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Influence of plant growth regulators and fertigation on yield and economic feasibility of pomegranate (*Punica granatum* L.) cv. Sinduri under high density planting system

Mahaveer Suman and MC Jain

Abstract
An experiment was conducted in the pomegranate orchard established under high density planting system, during July 2018 to December 2018 and again during July 2019 to December 2019. The experiment was laid out in Factorial Randomized Block Design and experiment comprised of 27 treatment combinations consisting of plant growth regulators levels (NAA 0, 50 and 100 ppm and ethrel 0, 150 and 250 ppm) and fertigation levels (0, 75 and 100% recommended dose of fertilizers). Results revealed that maximum mean yield per plant (6.80 kg) and yield per hectare (75.52 quintal) was recorded under F_2 (fertigation 100% recommended dose of fertilizers). However, interaction effect of NAA, ethrel and fertigation were found to be relatively higher to their individual effect. In interaction effect maximum mean yield per plant (8.09 kg) and yield per hectare (89.85 quintal) was recorded under $N_2E_1F_2$ (100 ppm NAA + 150 ppm ethrel + 100% RDF through fertigation). In the same way, maximum gross return of Rs. 2,32,400/ha and Rs. 3,07,360/ha which was Rs. 1,06,250/ha and Rs. 1,41,740/ha excess over control during 2018 and 2019, respectively was recorded under $N_2E_1F_2$ (100 ppm NAA + 150 ppm ethrel + 100% RDF through fertigation).

Keywords: Fertilizers, economic, income, plant growth regulators, profit

Introduction
Pomegranate (*Punica granatum* L.) is one of the most promising fruit crops of India. It is distinctly known in the family *Lythraceae*, which comprises only one genus (*Punica*) and two species; *P. granatum* and *P. protopunica* (Samir, 2010) [11]. It is an economically important species of the tropical and subtropical regions of the world due to its delicious edible fruits and pharmaceutical and ornamental usage. Pomegranate is considered native to Iran, Afghanistan and Southern Pakistan's Baluchistan region to the Himalayas in Northern India. It has been widely cultivated throughout drier parts of South East Asia, Malaysia, the East Indies tropical Africa and India (Raj and Kanwar, 2008) [9]. India is the largest producer of pomegranate in the world. The recent area and production of pomegranate is 0.24 mh and 2.86 mt, respectively (Anon. 2018-19) [1]. In India pomegranate is commercially cultivated in Maharashtra, Karnataka, Gujarat, Andhra Pradesh, Madhya Pradesh, Tamil Nadu and Rajasthan. Maharashtra is the leading state of pomegranate area, production and productivity followed by Karnataka and Gujarat. Rajasthan being a largest state geographically in India and it covers 40 per cent area under desert including saline alkaline and wasteland. Pomegranate has tremendous potential on expansion of such areas for cultivation as it can grow successfully.
The plant growth regulator such as ethrel is a naturally occurring plant growth substance that has numerous effects on the growth, development and storage life of many fruits. The detrimental effect of ethylene on quality center on altering or accelerating the natural processes of development ripening and senescence, while the beneficial effect of ethylene on quality center on roughly the same attributes as the detrimental effect, but differ in both degree and direction (Mikal, 1999) [8]. Similarly, effect of NAA on plant growth is greatly dependent on the time of admission and concentration. NAA has been shown to greatly increase cellulose fiber formation in plants. In majority of fruit plants fruit drop is controlled by spraying of NAA in different fruit crops in different concentration. However, application of fertilizers through fertigation, improves fertilizer and water use efficiency, helps to maintain nutritional balance and nutrient concentration at optimum level, provides opportunity to apply the

nutrients at critical stages of crop growth and minimizes hazard of ground water pollution due to nitrate leaching as compared to conventional practice of fertilizers application. Plant growth regulators and fertigation are the most important inputs which directly affect the plant growth, development, yield and quality of produce. The farmers are become aware about the value of quality production, as quality fruits fetches higher price in the market. Foliar spray of plant growth regulators and fertigation at proper time helps in improving growth, yield and quality characteristics of pomegranate. Plant growth regulators and fertigation are the most imperative inputs which directly have an effect on the growth of plant, expansion, yield and quality of produce. Farmers are using solid fertilizers for fruit crop production but these are not completely water soluble and hence are less accessible to plants and several of the fertilizers hold salts of sodium and chloride which not only influence the quality of crop but they are also dangerous to the soil. However, the information regarding plant growth regulators and fertigation scheduling in pomegranate under high density planting system is lacking. Keeping these aspects in view, the present investigation was undertaken to study the influence of fertigation along with plant growth regulators application on yield and economic feasibility of pomegranate cv. Sinduri under high density system of planting.

Materials and Methods

The experiment was carried out under the Department of Fruit Science, College of Horticulture and Forestry, Jhalawar (Agriculture University, Kota). The experiment was conducted in the pomegranate orchard established under high density planting system (3 m × 3 m) at the Krishi Vigyan Kendra, Jhalawar in the near vicinity of the college during July 2018 to December 2018 and again during July 2019 to December 2019. Six years old pomegranate plants of uniform size and growth were selected at the Krishi Vigyan Kendra, Jhalawar, (Agriculture University, Kota) for experimentation. The experiment was laid out in Factorial Randomized Block Design and each treatment was replicated thrice and per treatment two plants were used. The treatments consisted of two different plant growth regulators namely NAA and ethrel, and fertigation of recommendation dose of fertilizers with three levels of each (NAA 0, 50 and 100 ppm and ethrel 0, 150 and 250 ppm) and fertigation levels (0, 75 and 100% recommended dose of fertilizers). Recommended dose of urea, phosphoric acid and muriate of potash were applied @ 625, 250, and 250 g per plant respectively, for six years old pomegranate plants. Water soluble fertilizers were applied through drip irrigation system (fertigation). Amount of water soluble fertilizers were determined by calculating amount of nitrogen, phosphorus and potassium in recommended dose. The plain distilled water and basal dose of fertilizers were applied on the plants for control. In this way total twenty seven treatments were used in this experiment. The plant growth regulators were sprayed at pre flowering and post flowering stage and fertigation were applied monthly in four equal split dose from 1 July to 1 October on both years, after recording initial (base) growth parameters of plants. The desired quantities of plant growth regulators and fertilizers were procured from different sources for the purpose of experiment and required quantities of these materials were applied on individual plant. Yield per plant was computed by marking the summation of yield values at each harvest till the last harvest and the yield per hectare (quintal) was calculated by multiplying the value of yield per plant (kg) by total number of plants per hectare and dividing the result by hundred and relative economics of different treatments were determined on the basis of cost of treatment, gross income and net profit for each treatment. The data obtained during the experimentation were subjected to statistical analysis using Fisher's (1950) analysis of variance technique. The significance of the treatments was tested through 'F' test at 5 per cent level of significance. The critical difference CD was calculated to assess the significance of difference among the different treatments.

Results and Discussion

The data obtained on yield in response to application of different levels of plant growth regulators and fertigation are summarized in Table 1. The maximum mean yield (6.77 kg/plant) and (75.26 quintal/hectare) was recorded in the treatment N_2. Significant difference on yield per plant was observed among the various levels of ethrel treatment. The maximum yield per plant was observed in the treatment E_2 having values of (6.49 kg/plant) and (72.13 quintal/hectare). Yield per plant was significantly different among the fertigation treatments during 2018 and 2019. The maximum mean yield (6.80 kg/plant) and (75.52 quintal/hectare) was observed in treatment F_2 which consist of 100 per cent recommended dose of fertilizers. The data in Table 2 further reveal that interaction effect of NAA, ethrel and fertigation was significantly observed in yield of pomegranate. The yield (8.09 kg/plant) and (89.85 quintal/hectare) was recorded maximum with treatment combination of $N_2E_1F_2$ (NAA @ 100 ppm + ethrel @ 150 ppm + fertigation @ 100% RDF). The increase in yield of pomegranate fruits by application of plant growth regulators and fertigation treatments may be due to its leads to improvement in yield contributing characters like size and weight of fruits, fruit set percent, fruit retention per cent as evident by the present study which finally increased the yield. Furthermore, uniform application and quantity of nutrients directly in vicinity of the root zone throughout crop growth period increased the nutrient use efficiency which leads to enhance yield of crop coupled with increase in physiological processes and efficient translocation of photosynthates towards reproductive growth. Moreover, the increase yield may also be due to the fact that nitrogen and phosphorus fertilizers not only augment the availability of nitrogen and phosphorus to the plants but also raise their translocation from root to flowers through plant foliage (Singh *et al.*, 2019) [12]. Same trends on yield attributes by fertigation also recorded by Haneef *et al.*, (2014) [5] in pomegranate. However, the increase in yield of pomegranate by application of plant growth regulators may be attributed to the fact that partitioning of assimilates by NAA more towards the fruit development which may leads to improvement in yield contributing characters like size and weight of fruits as evident by the present study which ultimately increased the yield Similar finding is in agreement with the findings in pomegranate by Kumar *et al.*, (2018) [6] and Gaikwad *et al.*, (2019) [4]. The low yield recorded in the control might be due to the poor accessibility of nutrients, resulting in lower effectiveness of photosynthetic accumulation of assimilates and slighter dry matter production. The yield attributing traits like fruit weight, volume, diameter, aril weight etc. was also low in the above said treatment. Similar reports on yield decrease due to lower nutritional levels were made by Chandel (2008) [2] in kiwi fruit.

The economics of different plant growth regulators and fertigation treatments used at various levels in the present investigation under high density system of planting are calculated and presented in Table 3 and 4 during 2018 and 2019, respectively. The economic feasibility of various treatments clearly showed that the application of NAA @ 100 ppm + ethrel @ 150 ppm + fertigation @ 100% RDF ($N_2E_1F_2$) treatment in combination has resulted the maximum gross return of Rs. 2,32,400/ha and Rs. 3,07,360/ha which was Rs. 1,06,250/ha and Rs. 1,41,740/ha excess over control during 2018 and 2019, respectively. Further, the highest net profit (Rs. 84,417/ha and 1,19,907) was estimated which was 84.23 per cent 85.57 per cent higher than control during 2018 and 2019 respectively. The higher net profit due to fertilizers application through drip irrigation is one of the latest and the fastest adopting technologies in horticulture. Irrigation and fertilization were regarded as important input management practices, enterprising farmers and scientists attempted to let fertilizer be distributed through irrigation with yield advantages. Increase the net profit by fertigation and plant growth regulators was also recorded by Rani *et al.*, (2019) [10] in Coconut and Maneesha *et al.*, (2019 a) [7] in pineapple.

Table 1: Effect of plant growth regulators and fertigation on yield attributes of pomegranate cv. 'Sinduri' under high density planting system

Treatment	Yield per plant (kg)			Yield per hectare (q)		
	2018	2019	Pooled	2018	2019	Pooled
N_0	4.56	6.09	5.32	50.64	67.64	59.13
N_1	5.55	7.38	6.46	61.68	81.94	71.82
N_2	5.82	7.73	6.77	64.64	85.93	75.26
SEm±	0.03	0.04	0.03	0.28	0.32	0.31
C.D. at 5%	0.09	0.12	0.07	0.78	0.90	0.87
E_0	4.84	6.49	5.66	53.81	72.07	62.92
E_1	5.51	7.30	6.41	61.19	81.13	71.16
E_2	5.58	7.41	6.49	61.96	82.31	72.13
SEm±	0.03	0.04	0.03	0.28	0.32	0.31
C.D. at 5%	0.09	0.12	0.07	0.78	0.90	0.87
F_0	4.57	6.12	5.34	50.73	67.98	59.36
F_1	5.54	7.31	6.42	61.51	81.20	71.34
F_2	5.83	7.77	6.80	64.73	86.33	75.52
SEm±	0.03	0.04	0.03	0.28	0.32	0.31
C.D. at 5%	0.09	0.12	0.07	0.78	0.90	0.87

N_0 – NAA 0 ppm E_0 – Ethrel 0 ppm F_0 – RDF 0% Fertigation
N_1 – NAA 50 ppm E_1 – Ethrel 150 ppm F_1 – RDF 75% Fertigation
N_2 – NAA 100 ppm E_2 – Ethrel 250 ppm F_2 – RDF 100% Fertigation

Table 2: Interaction effect of plant growth regulators and fertigation on yield attributes of pomegranate cv. 'Sinduri' under high density planting system

Treatment	Yield per plant (kg)			Yield per hectare (q)		
	2018	2019	Pooled	2018	2019	Pooled
$N_0E_0F_0$	3.79	4.97	4.38	42.05	55.21	48.67
$N_0E_0F_1$	4.46	5.76	5.11	49.60	63.99	56.77
$N_0E_0F_2$	4.70	6.32	5.51	52.22	70.20	61.19
$N_0E_1F_0$	4.22	5.59	4.91	46.88	62.07	54.50
$N_0E_2F_0$	4.26	5.75	5.00	47.37	63.84	55.55
$N_1E_0F_0$	4.36	5.99	5.17	48.39	66.62	57.47
$N_2E_0F_0$	4.43	6.04	5.23	49.21	67.11	58.13
$N_0E_1F_1$	4.62	6.38	5.50	51.31	70.90	61.12
$N_0E_1F_2$	4.87	6.68	5.78	54.17	74.23	64.20
$N_0E_2F_1$	4.93	6.59	5.76	54.83	73.19	64.01
$N_0E_2F_2$	5.16	6.76	5.96	57.36	75.12	66.19
$N_1E_1F_0$	4.99	6.55	5.77	55.42	72.75	64.14
$N_1E_2F_0$	5.00	6.63	5.82	55.61	73.66	64.66
$N_1E_0F_1$	5.20	7.05	6.12	57.79	78.31	67.97
$N_1E_0F_2$	5.55	7.43	6.48	61.52	82.50	71.98
$N_2E_1F_0$	5.12	6.72	5.92	56.86	74.70	65.77
$N_2E_2F_0$	4.93	6.83	5.88	54.75	75.83	65.33
$N_2E_0F_1$	5.51	7.30	6.41	61.27	81.14	71.18
$N_2E_0F_2$	5.60	7.52	6.56	62.27	83.54	72.91
$N_1E_1F_1$	6.00	7.80	6.90	66.67	86.72	76.70
$N_1E_2F_2$	6.32	8.36	7.35	70.27	92.88	81.63
$N_1E_1F_2$	6.36	8.45	7.41	70.73	93.85	82.33
$N_1E_2F_1$	6.18	8.12	7.15	68.70	90.19	79.48
$N_2E_1F_1$	6.41	8.32	7.37	71.19	92.49	81.84
$N_2E_2F_2$	6.89	9.20	8.04	76.54	102.22	89.37
$N_2E_1F_2$	6.97	9.22	8.09	77.47	102.45	89.85
$N_2E_2F_1$	6.50	8.45	7.47	72.24	93.87	82.97
SEm ±	0.09	0.13	0.08	0.83	0.95	0.92
C.D.at 5%	0.26	0.36	0.22	2.34	2.70	2.60

Table 3: Economic feasibility of plant growth regulators and fertigation treatments in pomegranate cv. 'Sinduri' under high density planting system (2018)

Treatment	Additional treatment cost	Yield (quintal/ha)	Gross return (@ Rs. 30/kg)	Excess income over control	Net profit due to treatment	Per cent increase in yield over control	Per cent increase in net profit over control
$N_0 E_0 F_0$	0.00	42.05	126150	0.00	0.00	0.00	0.00
$N_0 E_0 F_1$	10824	49.60	148800	22650	11826.00	17.95	9.37
$N_0 E_0 F_2$	14433	52.22	156665	30515	16082.11	24.19	12.75
$N_0 E_1 F_0$	4400	46.88	140650	14500	10100.00	11.49	8.01
$N_0 E_2 F_0$	6200	47.37	142100	15950	9750.00	12.64	7.73
$N_1 E_0 F_0$	2300	48.39	145170	19020	16720.00	15.08	13.25
$N_2 E_0 F_0$	3800	49.21	147621	21471	17670.76	17.02	14.01
$N_0 E_1 F_1$	15224	51.31	153929	27779	12554.99	22.02	9.95
$N_0 E_1 F_2$	18833	54.17	162500	36350	17517.00	28.81	13.89
$N_0 E_2 F_1$	17024	54.83	164480	38330	21306.00	30.38	16.89
$N_0 E_2 F_2$	20633	57.36	172080	45930	25297.00	36.41	20.05
$N_1 E_1 F_0$	5900	55.42	166260	40110	34210.00	31.80	27.12
$N_1 E_2 F_0$	7700	55.61	166833	40683	32983.26	32.25	26.15
$N_1 E_0 F_1$	13124	57.79	173371	47221	34096.66	37.43	27.03
$N_1 E_0 F_2$	16733	61.52	184550	58400	41667.00	46.29	33.03
$N_2 E_1 F_0$	7400	56.86	170590	44440	37040.00	35.23	29.36
$N_2 E_2 F_0$	9200	54.75	164264	38114	28914.30	30.21	22.92
$N_2 E_0 F_1$	14624	61.27	183810	57660	43036.00	45.71	34.11
$N_2 E_0 F_2$	18233	62.27	186823	60673	42439.93	48.10	33.64
$N_1 E_1 F_1$	16724	66.67	200020	73870	57146.00	58.56	45.30
$N_1 E_2 F_2$	22133	70.27	210800	84650	62517.00	67.10	49.56
$N_1 E_1 F_2$	20333	70.73	212200	86050	65716.92	68.21	52.09
$N_1 E_2 F_1$	18524	68.70	206100	79950	61426.00	63.38	48.69
$N_2 E_1 F_1$	18224	71.19	213570	87420	69196.00	69.30	54.85
$N_2 E_2 F_2$	23633	76.54	229615	103465	79831.59	82.02	63.28
$N_2 E_1 F_2$	21833	77.47	232400	106250	84417.00	84.23	66.92
$N_2 E_2 F_1$	20024	72.24	216720	90570	70546.00	71.80	55.92

Table 4: Economic feasibility of plant growth regulators and fertigation treatments in pomegranate cv. 'Sinduri' under high density planting system (2019)

Treatment	Additional treatment cost	Yield (quintal/ha)	Gross return (@ Rs. 30/kg)	Excess income over control	Net profit due to treatment	Per cent increase in yield over control	Per cent increase in net profit over control
$N_0 E_0 F_0$	0.00	55.21	165620.32	0.00	0.00	0.00	0.00
$N_0 E_0 F_1$	10824	63.99	191967.06	26347	15523.06	15.90	9.37
$N_0 E_0 F_2$	14433	70.20	210610.00	44990	30557.00	27.16	18.45
$N_0 E_1 F_0$	4400	62.07	186200.00	20580	16180.00	12.42	9.77
$N_0 E_2 F_0$	6200	63.84	191526.16	25906	19706.16	15.63	11.90
$N_1 E_0 F_0$	2300	66.62	199850.00	34230	31930.00	20.66	19.28
$N_2 E_0 F_0$	3800	67.11	201340.00	35720	31920.00	21.56	19.27
$N_0 E_1 F_1$	15224	70.90	212710.00	47090	31866.00	28.42	19.24
$N_0 E_1 F_2$	18833	74.23	222680.84	57061	38227.84	34.44	23.08
$N_0 E_2 F_1$	17024	73.19	219580.00	53960	36936.00	32.57	22.30
$N_0 E_2 F_2$	20633	75.12	225350.14	59730	39097.14	36.06	23.61
$N_1 E_1 F_0$	5900	72.75	218260.74	52641	46740.74	31.78	28.22
$N_1 E_2 F_0$	7700	73.66	220990.00	55370	47670.00	33.42	28.78
$N_1 E_0 F_1$	13124	78.31	234920.00	69300	56176.00	41.83	33.92
$N_1 E_0 F_2$	16733	82.50	247490.00	81870	65137.00	49.42	39.33
$N_2 E_1 F_0$	7400	74.70	224100.00	58480	51080.00	35.30	30.84
$N_2 E_2 F_0$	9200	75.83	227500.00	61880	52680.00	37.35	31.81
$N_2 E_0 F_1$	14624	81.14	243420.00	77800	63176.00	46.97	38.15
$N_2 E_0 F_2$	18233	83.54	250620.00	85000	66767.00	51.31	40.31
$N_1 E_1 F_1$	16724	86.72	260160.00	94540	77816.00	57.07	46.98
$N_1 E_2 F_2$	22133	92.88	278630.00	113010	90877.00	68.22	54.87
$N_1 E_1 F_2$	20333	93.85	281540.00	115920	95587.00	69.98	57.71
$N_1 E_2 F_1$	18524	90.19	270560.00	104940	86416.00	63.35	52.18
$N_2 E_1 F_1$	18224	92.49	277470.00	111850	93626.00	67.52	56.53
$N_2 E_2 F_2$	23633	102.22	306670.00	141050	117417.00	85.15	70.90
$N_2 E_1 F_2$	21833	102.45	307360.00	141740	119907.00	85.57	72.40
$N_2 E_2 F_1$	20024	93.87	281600.00	115980	95956.00	70.02	57.94

Conclusion

Based on the overall effect of the treatment it may be concluded that the individual effect of different plant growth regulating substances and fertigation at various levels was found significant but not much affected the yield and net income of the pomegranate but in interaction effect yield was significantly higher in $N_2E_1F_2$ (NAA @ 100 ppm + ethrel @ 150 ppm + fertigation @ 100% RDF) and the treatment being at par with $N_2E_2F_2$ in yield and economic feasibility of pomegranate hence treatment, $N_2E_1F_2$ (NAA @ 100 ppm + ethrel @ 150 ppm + fertigation @ 100% RDF) may be considered worth for application in pomegranate for better harvest of the crop.

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