

Original Research Article

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## Productivity, Water Use, Quality and Economics of Pomegranate Fertigation in Semiarid Conditions of India

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### ABSTRACT

Field experiment was conducted in semi-arid western India for three consecutive years (2008-2010) to study the response of drip fertigation on yield, quality and economics of pomegranate. The experiment was laid out in a randomized block design with seven treatments replicated three times. The experiment comprised of 100, 80 and 60 % water soluble fertilizers applied through drip in 20 equal weekly splits and results were compared with four control treatments. The study indicated the beneficial effects of drip irrigation in terms of 23.5 % increase in yield and 48.6 % water saving whereas drip with fertigation resulted into 40 to 61 % increase in pomegranate yield as compared to conventional method. The 100 % recommended dose of fertilizer through drip in 20 weekly splits showed 61 % increase in yield (14.6 t ha<sup>-1</sup>). However, it was on par with 80 % fertigation treatment (13.7 t ha<sup>-1</sup>). The pomegranate fruit yield obtained under 60 % fertigation (12.6 t ha<sup>-1</sup>) produced 38.9 % more yield as compared to farmer's practice (9.05 t ha<sup>-1</sup>) indicating 40 % fertilizer saving due to fertigation. Maximum water use efficiency (79 kg ha<sup>-1</sup>mm<sup>-1</sup>) was obtained in 100 % fertigation. The fertigation resulted into B:C ratio in pomegranate in spite of very high market prices of water soluble fertilizers. The maximum net seasonal income (Rs. 475758 ha<sup>-1</sup>), total net income (Rs. 922546), net extra income over conventional method (Rs. 217984 ha<sup>-1</sup>) and maximum water productivity (Rs. 4607 mm<sup>-1</sup> of water) were obtained in 100 % fertigation however all the economical parameters were on par with 80% fertigation applied in 20 equal weekly splits.

### Keywords

Drip irrigation,  
Fertigation,  
Pomegranate yield,  
Weekly splits,  
Water soluble  
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### Introduction

India is the largest producer of pomegranates (*Punica granatum*) in the world. Pomegranate is an important fruit crop and plays vital role in Indian agriculture economy. It is estimated that approximately 2 million tons of pomegranate are produced in the world. Out of this, 1 million ton are produced in India on

1.25 lakh ha area under cultivation of pomegranate. There has been a steady increase in area and production in the country and. by the year 2025, the area under pomegranate is projected to increase to 7.5 lakhs ha, from 1.25 lakhs ha at present. Consequently, production is expected to increase by 10 folds and export by 6.97 folds by the year 2025 (Anonymous, 2008). The

total production of pomegranate in country is mainly concentrated in the western part (Maharashtra state). The area has acreage of pomegranate around 1 lakh ha with annual production of 8 lakh tons having average productivity of 8 t ha<sup>-1</sup> (Anonymous, 2010). However, the productivity of state is lowest as compared to all other states. The major factors responsible for low pomegranate productivity in the region are poor irrigation management and imbalanced use of fertilizers. Thus, scientific control in the application of these two inputs certainly needed to improve pomegranate yield.

Most of the farmers in this region are now cultivating pomegranate on drip due to its potential to improve productivity as well as obtaining high remunerative returns. The increasing popularity of drip for pomegranate undoubtedly raised opportunities for improved fertilizer management but it leads to higher cost of cultivation including cost of fertilizers and their application. Recently, drip irrigation combined with fertigation has been found to benefit farmers because of the very high efficiency of fertilizer use (Solaimalai *et al.*, 2005). Few research experiments have clearly demonstrated that the average yield increased to the tune of 40 % by applying drip fertigation on pomegranate as compared to traditional irrigation and soil application (Firake and Kumbhar, 2002; Anonymous, 2010). Application of fertigation can enhance the fertilizer use efficiency, improves quality parameters and minimizes the water and nutrient losses to the extent of 25-30 % (Singh *et al.*, 2006; James Ayars 2011). The application of water soluble fertilizer with appropriate apportioned splits through drip irrigation may lead to decrease in cost of cultivation and to improve the quality and quantity of fruit yields (Dhanumjaya Rao and Subramanyam, 2009). However, optimal schedule of fertilizer application through drip fertigation for pomegranate cultivation is not

available. Thus, research studies on standardization of fertigation schedule for pomegranate and to assess its effect on growth, yield and quality in western India was undertaken.

## **Materials and Methods**

The field experiment was conducted during three consecutive seasons from 2008 to 2010 at research farm of Mahatma Phule Krishi Vidyapeeth, Rahuri. Agroclimatically, the area falls under the scarcity zone of Maharashtra with annual average rainfall of 520 mm which is mostly erratic and uncertain in nature. The experimental plot was uniform and levelled with well drained, light medium soil, with pH as 7.40. The soil depth was 60 cm with hydraulic conductivity and organic carbon as 1.31 cm hr<sup>-1</sup> and 0.65 %, respectively. The soil texture was sandy clay loam with 11.67 % coarse sand, 40.63 % fine sand, 23.05 % silt and 24.62 % clay. The bulk density of soil was 1.43 g cc<sup>-1</sup> and electrical conductivity was 0.18 dSm<sup>-1</sup>. The soil was high in available N (155.2 kg ha<sup>-1</sup>), and P (15.81 kg ha<sup>-1</sup>) and very high in available K (300 kg ha<sup>-1</sup>) content. The soil was having moisture contents at field capacity, permanent wilting point and available soil moisture as 29.90, 14.31 and 15.59 % respectively. The experiment was conducted in newly established orchard planted at a spacing of 4.5 x 3.0 m during November, 2005. The harvesting was done in August 2008, 2009 and 2010, respectively.

The field experiment was laid out in Randomized Block Design (RBD) with seven treatments replicated thrice with 8 plants under each plot. The treatments comprised of 100, 80 and 60 % recommended dose in form of water soluble fertilizers (WSF) in 20 equal weekly splits (T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub>), only N fertigation P & K through soil (T<sub>4</sub>), drip irrigation without fertigation (T<sub>5</sub>) conventional method of

irrigation and fertilizer application (T<sub>6</sub>) and farmer's practice (T<sub>7</sub>). The recommended dose of fertilizer considered for pomegranate was 625:250:250 N: P<sub>2</sub>O<sub>5</sub>: K<sub>2</sub>O, g plant<sup>-1</sup>. The fertilizer dose for farmer's practice was 1382:320:602 gm plant<sup>-1</sup>. In fertigation treatments water soluble fertilizer treatments, urea (46:0:0), urea phosphate (17:44:0) and muriate of potash (0:0:60) were used for fertigation. In 'N' fertigation (T<sub>4</sub>), all the 'N' was applied through urea in 20 equal weekly splits. In treatments T<sub>4</sub> (P & K), T<sub>5</sub> and T<sub>6</sub>, the nutrients were applied through soil as per conventional practice.

The drip irrigation system was installed to meet out crop water requirement and for fertigation of water soluble fertilizers. The amount of water (litres day<sup>-1</sup>) to be applied through drip irrigation was calculated by the climatological approach method (Allen. et. al, 1994). The reference evapotranspiration was estimated using Evapotranspiration Monitoring Station (ICT International, Australia) installed at research farm. The lateral lines of 16 mm diameter LDPE pipes were laid along the crop rows and each lateral served each row of crop. The laterals were provided with two on-line drippers of 8 lph discharge capacity plant<sup>-1</sup>. The spacing between two adjacent laterals and emitters within plot was 4.50 m and 0.75 m from the trunk of either side, respectively. In case of surface irrigation, 80 mm depth of irrigation was applied at 75 mm of cumulative pan evaporation. The depth of water in surface method of irrigation was estimated using standard methodology. The growth, yield and quality parameters and its economics of pomegranate were studied.

## Results and Discussion

### Yield contributing characters

The pooled data for three years revealed that the fertigation significantly increased the

yield and yield contributing characters of pomegranate as compared to drip irrigation without fertigation. The pooled yield contributing characters viz., number of fruits plant<sup>-1</sup> (93.57), size of fruit (8.98 cm), weight of fruit (0.21 kg) and 100 arils weight (12.38 g) were observed maximum in 100% WSF fertilizers were applied in 20 splits over all other treatments. The drip irrigation with conventional fertilizers produced only 82.93 fruits. The surface method of irrigation produced only 68.14 fruits, which were lowest among all treatments. The weight of single fruit in 10 % fertigation dose was at par with 80 % and 60 %. The surface method of irrigation produced lowest weight of single fruit (0.18 Kg). The values of yield contributing characters recorded in 'N' fertigation were also sizably high. This fact is supported by the works of Firake and Deolankar (2000) that the higher number of fruits plant<sup>-1</sup>, size of fruit and greater weight of fruit can be achieved with fertigation.

### Fruit yield

The three years pooled data of pomegranate yield ranged between 9.05 t ha<sup>-1</sup> to 14.58 t ha<sup>-1</sup> (Table 1). Among various treatments, the significantly highest yield of 14.58 t ha<sup>-1</sup> of pomegranate fruit was obtained in 100% recommended dose of fertilizer was applied in the form of urea phosphate, urea and muriate of potash through drip. The yield under 100 % fertigation dose was 60.8 % more than farmer's practice. However, it was at par with 80% dose in 20 weekly splits.

The fruit yield obtained under drip irrigation without fertigation (N, P & K through soil) was 11.19 t ha<sup>-1</sup> which was found to be quite less than 60 % fertigation (12.60 t ha<sup>-1</sup>). It indicated that fertigation using WSF can save fertilizer dose upto 40% with increase in yield. It is also revealed in N fertigation (P and K through soil) that incurring slightly more cost, pomegranate yield can be

increased sizably ( $12.70 \text{ t ha}^{-1}$ ) by applying urea through drip irrigation. The lowest yield of  $9.05 \text{ t ha}^{-1}$  was obtained farmers' practice. The reasons of low yield in surface irrigation might be that crop had to undergo water stress between two irrigations. The results are in conformity with Singh *et al.*, (2006).

### Quality of juice

The data indicated that the quality parameters viz., total soluble solids (TSS) and acidity were observed to be improved due to drip and fertigation significantly as compared to conventional method of irrigation (Table 2). The pH, TSS were found maximum and minimum in acidity in fertigation @ 100 % which was at par with 80 % dose. Application of water soluble fertilizers had a positive effect on TSS content. It is observed that as the fertilizer level increased, TSS content also increased. Increased moisture stress in surface irrigated treatments resulted into increased acidity of fruit.

### Organoleptic characteristics

The organoleptic characters viz., colour, taste and texture of pomegranate (Table 2) were improved due to drip irrigation and fertigation. The 100% recommended dose as WSF through drip recorded superior taste, colour and texture, which was at par with 80 % dose. The surface method of irrigation (farmer's practice) recorded lowest colour rating (6.5). The surface method of irrigation also recorded minimum ratings for texture (6.70). The fertigation and drip irrigation treatments recorded the better taste rating as compared to conventional methods. The reasons for low quality of fruits in surface irrigation might be the high application of irrigation water leached down the nutrients below the root zone of crop. Similar trend of result are also reported by Firake and Kumbhar (2002).

### Water use

The drip method of irrigation resulted into lowest water requirement (194.2 mm) as compared to surface method of irrigation (376.97 mm) and thus resulted into 48.73 % water saving (Table 3). Thus, 100 % recommended dose of fertilizer applied through drip resulted into 60.8 % increase in yield with 48.73 % water saving, where as only drip (without any fertigation) resulted into 23.48 % increase in pomegranate yield with similar water saving. The treatment T<sub>3</sub> (60% WSF in 20 splits) resulted into 38.81 % increase in yield with 40% saving in fertilizer and 48.73 % saving in water. The drip irrigation and fertigation treatments resulted into higher values of water use efficiency ( $68.92$  to  $78.99 \text{ kg ha}^{-1}\text{mm}^{-1}$ ) as compared to farmer's practice of irrigation ( $25.46 \text{ kg ha}^{-1}\text{mm}^{-1}$ ). The water use efficiency was increased to the tune of more than 3 times than conventional method. This is in confirmation with the findings of James Ayars (2011) that drip can increase the field water use efficiency.

### Cost economics

The total cost of cultivation was computed by adding the seasonal fixed cost of drip irrigation with operational cost (Table 4). The seasonal fixed cost of drip system for pomegranate was estimated as Rs. 15658 considering 12 months crop period. It is revealed that more cost of cultivation was estimated in 100% fertigation treatments (Rs. 146815  $\text{ha}^{-1}$ ) because of high market cost of water soluble fertilizers.

The drip method (without fertigation) and drip method with N through drip recorded the cost of cultivation as Rs. 125294  $\text{ha}^{-1}$ . The lowest cost of cultivation was obtained for conventional method (Rs. 119287  $\text{ha}^{-1}$ ).

### Net seasonal income and B: C ratio

The maximum net seasonal income of Rs 4, 75, 758 ha<sup>-1</sup> was recorded in 100% WSF in 20 weekly splits (T<sub>1</sub>) which was on par with 80% WSF in 20 splits (T<sub>2</sub>). Though, ‘N’ fertigation resulted into 1.88 tonnes less yield of pomegranate, it resulted into slightly lower net income (Rs. 413120 ha<sup>-1</sup>) than 100 % fertigation due to low cost of cultivation. However, N fertigation recorded maximum B: C ratio (3.84) which was at par with 100 % (3.83) and 80 % fertigation dose (3.73).

The farmer’s practice recorded lowest net seasonal income than any other treatments (Rs. 257774 ha<sup>-1</sup>). The minimum B: C ratio of 2.89 was observed in farmer’s practice. Singh *et. al.* (2006) also reported higher seasonal income accrued under fertigation in spite of high cost of water soluble fertilizers.

### Total net income

The drip irrigation for pomegranate resulted into 48.63 % water saving (average of three years) over conventional method of irrigation. Thus, it can bring 0.94 ha of additional area under irrigation (Table 4). The total net income calculated taking into consideration the additional area that can be brought under irrigation due to water saving in drip was found to the extent of Rs 9, 22, 545 ha<sup>-1</sup> in 100 % fertigation, which was maximum followed by 80 % fertigation with total net income as Rs. 8, 54, 087 ha<sup>-1</sup>.

### Net extra income over farmer’s practice

The drip irrigation without fertigation resulted into Rs. 85462 ha<sup>-1</sup> (average over three years) net extra income ha<sup>-1</sup> over farmer’s practices. The drip irrigation with 100 % fertigation produced Rs. 2, 17,984 ha<sup>-1</sup> net extra income over control.

**Table.1** Pooled yield and yield contributing characters of pomegranate fruit under different treatments of water soluble fertilizers (2007-2010)

Tr. no.	Treatments	No. fruits plant <sup>-1</sup>	Size of fruit (cm)	Weight of fruit (Kg)	100 arils weight (g)	Yield (t ha <sup>-1</sup> )
T <sub>1</sub>	100% WSF	93.57	8.98	0.21	12.38	<b>14.58</b>
T <sub>2</sub>	80% WSF	90.72	8.64	0.20	11.90	<b>13.63</b>
T <sub>3</sub>	60% WSF	86.54	7.89	0.20	11.61	<b>12.60</b>
T <sub>4</sub>	100% CF (NTD)	88.52	7.81	0.19	11.25	<b>12.70</b>
T <sub>5</sub>	100% CF +DI	82.93	7.68	0.18	10.32	<b>11.19</b>
T <sub>6</sub>	100% CF +SI	71.92	7.56	0.19	10.32	<b>9.80</b>
T <sub>7</sub>	Farmer’s practice	68.14	7.19	0.18	9.86	<b>9.05</b>
SE ±		0.69	0.05	0.003	0.22	<b>0.34</b>
CD at 5%		<b>2.01</b>	<b>0.15</b>	<b>0.010</b>	<b>0.66</b>	<b>0.99</b>

**Table.2** Quality and organoleptic parameters of pomegranate (Cv. Bhagwa) as influenced by different treatments (Pooled data of three years)

Tr. no.	Treatments	TSS	pH	Acidity	Colour	Taste	Texture
T <sub>1</sub>	100% WSF	19.26	2.99	0.31	8.09	8.05	<b>7.23</b>
T <sub>2</sub>	80% WSF	19.08	2.96	0.31	7.88	7.57	<b>7.09</b>
T <sub>3</sub>	60% WSF	18.94	3.06	0.31	7.62	7.48	<b>6.98</b>
T <sub>4</sub>	100% CF (NTD)	18.56	3.01	0.31	7.51	7.47	<b>6.85</b>
T <sub>5</sub>	100% CF +DI	18.35	2.97	0.32	7.08	7.24	<b>6.71</b>
T <sub>6</sub>	100% CF +SI	18.37	2.94	0.33	6.64	7.08	<b>6.54</b>
T <sub>7</sub>	Farmer's practice	17.55	2.95	0.34	6.50	6.70	<b>6.35</b>
SE ±		0.07	0.02	0.002	0.08	0.04	<b>0.06</b>
CD at 5%		<b>0.21</b>	<b>0.06</b>	<b>0.007</b>	<b>0.25</b>	<b>0.11</b>	<b>0.18</b>

**Table.3** Water use of pomegranate (average of three years 2007-2010) under different treatments

Treatments	Water applied (mm)	Effective rainfall (mm)	Total water use (mm)	FWUE (Kg ha <sup>-1</sup> mm <sup>-1</sup> )	Water saving over farmer's practice (%)	Increase in yield over farmer's practice (%)
<b>100% WSF</b>	120.25	73.95	194.20	78.99	48.63	<b>60.81</b>
<b>80% WSF</b>	120.25	73.95	194.20	73.73	48.63	<b>50.24</b>
<b>60% WSF</b>	120.25	73.95	194.20	68.13	48.63	<b>38.81</b>
<b>100% CF (NTD)</b>	120.25	73.95	194.20	68.92	48.63	<b>40.03</b>
<b>100% CF +DI</b>	120.25	73.95	194.20	61.37	48.63	<b>23.48</b>
<b>100% CF +SI</b>	213.95	146.43	360.38	28.63	4.43	<b>8.08</b>
<b>Farmer's practice</b>	<b>230.54</b>	<b>146.43</b>	<b>376.97</b>	<b>25.46</b>	<b>0.00</b>	<b>0.00</b>

**Table.4** Economic analysis of pomegranate (Rs ha<sup>-1</sup>) as influenced by different treatments (pooled data of three years)

Treatment	Seasonal Cost	Net seasonal income	Total net income	B:C ratio	Net extra income over farmer's practice	Payback period of drip (months)	Net profit Rs. mm <sup>-1</sup> of water use
<b>100% WSF</b>	162473	475758	922546	3.83	217984	0.28	<b>4607</b>
<b>80% WSF</b>	155737	440495	854087	3.73	182721	0.33	<b>4262</b>
<b>60% WSF</b>	149000	401293	778045	3.60	143519	0.42	<b>3884</b>
<b>100% CF (NTD)</b>	140952	413120	801209	3.84	155346	0.39	<b>4023</b>
<b>100% CF +DI</b>	140952	343236	666012	3.37	85462	0.70	<b>3380</b>
<b>100% CF +SI</b>	123626	288703	296635	3.05	30929	--	<b>802</b>
<b>Farmer's practice</b>	120767	257774	257774	2.89	0	--	<b>674</b>
SE ±	--	14760	14760	0.1	10708	--	<b>83.3</b>
CD at 5%	--	<b>39995</b>	<b>39995</b>	<b>0.2</b>	<b>32996</b>	--	<b>243.2</b>

### Water productivity and payback period

The net income obtained per unit of water was improved considerably to Rs. 4607 mm<sup>-1</sup> in drip method of irrigation as compared to Rs. 802 in surface method of irrigation. This was followed by net profit of Rs. 4262 mm<sup>-1</sup> obtained when 80% WSF were applied through drip. The drip with only N fertigation resulted into Rs. 4023 mm<sup>-1</sup> of water whereas farmer's practice resulted into Rs. 674 mm<sup>-1</sup> water productivity. Thus, drip coupled with fertigation showed its usefulness in using water six times more productively than conventional method of irrigation and fertilization.

Drip irrigation without fertigation come with Rs. 85462 ha<sup>-1</sup> additional net income over surface method, thus payback period of drip system is 0.70 years which reflected that cost of drip can be recovered within one season (Table 4). This emphasized the utility of drip irrigation for pomegranate irrespective of using water soluble fertilizers. The lower payback period was found when drip coupled with fertigation in treatments (0.28- 0.42 year).

Water soluble fertilizers resulted into higher growth, yield and good quality of pomegranate fruit. fertigation @ 100 % in 20 splits resulted into 60.81 % more yield with 48.63% water saving where as only drip (without any fertigation) resulted into 23.5 % increase in yield with similar water saving. The 60% fertigation resulted into 38.9 % increase in yield as that of 100 % recommended fertilizer (N, P & K through soil), indicating 40% saving in fertilizers due to use of water soluble fertilizer. The application of 100 % WSF through drip also resulted into higher economical parameters but at par with 80 % WSF through drip. The drip fertigation at 80% of recommended dose of water soluble fertilizers in 20 weekly splits

through drip irrigation is found useful to pomegranate growers for increasing the yields, saving the fertilizers and water.

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