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Influence of Growth Regulators Combined with Chemicals to Improve Post-harvest Fruit Quality in Banana cv. Nendran (*Musa* AAB)

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Abstract

A study was undertaken at TNAU, Coimbatore to envisage the effect of different chemicals and growth regulators in combination with Thiabendazole (Fungicide) on post-harvest quality and shelf life of banana cv. Nendran (French Plantain Musa AAB). Various concentration of, GA3, BA, CaCl2 and Hot water treatment either alone or in combination with Thiabendazole was applied to fruits after harvest to study their impact on post-harvest quality and shelf life. Exogenous application of chemicals, growth regulators in combination with Thiabendazole significantly decreased post-harvest disease incidence leading to increase in post- harvest fruit quality and shelf life. Among the treatments, post-harvest dipping of fruits in 150 ppm GA3 + 200 ppm Thiabendazole significantly increased firmness (3.70 kg/cm2) titrable acidity (0.09%) and storage life of fruits (18.00 days). While the parameters like PLW (13.53%), TSS (25.45oB), total sugars (18.88%), reducing sugars (17.11%) and percent disease incidence (5.55) was observed minimum in the same treatment after 12th day of storage.

Keywords: Growth regulators; Chemicals; Quality; Banana

Introduction

Banana (*Musa* spp) is one of the major commercial fruit crops grown in tropics, subtropics and plays a key role in the economy of developing countries. Among the banana varieties grown in India, the French Plantain cultivar 'Nendran' belonging to the 'Plantain' group (*Musa* AAB) is the most popular variety among growers and consumers, particularly in Tamil Nadu and Kerala for domestic and export markets. Unfortunately, 25 to 30% of the harvested fresh produce deteriorates due to spoilage after the harvest in each year, with losses being higher in the tropical regions [1]. Since banana is a climacteric and highly perishable fruit, application of chemicals and growth regulators as pre harvest and post-harvest sprays becomes necessary to extend the shelf-life with quality and minimal post-harvest losses.

Apart from pre harvest sprays, handling of fruits after harvest assumes importance to achieve better shelf life. Post-harvest deterioration of fruits can be caused by many factors including high respiration rates, biochemical changes associated with respiratory metabolism, ethylene biosynthesis, compositional changes, anatomical changes associated with growth and development, physical injuries, water loss and pathological breakdown [2]. Post-harvest dipping of fruits in various chemicals and growth regulators with or without fungicides has been used to delay the ripening to reduce losses and to improve and maintain the color and quality by slowing down the metabolic activities of the produce which results in increased shelf life and marketability of the fruits for a longer time [3].

Thiabendazole is a systemic benzimidazole fungicide, used to control fruit and vegetable diseases such as mould, anthrachnose and blight. It is also effective against storage diseases by inhibition of mitochondrial helminth-specific enzyme, fumarate reductase, with possible interaction with endogenous quinine [4]. With this background, the present investigation was carried out with an objective to improve the shelf life and quality attributes of Nendran bananas by post-harvest application of certain chemicals and growth regulators.

Materials and Methods

The best pre harvest treatment (2% Sulphate of Potash + 2 ppm Brassionosteroid) fruits were selected based on the bunch weight, finger size, total fruit yield and were subjected to post-harvest treatments and quality parameters were evaluated along with control. The treatments were replicated thrice (Table 1).

The experiment was conducted with factorial design by keeping the two locations as main factors. The bunch from the best treatment were dehanded and subjected to post harvest treatments and the observations on quality parameters were periodically recorded on 3rd, 7th and 12th day of storage. Firmness (kg/cm^2) of the fruits measured using a penetrometer (LT Luron model FG 5000 USA). The physiological loss in weight was calculated by using below given formula:

$$\text{PLW}(\%) = \frac{\text{Initial weight of the fruit} - \text{Final weight ofthe fruit}}{\text{Initialweight of the fruit}} \times 100$$

Days taken by the fruits to lose their edible quality by over softening

Treatments	Treatment details
T_1	Dipping fruits in GA_3 @ 150 ppm
T_2	Dipping fruits in BA @ 50 ppm
T_3	Dipping fruits in $CaCl_2$ @ 1000 ppm
T_4	Dipping fruits in Thiabendazole @ 200 ppm
T_5	Dipping fruits in GA_3 @ 150 ppm + Thiabendazole @ 200 ppm
T_6	Dipping fruits in BA @ 50 ppm + Thiabendazole @ 200 ppm
T_7	Dipping fruits in $CaCl_2$ @ 1000 ppm + Thiabendazole @ 200 ppm
T_8	Dipping fruits in hot water @ 52°C
T_9	Control (Dipping fruits in normal water)

Table 1: Treatment and its details.

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and decay is taken for calculating shelf life of fruits and expressed in number of days. The biochemical parameters include total soluble solids which has determined by using Carl-Zeiss hand refractrometer and expressed in degree brix. Total sugars, reducing sugars and Non-reducing sugars were estimated as per the method suggested by [5]. Titrable acidity was expressed by A.O.A.C method (1960) using 0.1% NaOH and expressed in percentage. The ascorbic acid content was determined using 2, 6-dichlorophenol Indophenol Dye after extraction with four per cent oxalic acid and expressed as milligrams of ascorbic acid per 100 gram of fruit pulp. The carotene content was determined as per the method suggested by Ranganna [6]. Per cent Disease Incidence (PDI) was calculated based on the infection caused by these organisms was identified based on their symptoms and indexed as follows [7] and expressed in percentage.

$$PDI(\%) = \frac{\text{Sum of all the individual ratings}}{\text{Total number of fruits observed} \times \text{maximum disease rate}} \times 100$$

Results

Fruits obtained from the best preharvest treatment (2% Sulphate of Potash + 2 ppm Brassionosteroid) were subjected to different chemicals and growth regulators in coupled with fungicide (Thiobendazole) and hot water treatments. Location effects were observed in PLW, firmness, TSS and carotene content due to treatments interaction with location and the results are furnished below:

Physiological Loss in Weight (PLW) (%)

The results obtained on the effect of post-harvest treatments on physiological loss in weight of fruits are furnished in the Table 2.

The physiological loss in weight of stored fruits ranged from 2.21 per cent at 3rd DOS to 20.87 per cent at 12th DOS. Among the location, the least PLW of 4.55, 7.17 and 15.17 on 3rd, 7th and 12th DOS was observed in location I while it was significantly different from location II.

Among the treatments, the lowest PLW of 2.26, 5.41 and 13.53 per cent were observed in T_5 (150 ppm GA_3 + 200 ppm Thiabendazole) on 3rd, 7th and 12th Days of Storage (DOS) respectively, followed by T_7 (2 % $CaCl_2$ + 200 ppm Thiabendazole). The highest PLW of 7.34, 9.42 and 21.26 per cent on three stages was observed in T_9 (control). Interaction effect of location and treatments were significant. The least physiological loss in weight of 2.2, 5.34 and 13.51per cent was observed in L_1T_5 combination (150 ppm GA_3 + 200 ppm Thiabendazole of location I) on 3rd, 7th and 12th DOS respectively and on par with treatment L_1T_7.The PLW was maximum in L_2T_9 (7.42,9.48 and 21.64 per cent on 3rd, 7th and 12th DOS respectively).

Firmness (kg cm^{-2})

The results on the effect of post-harvest treatments on firmness of fruits are furnished in the Table 3.

Among the location, the highest firmness of 5.4, 3.8 and 1.8 kg cm^{-} was observed on 3rd, 7th and 12th DOS respectively at location I while it was lowest at location II.

The firmness of stored fruits ranged from 6.7 kg cm^{-2} at 3rd DOS to 1.2 kg cm^{-2} at 12th DOS. Among the treatments the highest firmness of 6.65, 4.40 and 3.70 kg cm^{-2} were observed in T_5 (150 ppm GA_3+ 200 ppm Thiabendazole) on 3rd, 7th and 12th DOS respectively followed by T_7 (2 % $CaCl_2$ + 200 ppm Thiabendazole. The lowest firmness of 4.2, 3.5 and 2.2 kg cm^{-} on different stages was observed in T_9 (control).

In case of interaction effect due to location and treatments, the highest firmness of 6.7, 4.7 and 3.7 kg cm^{-2} was observed in L_1T_5 (150 ppm GA_3 + 200 ppm Thiabendazole at location I) on 3rd, 7th and 12th DOS respectively. The firmness was minimum in L_2T_9 (4.2, 3.2 and 1.2 kg cm^{-2}) on 3rd, 7th and 12th DOS respectively.

Total soluble solids (°brix)

Significant differences were observed in the total soluble content of fruits due to location and treatments and data furnished in Table 4.

Among the locations, the highest total soluble solids 17.93, 23.03, 28.26 °brix on 3rd, 7th and 12th DOS respectively was observed in location I and it was low in location II.

The total soluble solid in stored fruits was ranged from 17.15 °brix at 3rd DOS to 28.51 °brix at 12th DOS. Among the treatments, the highest total soluble solids of 18.22, 23.09 and 28.38 °brix were observed in T_9 (control) on 3rd, 7th and 12th DOS respectively followed by T_8 (Hot water treatment). The lowest total soluble solid of 17.34, 20.78 and 25.55

Treatments	Physiological Loss in Weight (%)								
	3rd DOS			7th DOS			12th DOS		
	Location I	Location II	Mean	Location I	Location II	Mean	Location I	Location II	Mean
T_1	5.71	5.78	5.75	7.94	8.42	8.18	14.63	14.67	14.65
T_2	5.89	5.98	5.94	8.12	8.50	8.31	14.84	15.04	14.94
T_3	5.97	6.10	6.04	8.20	8.64	8.42	15.47	15.38	15.43
T_4	6.15	6.21	6.18	8.54	8.62	8.58	15.88	15.98	15.94
T_5	2.21	2.31	2.26	5.34	5.47	5.41	13.51	13.55	13.53
T_6	2.48	2.63	2.56	5.77	6.02	5.09	14.45	14.56	14.51
T_7	2.32	2.40	2.36	5.46	5.64	5.55	12.36	16.13	14.25
T_8	6.52	6.62	6.56	8.86	8.94	8.90	16.13	16.20	16.16
T_9	7.25	7.42	7.34	9.35	9.48	9.42	20.87	21.64	21.26
Mean	4.55	4.66	4.60	7.17	7.45	7.31	15.17	15.85	15.51
SE d	L	T	L x T	L	T	L x T	L	T	L x T
	0.0051	0.0095	0.0134	0.002	0.003	0.005	0.007	0.013	0.019
CD (0.05)	0.0104	0.0194	0.0275	0.004	0.007	0.010	0.014	0.027	0.038

T1 – 150 ppm GA_3 **T4** – 200 ppm Thiabendazole **T7** – 1000 ppm $CaCl_2$ + 200 ppm Thiabendazole
T2 – 200 ppm BA **T5** – 150 ppm GA3 + 200 ppm Thiabendazole **T8** – Hot water at 54°C
T3 – 1000 ppm $CaCl_2$ **T6** – 200 ppm BA + 200 ppm Thiabendazole **T9** – Control (Dipping fruits in normal water)

Table 2: Effect of post harvest treatments on Physiological Loss in Weight (%) in fruits of banana cv. Nendran (AAB).

Treatments	Firmness (kg cm^{-2})								
	3rd DOS			7th DOS			12th DOS		
	Location I	Location II	Mean	Location I	Location II	Mean	Location I	Location II	Mean
T_1	5.70	5.00	5.70	3.80	3.90	3.70	1.80	2.90	2.35
T_2	5.10	5.40	5.30	3.40	3.50	3.50	1.60	2.50	2.05
T_3	4.80	5.10	5.00	3.60	3.70	3.50	1.70	2.70	2.20
T_4	4.60	4.70	4.70	3.30	3.30	4.00	1.40	2.30	1.85
T_5	6.60	6.70	6.65	4.60	4.70	4.40	2.30	3.70	3.00
T_6	5.70	6.00	5.90	4.10	4.20	4.20	1.90	3.20	2.55
T_7	5.80	6.50	6.20	4.30	4.40	3.80	2.10	3.40	2.75
T_8	4.30	4.40	4.40	3.20	3.30	3.20	1.50	2.30	1.90
T_9	4.25	4.20	4.20	3.10	3.20	3.50	1.20	2.20	1.70
Mean	5.20	5.40	5.30	3.70	3.80	3.80	1.70	1.80	1.75
SE d	L	T	L x T	L	T	L x T	L	T	L x T
	0.0317	0.0224	0.0105	0.0266	0.0188	0.0088	0.0298	0.0211	0.0099
CD (0.05)	0.06261	0.0442	0.02087	0.0525	0.0371	0.0490	0.0589	0.0468	0.0196

T1 – 150 ppm GA_3 **T4** – 200 ppm Thiabendazole **T7** – 1000 ppm $CaCl_2$ + 200 ppm Thiabendazole
T2 – 200 ppm BA **T5** – 150 ppm GA3 + 200 ppm Thiabendazole **T8** – Hot water at 54°C
T3 – 1000 ppm $CaCl_2$ **T6** – 200 ppm BA + 200 ppm Thiabendazole **T9** – Control (Dipping fruits in normal water)

Table 3: Effect of post harvest treatments on firmness (kg cm-2) in fruits of banana cv. Nendran (AAB).

Treatments	Total soluble solids (%)								
	3rd DOS			7th DOS			12th DOS		
	Location I	Location II	Mean	Location I	Location II	Mean	Location I	Location II	Mean
T_1	17.86	17.42	17.64	23.08	21.86	21.86	26.95	26.55	26.75
T_2	18.13	17.62	17.88	22.85	22.01	22.43	27.39	27.12	27.25
T_3	17.88	17.96	17.92	23.50	23.68	23.59	27.03	27.35	27.19
T_4	18.20	17.76	17.98	22.72	21.87	22.30	27.73	27.43	27.58
T_5	17.48	17.20	17.34	21.48	20.08	20.78	25.68	25.42	25.55
T_6	17.72	17.31	17.52	23.12	22.10	22.61	26.85	26.58	26.71
T_7	17.65	17.15	17.40	23.41	22.60	23.01	26.25	26.15	26.20
T_8	18.16	18.32	18.24	23.42	22.10	23.76	27.83	27.64	27.73
T_9	18.34	17.90	18.22	23.75	22.42	23.09	28.51	28.26	28.38
Mean	17.93	17.62	17.79	23.03	22.08	22.60	27.13	28.26	27.04
SE d	L	T	L x T	L	T	L x T	L	T	L x T
	0.0080	0.0150	0.0212	0.0160	0.0300	0.0424	1.4478	1.0237	0.4826
CD (0.05)	0.0164	0.0307	0.0435	0.0328	0.0614	0.0868	2.8594	2.0219	NS

T1 – 150 ppm GA_3 **T4** – 200 ppm Thiabendazole **T7** – 1000 ppm $CaCl_2$ + 200 ppm Thiabendazole
T2 – 200 ppm BA **T5** – 150 ppm GA3 + 200 ppm Thiabendazole **T8** – Hot water at 54°C
T3 – 1000 ppm $CaCl_2$ **T6** – 200 ppm BA + 200 ppm Thiabendazole **T9** – Control (Dipping fruits in normal water)

Table 4: Effect of post harvest treatments on total soluble solids (%) in fruits of banana cv. Nendran (AAB).

°brix on different stages was observed in T_5 (150 ppm GA_3 + 200 ppm Thiabendazole).

In case of interaction effect, the highest total soluble solids of 18.34, 23.75 and 28.51°brix was observed in L_1T_9 (control of location I) on 3rd, 7th and 12th DOS respectively. The total soluble solids was minimum in L_1T_5 (17.20, 20.08 and 25.42 °brix of location I) on 3rd, 7th and 12th DOS respectively).

Total sugars (%)

The data on the effect of post-harvest treatments on total sugars (%) of fruits are furnished in the Table 5.

The total sugars of stored fruits ranged from 11.16 per cent at 3 DOS to 22.53 percent at 12th DOS. Among the treatments, the highest total sugars of 13.04, 17.18 and 22.50 per cent were observed in T_9 (control) on 3rd, 7th and 12th DOS respectively and on par with the treatment T_8 (Hot water treatment). The lowest total sugar of 11.03, 14.63 and 18.80 per cent was recorded in T_5 (150 ppm GA_3 + 200 ppm Thiabendazole) at three stages of observation during storage. There is no significant difference due to interaction of location and post-harvest treatments.

Reducing sugars (%)

There were significant differences in reducing sugar contents due to location and post-harvest treatments on all three stages of observation (Table 6). The reducing sugars of stored fruits ranged from 9.95 per cent at 3rd DOS to 20.57 per cent at 12th DOS. Among the different post-harvest treatments, the highest reducing sugars of 11.62, 14.12 and 20.53 per cent were observed in T_9 (control) on 3rd, 7th and 12th DOS respectively. The lowest reducing sugars of 10.07, 11.07 and 17.11 per cent were observed in T_5 (150 ppm GA_3 + 200 ppm Thiabendazole) at all three stages of observation. There is no significant differences were observed due to interaction and location and post-harvest treatments.

Non- Reducing sugars (%)

The data registered on the effect of post-harvest treatments on non-reducing sugars of fruits are furnished in the Table 7.

Treatments	Total sugars (%)								
	3rd DOS			7th DOS			12th DOS		
	Location I	Location II	Mean	Location I	Location II	Mean	Location I	Location II	Mean
T_1	12.35	11.97	12.16	15.82	14.79	15.30	20.82	20.16	20.49
T_2	12.84	11.83	12.33	16.34	15.47	15.90	21.06	20.97	21.01
T_3	12.51	11.99	12.25	16.21	15.24	15.72	20.97	20.61	20.79
T_4	13.30	12.77	13.03	16.55	15.64	16.09	21.24	21.53	21.38
T_5	11.16	10.91	11.03	15.11	14.16	14.63	19.66	17.95	18.80
T_6	11.88	11.63	11.75	15.66	14.68	15.17	20.35	20.07	20.21
T_7	11.35	11.22	11.28	15.62	14.62	15.12	19.89	19.49	19.69
T_8	13.42	13.26	13.34	17.13	16.32	16.72	21.8	21.89	21.84
T_9	13.56	12.52	13.04	17.77	16.6	17.18	22.47	22.53	22.50
Mean	12.49	12.02	12.25	13.89	13.75	13.82	20.92	20.58	20.75
SE d	L	T	L x T	L	T	L x T	L	T	L x T
	0.3050	0.4252	0.6013	0.3578	0.5469	0.7735	0.3392	0.7197	1.0178
CD (0.05)	NS	0.8624	NS	NS	1.1093	NS	NS	1.4598	NS

T1 – 150 ppm GA_3 **T4** – 200 ppm Thiabendazole **T7** – 1000 ppm $CaCl_2$ + 200 ppm Thiabendazole
T2 – 200 ppm BA **T5** – 150 ppm GA3 + 200 ppm Thiabendazole **T8** – Hot water at 54°C
T3 – 1000 ppm $CaCl_2$ **T6** – 200 ppm BA + 200 ppm Thiabendazole **T9** – Control (Dipping fruits in normal water)

Table 5: Effect of post harvest treatments on total sugars (%) in fruits of banana cv. Nendran (AAB).

Treatments	Reducing sugars (%)								
	3rd DOS			7th DOS			12th DOS		
	Location I	Location II	Mean	Location I	Location II	Mean	Location I	Location II	Mean
T_1	11.18	10.85	11.02	14.25	13.25	12.02	18.98	18.36	18.68
T_2	11.56	10.58	11.07	14.65	13.82	12.07	19.16	19.13	19.15
T_3	11.28	10.79	11.04	14.56	13.62	12.04	19.1	18.74	18.92
T_4	11.94	11.46	11.70	14.82	13.94	12.70	19.31	19.63	19.47
T_5	10.18	9.95	10.07	13.65	12.73	11.07	17.94	16.27	17.11
T_6	10.75	10.52	10.64	14.13	13.18	11.64	18.55	18.31	18.43
T_7	10.27	10.16	10.22	14.12	13.16	11.22	18.13	17.76	17.95
T_8	12.02	11.91	11.97	15.36	14.58	12.97	19.84	19.95	19.90
T_9	12.12	11.12	11.62	15.96	14.82	14.12	20.49	20.57	20.53
Mean	11.26	10.82	11.04	12.26	12.15	12.20	19.06	18.75	18.90
SE d	L	T	L x T	L	T	L x T	L	T	L x T
	0.2805	0.3830	0.5417	0.3351	0.4907	0.6940	0.3091	0.6557	0.9273
CD (0.05)	NS	0.7769	NS	NS	0.9954	NS	NS	1.3300	NS

T1 – 150 ppm GA_3 **T4** – 200 ppm Thiabendazole **T7** – 1000 ppm $CaCl_2$ + 200 ppm Thiabendazole
T2 – 200 ppm BA **T5** – 150 ppm GA3 + 200 ppm Thiabendazole **T8** – Hot water at 54°C
T3 – 1000 ppm $CaCl_2$ **T6** – 200 ppm BA + 200 ppm Thiabendazole **T9** – Control (Dipping fruits in normal water)

Table 6: Effect of post harvest treatments on reducing sugars (%) in fruits of banana cv. Nendran (AAB).

The non-reducing sugars of stored fruits were ranged from 0.96 per cent at 3rd DOS to 1.98 per cent at 12th DOS. The highest non reducing sugars of 1.42, 1.80 and 1.97 per cent were observed in T_9 (control) on 3rd, 7th and 12th DOS respectively and significantly different from treatment T_8 on 3rd and 7th DOS and on 12th day of storage. The lowest reducing sugars of 0.97, 1.45 and 1.70 per cent were observed in T_5 (150 ppm GA_3 + 200 ppm Thiabendazole) on 3rd, 7th and 12th DOS respectively and there were no significant differences due to interaction of location and post-harvest treatments on non- reducing sugar contents at all the three stages of observation.

Carotene content (mg/100 g)

The data on the effect of post-harvest treatments on carotene content (mg/100g) of fruits are furnished in the Table 8.

The carotene content of stored fruits was ranged from 18.78 mg/100 g at 3 DOS to 24.30 mg/100 g at 12th DOS. The highest carotene content (mg/100 g) of 21.17, 21.89 and 22.54 mg/100g on 3rd, 7th and 12th DOS respectively was observed in location I and it was lowest in location II.

Among the post-harvest treatments, the highest carotene content of 22.46, 23.17 and 23.80 mg/100 g were observed in T_9 (control) on 3rd, 7th and 12th DOS respectively followed by T7 (2% $CaCl_2$ + 200 ppm Thiabendazole). The lowest carotene content of 19.36, 20.07 and 20.80 mg/100 g on different stages of observation were observed in T_5 (150 ppm GA3 + 200 ppm Thiabendazole).

Significant differences were observed in carotene content at both locations. There is no significant difference due to interaction of location and post-harvest treatments at all the three stages of observation.

Ascorbic acid (mg/100 g)

The data registered on the effect of post-harvest treatments on ascorbic acid of fruits are furnished in the Table 9.

The ascorbic acid (mg/100 g) in stored fruits ranged from 7.15 mg/100 g at 3 DOS to 15.45 mg/100 g at 12th DOS. There is no significant effect due to location and their interaction on ascorbic acid content of fruits on 3 day of storage.

Treatments	Non- reducing sugars (%)								
	3rd DOS			7th DOS			12th DOS		
	Location I	Location II	Mean	Location I	Location II	Mean	Location I	Location II	Mean
T_1	1.17	1.12	1.15	1.57	1.54	1.56	1.84	1.80	1.82
T_2	1.28	1.25	1.27	1.69	1.65	1.67	1.90	1.84	1.87
T_3	1.23	1.20	1.22	1.65	1.62	1.64	1.87	1.87	1.87
T_4	1.36	1.31	1.34	1.73	1.70	1.72	1.93	1.90	1.92
T_5	0.98	0.96	0.97	1.46	1.43	1.45	1.72	1.68	1.70
T_6	1.13	1.11	1.12	1.53	1.50	1.52	1.80	1.76	1.78
T_7	1.08	1.06	1.07	1.5	1.46	1.48	1.76	1.73	1.75
T_8	1.4	1.35	1.38	1.77	1.74	1.76	1.96	1.94	1.95
T_9	1.44	1.40	1.42	1.81	1.78	1.80	1.98	1.96	1.97
Mean	1.23	1.20	1.21	1.63	1.60	1.62	1.86	1.83	1.85
SE d	L	T	L x T	L	T	L x T	L	T	L x T
	0.0199	0.0423	0.0598	0.0265	0.5621	0.0795	1.1674	2.4765	3.5023
CD (0.05)	NS	0.0858	NS	NS	0.1140	NS	NS	NS	NS

T1 – 150 ppm GA_3 **T4** – 200 ppm Thiabendazole **T7** – 1000 ppm $CaCl_2$ + 200 ppm Thiabendazole
T2 – 200 ppm BA **T5** – 150 ppm GA3 + 200 ppm Thiabendazole **T8** – Hot water at 54°C
T3 – 1000 ppm $CaCl_2$ **T6** – 200 ppm BA + 200 ppm Thiabendazole **T9** – Control (Dipping fruits in normal water)

Table 7: Effect of post harvest treatments on non reducing sugars (%) in fruits of banana cv. Nendran (AAB).

Treatments	Carotene content (mg/100g)								
	3rd DOS			7th DOS			12th DOS		
	Location I	Location II	Mean	Location I	Location II	Mean	Location I	Location II	Mean
T_1	20.73	19.56	20.15	21.45	20.26	20.86	22.1	20.1	21.10
T_2	21.28	20.33	20.81	22	21.03	21.52	22.65	21.65	22.15
T_3	20.95	20.00	20.48	21.67	20.70	21.19	22.32	21.32	21.82
T_4	21.68	20.73	21.21	22.4	21.43	21.92	23.05	22.05	22.55
T_5	19.93	18.78	19.36	20.65	19.48	20.07	21.3	20.30	20.80
T_6	20.51	19.30	19.91	21.23	20.00	20.62	21.88	20.88	21.38
T_7	20.25	18.98	19.62	20.97	19.68	20.33	21.62	20.62	21.12
T_8	22.23	21.28	21.76	22.95	21.98	22.47	23.60	22.60	23.10
T_9	22.93	21.98	22.46	23.65	22.68	23.17	24.30	23.30	23.80
Mean	21.17	20.10	20.64	21.89	20.80	21.35	22.54	21.42	21.98
SE d	L	T	L x T	L	T	L x T	L	T	L x T
	0.3374	0.7158	0.0123	0.3490	0.7404	1.0471	0.3593	0.7623	1.0781
CD (0.05)	0.6844	1.4519	2.0533	0.7079	1.5017	NS	0.7289	1.5463	NS

T1 – 150 ppm GA_3 **T4** – 200 ppm Thiabendazole **T7** – 1000 ppm $CaCl_2$ + 200 ppm Thiabendazole
T2 – 200 ppm BA **T5** – 150 ppm GA3 + 200 ppm Thiabendazole **T8** – Hot water at 54°C
T3 – 1000 ppm $CaCl_2$ **T6** – 200 ppm BA + 200 ppm Thiabendazole **T9** – Control (Dipping fruits in normal water)

Table 8: Effect of post harvest treatments on carotene content (mg /100g) in fruits of banana cv. Nendran (AAB).

Treatments	Ascorbic acid (mg /100 g)								
	3rd DOS			7th DOS			12th DOS		
	Location I	Location II	Mean	Location I	Location II	Mean	Location I	Location II	Mean
T_1	14.88	15.02	14.95	11.02	11.21	11.11	8.11	8.26	8.18
T_2	14.42	14.6	14.51	10.86	10.98	10.92	7.96	8.05	8.00
T_3	14.65	14.82	14.73	10.68	10.85	10.76	7.75	7.88	7.81
T_4	14.26	14.42	14.34	10.46	10.62	10.54	7.50	7.65	7.57
T_5	15.52	15.70	15.61	11.52	11.70	11.61	8.66	8.95	8.80
T_6	15.05	15.18	15.11	11.18	11.32	11.25	8.24	8.38	8.31
T_7	15.28	15.45	15.36	11.35	11.52	11.43	8.48	8.56	8.52
T_8	14.10	14.26	14.18	10.24	10.42	10.33	7.32	7.46	7.39
T_9	13.95	14.08	14.01	10.02	10.18	10.10	7.15	7.24	7.19
Mean	14.67	14.83	14.75	10.81	10.97	10.89	7.90	8.04	7.97
SE d	L	T	L x T	L	T	L x T	L	T	L x T
	0.2412	0.5117	0.7237	0.1781	0.3778	0.5343	0.1305	0.2769	0.3916
CD (0.05)	NS	NS	NS	NS	0.7663	NS	NS	0.5616	NS

T1 – 150 ppm GA_3 **T4** – 200 ppm Thiabendazole **T7** – 1000 ppm $CaCl_2$ + 200 ppm Thiabendazole
T2 – 200 ppm BA **T5** – 150 ppm GA3 + 200 ppm Thiabendazole **T8** – Hot water at 54°C
T3 – 1000 ppm $CaCl_2$ **T6** – 200 ppm BA + 200 ppm Thiabendazole **T9** – Control (Dipping fruits in normal water)

Table 9: Effect of post harvest treatments on ascorbic acid (mg /100 g) in fruits of banana cv. Nendran (AAB).

Treatments	Acidity (%)								
	3rd DOS			7th DOS			12th DOS		
	Location I	Location II	Mean	Location I	Location II	Mean	Location I	Location II	Mean
T_1	0.33	0.33	0.33	0.142	0.14	0.14	0.08	0.07	0.08
T_2	0.33	0.34	0.34	0.15	0.16	0.16	0.10	0.08	0.09
T_3	0.33	0.33	0.33	0.15	0.15	0.15	0.10	0.07	0.08
T_4	0.33	0.34	0.34	0.16	0.16	0.16	0.10	0.09	0.09
T_5	0.31	0.32	0.32	0.18	0.19	0.18	0.12	0.08	0.10
T_6	0.32	0.33	0.33	0.13	0.13	0.13	0.09	0.06	0.08
T_7	0.32	0.32	0.32	0.12	0.13	0.12	0.08	0.06	0.07
T_8	0.33	0.35	0.34	0.11	0.13	0.12	0.07	0.10	0.09
T_9	0.35	0.35	0.35	0.12	0.17	0.14	0.07	0.11	0.09
Mean	0.33	0.33	0.33	0.15	0.15	0.15	0.09	0.08	0.09
SE d	L	T	L x T	L	T	L x T	L	T	L x T
	0.0054	0.0115	0.0163	0.0025	0.0053	0.0075	0.3374	0.7158	1.0123
CD (0.05)	NS	NS	NS	0.0050	0.0108	NS	0.6844	1.4519	NS

T1 – 150 ppm GA_3
T2 – 200 ppm BA
T3 – 1000 ppm $CaCl_2$
T4 – 200 ppm Thiabendazole
T5 – 150 ppm GA3 + 200 ppm Thiabendazole
T6 – 200 ppm BA + 200 ppm Thiabendazole
T7 – 1000 ppm $CaCl_2$ + 200 ppm Thiabendazole
T8 – Hot water at 54°C
T9 – Control (Dipping fruits in normal water)

Table 10: Effect of post harvest treatments on acidity (%) in fruits of banana cv. Nendran (AAB).

Treat ments	Percent of Disease Incidence (PDI)									Shelf life (days)		
	3rd DOS			7th DOS			12th DOS					
	Location I	Location II	Mean	Location I	Location II	Mean	Location I	Location II	Mean	Location I	Location II	Mean
T_1	0.00	0.00	0.00	0.00 (1.65)	0.00 (1.65)	0.00	8.38 (9.45)	8.56 (9.62)	7.47	15.33	15.66	15.49
T_2	0.00	0.00	0.00	0.5 (2.55)	0.00 (1.65)	0.25	8.81 (9.35)	8.45 (9.35)	6.83	14.50	15.00	14.75
T_3	0.00	0.00	0.00	0.5 (2.25)	0.00 (1.65)	0.25	8.41 (9.59)	8.25 (9.52)	6.63	15.00	15.33	15.16
T_4	0.00	0.00	0.00	00 (1.65)	0.0 (2.25)	0.00	7.56 (8.59)	7.11 (8.05)	7.38	14.00	14.33	14.16
T_5	0.00	0.00	0.00	0.00 (1.65)	0.00 (1.65)	0.00	6.38 (12.08)	5.55 (12.08)	5.97	17.50	18.50	18.00
T_6	0.00	0.00	0.00	0.00 (1.65)	0.00 (1.65)	0.00	6.55 (6.85)	7.80 (8.60)	7.18	15.67	16.00	15.83
T_7	0.00	0.00	0.00	0.00 (1.65)	0.00 (1.65)	0.00	6.45 (13.56)	6.38 (12.85)	6.42	16.00	18.33	17.16
T_8	0.00	0.00	0.00	6.38 (12.85)	5.55 (6.68)	5.95	14.55 (22.35)	13.81 (20.65)	14.18	13.50	14.00	13.75
T_9	0.00	0.00	0.00	7.80 (8.60)	6.42 (7.08)	7.15	25.93 (30.50)	22.93 (27.35)	24.43	12.33	12.66	12.49
Mean	0.00	0.00	0.00	1.68	1.33	4.93	10.92	9.98	10.47	14.77	15.14	14.96
SE d	L	T	L x	L	T	L x T	L	T	L x T	L	T	L x T
	0.00	0.00	0.00	(0.250)	(0.262)	(4.52)	(3.455)	(1.282)	(5.725)	0.2452	0.5206	0.7356
CD (0.05)	0.00	0.00	0.00	NS	NS	NS	NS	2.620	NS	NS	1.0550	NS

T_1 - 150 ppm GA_3
T_2 - 200 ppm BA
T_3 - 1000 ppm $CaCl_2$
T_4 - 200 ppm Thiabendazole
T_5 - 150 ppm GA_3 + 200 ppm Thiabendazole
T_6 - 200 ppm BA + 200 ppm Thiabendazole
T_7 - 1000 ppm $CaCl_2$ + 200 ppm Thiabendazole
T_8 – Hot water at 54 ^{0}C
T_9 - Control (Dipping fruits in normal water

Table 11: Effect of post harvest treatments on Percent of Disease Incidence (PDI) (%) and shelf life (days) of banana cv. Nendran (AAB).

On 7th and 12th day of storage, the treatment T_5 (150 ppm GA_3 + 200 ppm Thiabendazole) recorded the highest ascorbic acid content of 11.61 and 8.80 mg/100g and on par with T_7 (11.43 and 8.52 mg/100g) respectively. The lowest ascorbic acid content was observed in T_9 (10.10 and 7.19 mg/100 g) on 7th and 12th DOS respectively. There is no significant difference due to interaction of location and post-harvest treatments on ascorbic acid contents at all the three stages of observation.

Acidity (%)

The data registered on the effect of post-harvest treatments on acidity (%) of fruits are furnished in the Table 10. The acidity of stored fruits ranged from 0.07 per cent at 3 DOS to 0.35 per cent at 12th DOS. There is no significant effect due location and their interaction with treatments on acidity content of fruits on 3 day of storage.

On 7th day of storage, among the treatments, T_5 (150 ppm GA_3 + 200 ppm Thiabendazole) recorded the highest acidity content (0.18%) and significantly different from rest of the treatments. The lowest acidity content was observed in T_8 (0.12%). Among the location, the location II registered the highest acidity content (0.15%) and highly significant from the location I (0.14%). Similarly on 12th day of storage, the T_5 (150 ppm GA_3 + 200 ppm Thiabendazole) recorded the highest acidity content (0.09%) and significantly different from rest of the treatments.

Percent Disease Incidence (PDI) and Shelf life (days)

The data on the effect of post-harvest treatments on percent disease incidence and shelf life of fruits are furnished in the Table 11. Disease incidence was not observed in any of the fruits until the third day of storage. There were significant differences due to post harvest treatments alone on 12th day of storage. On the 12th day of storage, the percent of disease incidence of 24.43 was observed in control (T_9) in location I. The lowest PDI of 5.97 was observed in T_5 (150 ppm GA_3 + 200 ppm Thiabendazole) and on par with T_7 treatment.

There was highly significant difference among the post-harvest treatments alone on shelf life of fruits and T_5 (150 ppm GA3 + 200 ppm Thiabendazole) recorded the highest shelf life of 18.00 days and on par with T_7 (17.16 days).

Discussion

The combined treatment of chemicals and growth regulators revealed significant influence on quality and shelf life attributes of cv. Nendran in the present study. The results are discussed hereunder.

The physiological loss in weight represents the weight loss due to reduction in moisture and also substrates during ripening and affects the saleable weight. It may eventually makes the material becomes unusable as a result of wilting and shrinking [8]. In the present study, fruits treated with GA_3 @ 150 ppm + Thiabendazole @ 200 ppm recorded the least PLW than other treatment combinations during the different days of storage. Reduction in weight loss might be due to decreased rate of respiration and transpiration, restricting ethylene accumulation and production in fruits during ripening and Thiabendazole preventing pathogenic infection by antifungal activity. Reduction in PLW by post-harvest GA_3 treatment was also observed in several of banana cultivars earlier by Rao and Chundawat, Patel [9] and Deepak [10] in cv. Harichal, Patel and Bhalerao in cv. Grand Naine, Macwan in cv. Robusta and Hakim [11] in cv. Sabri and Amritsagar.

Similarly, treating the fruits with $CaCl_2$ @ 1000 ppm + 200 ppm Thiabendazole also recorded the lowest physiological loss in weight. This may be due to role of calcium on limiting respiration which was attributed to altered membrane permeability, as calcium could have reduced the endogenous substrate catabolism during respiration by limiting the diffusion of substrate from the vacuole to the cytoplasm and favoured the uptake of sorbitol thus disallowing its involvement in reactions related to internal breakdown [12]. The reduction in loss of physiological weight may be also due to thickened cell wall consequent to calcium addition and checking of ethylene biosynthesis in addition to restricting gas exchange. Similar reasons were attributed by Rajkumar et al. [13] in papaya, Rajput in guava and Asif Wali and Zubair Hussian in persimmon.

Fruit firmness was found to decrease as ripening advanced in both locations. Textural changes in fruit involved a number of factors including loss of cell wall integrity, change in turgor pressure and anatomical modifications. In general, softening of fruits during ripening is attributed to increased solubilization of cell wall pectin methyl esterase (PME) and Polygalactouronase (PG).

The data registered in the present investigation indicated that GA_3 (150 ppm) + Thiabendazole (200 ppm) treated fruits retained higher stability of firmness during the period of observations and the treatment combination of $CaCl_2$ (1000 ppm)+ Thiabendazole (200 ppm) was statistically on a par with GA_3 (150 ppm). The better firmness of banana obtained with GA_3(150 ppm) + Thiabendazole (200 ppm) might be due to retarded and slow degradation of polymers like starch, cellulose and hemicelluloses. It may also due to its antagonistic effect on IAA which enhances hydrolytic and oxidative enzymes like amylase, phosphorylase, phosphatase, polygalactouronase and pectin methyl esterase (PME) by protecting stiff pectin macromolecules against demethylation (or) reduced depolymarization of polygalactouronase as reported by Macwan et al. in banana. The synergistic effect of SOP and GA_3 enhances the auxin synthesis and thus resulting in better shelf life.

Exogenous application of GA_3 generally reduces the ethylene level in fruits. Higher level of ethylene might cause softening of cell wall and decrease the firmness of fruit. GA_3 retarded degradation of polymers like starch, cellulose and hemicelluloses, thus maintaining the firmness of fruit. These results are in concordance with Bhalerao [14] in cv. Grand Naine, Macwan in cv. Robusta banana. The fruits from control recorded the highest TSS and total sugars in both locations. This may be due to the higher activity of ripening related enzymes like α amylase, β amylase and starch phosphorylase resulting increased TSS and sugars.

The fruits treated with GA_3(150 ppm) + Thiabendazole (200 ppm) recorded lowest total sugars and higher starch content at full ripe stage. This may be due to slow hydrolysis of starch to sugars by antagonistic effect on autocatalytic biosynthesis of ethylene and inhibit the activity of α amylase, β amylase and starch phosphorylase this maintaining the organic acid and acidity level which results in low sugar content and higher starch in fruits at ripening.

Chemical fungicide in combination with GA_3 may also have prevented deterioration by inhibiting fungal infection. Many post-harvest pathogens causes cellular damage by synthesizing enzymes affecting cell wall. Application of fungicide could have prevented the tissue damage and respiration resulting in increased total sugars. The similar results were agreement with that of Rao and Chundawat, Kaviarasu in banana and Fatemi and Hasan [15] in Valencia Orange.

The titrable acidity showed a constant decrease during the storage period. The decline in acidity may be attributed to the utilization of acids in the process of ripening in the presence of reduced supply of sugar as a substrate of respiration which might be due to lower rate of starch degradation during the ripening. The highest titrable acidity was observed with fruits treated with GA_3 (150 ppm) +200 ppm of Thiabendazole. This may be due to less utilization of organic acids in respiration by antisenscent action of GA_3 which delays the ripening mechanism through reduced rate of starch degradation. This finding of the present study was in accordance with Sudha [16] in sapota, Bhalerao and Macwan and Vihol [17] in banana.

With regard to ascorbic acid content, the higher levels of ascorbic acid recorded in GA_3 + Thiabendazole treated fruits. This may be due reduced oxidization of ascorbic acid into dehydroascorbic acid in GA_3 treated fruits and also changes in the metabolism of carbohydrates and biosynthesis of glucose which is considered to be the precursor of Vit-C. Such increase in acidity and ascorbic acid GA_3 was also reported by Sushma in banana, Singh and Singrot in lemon and Bhalerao in banana. The similar response may be the reason for higher acidity and ascorbic acid in GA_3 treatment in the present study.

Post-harvest treatments significantly influenced the carotene content. The highest carotene content was observed in control while lowest was observed in GA_3 treatment. GA3 treatment decreases the activity of chlorophyllase and Mg-dechelatase which are responsible for breakdown of chlorophyll [18].

The inhibition of chlorophyll degradation could have caused delay in carotenoids formation. Similar findings were also reported by Rajkumar et al. in papaya, Deepak and Kathiya and Patel and Padhiar in banana. A perusal of data in the present study indicated that no disease symptoms were observed till third day of storage. Afterwards, the lowest disease incidence was observed in fruits treated with GA_3 (150 ppm) + 200 ppm of Thiabendazole during the period of storage. This might be due to reduced level of respiration and transpiration loss as GA_3 treated fruits having thick skin which prevented the entry of microbes and maintained low rate of various metabolic processes which in turn increased the resistance to microbial entry. Further, TBZ is a known anti-fungal chemical. Good control of post-harvest pathogenic infections by TBZ has been reported earlier in crops like banana, apple and oranges.

GA3 may also delay the appearance of disease symptoms. El Ghoauth et al. [19] reported that post-harvest treatment with GA_3 reduces the fruit decay and attributed its enhanced level of defense related enzymes like POD, PPO's and lipid oxidase which are known to be involved in synthesis of the various antifungal volatile compounds that could act to restrict pathogen.

The fruits treated with GA_3 in combination with Thiabendazole recorded the maximum shelf life of 18 days as compared to 12 days in control. Post-harvest GA_3 dips have shown to increase the shelf life in a range of banana cultivars as it inhibits the ethylene biosynthesis by its antisenescent action. Extension of shelf-life is also possible by suppression of pathogenic infections and increased synthesis of nucleic acids. Thiabendazole is a systemic benzimidazole fungicide, which is effective against storage diseases. TBZ works by inhibition of mitochondrial helminth-specific enzyme, fumarate reductase, with possible interaction with endogenous quinine. Possibly, a similar role may be in play enhancing the shelf-life of banana hands treated with thiabendazole both at 200 ppm in the present study.

Apart from GA3 and TBZ, the treatment with calcium chloride and TBZ also showed promise in reducing disease incidence and extending shelf life. Calcium dip was effective in inhibiting spore germination, thus provided a good control of *Colletotrichum gloeosporiodes* infection on papaya.Similar effect of Ca was reported to inhibit the growth of *Botryosphaeria dothidea* on apple and *Monilinia fructicola* on peach. Calcium chloride application as postharvest treatment has been reported to markedly elevate Ca content in the fruit peel, fruit firmness and reduce post-harvest disease caused by anthracnose in apple, peach papaya and dragon fruit. The findings in the present study also indicate that calcium chloride may serve as an effective postharvest treatment.

The study conclude that combined pre-harvest sprays of 2 per cent SOP + 2 ppm BR followed by post-harvest dipping of fruits with 150 ppm GA3 + 200 ppm Thiabendazole or 1000 ppm $CaCl_2$ + 200 ppm Thiabendazole may be followed by producers to attain maximum yield, quality and post-harvest life with reduced physiological loss in weight and disease incidence.

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