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Research article

Effect of fertigation of primary nutrients on pomegranate (*Punica granatum* L.) fruit productivity and quality

Nekha Tanari[1], Suma Ramegowda[2]*, Anusree Thottan[1] and Manjunatha Girigowda[3]

[1]Department of Soil Science and Agricultural Chemistry, College of Horticulture,
University of Horticultural Sciences, Bagalkot, Karnataka, India
[2]Zonal Agricultural Research Station, V.C.Farm, Mandya, Karnataka, India
[3]Regional Horticulture Research and Extension, Centre, GKVK, Bangalore, Karnataka, India

***Corresponding Author:** sumassac@gmail.com [Accepted: 19 November 2019]

Abstract: The present research work was conducted in 5year-old pomegranate orchard cultivating Bhagwa variety to evaluate the effect of fertigation and soil application of primary nutrient on its fruit yield and quality parameters. The experiment comprised of six treatments with four replications that included application of 100% recommended dose of fertilizer (RDF) through soil application (SA) (T1) and fertigation (F) (T6), supplementing 50% (T2 and T3) and 75% (T4 and T5) of RDF through fertigation following two different nutrient application schedules. In schedule-1, nutrient application rate and time was retained closer to existing soil application recommendation *i.e*., percent RD N: P_2O_5: K_2O at the rate of 20:20:20 as basal, 50:50:50 at active growth stage and 30:30:30 at rest period. But in schedule-2 nutrient rate at basal and rest application was reduced to 5:15:15 and 20:10:10 percent respectively and relatively higher nutrient rate (75:75:75) was applied during active growth. The result indicated that 75% supplementation of nutrient through fertigation (T_5-25% SA + 75% F) following schedule-2 has produced highest fruit yield (18.49 kg plant^{-1}), number of fruits per plant (67.25) and hermaphrodite flowers (128). The fruit quality parameters *viz*., fruit weight (288.50 g), fruit size, peel weight (98.3 g), aril to peel ration (1.87), aril weight (183.4 g) and aril size and juice quality parameter *viz*., titrable acidity, ascorbic acid, phenolic content and antioxidant activity in peel and juice was found highest in 100%fertigation (T_6). The mineral content of pomegranate juice was in the order of K>N>P>S>Ca>Mg and seed was in the order of N>K>P>Ca>S>Mg and was found in higher concentration in T_6 (100% F) than T_1 (100% SA). The fertigation schedule-2 was found superior in enhancing pomegranate fruit yield and quality as compared to schedule-1.
Keywords: Antioxidant activity - Aril to peel ratio - Ascorbic acid - Soil application.

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INTRODUCTION

The sustainability of any production system requires optimum utilization of resources like water, fertilizer and soil. Fertigation is a modern agro technique that has the potential to combining water and fertilizer application through irrigation and provides an excellent opportunity to maximize yield and nutrient use efficiency besides, minimizing the crop requirement and environmental pollution (Li *et al.* 2002, Kafkafi & Tarchitzky 2011). In semi-arid and arid climatic conditions optimum water supply depends on irrigation. Drip irrigation system has gained wide popularity in areas of acute water scarcity and in the areas where horticultural crops are grown. The water use efficiency is much higher in pressurized irrigation systems and coupling nutrient application in this drip irrigation system will have added advantage of improving nutrient management. Thus, fertigation technique coupled with drip system can economize the use of fertilizer.

Among the various factors responsible for increasing crop production, the use of balanced fertilizer at the right time, right quantity, source and method plays a vital role in enhancing productivity. Since pomegranate is high-value crop most of farmers are following drip irrigation method and are in need of proper fertigation

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schedule for enhancing crop productivity. Pomegranate (*Punica granatum* L.) is one of the important fruit crops of semi-arid region and extensively exported from India. To boost production, its management practices need to be refined of which mineral nutrition plays major role in determining yield and quality of the fruits. Under sub-tropical conditions, pomegranate bears heavily which can exhaust the essential elements in soil, needed for proper growth and development. A regular supply of these nutrients needs to be ensured for sustainable production. Balanced nutrition and proper irrigation scheduling are very essential for proper growth, development and maximum productivity of the plant.

The literature on fertigation of nutrients to pomegranate indicated it as an effective means of controlling the timing and placement of fertilizers to the root zone of the crop. This is known to improve the fertilizers use efficiency by reducing nutrient loss from leaching, volatilization and by fixation in the soil to less available forms. Firake & Deolankar (2000) compared the effect of various levels (75, 100 and 125% RD) of solid soluble fertilizers applied through a drip system on the yield and quality of pomegranate. They reported that highest yield, number of fruits per plant was obtained under the treatment comprising 100% RD of fertilizers. However, fertigation with 75% RD of NPK (625 g N, 250 g P_2O_5 and K_2O / plant) through fertilizer was as good as the 100% RD of conventional fertilizers. Idate *et al*. (2001) reported that application 75% RD of fertilizers through fertigation recorded the maximum yield without impairing the quality of fruits, thus suggesting 25% fertilizers savings over conventional soil fertilization. Firake & Kumbhar (2002) reported 30% saving in the fertilizer dose and 36% increase in yield with application of 70% RD of NPK through fertigation technique as compared to 100% RD of NPK through conventional soil application.

Agarwal *et al*. (2004) indiacted application of 80% nutrienet application using water soluble fertilizers resulted in the economic yield of 52.5 q $ha^{-1}$with benefit-cost ratio of 3.21. Similarly, drip irrigation found beneficial in enhancing pomegranate groth parameter *viz*., tree height, stem diameter and canopy spread (Sulochanamma *et al*. 2005) besides, fruit yield and fruit weight (Prasad *et al*. 2003). Adequate soil moisture throughout the growing season is a key factor in pomegranate production, particularly as harvest approaches in late summer and early autumn, because it helps to reduce the number of split fruit (Larue 1980). It is especially important to avoid drought stress during initial fruit set (Still 2006). Singh *et al*. (2006) recording highest yield (14.89 kg $plant^{-1}$) for 100%RD through fertigation however, 75% RD through fertigation recorded highest number of fruit per plant, aril weight, fruit weight, fruit volume and rind thickness in pomegranate cv. Ganesh. Besides the nutrient quantity, the time of its application plays vital role in yield and quality of pomegranate. Rao & Subramanyam (2009) reported highest plant height, stem girth with 50% recommended dose of nitrogen at fortnight intervals followed by 50% recommended dose of nitrogen at monthly intervals. Dhankar *et al*. (2010) observed that fertigation level at 100% recommended dose of fertilizers at alternate day showed significantly higher vegetative growth and physico-chemical characteristics.

Shanmugasundaram & Balakrishnamurthy (2013) revealed that application of 50% recommended dose of fertilizers through fertigation enhanced flower, fruit yield & fruit quality parameters *viz*., fruit weight (211.43 g), fruit volume (228.75 cc), peel weight (62.83 g), total aril weight (127.53 g), 100 aril weight (22.31 g), total seed weight (14.87 g) and fruit yield (11.1 kg/ plant) as compared to soil application. Jhakar (2010) found significant effect of 100% recommended dose of fertilizers through fertigation on relative growth rate of shoots, plant spread and height in pomegranate. Haneef *et al*. (2014) recorded highest vegetative growth and yield contributing characteristics, yield and leaf N, P & K contents along with minimum acidity, juice content, TSS and organoleptic score in pomegranate cv. Bhagwa with 125% recommended dose of fertilizers. Whereas TSS: acid ratio was high at 100% RDF through fertigation.

The existing nutrient recommendation for pomegranate are basically for soil application and vary considerably among different farm institutes (400–625:200–250:200–250 $N:P_2O_5:K_2O$ g $plant^{-1}$) and from place to place (*viz*. 500–1000: 500: 250–500 - $N:P_2O_5:K_2O$ g $plant^{-1}$) (Singh *et al*. 1988, Prasanna & Dhander 1999). Further, the time of nutrient application has also known to have significant influence on pomegranate yield and quality *viz*., nitrogen on flowering pattern, potassium on fruit colour, calcium and boron on fruit cracking *etc*. (Gosh *et al*. 1996). Thus, there is need to study effective use of fertilizer nutrients with a goal to match nutrient supply with crop requirements and minimize nutrient losses from fields.

Fertigation technique allows uniform and exact measured amount of nutrient application to plant rhizosphere. However, this technique is associated with certain limitation *viz*., relatively higher initial and maintenance cost, water pressure for uniform distribution of nutrients to all plants in the fields, clogging of emitter, undulating field condition that restricts uniform water and nutrient application, power problem for running the system, lack of availability of expertise for effective use of the system, lack of fertigation schedule to supply the optimum nutrient *etc*. Hence, it is sometimes difficult to completely relay on fertigation for nutrient management. Combining various fertilizer application methods thus becomes important in optimizing nutrient schedule to meet crop requirement and farmers need. In this context the present study was formulated with the aim to study the quantity and time of primary nutrient application at various pomegranate growth stages through fertigation and soil application on its yield and quality

MATERIAL AND METHODS

Field experiment

A field experiment was carried out in a five-year-old pomegranate orchard at Udyanagiri, Navanagar, Bagalkot, India. The location comes under northern dry zone of Karnataka and situated at 16.16º N latitude and 75.65º E longitude at an altitude of 678.00 m above Mean Sea Level (MSL). The plant spacing was 4.5 × 4.5 m with a plant population of 493 plants ha^{-1}. The experiment was laid out with six levels of NPK and replicated four times. The cropping season was *Hasta bahar*, where in pomegranate plants were put into artificial stress by withholding water for one month and leaves were defoliated during third week of August by spraying ethrel (2.0–2.5 ml $litre^{-1}$). The plants were then pruned, lightly irrigated and applied with recommended dose of fertilizer. The new flushes appeared on the tree between 15–20 days and profuse flowering were observed during second fortnight of September. The observations were recorded at various stages uniformly for all the treatments.

Treatment details

The nutrient recommendation for pomegranate as given by University of Horticultural Sciences, Bagalkot *i.e* 400:200:200 N:P_2O_5:K_2O gram $plant^{-1}$ was followed to implement the experiment that comprise six treatments and four replication as described below,

T_1 : 100% SA
T_2 : 50% SA + 50% F (Schedule-1)
T_3 : 50% SA + 50% F (Schedule-2)
T_4: 25% SA + 75% F (Schedule-1)
T_5: 25% SA + 75% F (Schedule-2)
T_6: 100% F

The recommended dose of nutrients required for different treatments were applied using soluble fertilizers *viz*., mono ammonium phosphate (12-60-0), urea, sulphate of potash and phosphoric acid through fertigation and di-ammonium phosphate, urea and sulphate of potash for soil application. Two fertigation schedules were followed to fulfill the recommended dose of primary nutrients to pomegranate plants. In schedule-1 nutrient application rate and time was retained closer to recommendation *i.e.*, percent RD N: P_2O_5: K_2O as 20:20:20 as basal, 50:50:50 at active growth stage and 30:30:30 at rest period. The basal and rest period nutrient application rate was reduced to 5:15:15 and 20:10:10 percent RD N: P_2O_5: K_2O respectively in fertigation schedule-2 however, high nutrient rate (75:75:75% RD N: P_2O_5: K_2O) was applied during active growth stage as following,

	Percent recommended dose of N: P_2O_5: K_2O	
	Schedule-1	**Schedule-2**
Basal	20:20:20	5:15:15
Active growth stage	50:50:50	75:75:75
Rest period	30:30:30	20:10:10

Fertigation was done through a pressure differential tank system. This system utilizes an pressure metal tank with anti-acid internal wall protection in which a pressure differential is created by a throttle valve that diverts part of the irrigation water into the tank; and the entire fertilizer amount in the tank is delivered to the irrigation area. Weighed quantity of soluble fertilizers as per schedule was dissolved in tank and then into lateral lines as per the treatment. Fertigation was done on weekly basis through drip irrigation.

Flowering Pattern

The number of male, intermediate flowers and hermaphrodite flowers were counted after thirty days of *bahar* treatment and their percentile was computed.

Harvesting and Grading

The pomegranate fruits were harvested in four pickings from April to May 2017. The marketable fruits harvested from each plant were graded as per the guidelines from Directorate of Marketing and Inspection

(DMI), India and accordingly fruits were categorized in to three grades *viz*., < 250 g, 250-300 g and > 300 g. The weight of the fruit harvested from pomegranate plant at each picking was measured and pooled weight was used to express fruit yield per plant in kilogram.

Fruit quality parameter

The five fruits picked randomly (1 from >300 g, 3 from 250–300 g and 1 from <250 g) in each replication were used to record the fruit parameters *viz*., average fruit weight, average fruit diameter (horizontal axis) and length (vertical axis) using vernier calipers, average peel weight including lamella and aril weight. The aril weight was divided by the peel weight to obtain aril to peel ratio and randomly chosen five aril's broadest length and width was measured using vernier calipers and average was computed.

Juice quality parameter

The pH of fresh pomegranate juice was estimated by using digital pH meter having a combined electrode as described by Jackson (1973). The total soluble solids (TSS) of the fresh juice were recorded using digital refractometer (Model HI 9680I) at 26.5ºC and expressed in ^{0}Brix. The total titrable acidity of juice samples were estimated by titrating known quantity of juice sample against 0.01 N NaOH using phenolphthalein. The value was expressed in terms of percent titrable acidity equivalent to citric acid (AOAC 1984). Ascorbic acid content of fresh pomegranate juice was estimated titrimetrically using 2, 6- dicholrophenol indophenol dye as per the modified procedure of AOAC. Known quantity of juice was diluted to known volume with four per cent oxalic acid and an aliquot of five ml was titrated against 2, 6-dichlorophenol indophenols to express the result as mg of ascorbic acid per 100 ml of fruit juice. The percentage of 2,2- diphenyl 1- picrylhydrazyl (DPPH) radical scavenging activity of pomegranate juice and fresh peel samples were used to determine their antioxidant activity as described by Eghdami & Asli (2010). A known weight of fresh peel was crushed with 2 ml of methanol and vortexed thoroughly for 10 minutes. The supernatant sample was then mixed 3.9 ml of 25 mg L^{-1} methanolic solution of DPPH, vortexed for 1 minute and kept for 30 minutes in darkness at 37ºC. A blank was prepared similarly with methanol. Then samples were read at spectrophotometer at 517 nm and calculated as following,

$$\text{Antioxidant activity (\%)} = \frac{\text{A 517nm of control} - \text{A 517nm of sample}}{\text{A 517 nm of control}} \times 100$$

The phenolic content in known weight of fresh peel and juice was extracted with 80% ethanol and treated with Folin Ciocalteau reagent and sodium carbonate. The intensity of color developed was read using spectrophotometer at 650 nm. The total phenol content was calculated by referring to standard graph and expressed in mg per gram of fresh sample (Sadasivam & Manickam 2005).

Pomegranate juice and seed mineral content

Pomegranate fruits were cut into four to six parts by stainless steel knife. Then the peel and arils were separated manually. Juice was extracted from arils by using manual juice extractor and immediately subjected to quality and nutrient analysis. The seeds separated during the extraction of juice were collected and washed with distilled water and oven dried at 65ºC. Later, powdered the samples using stainless steel mixer jar and preserved in paper cover and stored for the further analysis.

Table 1. Analytical methods followed for determination of mineral content in pomegranate juice and seeds.

Parameters	**Methods**	**Reference**
Total Nitrogen	Kjeldhal Distillation method	Piper (1966)
Total Phosphorus	Vanadomolybdate method	
Total Potassium	Flame photometry	
Total Calcium	Versenate titration method	
Total Magnesium	Versenate titration method	
Total Sulfur	$BaCl_2$ Turbidimetry	

The pomegranate juice was acid digested for determining its mineral composition except for nitrogen done by siphoning 25 ml of the extracted juice and treated with di-acid (HNO_3 : $HClO_4$- 10:4). Further, it was digested on the sand bath and the sample was used to determine the mineral content in the juice sample by adopting the standard protocols as indicated in table 1. 0.5 g of oven dried pomegranate seeds were acid digested similar to juice as described to find its mineral content.

Nitrogen content in juice was estimated using 15 ml of the extracted juice sample by digesting with conc. H_2SO_4 in presence of digestion mixture ($CuSO_4$: K_2SO_4: Se in 100:40:1). The digested sample was distilled under alkaline condition (by adding 40% NaOH solution) and the distilled ammonia was trapped in 4% boric acid plus mixed indicator solution. The ammonia collected in boric acid was titrated against standard acid for estimation (Piper 1966). Similarly 0.5 g of oven-dried pomegranate seeds was used to find its nitrogen content by following the above-said protocol.

RESULTS AND DISCUSSION

Effect of fertigation on pomegranate flowering

Development of flowers after bahar treatment and the type of flowers are the key factors that govern fruit yield and quality in pomegranate cultivation. Pomegranate is characterized by having both bisexual (hermaphrodite) and functionally male flowers on the same tree, a condition referred to as andromonecy (Wetzstein *et al*. 2015). Some authors also signify an intermediate type flowers that exhibit weak pistil development (Wetzstein *et al*. 2015) that also have bisexual character. In the present investigation, the highest number of flowers was observed in schedule-2 (T_5- 222.0 and T_3- 214.0) and 100% fertigation (T_6- 199.0) treatments as compared to schedule-1 (T_2-160.0 and T_4-172.0) and 100% soil application (T_1- 162.0) (Table 2). This could be attributed to the supply of N to pomegranate plants. Abundant nitrogen supply with ample opportunity for carbohydrate synthesis is known to produce vegetative growth and reduce flowering (Corbesier *et al*. 2002). Bernier *et al*. (1981) and Rideout *et al*. (1992) reported wider C:N endogenous ratio promotes flowering in plants while, narrow ratio stimulated vegetative growth. Amongst various treatments high leaf N content was observed in 100% soil application (T_1- 2.09%) and schedule-1 (T_2- 2.01% and T_4- 1.98%) fertigation treatments (data not given). This might have reduced flowering by enhanced vegetative growth during bud differentiation (Corbesier *et al*. 2002). The hermaphrodite flowers that possess positive correlation with fruit yield (Shanmugasundaram & Balakrishnamurthy 2013) were significantly higher in treatments that received lower basal application of N *viz*., T_5 (123.0) T_4 (128.0) and T_6 (107.0).

Table 2. Pomegranate flowering pattern as influenced by fertigation.

Treatments	No. of male flower	No. of hermaphrodite flower	Total number of flowers
T_1- 100% SA	78.0 (48.1)	84.0 (51.9)	162.0
T_2- 50% SA + 50% F (S1)	78.0 (48.8)	82.0 (51.2)	160.0
T_3- 50% SA + 50% F (S2)	92.0 (43.1)	122.0 (56.9)	214.0
T_4- 25% SA + 75% F (S1)	83.0 (48.3)	89.0 (51.7)	172.0
T_5- 25% SA + 75% F (S2)	94.0 (42.4)	128.0 (57.6)	222.0
T_6- 100% F	92.0 (46.2)	107.0 (53.8)	199.0
SEm±	3.21	8.72	6.3
CD at 5%	9.84	26.76	19.27

Note: Numbers in the parenthesis indicate the per cent number of flowers to the total number of flowers.

Effect of fertigation on pomegranate fruit yield and yield parameters

Number of Fruits: The optimum number of fruits determine fruit yield and quality in pomegranate and it is directly correlated with flowering pattern. The highest number of fruits were recorded in T_5 (67.25) followed by T_3 (54) and T_6 (58.75) (Table 3). The hermaphrodite flowers has positive correlation with fruit bearing in pomegranate (NRCP 2011). Relatively lower number of hermaphrodite flowers in schedule-1 fertigation and 100% soil application (T_1) might have reduced fruit number in these treatments. The findings of Singh *et al*. (2006), Shanmugasundaram & Balakrishnamurthy (2013) and Haneef *et al*. (2014) also confirm higher number of fruits with the fertigation treatment in pomegranate.

Table 3. Effect of fertigation on pomegranate fruit yield and yield parameters.

Treatments	No. of fruits per plant	Fruit Weight (g)	Fruit Diameter (mm)	Fruit Length (mm)	Fruit Yield (kg plant $^{-1}$)
T_1- 100% SA	52.25	198.4	72.09	70.60	11.36
T_2- 50% SA + 50% F (S1)	50.50	210.5	72.75	71.53	12.06
T_3- 50% SA + 50% F (S2)	59.00	247.6	73.98	74.74	14.98
T_4- 25% SA + 75% F (S1)	51.50	236.5	76.02	75.92	13.46
T_5- 25% SA + 75% F (S2)	67.25	270.3	78.78	80.03	18.49
T_6- 100% F	58.75	288.5	79.71	76.07	16.89
SEm±	1.57	9.62	1.70	1.75	0.57
CD at 5%	4.80	29.52	5.21	5.37	1.76

Fruit weight and Size: The average fruit weight of pomegranate varied from 198.40 g to 288.50 g in different treatments (Table 3). The highest fruit weight (288.50 g) was observed in 100% fertigation (T_6) that was on par with T_5 (75% F schedule-2- 270.30 g) and the lowest fruit weight (198.40 g) was observed in 100% soil application (T_1). The maximum fruit diameter of 79.71 mm was found in T_6 (100% F) treatment, while fruit length was highest in T_5 (75% F– 80.03 mm). The treatment receiving 100% soil application recorded lowest fruit diameter (72.09 mm) and length (70.60 mm). Continuous supply of primary nutrients through fertigation till fruit enlargement stage might have resulted in maintenance of high nutrient availability throughout the crop growth hence, promoting better fruit size and weight. The increase in fruit size and weight with increasing quntity of N, P, K fertilizers through fertigation was also reported by Shirgure *et al*. (2001), Mahalakshmi *et al*. (2001) and Thakur & Singh (2004).

Fruit yield: The highest marketable fruit yield of 18.49 kg plant^{-1} was recorded in T_5 (25% SA+ 75% F with schedule-2) that was on par with T_6 (100% F- 16.89 kg plant^{-1}) (Table 3). The treatment receiving 100% soil application of primary nutrients recorded the lowest fruit yield 11.36 kg plant^{-1}. Further, partial supplementation of major nutrients through fertigation enhanced the fruit yield recording 14.98 kg plant^{-1}, 13.46 kg plant^{-1} and 12.06 kg plant^{-1} in T_3, T_4 and T_2 respectively. This could be attributed to slower vegetative growth during bahar initiation followed by higher number of hermaphrodite flowers, higher number of fruits and fruit weight in these treatments. Keeping lower dose of basal application of major nutrients (5:15:15 % RD N: P_2O_5: K_2O) and applying relatively higher quantity (75:75:75% RD N: P_2O_5: K_2O) during active growth stages with higher number of split application has resulted in high amount of nutrient availability at critical growth stages. These factors might have enhanced fruit yield in fertigation treatments compared to soil application. Enhanced fruit yield with fertigation was also observed by Shirgure *et al*. (2001), Mahalakshmi *et al*. (2001) and Thakur & Singh (2004).

Effect of fertigation on pomegranate fruit quality parameters

Pomegranate fruit peel weight, aril weight, aril to peel ratio, aril length and aril breadth are the quality parameters that significantly influences its shelf life and consumer preference (Table 4). Application of primary nutrients 100% through fertigation (T_6) recorded significantly higher aril weight (183.4 g), peel weight (98.30 g) and aril to peel ratio (1.87) and found on par with T_5 (169.43 g, 91.6 g and 1.84 respectively). Application of 50% RDF through schedule-2 fertigation recorded relatively higher quality parameters as compared to 75% RDF through schedule-1 fertigation. The 100% soil application recorded the lowest quality parameters as compared to all other treatments. A similar trend was observed with aril length and aril breadth where T_6 recorded maximum values of 10.89 and 7.13 mm respectively that were on par with T_5 (10.82 mm and 7.04 mm) and T_3 (10.74 mm and 6.93 mm). The nutrient supply and its assimilation by crop are known to have significant influence on fruit quality parameters. Potassium is required for translocation of photosynthates from source (leaves) to sink (fruit) (Khayyat *et al*. 2012). Similarly, the optimum nitrogen is required for accumulation of protein and for fleshiness of fruit (Rao & Subramanyam 2009). Optimum calcium supply is required for thickness of peel and to avoid cracking of fruits (Korkmaz & Askin 2015). All these factors might have contributed to better quality parameters in treatments receiving higher quantity of primary nutrients through fertigation. Fruit maturation stage requires relatively higher K to improve fruit quality which might have fulfilled in fertigation treatments. Study of Singh *et al*. (1988) and Khayyat *et al*. (2012) also indicated improved fruit quality parameters with application of K during fruit maturity stage.

Table 4. Effect of fertigation on pomegranate fruit quality parameters.

Treatments	Peel Weight (g/fruit)	Arils Weight (g/fruit)	Aril/ Peel	Aril Length (mm)	Aril Breadth (mm)
T_1- 100% SA	79.75	110.25	1.32	9.60	6.14
T_2- 50% SA + 50% F (S1)	83.25	122.30	1.41	10.37	6.65
T_3- 50% SA + 50% F (S2)	86.00	153.23	1.76	10.74	6.93
T_4- 25% SA + 75% F (S1)	86.25	144.45	1.68	10.44	6.86
T_5- 25% SA + 75% F (S2)	91.60	169.43	1.84	10.82	7.04
T_6- 100% F	98.30	183.40	1.87	10.89	7.13
SEm±	3.19	8.57	0.10	0.23	0.18
CD at 5%	9.79	26.30	0.30	0.71	0.54

Effect of fertigation on pomegranate fruit juice quality parameters

The pomegranate juice pH and TSS did not record significant variation due to different treatments while, titrable acidity and ascorbic acid content varied significantly among different treatments (Table 5). The juice pH ranged from 3.46-3.65 and TSS from 15.05-15.85°B. The titrable acidity and ascorbic acid content was highest in T_6 recording 0.91% and 23.93 mg / 100 ml respectively followed by T_5 (0.85% and 21.34 mg / 100 ml respectively). The variation in these parameters could be due to higher K and N content in these treatments. Khayyat *et al*. (2012) reported increased titrable acidity and ascorbic acid content in pomegranate fruit juice with the application of 250 mg L^{-1} $plant^{-1}$ of K during fruit enlargement stage owing to its role in accumulation of higher photosynthates (carbohydrates) in fruits. Further, higher levels of nitrogen stimulate synthesis and catalytic activity of several enzymes and co-enzymes which are instrumental in ascorbic acid synthesis (Boora & Singh 2000, Sheikh & Manjula 2012).

Table 5. Effect of fertigation on pomegranate fruit juice quality parameters.

Treatments	pH	TSS (^{o}B)	Titrable acidity (%)	Ascorbic acid (mg/100 ml)
T_1- 100% SA	3.65	15.33	0.72	19.13
T_2- 50% SA + 50% F (S1)	3.61	15.70	0.76	19.29
T_3- 50% SA + 50% F (S2)	3.60	15.05	0.82	20.82
T_4- 25% SA + 75% F (S1)	3.59	15.58	0.80	20.30
T_5- 25% SA + 75% F (S2)	3.53	15.85	0.85	21.34
T_6- 100% F	3.46	15.60	0.91	23.93
SEm±	NS	NS	0.03	0.83
CD at 5%	NS	NS	0.08	2.56

The pomegranate juice recorded highest phenolic content and antioxidant activity in 100% fertigation treatment (0.66 mg g^{-1} and 52.55% respectively) followed by T_5 (0.63 mg g^{-1} and 50.05% respectively) (Table 6). A similar trend was observed in the fruit peel. The exact reason for higher accumulation is obscure. However, some literature reveals a positive correlation between K and phenols, K and antioxidant activity (Dani *et al*. 2007, Tamuly *et al*. 2013).

Table 6. Effect of fertigation on phenolic content and antioxidant activity of pomegranate fruit.

Treatments	Phenolic content (mg g^{-1})		Antioxidant activity (%)	
	Juice	Peel	Juice	Peel
T_1- 100% SA	0.53	0.84	42.75	68.87
T_2- 50% SA + 50% F (S1)	0.57	0.87	44.14	69.20
T_3- 50% SA + 50% F (S2)	0.61	0.93	48.52	70.40
T_4- 25% SA + 75% F (S1)	0.62	0.91	46.77	71.94
T_5- 25% SA + 75% F (S2)	0.63	0.93	50.05	77.41
T_6- 100% F	0.66	0.99	52.55	79.43
SEm±	0.02	0.02	2.00	2.24
CD at 5%	0.06	0.07	6.14	6.89

Effect of fertigation on pomegranate juice and seed mineral content

Table 7. Effect of fertigation on pomegranate juice mineral content.

Treatments	N		P		K	
	Juice (g L^{-1})	Seed (%)	Juice (g L^{-1})	Seed (%)	Juice (g L^{-1})	Seed (%)
T_1- 100% SA	4.34	1.51	1.95	0.33	7.68	0.78
T_2- 50% SA + 50% F (S1)	4.87	1.53	2.32	0.43	7.86	0.81
T_3- 50% SA + 50% F (S2)	5.00	1.59	2.44	0.44	8.13	0.91
T_4- 25% SA + 75% F (S1)	5.20	1.62	2.59	0.43	7.93	0.86
T_5- 25% SA + 75% F (S2)	5.40	1.73	2.48	0.47	8.85	1.06
T_6- 100% F	5.87	1.77	2.78	0.49	9.31	1.04
SEm±	0.25	0.04	0.14	0.02	0.34	0.05
CD at 5%	0.76	0.13	0.43	0.08	1.03	0.14
	Ca		**Mg**		**S**	
	Juice (g L^{-1})	**Seed (%)**	**Juice (g L^{-1})**	**Seed (%)**	**Juice (g L^{-1})**	**Seed (%)**
T_1- 100% SA	0.66	0.41	0.42	0.30	1.75	0.10
T_2- 50% SA + 50% F (S1)	0.69	0.39	0.45	0.32	1.81	0.11
T_3- 50% SA + 50% F (S2)	0.73	0.48	0.44	0.36	1.91	0.14
T_4- 25% SA + 75% F (S1)	0.68	0.44	0.49	0.34	1.83	0.11
T_5- 25% SA + 75% F (S2)	0.84	0.50	0.50	0.40	2.12	0.16
T_6- 100% F	0.86	0.51	0.51	0.42	2.34	0.18
SEm±	NS	NS	NS	0.02	0.08	0.008
CD at 5%	NS	NS	NS	0.06	0.26	0.023

The mineral content in pomegranate juice showed significant variation due to various treatments with respect to N, P, K and S while, the treatment effect was insignificant on Ca and Mg (Table 7). In general the concentration of nutrient content in juice were in the order of K>N>P>S>Ca>Mg (Raghupathi & Bhargava 1996). Amongst the major nutrients, highest K was noticed in T_6 (100% F- 9.31g L^{-1}) followed by T_5 (25% SA+ 75% F with schedule-2- 8.85 g L^{-1}). Similarly highest P and N content was observed in T_6 (2.78 g L^{-1} and 5.87 g L^{-1} respectively) followed by T_5 (2.48 and 5.40 g L^{-1}).

The mineral content in seeds varied significantly due to the effect of various treatments except for Ca. The content of these nutrients in seeds followed the order N>K>P>Ca>S>Mg (Raghupathi & Bhargava 1996). The concentration of N was maximum compared to other nutrients and highest was recorded in 100% fertigation (T_6- 1.77%). The P content was found highest in T_6 (0.49%) followed by T_5 (0.47) but, the K content was higher in T_5 (1.06%) followed by T_6 (1.04%). This could be attributed to the higher rate and number of split application of primary nutrients during active growth stage resulting in higher accumulation in leaves and further translocation to fruits (Rao & Subramanyam 2009). The Mg and S content also high in 100% fertigation (T_6- 0.42 and 0.18% respectively) followed by T_5 (0.40 and 0.16% respectively).

CONCLUSION

The present investigation revealed that T5 treatment that includes application of primary nutrients 25% through soil application and 75% through fertigation schedule-2 was most effective in obtaining higher pomegranate fruit yield. However, the pomegranate fruit quality was superior with 100% fertigation (T6) of primary nutrients. The present study emphasizes need for applying relatively higher amount of primary nutrients during active growth stage by maintaining optimal supply at basal and rest period for enhancing pomegranate fruit productivity. Fertigation is a better option for obtaining quality fruit that assures higher number of split application of nutrients throughout active growth period.

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