and

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Ganesh etc. are major pomegranate cultivar in India. Among the popular varieties, Jalore seedless was performing better compare to other varieties due to well acclimatize habit under hot arid condition of western, Rajasthan. This crop has the potential to replace subsistence farming and alleviating poverty of farmers under hot arid ecosystem of western Rajasthan (Pareek, 1978; Haldhar et al. 2022). Also, solving of farmer's problem regarding the sub-standard fruit quality and fruit cracking is substantial. Therefore, identification of suitable variety for hot arid region is utmost important for delivering sustainable economic gain for farmers and hence, an experiment was designed with five commercial pomegranate varieties to identify promising variety for hot arid region.

Materials and Methods

The experiment was conducted during 2016-2021 at ICAR-Central Institute for Arid Horticulture, Bikaner, Rajasthan, India. The experimental site was situated on 28° N latitude, 73° 18' E longitude and at an altitude of 234.84 m above sea level. The soil of the experimental site was sandy, desertic, poor in fertility and water holding capacity. The soil nutrient content was analyzed at three different depths (30-90 cm depth) using Auger-Auger for soil profiling system and samples were analyzed and recorded viz. pH 8.3-8.5 (alkaline), EC 0.28-0.24 dsm⁻¹(medium), potassium 210-249 kg ha⁻¹ (medium), phosphorus 12-15 kg ha⁻¹ (medium), and organic carbon 0.16-0.14 % (low) value, respectively. The water used for irrigation was having pH value of 7.58, EC 2.73 dsm⁻¹ and TDS 1700.47 ppm. The average rainfall of this region was about 230 mm/annum. May-June was the hottest month (mean maximum temperature 42.9°C and mean minimum temperature 29.6°C) and December-January were the coldest month of the year (mean maximum temperature 23.7°C and mean minimum temperature 8.9°C). Occasional frost was also experienced during January and February. Experiment was planned on commercial pomegranate varieties namely Jalore Seedless, Ganesh, Mridula, Bhagwa and

Phule Arakta under hot arid ecosystem of western region. The experimental plot was laid out with Randomized Complete Block Design replicated thrice with 29 plants per replication. These five varieties were evaluated for growth, yield attributes, yield (plant⁻¹ & ha⁻¹) and quality parameters (juice per cent, TSS, Acidity per cent) as per standard methodology by using measuring scale (plant height, spread), vernier calliper (fruit diameter, aril size), counted basis (number of fruits plant⁻¹ and aril fruit⁻¹), weighing balance (fruit weight, aril weight, seed index (100 aril weight), test weight (1000 aril weight) and yield. Canopy volume was calculated as per the method described by Samaddar and Chakrabarti (1998), which can be expressed in (m³).

$$\text{Canopy volume} = r^3 x \left(\frac{2}{3} - x + \frac{x^3}{3} \right)$$

Whereas r = Radius of crown (m), x = Crown height (m) The fruit volume of individual fruit was measured by the water displacement method and specific gravity of fruits was calculated by dividing fruit weight to fruit volume; shape index by dividing equatorial to polar diameter of fruit. Yield per plant was total weight of fruits harvested on each picking and multiplied that weight by total plant population per hectare. Observations of general fruit characters was recorded using crop descriptor and quality components and estimation of acidity was done as per AOAC (1990) and observations on TSS was recorded using hand refractometer.

Results and Discussion

Plant growth characteristics

All varieties showed evergreen growth behaviour, however, growth habit varies from vigorous to dwarf. Variation in fruit rind colour and aril colour was also noticed among varieties. Yellow rind colour with red tinge was found in Jalore Seedless and Ganesh, while light red, red and deep red colour was noticed in Bhagwa, Mridula and Phule Arakta, respectively. Similarly, variation in aril colour was also observed among varieties (Table 1).

Table 1. Evaluation of different varieties of pomegranate for growth and fruit morphology traits

Varieties	Growth behaviour	Growth habit	Rind colour	Aril colour	Taste	Seed mellowness
Jalore Seedless	Evergreen	Vigorous	Yellow red tinge	Light pink	Very sweet	Soft
Mridula	Evergreen	Semi dwarf	Red	Dark Red	Sweet	Very Soft
Phule Arakta	Evergreen	semi dwarf	Deep red	Blood red	Sweet	Soft
Bhagwa	Evergreen	Spreading	Light red	Red	Sweet	Soft
Ganesh	Evergreen	dwarf	Yellow red tinge	Pink	Sweet	Soft

The vegetative characteristics of pomegranate showed non-significant differences between varieties except canopy volume. The maximum canopy volume was recorded in Jalore seedless (1.73 m³), followed by Bhagwa (0.78 m³) and the minimum in Ganesh (0.40 m³). Plant height and canopy spread were higher in the same variety with values are 2.63 m and 2.59 east-west, and 2.37 north-south, respectively. A significant difference was noticed in fruit diameter. The maximum fruit

diameter, both polar and equatorial, was recorded in Jalore Seedless (8.94 and 7.28 cm) followed by Ganesh and least in Phule Arakta (Table 2). The variation in vegetative growth may be due to the genetic makeup of varieties and agroclimatic conditions (altitude, soil nutritional status, cultural practices and environment). A similar type of variation in plant height and plant spread has been reported by different researchers (Sharma & Bist 2005; Mir et al. 2007).

Table 2. Evaluation of pomegranate varieties for growth and fruit characters

Varieties	Plant height (m)	Canopy spread (m)		Canopy volume	Fruit diameter (cm)		Shape index (E/P)
		E-W	N-S		Polar	Equatorial	

				(m ³)			
Jalore Seedless	2.63	2.59	2.37	1.73a	8.94 ^a	7.28 ^d	0.82
Mridula	2.31	2.28	2.26	0.67c	7.57 ^b	6.22 ^{bc}	0.83
Phule Arakta	2.35	2.33	2.25	0.76bc	6.50 ^c	5.78 ^c	0.89
Bhagwa	2.30	2.44	2.37	0.78b	7.64 ^b	6.34 ^{abc}	0.85
Ganesh	2.14	2.29	2.14	0.40c	8.15 ^{ab}	6.96 ^{abc}	0.86
SE.m±	0.11	0.10	0.09	0.22	0.30	0.33	0.06
CD at 5%	NS	NS	NS	0.07	0.91	1.00	NS

Fruit characters and yield attributes

The physical yield attributing characters of the pomegranate variety Jalore Seedless was recorded as significantly superior over other varieties. The maximum fruit weight (189.8 g), fruit volume (127.2 cc), test weight (282.2 g), total aril weight/fruit (123.8 g), number of fruits/plant (66.6) and yield/plant (12.63 kg) was recorded in Jalore Seedless followed by Ganesh and minimum was recorded in Phule Arakta such as fruit weight (128.2 g), fruit volume (89.2 cc), test weight

(174.0 g), number of fruits/plant (46.2) and yield/plant (5.00 kg). It might be due to well acclimatization of Jalore Seedless under hot arid conditions of western Rajasthan. Misra et al. (1983) reported that out of 10 pomegranate varieties, only Srinagar Special gave the highest yield (18.45 kg plant⁻¹). Thus, among the varieties studied, on the basis of plant growth, fruit yield and quality, Jalore Seedless is a potential variety for sustainable economic return in hot arid dry regions.

Table 3. Evaluation of different varieties of pomegranate for fruit characters

Varieties	Fruit weight (g)	Fruit volume (cc)	Specific gravity (cc/g)	Seed index (g)	Test weight (g)	Rind weight (g)
Jalore Seedless	189.8 ^a	127.2 ^a	0.68	28.12 ^a	282.2 ^a	56.63
Mridula	132.8 ^b	118.2 ^b	0.94	24.53 ^a	246.4 ^a	52.87
Phule Arakta	128.2 ^b	89.2 ^c	0.70	16.30 ^b	174.0 ^b	37.76
Bhagwa	136.8 ^b	118.8 ^b	0.88	25.36 ^a	254.6 ^b	37.45
Ganesh	174.2 ^{ab}	123.2 ^{ab}	0.73	27.97 ^a	278.6 ^a	54.98
S E.m±	12.86	18.87	0.08	1.31	17.17	2.70
CD at 5%	38.91	6.24	NS	3.98	51.93	8.16

The physical attributes of aril viz., aril weight, length, width and aril weight fruit⁻¹ were recorded as statistically significant in Jalore Seedless but it was found statistically at par with variety Ganesh (Table 3). The variety Jalore seedless exhibited maximum values of aril weight (0.28 g), aril length & width (9.99 x 7.22 mm), test weight (282.2 g), seed index (28.12 g), rind weight (56.63g). The least aril-weight was recorded in cv. Phule Arakta (0.18 g), followed by Bhagwa (0.25 g). However,

the varieties, Jalore seedless and Ganesh were found statistically at par to each other in all the aril physical parameters (Table 4). Mir et al. (2007) also observed high range of variability in pomegranate for fruit weight, fruit volume, number of seeds, fruit colour and general appearance among the cultivars under study. The results obtained are also in agreement with the findings of Misra et al (1983).

Table 4. Evaluation of different varieties of pomegranate for aril characters

Varieties	Aril size (mm)		Aril weight (g)	No. of arils/fruit	Total aril weight/fruit (g)	Number fruits/plant
	Length	Width				
Jalore Seedless	9.99 ^a	7.22 ^a	0.28 ^a	443.0	123.8 ^a	66.6
Mridula	8.81 ^b	6.61 ^{ab}	0.25 ^a	332.4	77.4 ^b	54.0
Phule Arakta	8.28 ^b	6.01 ^b	0.18 ^b	460.2	74.6 ^b	46.2
Bhagwa	9.81 ^{ab}	6.63 ^{ab}	0.25 ^a	392.2	90.5 ^b	63.2
Ganesh	8.44 ^a	7.00 ^a	0.27 ^a	426.8	116.7 ^a	58.0
S E.m±	0.43	0.22	0.02	32.59	8.02	5.96
CD at 5%	1.32	0.67	0.06	NS	24.25	NS

Fruit juice biochemical attributes

Pomegranate being non-climacteric fruit should be picked when fully ripe. Harvesting of immature or overripe fruits reduces the quality. The fruits are ready for harvest in 5 to 6 months after the appearance of blossom. The fruits are harvested when the skin turns slightly yellow and fruit gives a metallic sound when tapped or pressed. In the present study, the juice per cent differed significantly among varieties. Maximum juice per cent was recorded in Mridula (58.8) followed by Jalore Seedless (56.0), Bhagwa (50.4), Phule Arakta (45.8) and the minimum was noticed in Ganesh (37.4%). However,

the difference in juice per cent was non-significant between Mridula and Phule Arakta (Table 5). Similarly, significant variation was noticed with respect to juice TSS (°Brix) and titrable acidity (%) among varieties. Maximum TSS was observed in Jalore Seedless (17.02 °Brix) followed by Ganesh (16.52 °Brix), Bhagwa (15.18 °Brix), Phule Arakta (14.80 °Brix) and the minimum was noticed in Mridula (13.26 °Brix). The same trend was followed by titrable acidity (%) and TSS/acid ratio. Differences in juice per cent parameters may be due to the diverse origin and genetic makeup of varieties evaluated. Similar variation for biochemical attributes of

juice in pomegranate varieties was noticed in different studies (Verma et al, 2013; Bhat et al, 2019).

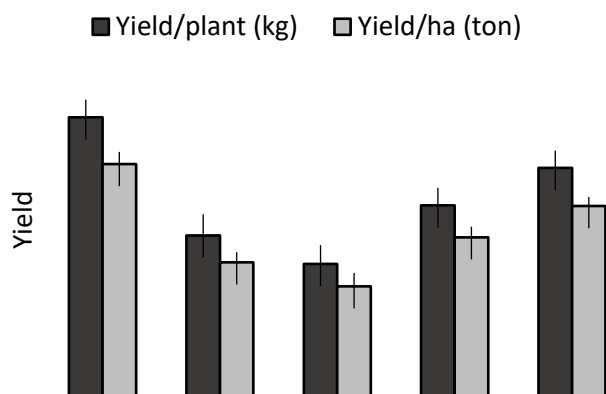


Figure 1. Yield of pomegranate varieties grown under hot arid eco-system

Table 5. Evaluation of pomegranate varieties for fruit juice biochemical attributes

Varieties	Juice per cent	TSS (°Brix)	Titration acidity (%)	TSS/ Acid ratio
Jalore Seedless	56.0 ^{ab}	17.02 ^{ab}	0.71 ^a	24.34
Mridula	58.8 ^a	13.26 ^b	0.70 ^a	18.96
Phule Arakta	45.8 ^b	14.80 ^b	0.65 ^{ab}	22.89
Bhagwa	50.4 ^{ab}	15.18 ^{ab}	0.56 ^b	27.72
Ganesh	37.4 ^b	16.52 ^{ab}	0.69 ^a	24.45
S Em±	4.18	0.83	0.03	2.12
CD at 5%	12.64	2.52	0.10	NS

Conclusion

The performance of five pomegranate varieties was evaluated on the basis of vegetative growth, morphology, yield and quality attributes of fruits to find suitable varieties for hot arid conditions of western Rajasthan. Out of the five varieties evaluated Jalore Seedless was more vigorous than others and showed superiority concerning fruit size, fruit weight, number of fruits/plant and yield/plant than other tested varieties.

Declarations of interests

All authors of this manuscript declare that they have no conflict of interest.

Data sharing

All relevant data are within the manuscript.

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