Toxicology International, *Vol 27(3&4), 174-187, 2020, DOI: 10.18311/ti/2020/v27i3&4/25918*

Original Research
ISSN (Print): 0971-6580
ISSN (Online): 0976-5131

Effect of Plant Growth Regulators and Fertigation on Growth of Pomegranate cv. Sinduri under High Density Planting System in Sub-humid Plains of South Eastern Rajasthan

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Abstract

An investigation was carried out under the Department of Fruit Science, College of Horticulture and Forestry, Jhalawar. The experiment was conducted in the pomegranate orchard established under high density planting system 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. 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 per cent increase in plant height (10.34), plant spread viz., East-West (7.01) and North-South (6.62), canopy volume (25.87) and leaf area (19.51 cm^2) 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 per cent increase in plant height (13.28), plant spread viz., East-West (8.03) and North-South (7.71), canopy volume (31.72) and leaf area (23.55 cm^2) was recorded under $N_2E_1F_2$ (100 ppm NAA + 150 ppm ethrel + 100% RDF through fertigation).

Keywords: Fertigation, High Density Planting, Plant Growth, Pomegranate

1. Introduction

Pomegranate *(Punica granatum* L.) is one of the most promising fruit crops of India. It is generally known in a distinct family *Lythraceae.* 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. 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

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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 growth of pomegranate cv. Sinduri (Bhagwa) under high density system of planting.

2. Materials and Methods

2.1 Location

Jhalawar district is located at $23^0 4'$ to $24^0 52'$ N-Latitude and $75^0 29'$ to $76^0 56'$ E-Longitude in South-Eastern, Rajasthan. Agro-climatically, the district falls in Zone V, known as Humid South Eastern Plain. About 84.22% population of the district is rural whose main occupation is agriculture. Average rainfall in the region is 954.7 mm. Maximum temperature range in the summer is 43^0-48^0 C and minimum 3^0-5^0 C during winter. Agriculture and forest lands occupy 73.5% area, respectively in the district.

2.2 Planting Material

The Sinduri variety of pomegranate was planted at a distance of 3 x 3 m^2. Six years old pomegranate plants of uniform size and growth were selected at the Krishi Vigyan Kendra, Jhalawar, (Agriculture University, Kota) for experimentation. For this experiment, 162 pomegranate plants were selected from the block during two successive years i.e. 2018 and 2019.

2.3 Experimental Details

The experiment was laid out in Factorial Randomized Block Design and each treatment was replicated thrice and per treatment two plants were used and experimentation comprising of 27 treatment combinations for the study. 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). The fertigation schedule of recommendation dose (625:250:250 g $plant^{-1}$ $year^1$) for six years old pomegranate plants was fixed[10]. The plain distilled water and basal dose of fertilizers were applied on the plants for control. 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 and development 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.

2.4 Parameter Recorded

2.4.1 Plant Height (m)

The height of plant was measured from the base of the plant at soil surface to the highest tip of the plant with the help of measuring tape.

2.4.2 East-West and North-South Plant Spread (m)

The area occupied by plant canopy was measured in E-W and N-S direction, with the help of measuring tape.

2.4.3 Canopy Volume (m^3)

The canopy volume was calculated with the help of data observed as plant spread and height of the plant by using following formula:

$$Canopy\ volume\left(m^3\right)=\frac{\left(E-W+N-S\right)^2}{4}\times\frac{1}{2}Plant\ height\times 4.19$$

2.4.4 Leaf Area (cm^2)

From each experimental tree, 20 fully developed and matured leaves were randomly selected from all the four directions of the tree periphery and detached at the harvest stage. These leaves were then pressed overnight between the herbarium sheets for full expansion. The leaf area was computed by using a graph paper and average leaf area of each treatment was recorded.

3. Result

3.1 Plant Height

The data on growth of pomegranate fruits as influenced by the application of different plant growth regulators and fertigation treatments. The data evident from the Table 1 showed that plant height of pomegranate increased significantly by the application of NAA, ethrel and fertigation during 2018 and 2019. Among the various

levels of NAA treatment, application of 100 ppm NAA (N_2) recorded maximum mean percent increase in plant height (10.30%) on 120 days after treatment. In the ethrel treatment maximum mean per cent increase in plant height (9.52%) was observed under the 250 ppm ethrel (E_2). Plant height of pomegranate was significantly influenced by the application of different fertigation treatments. Under the different levels of fertigation treatments, maximum mean per cent increase in plant height (10.34%) was noticed in F_2 which consist of 100% RDF through fertigation. However, 100 ppm NAA (N_2) was found to be at par with F_2 (fertigation 100% RDF). Further, treatment combination of NAA 100 ppm + ethrel 150 ppm + fertigation 100% RDF ($N_2E_1F_2$) was recorded maximum mean percent increase in plant height (13.28%) as compared to other treatments including control. However, treatment combination NAA 100 ppm + ethrel 250 ppm + fertigation 100% RDF ($N_2E_2F_2$) was found at par with it. On the other hand, minimum per cent increase in plant height (5.14%) was recorded in control (Table 2).

Table 1. Effect of plant growth regulators and fertigation on per cent increase in plant height of pomegranate under high density planting system

Tr.	30 days after treatment			60 days after treatment			90 days after treatment			120 days after treatment		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
NAA (N)												
N_0	2.45	3.25	2.86	4.46	5.69	5.07	5.52	6.22	5.87	6.58	7.05	6.82
N_1	3.48	4.19	3.86	5.92	7.11	6.51	7.35	7.94	7.65	9.11	9.51	9.31
N_2	3.92	4.59	4.26	6.49	7.73	7.11	8.18	8.86	8.52	10.07	10.54	10.30
SEm+	0.03	0.02	0.02	0.02	0.06	0.04	0.02	0.05	0.02	0.04	0.05	0.04
C.D. at 5%	0.08	0.07	0.06	0.07	0.18	0.11	0.06	0.13	0.07	0.12	0.14	0.10
Ethrel (E)												
E_0	2.76	3.55	3.17	4.87	6.13	5.49	6.09	6.77	6.43	7.50	7.78	7.64
E_1	3.51	4.22	3.86	5.89	7.11	6.50	7.37	8.02	7.70	8.95	9.58	9.27
E_2	3.58	4.27	3.95	6.10	7.30	6.71	7.58	8.24	7.91	9.31	9.74	9.52
SEm+	0.03	0.02	0.02	0.02	0.06	0.04	0.02	0.05	0.02	0.04	0.05	0.04
C.D. at 5%	0.08	0.07	0.06	0.07	0.18	0.11	0.06	0.13	0.07	0.12	0.14	0.10
Fertigation (F)												
F_0	2.18	3.03	2.61	4.06	5.32	4.69	5.03	5.70	5.37	5.99	6.54	6.26
F_1	3.73	4.40	4.08	6.25	7.44	6.84	7.80	8.45	8.12	9.69	9.99	9.84
F_2	3.94	4.61	4.28	6.54	7.77	7.15	8.22	8.88	8.55	10.09	10.58	10.34
SEm+	0.03	0.02	0.02	0.02	0.06	0.04	0.02	0.05	0.02	0.04	0.05	0.04
C.D. at 5%	0.08	0.07	0.06	0.07	0.18	0.11	0.06	0.13	0.07	0.12	0.14	0.10

N_0 – NAA 0 ppm
N_1 – NAA 50 ppm
N_2 – NAA 100 ppm

E_0 – Ethrel0 ppm
E_1 – Ethrel150 ppm
E_2 – Ethrel250 ppm

F_0 – RDF 0% Fertigation
F_1 – RDF 75% Fertigation
F_2 – RDF 100% Fertigation

Table 2. Interaction effect of plant growth regulators and fertigation on per cent increase in plant height of pomegranate under high density planting system

Tr.	30 days after treatment			60 days after treatment			90 days after treatment			120 days after treatment		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
$N_0E_0F_0$	1.38	2.38	1.88	2.83	4.04	3.44	3.85	4.66	4.26	4.82	5.46	5.14
$N_0E_0F_1$	2.29	3.06	2.68	4.16	5.59	4.88	4.99	5.81	5.40	6.12	6.47	6.29
$N_0E_0F_2$	2.45	3.14	2.79	4.30	5.72	5.02	5.42	6.14	5.78	6.46	6.86	6.66
$N_0E_1F_0$	1.67	2.65	2.16	3.47	4.89	4.18	4.15	5.10	4.62	5.24	5.67	5.45
$N_0E_2F_0$	1.72	2.65	2.19	3.58	4.89	4.23	4.43	5.19	4.81	5.39	5.70	5.55
$N_1E_0F_0$	1.89	2.82	2.40	3.75	4.95	4.35	4.75	5.34	5.04	5.61	5.81	5.71
$N_2E_0F_0$	2.07	2.86	2.47	4.12	5.54	4.83	4.93	5.72	5.34	5.87	5.96	5.92
$N_0E_1F_1$	2.97	3.74	3.36	5.14	6.25	5.70	6.27	6.83	6.55	7.26	8.06	7.66
$N_0E_1F_2$	3.14	3.81	3.48	5.34	6.26	5.80	6.71	7.17	6.94	7.70	8.31	8.00
$N_0E_2F_1$	3.18	3.82	3.50	5.53	6.63	6.08	6.81	7.51	7.16	8.05	8.35	8.20
$N_0E_2F_2$	3.31	4.04	3.67	5.64	6.94	6.29	7.01	7.61	7.31	8.21	8.61	8.41
$N_1E_1F_0$	2.60	3.22	2.91	4.32	5.76	5.04	5.48	6.04	5.76	6.57	7.33	6.95
$N_1E_2F_0$	2.72	3.36	3.04	4.62	5.77	5.20	5.63	6.11	5.87	6.63	7.44	7.03
$N_1E_0F_1$	3.54	4.12	3.83	5.74	6.66	6.20	7.13	7.72	7.43	8.72	8.92	8.82
$N_1E_0F_2$	3.59	4.33	3.94	6.04	7.33	6.69	7.51	7.92	7.71	9.22	9.46	9.34
$N_2E_1F_0$	2.80	3.64	3.21	4.87	5.79	5.33	5.93	6.36	6.15	6.72	7.68	7.20
$N_2E_2F_0$	2.89	3.66	3.28	5.03	6.21	5.62	6.11	6.82	6.47	7.02	7.80	7.41
$N_2E_0F_1$	3.78	4.59	4.18	6.23	7.62	6.92	8.00	8.77	8.38	10.23	10.50	10.36
$N_2E_0F_2$	4.01	4.67	4.34	6.40	7.69	7.04	8.23	8.88	8.56	10.45	10.60	10.52
$N_1E_1F_1$	4.12	4.77	4.45	6.65	7.82	7.24	8.42	8.98	8.70	10.81	10.99	10.90
$N_1E_2F_2$	4.50	5.12	4.81	7.52	8.74	8.13	9.27	10.07	9.67	12.07	12.36	12.22
$N_1E_1F_2$	4.39	5.11	4.75	7.30	8.61	7.95	9.18	10.05	9.61	11.21	11.96	11.59
$N_1E_2F_1$	4.29	4.90	4.60	7.27	8.37	7.82	8.76	9.28	9.02	11.16	11.37	11.26
$N_2E_1F_1$	4.66	5.22	4.94	7.63	8.98	8.31	9.75	10.45	10.10	12.29	12.51	12.40
$N_2E_2F_2$	5.12	5.46	5.29	7.97	9.10	8.53	10.21	10.80	10.51	12.69	13.32	13.00
$N_2E_1F_2$	5.19	5.79	5.50	8.28	9.59	8.94	10.42	11.26	10.84	12.79	13.77	13.28
$N_2E_2F_1$	4.90	5.39	5.15	7.84	9.05	8.45	10.02	10.73	10.37	12.55	12.73	12.64
SEm+	0.08	0.07	0.06	0.07	0.19	0.12	0.06	0.14	0.07	0.13	0.15	0.11
C.D. at 5%	0.24	0.21	0.17	0.20	0.53	0.34	0.17	0.39	0.21	0.36	0.43	0.30

3.2 East-West and North-South Plant Spread

100 ppm NAA (N_2) gave better response on plant spread (E-W and N-S) of pomegranate. The maximum mean percent increase in plant spread (E-W 6.93 × N-S 6.53) on 120 days after treatment was observed with respective level of NAA. Similarly, 250 ppm ethrel (E_2) confer maximum mean percent increase in plant spread (E-W 6.71 × N-S 6.28). In the fertigation treatment, maximum mean percent increase in plant spread (E-W 7.01 × N-S 6.62) was noticed in the (F_2) 100 percent RDF through fertigation (Tables 3 and 5). Further, in interaction effect plant growth regulators and fertigation were found to be quite superior to their individual effect. Among the treatment combinations $N_2E_1F_2$ exhibited significantly higher values of percent increase in plant spread (E-W 8.03 × N-S 7.71) as compared to other treatments and control. However, treatment combination NAA 100 ppm + ethrel 250 ppm + fertigation 100% RDF ($N_2E_2F_2$) was found at par with it (Tables 4 and 6).

Table 3. Effect of plant growth regulators and fertigation on percent increase in plant spread (East-West) of pomegranate under high density planting system

Tr.	30 days after treatment			60 days after treatment			90 days after treatment			120 days after treatment		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
NAA (N)												
N_0	1.99	2.66	2.32	3.05	3.72	3.39	4.59	4.97	4.78	5.69	5.87	5.78
N_1	2.68	3.34	3.01	3.82	4.47	4.15	5.43	5.83	5.63	6.53	6.69	6.61
N_2	2.98	3.66	3.32	4.14	4.80	4.47	5.70	6.10	5.90	6.86	7.00	6.93
SEm+	0.03	0.03	0.03	0.04	0.04	0.03	0.04	0.02	0.05	0.05	0.03	0.04
C.D. at 5%	0.08	0.09	0.10	0.10	0.11	0.09	0.12	0.07	0.13	0.14	0.09	0.11
Ethrel (E)												
E_0	2.20	2.84	2.52	3.29	3.95	3.62	4.82	5.19	5.01	5.91	6.06	5.99
E_1	2.69	3.39	3.04	3.82	4.48	4.15	5.39	5.79	5.59	6.55	6.70	6.62
E_2	2.76	3.43	3.09	3.91	4.57	4.24	5.51	5.92	5.72	6.62	6.79	6.71
SEm+	0.03	0.03	0.03	0.04	0.04	0.03	0.04	0.02	0.05	0.05	0.03	0.04
C.D. at 5%	0.08	0.09	0.10	0.10	0.11	0.09	0.12	0.07	0.13	0.14	0.09	0.11
Fertigation (F)												
F_0	1.85	2.49	2.17	2.89	3.54	3.22	4.39	4.77	4.58	5.48	5.65	5.56
F_1	2.80	3.49	3.15	3.96	4.63	4.29	5.56	5.96	5.76	6.67	6.82	6.75
F_2	3.00	3.68	3.33	4.17	4.83	4.50	5.77	6.17	5.97	6.93	7.08	7.01
SEm+	0.03	0.03	0.03	0.04	0.04	0.03	0.04	0.02	0.05	0.05	0.03	0.04
C.D. at 5%	0.08	0.09	0.10	0.10	0.11	0.09	0.12	0.07	0.13	0.14	0.09	0.11

Table 4. Interaction effect of plant growth regulators and fertigation on percent increase in plant spread (East-West) of pomegranate under high density planting system

Tr.	30 days after treatment			60 days after treatment			90 days after treatment			120 days after treatment		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
$N_0E_0F_0$	1.22	1.70	1.46	1.94	2.62	2.29	3.24	3.32	3.29	3.96	4.10	4.03
$N_0E_0F_1$	1.90	2.57	2.24	3.00	3.72	3.36	4.52	4.96	4.74	5.67	5.85	5.76
$N_0E_0F_2$	1.98	2.58	2.25	3.08	3.75	3.42	4.60	5.06	4.83	5.73	5.93	5.83
$N_0E_1F_0$	1.72	2.42	2.07	2.67	3.33	3.00	4.19	4.61	4.40	5.31	5.49	5.40
$N_0E_2F_0$	1.77	2.46	2.11	2.88	3.52	3.21	4.35	4.75	4.56	5.46	5.64	5.55
$N_1E_0F_0$	1.85	2.48	2.17	2.90	3.58	3.24	4.38	4.79	4.59	5.50	5.66	5.58
$N_2E_0F_0$	1.88	2.52	2.20	2.98	3.63	3.31	4.44	4.84	4.64	5.60	5.79	5.70
$N_0E_1F_1$	2.25	2.99	2.62	3.35	4.04	3.70	4.89	5.28	5.09	6.13	6.31	6.22
$N_0E_1F_2$	2.28	3.00	2.64	3.41	4.07	3.74	4.95	5.31	5.13	6.21	6.37	6.29
$N_0E_2F_1$	2.36	3.03	2.70	3.45	4.12	3.78	5.26	5.73	5.50	6.24	6.48	6.36
$N_0E_2F_2$	2.43	3.20	2.82	3.67	4.34	4.00	5.32	5.74	5.53	6.54	6.69	6.61
$N_1E_1F_0$	2.00	2.65	2.31	3.09	3.77	3.43	4.68	5.10	4.89	5.79	5.95	5.87
$N_1E_2F_0$	2.01	2.68	2.35	3.15	3.78	3.45	4.70	5.13	4.91	5.82	5.98	5.90
$N_1E_0F_1$	2.59	3.28	2.97	3.77	4.43	4.10	5.41	5.82	5.62	6.59	6.76	6.67
$N_1E_0F_2$	2.67	3.37	3.02	3.89	4.55	4.22	5.57	5.95	5.76	6.64	6.80	6.72
$N_2E_1F_0$	2.06	2.69	2.37	3.17	3.82	3.50	4.76	5.19	4.97	5.87	6.05	5.96
$N_2E_2F_0$	2.15	2.78	2.47	3.22	3.84	3.53	4.80	5.24	5.02	6.02	6.18	6.10
$N_2E_0F_1$	2.80	3.49	3.14	3.97	4.62	4.30	5.60	5.98	5.79	6.75	6.83	6.79
$N_2E_0F_2$	2.92	3.56	3.24	4.05	4.67	4.36	5.62	6.01	5.82	6.77	6.87	6.82
$N_1E_1F_1$	3.02	3.72	3.37	4.18	4.83	4.50	5.72	6.10	5.91	6.78	6.94	6.86
$N_1E_2F_2$	3.55	4.14	3.84	4.69	5.32	5.01	6.29	6.69	6.49	7.43	7.59	7.51
$N_1E_1F_2$	3.33	3.99	3.66	4.51	5.16	4.84	6.17	6.56	6.37	7.36	7.51	7.43
$N_1E_2F_1$	3.07	3.73	3.40	4.23	4.85	4.54	5.92	6.31	6.11	6.84	6.99	6.92
$N_2E_1F_1$	3.59	4.30	3.95	4.76	5.41	5.09	6.35	6.73	6.54	7.50	7.61	7.55
$N_2E_2F_2$	3.86	4.53	4.20	5.00	5.75	5.38	6.59	6.97	6.78	7.73	7.88	7.81
$N_2E_1F_2$	3.95	4.72	4.34	5.22	5.85	5.54	6.82	7.21	7.01	7.96	8.11	8.03
$N_2E_2F_1$	3.63	4.32	3.97	4.89	5.64	5.26	6.36	6.74	6.55	7.55	7.65	7.60
SEm+	0.08	0.09	0.10	0.11	0.11	0.09	0.13	0.07	0.14	0.14	0.10	0.11
C.D. at 5%	0.24	0.26	0.29	0.30	0.32	0.27	0.37	0.20	0.39	0.41	0.27	0.32

Table 5. Effect of plant growth regulators and fertigation on percent increase in plant spread (North-South) of pomegranate under high density planting system

Tr.	30 days after treatment			60 days after treatment			90 days after treatment			120 days after treatment		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
NAA (N)												
N_0	1.39	1.63	1.51	2.66	2.89	2.78	3.89	4.32	4.11	5.03	5.20	5.12
N_1	2.02	2.25	2.13	3.47	3.65	3.56	4.83	5.24	5.04	6.17	6.33	6.25
N_2	2.36	2.57	2.47	3.75	3.94	3.84	5.12	5.52	5.32	6.46	6.60	6.53
SEm+	0.02	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.05	0.04
C.D. at 5%	0.06	0.07	0.05	0.09	0.08	0.09	0.12	0.12	0.11	0.13	0.13	0.12
Ethrel (E)												
E_0	1.58	1.80	1.69	2.91	3.10	3.01	4.19	4.61	4.40	5.34	5.50	5.42
E_1	2.07	2.29	2.18	3.44	3.64	3.54	4.79	5.21	5.00	6.12	6.27	6.19
E_2	2.13	2.36	2.24	3.53	3.74	3.63	4.88	5.27	5.08	6.21	6.36	6.28
SEm+	0.02	0.02	0.02	0.03	0.03	0.03	0.04	0.043	0.04	0.04	0.05	0.04
C.D. at 5%	0.06	0.07	0.05	0.09	0.08	0.09	0.12	0.123	0.11	0.13	0.13	0.12
Fertigation (F)												
F_0	1.24	1.46	1.35	2.52	2.72	2.62	3.73	4.14	3.94	4.79	4.97	4.88
F_1	2.17	2.40	2.28	3.58	3.79	3.68	4.94	5.36	5.15	6.32	6.46	6.39
F_2	2.37	2.59	2.48	3.77	3.97	3.87	5.18	5.58	5.38	6.54	6.69	6.62
SEm+	0.02	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.05	0.04
C.D. at 5%	0.06	0.07	0.05	0.09	0.08	0.09	0.12	0.12	0.11	0.13	0.13	0.12

3.3 Canopy Volume and Leaf Area

It is evident from the data presented in the Tables 7 and 9 that NAA, ethrel and fertigation levels had significant effect on the canopy volume and leaf area of pomegranate. Maximum mean percent increase in canopy volume (25.80%) and leaf area (19.46 cm^2) was recorded in NAA 100 ppm (N_2). Similarly, different levels of ethrel had significant effect on canopy volume and leaf area of pomegranate and maximum mean percent increase in canopy volume (24.33%) and leaf area (18.70 cm^2) was recorded under (E_2) ethrel 250 ppm. Among the different levels of fertigation, maximum mean percent increase in canopy volume (25.87%) and leaf area (19.51 cm^2) was recorded in the treatment fertigation 100 percent RDF (F_2). The interaction effect of NAA, ethrel and fertigation (Tables 8 and 10) were found to be quite better to their individual effect. Maximum mean percent increase in canopy volume (31.72%) and leaf area (23.55 cm^2) was recorded in $N_2E_1F_2$ which consists of NAA 100 ppm + ethrel 150 ppm + fertigation 100% RDF.

Table 6. Interaction effect of plant growth regulators and fertigation on percent increase in plant spread (North-South) of pomegranate under high density planting system

Tr.	30 days after treatment			60 days after treatment			90 days after treatment			120 days after treatment		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
$N_0E_0F_0$	0.98	1.21	1.10	1.49	1.72	1.60	2.23	2.69	2.46	2.97	3.19	3.08
$N_0E_0F_1$	1.22	1.44	1.33	2.67	2.86	2.77	3.91	4.33	4.12	4.90	5.08	4.99
$N_0E_0F_2$	1.27	1.55	1.41	2.70	2.89	2.80	3.97	4.39	4.18	5.04	5.23	5.14
$N_0E_1F_0$	1.10	1.34	1.22	2.43	2.67	2.55	3.56	3.97	3.77	4.58	4.76	4.67
$N_0E_2F_0$	1.11	1.35	1.23	2.48	2.71	2.60	3.74	4.15	3.94	4.66	4.84	4.75
$N_1E_0F_0$	1.17	1.36	1.26	2.61	2.77	2.69	3.78	4.18	3.98	4.75	4.92	4.83
$N_2E_0F_0$	1.19	1.40	1.30	2.63	2.80	2.71	3.84	4.25	4.04	4.84	5.00	4.92
$N_0E_1F_1$	1.63	1.88	1.76	2.99	3.17	3.08	4.23	4.77	4.50	5.62	5.79	5.71
$N_0E_1F_2$	1.72	1.92	1.82	2.93	3.22	3.08	4.32	4.69	4.50	5.74	5.91	5.83
$N_0E_2F_1$	1.74	1.95	1.85	3.07	3.27	3.17	4.40	4.78	4.59	5.82	5.98	5.90
$N_0E_2F_2$	1.76	2.03	1.90	3.22	3.48	3.35	4.69	5.13	4.91	5.92	6.05	5.99
$N_1E_1F_0$	1.31	1.54	1.42	2.71	2.92	2.81	4.01	4.46	4.23	5.20	5.39	5.29
$N_1E_2F_0$	1.37	1.74	1.56	2.74	2.93	2.83	4.11	4.50	4.31	5.29	5.45	5.37
$N_1E_0F_1$	1.93	2.16	2.04	3.36	3.58	3.47	4.80	5.27	5.03	6.16	6.29	6.23
$N_1E_0F_2$	1.99	2.21	2.10	3.47	3.68	3.58	4.96	5.38	5.17	6.36	6.50	6.43
$N_2E_1F_0$	1.40	1.58	1.49	2.79	2.97	2.88	4.14	4.53	4.33	5.38	5.56	5.47
$N_2E_2F_0$	1.54	1.61	1.58	2.85	3.04	2.94	4.16	4.55	4.35	5.47	5.63	5.55
$N_2E_0F_1$	2.14	2.37	2.26	3.57	3.78	3.68	5.00	5.41	5.21	6.43	6.57	6.50
$N_2E_0F_2$	2.29	2.50	2.39	3.67	3.85	3.76	5.19	5.57	5.38	6.58	6.73	6.66
$N_1E_1F_1$	2.37	2.60	2.49	3.81	3.99	3.90	5.24	5.65	5.44	6.67	6.80	6.73
$N_1E_2F_2$	2.90	3.06	2.98	4.34	4.48	4.41	5.65	6.02	5.83	7.14	7.35	7.24
$N_1E_1F_2$	2.67	2.87	2.77	4.13	4.22	4.17	5.58	5.98	5.78	7.04	7.17	7.11
$N_1E_2F_1$	2.47	2.68	2.57	4.03	4.31	4.17	5.37	5.76	5.56	6.94	7.07	7.01
$N_2E_1F_1$	2.98	3.23	3.11	4.36	4.52	4.44	5.75	6.12	5.93	7.16	7.28	7.22
$N_2E_2F_2$	3.24	3.46	3.35	4.63	4.83	4.73	6.01	6.40	6.21	7.40	7.53	7.47
$N_2E_1F_2$	3.47	3.67	3.57	4.86	5.04	4.95	6.25	6.69	6.47	7.64	7.78	7.71
$N_2E_2F_1$	3.01	3.31	3.16	4.39	4.60	4.50	5.78	6.17	5.97	7.21	7.30	7.25
SEm+	0.07	0.07	0.05	0.10	0.09	0.09	0.13	0.13	0.12	0.13	0.14	0.13
C.D. at 5%	0.19	0.20	0.14	0.28	0.25	0.26	0.36	0.37	0.34	0.38	0.39	0.36

Table 7. Effect of plant growth regulators and fertigation on percent increase in canopy volume of pomegranate under high density planting system

Tr.	30 days after treatment			60 days after treatment			90 days after treatment			120 days after treatment		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
NAA (N)												
N_0	5.60	7.78	6.69	10.40	12.79	11.60	14.59	16.34	15.47	18.15	19.30	18.73
N_1	8.54	10.10	9.32	13.90	16.06	14.98	18.83	20.25	19.54	23.78	24.18	23.96
N_2	9.70	11.25	10.48	15.07	17.33	16.20	20.30	21.90	21.10	25.39	26.20	25.80
SEm+	0.09	0.07	0.05	0.12	0.13	0.13	0.14	0.14	0.11	0.15	0.13	0.12
C.D. at 5%	0.24	0.19	0.15	0.35	0.36	0.37	0.40	0.41	0.31	0.43	0.37	0.34
Ethrel (E)												
E_0	6.53	8.43	7.48	11.48	13.80	12.64	15.87	17.52	16.70	19.99	20.65	20.32
E_1	8.56	10.25	9.41	13.76	15.99	14.87	18.69	20.21	19.45	23.45	24.26	23.83
E_2	8.75	10.45	9.60	14.14	16.38	15.26	19.16	20.76	19.96	23.88	24.78	24.33
SEm+	0.09	0.07	0.05	0.12	0.13	0.13	0.14	0.14	0.11	0.15	0.13	0.12
C.D. at 5%	0.24	0.19	0.15	0.35	0.36	0.37	0.40	0.41	0.31	0.43	0.37	0.34
Fertigation (F)												
F_0	5.08	7.14	6.11	9.92	12.03	10.98	13.89	15.34	14.62	17.45	18.16	17.81
F_1	9.05	10.73	9.89	14.37	16.77	15.57	19.46	21.22	20.34	24.40	25.21	24.81
F_2	9.72	11.26	10.49	15.08	17.39	16.24	20.38	21.93	21.15	25.47	26.31	25.87
SEm+	0.09	0.07	0.05	0.12	0.13	0.13	0.14	0.14	0.11	0.15	0.13	0.12
C.D. at 5%	0.24	0.19	0.15	0.35	0.36	0.37	0.40	0.41	0.31	0.43	0.37	0.34

4. Discussion

The maximum increase in plant height might be due to the favourable influence of plant growth regulators and fertigation management on vegetative characteristics. In the present experiment, it was found that fertigation treatments with higher levels of NPK and plant growth regulators had significant influence on plant growth characters. Significant increase in plant height recorded in the present investigation might be due to reduced loss of applied fertilizers by leaching and timely application of required nutrients as per the crop growth stage directly in the root zone of the plant and improving the FUE and the better utilization of resources such as water and nutrients through fertigation system[6]. Increase availability of nutrients in root zone in balanced manner resulted increase plant height. Furthermore, there was a uninterrupted supply of nutrients in fertigation as the fertilizers was applied in split doses for the duration of the entire growth period of the plants, which might have encouraged the plant in meeting the requirements of nutrients during the peak period of growth. Same result was found in respect to plant height in previous studies[2–3]. Moreover, increased the plant height due to NAA treatment enhances the growth of shoot by cell enlargement and cell elongation mechanism through increasing amylase activity, permeability, formation of energy rich phosphate (ATP) and cell wall plasticity while, decreases viscosity and

Table 8. Interaction effect of plant growth regulators and fertigation on percent increase in canopy volume of pomegranate under high density planting system

Tr.	30 days after treatment			60 days after treatment			90 days after treatment			120 days after treatment		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
$N_0E_0F_0$	3.88	5.39	4.63	6.41	8.62	7.52	9.26	11.04	10.15	11.87	12.94	12.41
$N_0E_0F_1$	4.77	7.24	6.01	10.23	12.67	11.46	14.04	15.85	14.94	17.65	18.42	18.03
$N_0E_0F_2$	5.21	7.47	6.34	10.54	12.88	11.71	14.87	16.37	15.62	18.91	19.15	19.03
$N_0E_1F_0$	3.69	6.59	5.14	8.93	11.27	10.10	12.69	14.32	13.51	16.12	16.90	16.51
$N_0E_2F_0$	3.95	6.64	5.30	9.11	11.59	10.35	12.79	14.85	13.82	16.21	17.05	16.63
$N_1E_0F_0$	4.30	6.82	5.56	9.56	11.70	10.63	13.52	15.04	14.28	17.06	17.75	17.41
$N_2E_0F_0$	4.39	6.90	5.65	10.00	12.40	11.20	13.57	15.53	14.55	17.11	17.78	17.45
$N_0E_1F_1$	6.89	8.97	7.93	11.85	14.10	12.98	16.34	18.21	17.27	20.41	21.70	21.05
$N_0E_1F_2$	7.21	9.00	8.11	12.01	14.22	13.12	16.44	18.23	17.34	20.45	22.13	21.29
$N_0E_2F_1$	7.23	9.37	8.30	12.03	14.63	13.33	16.73	18.73	17.73	20.72	22.19	21.46
$N_0E_2F_2$	7.62	9.38	8.50	12.53	15.16	13.84	18.19	19.49	18.84	21.05	23.21	22.13
$N_1E_1F_0$	5.98	7.56	6.77	10.37	12.91	11.64	15.44	16.40	15.92	19.07	19.27	19.17
$N_1E_2F_0$	6.21	7.81	7.01	11.79	13.03	12.41	15.72	16.47	16.09	19.70	20.09	19.89
$N_1E_0F_1$	8.52	9.81	9.17	13.44	15.71	14.58	18.39	19.97	19.18	22.47	23.08	22.77
$N_1E_0F_2$	8.74	10.28	9.51	14.00	16.35	15.17	19.18	20.51	19.84	23.92	24.54	24.23
$N_2E_1F_0$	6.63	8.16	7.40	11.48	13.08	12.28	15.93	16.94	16.44	19.81	20.58	20.19
$N_2E_2F_0$	6.67	8.42	7.55	11.67	13.64	12.66	16.09	17.48	16.78	20.14	21.10	20.62
$N_2E_0F_1$	9.22	10.84	10.03	14.41	16.94	15.68	19.78	21.52	20.65	25.26	25.91	25.58
$N_2E_0F_2$	9.77	11.14	10.45	14.71	16.98	15.85	20.25	21.84	21.04	25.68	26.28	25.98
$N_1E_1F_1$	10.08	11.53	10.81	15.35	17.58	16.46	20.64	22.17	21.40	26.23	26.76	26.49
$N_1E_2F_2$	11.27	12.84	12.06	17.22	19.50	18.36	22.61	24.47	23.54	29.25	29.49	29.37
$N_1E_1F_2$	11.12	12.25	11.68	16.76	18.89	17.83	22.00	23.43	22.71	28.51	28.68	28.42
$N_1E_2F_1$	10.66	11.99	11.33	16.60	18.84	17.72	21.94	23.77	22.86	27.82	28.01	27.91
$N_2E_1F_1$	11.89	13.35	12.62	17.69	20.16	18.93	23.45	25.13	24.29	29.36	29.95	29.66
$N_2E_2F_2$	12.96	14.07	13.52	18.62	20.81	19.72	24.55	26.00	25.28	30.37	30.97	30.67
$N_2E_1F_2$	13.55	14.87	14.21	19.36	21.68	20.52	25.31	27.05	26.18	31.09	32.34	31.72
$N_2E_2F_1$	12.22	13.52	12.87	17.72	20.25	18.99	23.80	25.58	24.69	29.68	30.91	30.29
SEm+	0.26	0.20	0.16	0.37	0.38	0.39	0.42	0.43	0.32	0.45	0.39	0.36
C.D. at 5%	0.73	0.57	0.45	1.06	1.08	1.11	1.19	1.23	0.92	1.28	1.10	1.03

Table 9. Effect of plant growth regulators and fertigation on Leaf area (cm^2) of pomegranate under high density planting system

Tr.	Leaf area (cm^2)		
	2018	2019	Pooled
NAA (N)			
N_0	15.08	16.69	15.88
N_1	17.30	18.97	18.14
N_2	18.59	20.33	19.46
SEm+	0.09	0.10	0.07
C.D. at 5%	0.26	0.30	0.21
Ethrel (E)			
E_0	15.59	17.23	16.41
E_1	17.50	19.23	18.37
E_2	17.87	19.53	18.70
SEm+	0.09	0.10	0.07
C.D. at 5%	0.26	0.30	0.21
Fertigation (F)			
F_0	14.45	16.10	15.27
F_1	17.88	19.51	18.70
F_2	18.63	20.38	19.51
SEm+	0.09	0.10	0.07
C.D. at 5%	0.26	0.30	0.21

wall pressure[1]. Similarly increased plant height by spray of NAA was found in pomegranate[5].

Canopy spread is important deciding factor in pomegranate for fruiting area which directly influences the vigor of the plant results in higher yield. Therefore, whenever these attributes are higher, the production potential of pomegranate plant will naturally be higher. This may be due to amount of nitrogen and potash increased in the soil due to fertigation which help in the formation of complex nitrogenous substances such as proteins and amino acids which are the building blocks of tissues. In the present investigation, the optimum quantity of nitrogen applied through fertigation has led to superior canopy spread. A number of reports on the same line were reported in pomegranate[7]. The NAA and ethrel spray significantly increase the canopy spread of plant. The highest canopy spread (East-West and North-South) was observed under the NAA than ethrel. However, canopy spread (E-W and N-S) was greater in NAA treatment might be due to immediate absorption of auxins, which increased the endogenous auxin level that resulted in cell elongation and enhanced vegetative growth[11]. In respect to canopy spread direction (East-West and North-South), the maximum spread was found towards the East-West direction in all treatments. The possible reason of more growth in East-West direction is the maximum availability of space and light for growth and development of the plant. Several reports on the same line were reported in kinnow mandarin in which, the canopy spread was enhanced by the foliar spray of PGRs[4-9].

Table 10. Interaction effect of plant growth regulators and fertigation on leaf area (cm^2) of pomegranate under high density planting system

Tr.	Leaf area (cm^2)		
	2018	2019	Pooled
$N_0E_0F_0$	11.99	13.13	12.56
$N_0E_0F_1$	14.65	16.34	15.49
$N_0E_0F_2$	15.37	17.09	16.23
$N_0E_1F_0$	12.86	14.69	13.78
$N_0E_2F_0$	14.00	15.66	14.83
$N_1E_0F_0$	14.13	15.84	14.99
$N_2E_0F_0$	14.16	15.80	14.98
$N_0E_1F_1$	16.23	17.91	17.07
$N_0E_1F_2$	16.90	18.38	17.64
$N_0E_2F_1$	16.60	18.21	17.40
$N_0E_2F_2$	17.07	18.78	17.93
$N_1E_1F_0$	15.41	16.95	16.18
$N_1E_2F_0$	15.62	17.39	16.51
$N_1E_0F_1$	17.03	18.76	17.90
$N_1E_0F_2$	17.30	19.01	18.16
$N_2E_1F_0$	15.80	17.59	16.69
$N_2E_2F_0$	16.06	17.83	16.95
$N_2E_0F_1$	17.52	19.21	18.36
$N_2E_0F_2$	18.17	19.86	19.01
$N_1E_1F_1$	18.52	20.15	19.34
$N_1E_2F_2$	19.74	21.26	20.50
$N_1E_1F_2$	19.13	20.87	20.00
$N_1E_2F_1$	18.81	20.54	19.68
$N_2E_1F_1$	20.32	21.80	21.06
$N_2E_2F_2$	21.69	23.46	22.58
$N_2E_1F_2$	22.33	24.76	23.55
$N_2E_2F_1$	21.25	22.68	21.96
SEm+	0.28	0.31	0.22
C.D. at 5%	0.78	0.89	0.63

Leaf area is an important fundamental trait whichdetermines the rate of photosynthesis is efficient interception of light energy and fixation of CO_2 facilitates dry matter production of crop plants. It is well known that the leaf area has the greater influence on photosynthetic efficiency through higher light interception, as well as higher light absorption. The increased number of successive leaf production by enhanced light utilization, higher uptake of plant nutrients and outstanding maintenance of soil, water and air continuum with higher oxygen deliberation in the root zone[14]. Augmenting uptake of nutrients mainly nitrogen under such specific fertigation system could be attributed to development of leaf area. The absorbed nitrogen eventually might have been utilized by the plants in the configuration of complex substances like protein and amino acids which in turn helped to build up new tissues. The supply of nutrients at sufficient amount would have increase the synthesis of auxin that stimulating the cell elongation and increasing the plant growth. Increased leaf area with fertigation also recorded in sweet orange and banana[12–15]. Same trends the increased leaf area by foliar spray of NAA was also found in previous studies[8–13].

5. Conclusion

Plant growth regulators and fertigation are the most imperative inputs which directly have an effect on the growth of plant. On the basis of results obtained from the above field experiment it may be concluded that the treatment, $N_2E_1F_2$ (NAA @ 100 ppm + ethrel @ 150 ppm + fertigation @ 100% RDF) had significantly superior effect over other treatments including control. This resulted in maximum increase in plant height, plant spread (East-West and North-South), canopy volume and leaf area.

6. Acknowledgements

This research paper is a part of doctoral thesis of corresponding author which has been approved by the university. We thank the College of Horticulture and Forestry, Jhalawar and Krishi Vigyan Kendra, Jhalawar (Agriculture University, Kota) for rendering all necessary facilities required for fulfillment of this research work.

7. Declaration of Competing Interest

No interests to declare.

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