



RESEARCH ARTICLE

# Influence of plant growth regulators on qualitative attributes and yield of pomegranate cv. Bhagwa under Red and Lateritic agro-climatic zone of West Bengal

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Received: 17 July 2025; Accepted: 17 November 2025; Available online: Version 1.0: 30 January 2026

**Cite this article:** Sudipta S, Soustav D, Tanmoy M, Susmita D, Rajdeep M, Sourav R, Chinmoy M, Tanushree S, Sushanta KS. Influence of plant growth regulators on qualitative attributes and yield of pomegranate cv. Bhagwa under Red and Lateritic agro-climatic zone of West Bengal. *Plant Science Today*. 2026; 13(sp1): 1-6. <https://doi.org/10.14719/pst.10712>

## Abstract

Pomegranates are grown in tropical and subtropical regions of the world. Pomegranate cultivation in West Bengal is expanding due to its drought-resistant nature, wider adaptability and suitability for marginal lands. The Potential of plant growth regulators in boosting the fruit size, yield and quality of pomegranate under agro-climatic conditions of southern West Bengal needs to be exploited. With this background, a research study was carried out to study the effect of plant growth regulators on flowering, fruiting as well as yield of pomegranate under the agro-climatic conditions of Bankura district. The present experiment was conducted during 2018-20 at four locations of Bankura district namely, Pathri, Bamunpathri, Damodarpur and Chhatna of West Bengal, where the Bhagwa variety of pomegranate had been planted at a spacing of 4.5 m × 4.5 m. The experiment was laid out in a randomized block design (RBD) with nine treatments and three replications: T<sub>1</sub>- NAA @ 30 ppm, T<sub>2</sub>- NAA @ 40 ppm, T<sub>3</sub>- GA<sub>3</sub> @ 75 ppm, T<sub>4</sub>- GA<sub>3</sub> @ 100 ppm, T<sub>5</sub>- 2, 4-D @ 40 ppm, T<sub>6</sub>- 2, 4-D @ 50 ppm, T<sub>7</sub>- brassinolides @ 100 ppm, T<sub>8</sub>- brassinolides @ 200 ppm and T<sub>9</sub>- control. The study found that NAA at 40 ppm increased fruit yield, weight, length, diameter, number of arils, rind weight, juice content, sugar content and fruit diameter. GA<sub>3</sub> at 30 ppm resulted in maximum flower buds, male flowers, hermaphrodite flowers, intermediate flowers, fruit diameter, rind thickness, fresh seed weight and TSS.

**Keywords:** plant growth regulators; pomegranate; qualitative yield

## Introduction

Pomegranate (*Punica granatum* L.) belonging to the family Punicaceae, has wide adaptability and are grown in tropical and subtropical regions of the world. It is enriched with organic acids, antioxidant, phenolic compounds, sugars, water-soluble vitamins, minerals, offering numerous health benefits such as preventing coronary heart diseases, cancers, cardiovascular disorders, diarrhoea, gastric ulcer, aging and brain disorders (1). Historical evidence indicates that pomegranate's primary centre of origin is Iran and from there it reached to India, possibly through ancient trade routes and it is extensively cultivated in Mediterranean countries like Spain, Iran, Egypt and Morocco. In India, pomegranate is commercially cultivated in Maharashtra and parts of Karnataka and Gujarat, where good quality fruits are produced

due to dry and hot climate. Presently pomegranate cultivation is gaining popularity in arid and semi-arid regions of India due to its wide range of adaptability, higher yield, nutritional and medicinal values, drought hardiness and tolerance to salinity (2). Recently, the area under pomegranate cultivation in West Bengal is increasing to a large extent due to its drought hardy nature, wider adaptability and suitability to marginal lands (3).

In subtropical central and western India, there are three distinct seasons of flowering namely, ambe bahar, mrig bahar and hasth bahar. Ambe bahar is commonly preferred by growers because of high yield consequent to profuse flowering compared to other flowering seasons. Further plant growth regulators (PGR's) have important role in enhancing productivity of many fruit crops. Earlier studies revealed brassinolide regulate diverse physiological

and developmental process in plant diversity such as cell elongation (stem and root), leaf expansion, photomorphogenesis, flower development process and male sterility (4). In pomegranate, PGRs significantly influence flower induction. Gibberellic acid (GA) treatments can promote flower bud formation and increase the number of flowers, while auxins, though not directly responsible for flower induction, can indirectly encourage flowering by affecting lateral bud differentiation. However, the response to PGRs may vary depending on the pomegranate variety, environmental conditions and the formulation used.

Therefore, the potential of plant growth regulators in boosting the fruit size, yield and qualitative attributes of pomegranate under agro-climatic region of southern West Bengal need to be exploited. Keeping these in mind, the present investigation was undertaken with the objective to analysis the influence of plant growth regulators on pomegranate under Red and Lateritic agro-climatic region of West Bengal.

## Materials and Methods

### Location of the experimental site and treatment specifications

The present experiment was conducted during 2018-20 at Taldangra Horticulture Research & Development Farm, Bankura, under the Dept. of FPI&H, Govt. of West Bengal where three years old tissue cultured plants of Bhagwa variety of pomegranate had been planted at a spacing of 4.5 m × 4.5 m. Geographically, the experimental fields were situated under red and lateritic agroclimatic zone of West Bengal. The experiment was laid out in a randomized block design (RBD) with nine treatments and three replications. Each replication had six plants, resulting in a total plant population of 54, spread over an area of 1100 m<sup>2</sup>. The nine treatments were T<sub>1</sub>- NAA @ 30 ppm, T<sub>2</sub>- NAA @ 40 ppm, T<sub>3</sub>- GA<sub>3</sub> @ 75 ppm, T<sub>4</sub>- GA<sub>3</sub> @ 100 ppm, T<sub>5</sub>- 2, 4-D @ 40 ppm, T<sub>6</sub>- 2, 4-D @ 50 ppm, T<sub>7</sub>- brassinolides @ 100 ppm, T<sub>8</sub>- brassinolides @ 200 ppm and T<sub>9</sub>- control (water spray).

### Time of spray of plant growth regulator

The plant growth regulators and water were sprayed on plants thrice in ambe bahar. The first spray was applied before flowering (during first week of October), then second spray was done at 30 days after the first and third spray at 15 days after the second during both years of experimental period.

### Observations recorded

The length of the shoots was measured with measuring tape. Fruit and rind weight were determined by using electric top-pan balance. Fruit size (length and diameter) and rind thickness were measured with the help of digital Vernier callipers. Arils juice volume was measured using a graduated measuring cylinder.

Flower drop percentage was calculated according to the following formula:

$$\text{Flower drop (\%)} = \frac{\text{Total numbers of flowers dropped per branch}}{\text{Total numbers of flowers produced per branch}} \times 100 \quad (\text{Eqn. 1})$$

Fruit set percentage was calculated according to the following formula:

$$\text{Fruit set \%} = \frac{\text{Total number of fruits set per branch}}{\text{Total number of hermaphrodite flowers per branch}} \times 100 \quad (\text{Eqn. 2})$$

Fruit drop percentage was calculated according to the following formula:

$$\text{Fruit drop \%} = \frac{\text{Total number of fruits set per branch} - \text{Total number of fruits at harvest per branch}}{\text{Total number of fruit set per branch}} \times 100 \quad (\text{Eqn. 3})$$

Rind percentage was calculated by following formula:

$$\text{Rind \%} = \frac{\text{Rind weight}}{\text{Fruit weight}} \times 100 \quad (\text{Eqn. 4})$$

Aril percentage was calculated by following formula:

$$\text{Aril (\%)} = \frac{\text{Aril weight}}{\text{Fruit weight}} \times 100 \quad (\text{Eqn. 5})$$

The total soluble solid of the fruit was determined by Erma-hand refractometer (0–32°Brix). The acidity of fruit juice was determined by titrating the fruit juice against 0.1 (N) NaOH solution using phenolphthalein as an indicator (5). The total sugar and reducing sugar content of fruits were determined with the help of freshly made mixture containing equal volumes of Fehling's solution A and B by copper reduction method (6). Ascorbic acid of the fruit was determined by using 2, 6-dichlorophenol indophenols dye titration method (5). The statistical analysis was done as per the procedures given by (7). Analysis of variance (one way classified data) for each parameter was performed by using OPSTAT software.

## Results and Discussion

The observation regarding annual shoot length revealed significant variation among the different treatments (Table 1). Pooled data of both the years showed maximum annual shoot length (59.50 cm) in GA<sub>3</sub> @ 75 ppm, while minimum was recorded with 2, 4-D @ 50 ppm (24.77 cm). The maximum number of flower buds per branch (25.18) were recorded with NAA @ 30 ppm and minimum (10.30) were recorded in the control. The highest plant height and shoot length recorded with GA<sub>3</sub> @ 75 ppm (8). However, they observed the maximum number of flowers per plant with GA<sub>3</sub> @ 75 ppm, which contrast with the findings of the present experiment, where NAA @ 40 ppm resulted in the highest number of flower buds per plants.

The data regarding the various PGR treatments on number of flowers/branch has been presented Table 2. Maximum numbers of male flowers per branch (18.63) were recorded with NAA @ 30 ppm, while minimum (6.75) was observed in the control. In pomegranate, sex expression may be influenced by hormonal factors and all the growth regulators increased the number of male flowers per branch (9). For pomegranate trees to remain healthy and bloom profusely, proper nourishment is essential. Flower induction may be hampered by an inadequate or unbalanced food supply, particularly with regard to critical macronutrients such as potassium, phosphorus and nitrogen (10).

The maximum hermaphrodite flowers per branch (5.76) was recorded with NAA @ 30 ppm, while the minimum (0.94) occurred in the control. Previous studies reported that NAA @ 50

**Table 1.** Annual shoot length and number of flower buds/ branch of pomegranate as affected by plant growth regulators

Treatment	Annual shoot length (cm)			Number of flower buds per branch		
	1 <sup>st</sup> year	2 <sup>nd</sup> year	pooled	1 <sup>st</sup> year	2 <sup>nd</sup> year	Pooled
T <sub>1</sub>	25.33	26.43	25.88	21.14	29.22	25.18
T <sub>2</sub>	25.87	25.66	25.76	16.30	24.11	20.20
T <sub>3</sub>	59.67	59.33	59.50	10.52	16.72	13.62
T <sub>4</sub>	56.64	54.66	55.65	12.20	17.23	14.72
T <sub>5</sub>	22.90	27.78	25.34	7.92	12.83	10.37
T <sub>6</sub>	23.84	25.70	24.77	8.98	14.33	11.65
T <sub>7</sub>	29.24	32.42	30.83	14.67	23.74	19.20
T <sub>8</sub>	25.76	29.37	27.56	16.86	22.75	19.80
T <sub>9</sub>	27.60	32.60	30.10	7.80	12.80	10.30
CD ( $p = 0.05$ )	5.301	4.367	4.289	3.505	6.867	4.957
SEm $\pm$	1.753	1.444	1.418	1.159	2.271	1.639

**Table 2.** Number of flowers per branches of pomegranate as affected by plant growth regulators

Treatment	Number of male flowers per branch			Number of hermaphrodite flowers per branch			Number of intermediate flowers per branch		
	1 <sup>st</sup> year	2 <sup>nd</sup> year	Pooled	1 <sup>st</sup> year	2 <sup>nd</sup> year	Pooled	1 <sup>st</sup> year	2 <sup>nd</sup> year	Pooled
T <sub>1</sub>	15.75	21.50	18.63	4.34	7.19	5.76	0.06	0.94	0.50
T <sub>2</sub>	13.15	15.62	14.38	3.49	6.49	4.99	0.03	0.13	0.08
T <sub>3</sub>	7.57	11.84	9.70	2.48	3.87	3.17	0.02	0.16	0.08
T <sub>4</sub>	9.35	10.44	9.89	2.68	3.66	3.17	0.04	0.59	0.32
T <sub>5</sub>	6.58	8.10	7.34	1.25	2.09	1.67	0.02	0.23	0.13
T <sub>6</sub>	7.52	9.51	8.52	1.43	1.99	1.71	0.04	0.23	0.13
T <sub>7</sub>	12.69	16.65	14.67	2.17	3.77	2.97	0.03	0.39	0.22
T <sub>8</sub>	14.16	16.64	15.40	2.19	3.48	2.84	0.02	0.19	0.10
T <sub>9</sub>	6.99	6.49	6.75	0.77	1.10	0.94	0.03	0.24	0.13
CD ( $p = 0.05$ )	2.943	3.022	2.881	0.673	2.075	1.220	NS	NS	NS
SEm $\pm$	0.973	0.999	0.953	0.222	0.686	0.403	0.022	0.168	0.093

NS: non-significant.

ppm was effective on increasing hermaphrodite flowers (11). The maximum number of intermediate flowers per branch (0.50) was recorded with NAA at 30 ppm, while minimum (0.08) was observed in NAA @ 40 ppm and GA<sub>3</sub> @ 75 ppm. Earlier reports also observed that NAA @ 20 ppm was among the most effective treatments for enhancing hermaphrodite flowers (12). These results are in accordance with findings of aonla (13, 14).

The data regarding flower drop per branch has been presented in Table 3. The maximum flower drop per branch (86.82

%) was recorded with the control and the minimum (76.98%) was observed in NAA @ 30 ppm. Pooled data of both the years showed maximum fruit set per branch (47.73 %) with the control, while minimum (15.05 %) was recorded in GA<sub>3</sub> @ 75 ppm. NAA @ 25 ppm produced higher fruit set and yield, while GA<sub>3</sub> @ 20 ppm produced at par with the control, which was the minimum (15).

Pooled data of both the years showed maximum fruit drop per branch (44.34 %) with GA<sub>3</sub> @ 75 ppm, while the minimum (17.15 %) was recorded in NAA @ 30 ppm (Table 4). It was observed that

**Table 3.** Flower drop/branch and fruit set perbranch of pomegranate as affected by plant growth regulators

Treatment	Flower drop/branch			Fruit set/branch		
	1 <sup>st</sup> year	2 <sup>nd</sup> year	Pooled	1 <sup>st</sup> year	2 <sup>nd</sup> year	Pooled
T <sub>1</sub>	77.85	74.48	76.98	14.35	46.45	37.17
T <sub>2</sub>	78.89	75.24	77.69	17.75	36.16	31.18
T <sub>3</sub>	75.06	77.73	77.73	31.23	19.44	15.05
T <sub>4</sub>	78.55	76.75	78.43	46.23	20.22	15.48
T <sub>5</sub>	84.00	78.50	82.93	37.12	33.53	26.43
T <sub>6</sub>	83.68	79.00	84.03	45.12	35.48	29.58
T <sub>7</sub>	85.24	81.10	84.05	58.19	49.12	34.66
T <sub>8</sub>	77.88	83.53	80.86	49.20	36.34	28.64
T <sub>9</sub>	89.32	79.62	86.82	46.52	48.37	47.73
CD ( $p = 0.05$ )	NS	3.877	5.545	NS	15.418	12.357
SEm $\pm$	3.114	1.282	1.834	18.154	5.099	4.087

NS: non-significant.

**Table 4.** Fruit drop per branch and yield of pomegranate as affected by plant growth regulators

Treatment	Fruit drop per branch			Yield (kg tree <sup>-1</sup> )		
	1 <sup>st</sup> Year	2 <sup>nd</sup> Year	Pooled	1 <sup>st</sup> Year	2 <sup>nd</sup> Year	Pooled
T <sub>1</sub>	14.35	19.94	17.15	2.443	4.433	3.438
T <sub>2</sub>	17.75	38.26	28.00	1.938	4.633	3.286
T <sub>3</sub>	31.23	57.45	44.34	0.843	0.953	0.898
T <sub>4</sub>	46.23	39.56	42.89	0.770	0.833	0.802
T <sub>5</sub>	37.12	38.49	37.80	0.857	0.984	0.920
T <sub>6</sub>	45.12	28.83	36.97	0.860	1.333	1.097
T <sub>7</sub>	58.19	20.06	39.13	0.992	2.833	1.913
T <sub>8</sub>	49.20	29.36	39.28	1.189	3.200	2.194
T <sub>9</sub>	46.52	29.67	38.09	0.293	1.017	0.655
CD ( $p = 0.05$ )	NS	NS	NS	0.668	0.757	0.533
SEm $\pm$	18.154	7.326	9.224	0.221	0.250	0.176

NS: non-significant.

NAA @ 50 ppm was found effective to the control fruit drop, which supports the recent finding (11). The maximum yield (3.438 kg) was recorded with NAA @ 30 ppm and the minimum (0.655 kg) was observed with the control. The previous studies observed that NAA @ 25 ppm resulted higher yield (15, 16). The data regarding the yield was also reported by (17). The application of NAA (50 mg/L) significantly increases the yield of pomegranate (18). The study indicated that NAA @ 15 ppm was the most effective in reducing the fruit drop at different months after fruit set, which resulted in doubling fruit production (19).

Among the physical characteristics of fruit, pooled data of both the years showed maximum fruit weight (140.54 g) in T<sub>2</sub> while minimum (35.34 g) was observed in the treatment T<sub>4</sub> (Table 5). Maximum fruit length (64.47 mm) was observed with NAA @ 40 ppm and the minimum (16.92 mm) was recorded with GA<sub>3</sub> @ 100 ppm. Maximum fruit diameter (66.78 mm) was recorded with NAA @ 30 ppm, while minimum (18.20 mm) was observed with GA<sub>3</sub> @ 100 ppm. The application of NAA @ 40 ppm is effective for fruit diameter and fruit volume (20).

Pooled data for both the years showed maximum rind thickness (3.66 mm) with NAA @ 30 ppm and the minimum (1.08 mm) with 2, 4-D @ 40 ppm (Table 6). The maximum rind weight (64.38 g) was recorded with NAA @ 40 ppm, while the minimum (12.66 g) was observed with GA<sub>3</sub> @ 75 ppm. In pooled data of both the years, the maximum rind weight percentage (48.17 %) was

recorded with the control and the minimum was found with GA<sub>3</sub> @ 75 ppm (32.33 %). The maximum number of arils per fruit (460.45) was recorded with NAA @ 40 ppm, while the minimum (103.00) was exhibited in GA<sub>3</sub> @ 100 ppm (Table 6). Similar results were also observed in earlier studies (21).

The pooled data of both the years showed maximum aril content (67.67 %) with GA<sub>3</sub> @ 75 ppm and the minimum (52.26 %) was recorded with the control (Table 7). The maximum fresh weight of seeds (29.08 g) was observed with NAA @ 30 ppm, while the minimum (6.67 g) was recorded with GA<sub>3</sub> @ 75 ppm. Pooled data of both the years showed maximum juice content per fruit (52.08 mL) with NAA @ 40 ppm and the minimum (9.58 mL) was recorded in GA<sub>3</sub> @ 100 ppm (Table 7). The results are in accordance with the findings reported by (22, 23).

Among the chemical characteristics of fruit, based on pooled data of both the years, total soluble solid content of fruits was the highest with NAA at 30 ppm (13.23 °Brix) and the minimum (11.53 °Brix) was recorded with the control (Table 8). The improvement in TSS of fruits due to auxins (NAA, 2, 4-D) and GA<sub>3</sub> spray (24). This may be due to the fact that application of these growth regulators after fruit set probably improved the physiology of leaves, thereby causing better translocation of vital components in the fruit followed by assimilation and utilization of photosynthesis by the developing fruit. GA has been reported to influence vegetative growth, flowering, fruiting and various

**Table 5.** Fruit weight, length and diameter of pomegranate as affected by plant growth regulators

Treatment	Fruit weight (g)			Fruit length (mm)			Fruit diameter (mm)		
	1 <sup>st</sup> year	2 <sup>nd</sup> year	Pooled	1 <sup>st</sup> year	2 <sup>nd</sup> year	Pooled	1 <sup>st</sup> year	2 <sup>nd</sup> year	Pooled
T <sub>1</sub>	127.15	149.00	138.07	62.71	65.33	64.02	64.67	68.90	66.78
T <sub>2</sub>	133.09	148.00	140.54	62.72	66.23	64.47	65.10	67.93	66.52
T <sub>3</sub>	37.00	41.00	39.00	28.83	30.70	29.76	33.03	33.37	33.20
T <sub>4</sub>	30.67	40.00	35.34	15.33	18.50	16.92	15.23	21.17	18.20
T <sub>5</sub>	34.11	43.67	38.89	17.53	20.37	18.95	18.85	22.50	20.67
T <sub>6</sub>	62.12	70.00	66.06	31.76	34.75	33.25	32.06	36.69	34.38
T <sub>7</sub>	84.67	102.00	93.34	39.78	42.27	41.03	41.56	43.88	42.73
T <sub>8</sub>	102.59	109.33	105.96	55.36	58.33	56.85	56.72	60.57	58.65
T <sub>9</sub>	106.92	111.67	109.29	53.22	54.92	54.06	56.79	56.83	56.81
CD ( $p = 0.05$ )	22.578	20.550	21.046	10.590	11.226	10.888	11.233	11.429	11.231
SEm $\pm$	7.467	6.796	6.960	3.502	3.712	3.601	3.715	3.780	3.714

**Table 6.** Rind thickness, rind weight and number of arils per fruit of pomegranate as affected by plant growth regulators

Treatment	Rind thickness (mm)			Rind weight (g)			Rind (%)			Number of arils fruit		
	1 <sup>st</sup> year	2 <sup>nd</sup> year	Pooled	1 <sup>st</sup> year	2 <sup>nd</sup> year	Pooled	1 <sup>st</sup> year	2 <sup>nd</sup> year	Pooled	1 <sup>st</sup> year	2 <sup>nd</sup> year	Pooled
T <sub>1</sub>	3.65	3.67	3.66	58.33	67.83	63.08	46.07	45.56	45.82	424.33	462.67	443.50
T <sub>2</sub>	3.16	3.16	3.16	63.34	65.42	64.38	47.58	44.37	45.97	457.56	463.33	460.45
T <sub>3</sub>	1.25	1.26	1.25	13.33	12.00	12.66	35.68	28.97	32.33	103.67	121.33	112.50
T <sub>4</sub>	1.31	1.32	1.32	15.33	16.67	16.00	52.34	42.13	47.24	87.00	119.00	103.00
T <sub>5</sub>	1.05	1.12	1.08	14.67	17.00	15.84	42.98	38.66	40.82	98.67	124.33	111.50
T <sub>6</sub>	1.72	1.76	1.74	30.22	31.00	30.61	48.15	44.57	46.36	210.23	257.67	233.95
T <sub>7</sub>	2.05	2.18	2.12	39.11	40.50	39.80	46.00	39.27	42.64	281.78	336.67	309.23
T <sub>8</sub>	3.27	3.27	3.27	51.33	45.50	48.42	50.05	41.69	45.87	363.33	411.00	387.17
T <sub>9</sub>	2.90	2.97	2.94	51.79	52.92	52.35	48.75	47.59	48.17	350.67	384.33	367.50
CD ( $p = 0.05$ )	0.628	0.582	0.602	10.442	11.440	9.805	NS	7.790	8.334	87.528	103.251	91.013
SEm $\pm$	0.208	0.192	0.199	3.453	3.783	3.243	3.742	2.576	2.756	28.946	34.146	30.099

**Table 7.** Aril content, fresh weight of seeds and juice content of pomegranate as affected by plant growth regulators

Treatment	Aril (%)			Fresh weight of seeds (g)			Juice content (mL)		
	1 <sup>st</sup> year	2 <sup>nd</sup> year	Pooled	1 <sup>st</sup> year	2 <sup>nd</sup> year	Pooled	1 <sup>st</sup> year	2 <sup>nd</sup> year	Pooled
T <sub>1</sub>	53.90	54.45	54.17	28.33	29.83	29.08	45.33	51.33	48.33
T <sub>2</sub>	51.94	55.38	53.66	18.29	26.75	22.52	48.66	55.50	52.08
T <sub>3</sub>	64.32	71.04	67.67	4.67	8.67	6.67	13.33	20.33	16.83
T <sub>4</sub>	63.56	57.87	60.72	4.67	11.50	8.08	7.33	11.83	9.58
T <sub>5</sub>	57.03	61.34	59.18	6.10	13.00	9.55	9.77	13.67	11.72
T <sub>6</sub>	51.84	55.84	53.84	9.99	16.50	13.25	18.00	22.67	20.33
T <sub>7</sub>	55.13	60.73	57.93	14.88	27.00	20.94	27.00	34.50	30.75
T <sub>8</sub>	49.68	61.33	55.50	14.54	28.33	21.44	33.34	38.67	36.00
T <sub>9</sub>	52.08	52.45	52.26	19.31	23.12	21.22	33.44	36.50	34.97
CD ( $p = 0.05$ )	8.379	7.253	6.834	5.020	6.536	4.346	8.847	10.071	9.237
SEm $\pm$	2.771	2.398	2.260	1.660	2.162	1.437	2.926	3.331	3.055

**Table 8.** TSS content, acidity and total sugar content of pomegranate as affected by plant growth regulators

Treatment	TSS (°B)			Acidity (%)			Total sugar (%)		
	1 <sup>st</sup> year	2 <sup>nd</sup> year	Pooled	1 <sup>st</sup> year	2 <sup>nd</sup> year	Pooled	1 <sup>st</sup> year	2 <sup>nd</sup> year	Pooled
T <sub>1</sub>	13.16	13.30	13.23	0.29	0.29	0.29	10.50	10.63	10.57
T <sub>2</sub>	12.83	12.93	12.88	0.33	0.34	0.34	10.73	10.90	10.82
T <sub>3</sub>	12.67	12.77	12.72	0.48	0.56	0.53	10.00	10.13	10.07
T <sub>4</sub>	12.53	12.60	12.57	0.43	0.50	0.47	10.17	10.23	10.20
T <sub>5</sub>	13.00	13.10	13.05	0.40	0.48	0.44	9.67	9.80	9.73
T <sub>6</sub>	12.87	12.93	12.90	0.39	0.45	0.43	9.87	9.97	9.92
T <sub>7</sub>	12.73	12.83	12.78	0.30	0.40	0.35	10.23	10.30	10.27
T <sub>8</sub>	12.60	12.67	12.63	0.29	0.30	0.30	10.40	10.47	10.43
T <sub>9</sub>	11.50	11.57	11.53	0.34	0.35	0.35	7.67	7.73	7.70
CD ( $p = 0.05$ )	0.879	0.884	0.880	0.028	0.049	0.033	0.550	0.624	0.582
SEm±	0.291	0.292	0.291	0.009	0.016	0.011	0.182	0.206	0.192

disorders in many fruit crops. The spray with GA<sub>3</sub> @ 75 ppm has increased fruit size and yield in pomegranate cv. Ganesh (25).

The treatment GA<sub>3</sub> @ 75 ppm recorded highest acidity (0.53 %), which was at par with GA<sub>3</sub> @ 100 ppm (0.47 %). The lowest was recorded with NAA @ 30 ppm (0.29 %). Pooled data of both the years regarding total sugar in fruits was highest with NAA @ 40 ppm (10.82 %) and the lowest (7.70 %) was recorded with the control. The application of NAA @ 25 ppm registered significantly maximum diameter of fruit, average weight and average volume of fruit, number of arils per fruit, highest reducing sugar and total sugar (26). The application of NAA @ 40 ppm was effective in increasing total sugar, reducing sugar and non-reducing sugar and TSS (20). The better sugar content might be obtained by the synergetic effect of plant growth regulators (27).

Pooled data showed highest reducing sugar (9.05 %) with GA<sub>3</sub> @ 75 ppm, while the lowest (5.57 %) was recorded with the control. The pooled data of both the years for non-reducing sugar was the highest (2.34 %) with NAA @ 40 ppm, while the lowest (1.02 %) was observed in GA<sub>3</sub> @ 75 ppm (Table 9). Ascorbic acid was the maximum (14.22 mg) with GA<sub>3</sub> @ 100 and the lowest (9.52 mg) was recorded with the control. The present finding is accordance with the results of (15).

## Conclusion

The experiment was carried out on tissue cultured plants of pomegranate cv. Bhagwa at Taldangra Horticulture Research & Development Farm, Bankura, under the Department of FPI & H, Government of West Bengal and it was laid out in a RBD with nine treatments and three replications per treatment. In view of the present experiment, it can be concluded that spraying NAA @ 40 ppm enhances yield and fruit quality of pomegranate cv. Bhagwa under the agro-climatic conditions of South Bengal. The outcome of the study provides a scientific basis for refining pomegranate production practices under the unique agro-climatic conditions of

West Bengal, thereby supporting wider adoption of plant growth regulator technologies in pomegranate cultivation.

## Acknowledgements

The authors gratefully acknowledge to Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal, India for providing necessary facilities to conduct the experiments.

## Authors' contributions

SS and SD<sup>1</sup> carried out the studies and drafted the initial manuscript. TM and SD<sup>2</sup> carried out the immunoassays. RM and SR participated in the sequence alignment. CM and TD participated in the design of the study and performed the statistical analysis. SKS conceived of the study and participated in its design and coordination. SD<sup>1</sup> stands for Soustav Datta and SD<sup>2</sup> stands for Susmita Dey.

## Compliance with ethical standards

**Conflict of interest:** Authors do not have any conflict of interest to declare.

**Ethical issues:** None

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**Table 9.** Reducing sugar, non-reducing sugar and ascorbic acid content of pomegranate as affected by plant growth regulators

Treatment	Reducing sugar (%)			Non-reducing sugar (%)			Ascorbic acid (mg/100 g)		
	1 <sup>st</sup> year	2 <sup>nd</sup> year	Pooled	1 <sup>st</sup> year	2 <sup>nd</sup> year	Pooled	1 <sup>st</sup> year	2 <sup>nd</sup> year	Pooled
T <sub>1</sub>	8.83	9.00	8.92	1.67	1.63	1.65	12.33	12.47	12.40
T <sub>2</sub>	8.17	8.27	8.22	2.57	2.11	2.34	13.17	13.33	13.25
T <sub>3</sub>	9.00	9.10	9.05	1.00	1.03	1.02	13.67	13.77	13.72
T <sub>4</sub>	8.83	8.97	8.90	1.33	1.27	1.30	14.17	14.27	14.22
T <sub>5</sub>	8.33	8.40	8.37	1.33	1.33	1.33	12.03	12.17	12.10
T <sub>6</sub>	8.43	8.60	8.52	1.43	1.37	1.40	11.90	12.00	11.95
T <sub>7</sub>	8.23	8.37	8.30	2.00	1.93	1.97	12.07	12.17	12.12
T <sub>8</sub>	8.33	8.43	8.38	2.07	2.03	2.05	12.20	12.27	12.23
T <sub>9</sub>	5.50	5.63	5.57	2.17	2.10	2.13	9.47	9.57	9.52
CD ( $p = 0.05$ )	0.616	0.655	0.632	0.644	NS	0.660	0.400	0.408	0.402
SEm±	0.204	0.217	0.209	0.213	0.257	0.218	0.132	0.135	0.133

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