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PHYTOHORMONES AND SIGNAL MOLECULES FOR SHELF LIFE ENHANCEMENT OF GRAND NAINE BANANA FRUIT

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ABSTRACT
The present investigation was carried out to evaluate the effect of phytohormones and signal molecules on shelf life improvement of banana fruit. According to the findings, fruits treated with 150ppm GA_3 retained the excellent fruit quality with the maximum fruit firmness (60.33N), highest score for colour, appearance, taste and flavour, overall acceptance and fruits were able to keep for 24.33 days and extended the shelf life for 8 days over control. The physiological weight loss of fruits, irrespective of treatments,increased with advancement of storage period. But, the minimum(4.58%)physiological weight loss of fruits was recorded in the fruits treated with 150ppm $GA_3$and maximum (28.57%) was observed in fruits treated with ABA 10μM at 20 days after storage.The maximum total carbohydrates (30g/100g), slow decline in the carbohydrate content and slow colour changes with the maximum green life (17.00days) was also observed in fruits treated with150ppm GA_3. The treatment with SNP 1mM exhibited the maximum yellow life (7.67days) and finally extended the shelf life up to 23 days. Thus, it can be inferred from the study that GA_3 extends the shelf life of banana fruit by maintaining fruit firmness, minimizing the rate of respiration and can be explored for improving post-harvest storage and marketing efficiency.

INTRODUCTION

Banana (*Musa* spp.) is a traditional tropical fruit regarded as "Queen of tropical fruits" and "Apple of Paradise". It provides well balanced diet to millions of people around the globe and also contributes to livelihood through crop production, processing and marketing (Singh, 2002) and thus plays a key role in the economy of many developing countries.In India, banana contributes 31.72 per cent of the total fruit production. India is the largest producer of banana in the world with an annual production of 284.55 lakh tones from an area of 7.96 lakh hectares (Anon, 2013). However, the export potential is too meager owing to its perishability and lack of technology for shelf life enhancement.

Banana is typically a climacteric fruit and hence it undergoes rapid ripening by an autocatalytic climacteric burst of gaseous hormone ethylene, which in turn controls various ripening related biochemical changes and sensorial attributes. Being a highly perishable fruit it is subjected to serious post-harvest losses due to poor handling and improper storage practices; hence export trading cannot be tapped although India is a major producer. Phytohormones have been used in horticultural practices to control growth and differentiation phenomenon. In the recent years their use has also been extended to control the physiological process in fruits after being detached from the plant and kept aside for ripening. Uses of phytohormones have been shown to extend the storage life by minimizing the loss in weight, spoilage and by delaying ripening process Yadav *et al.*, (2013). It also improves physical appearance of the fruit without affecting the edible quality. Ripening process governs fruit quality and shelf life, and hence nutrition and marketability. The signal molecules like Nitric Oxide (NO) plays a key role in orchestrating the pathways which modulate the secondary metabolism and improve quality attributes such as colour, texture, flavour and nutritional components of fruits which are currently being exploited commercially for their enormous health benefits (Zhu *et al.*, 2006). Hence, it necessitates the suitable studies to understand the ripening physiology and hormonal cross talks involved in the climacteric phase responsible for poor shelf life. Banana is an ideal fruit for fundamental studies of metabolic processes involving various physical and biochemical changes taking place during ripening. Hence, the present investigation was undertaken to evaluate the phyhormones and signal molecules to extend the shelf life of banana.

MATERIALS AND METHODS

Uniformly matured and freshly harvested Grand Naine banana fruits having uniform size, shape and colour were procured from the farmer's field located at Bagalkot district of Karnataka which formed the experimental material. Hands from bunches and fingers from hands were separated by discarding diseased and damaged fingers. Fruits were treated with thirteen treatments (T_1: IAA 25ppm, T_2: IBA 100ppm, T_3: GA_3 150ppm, T_4: Kinetin 0.5mg/L, T_5:ABA 10μM, T_6: SNP 1mM, T_7: SNP 0.5mM, T_8: Chitosan 0.1% for 10 min, T_9: Chitosan 0.1% for 1 hr, T_{10}: Chitosan 0.1% for 3 hr, T_{11}: Salicylic acid 100μM, T_{12}: Ethrel 1ml/L and T_{13}: untreated control) and replicated thrice. Chitosan solution was prepared by dissolving in 1 per cent glacial acetic acid on w/w basis.Fingers were washed thoroughly; air dried, dipped in the solutions of different

phytohormones and signal molecules for 3 hours except in treatments T_8 and T_9 where the dipping time was for 10 minutes and 1 hour respectively. Fruits treated with distilled water served as control. Then the fruits were kept at 25-27^p C and the observations were recorded at four days interval. Initial weight of the fruit and final weight of the fruit were recorded and physiological loss in weight was calculated by using the formula,

$$W_1 = \frac{W_0 - Wt \times 100}{W_0}$$

Where, W_1:Weight loss, W_0: Initial weight and Wt:Final weight.

Fruit firmness was measured by using hand held penetrometer (Breene, 1975) and expressed in terms of Newton (N= Kg force × 9.807). Reducing sugar was estimated by Di-nitrosalicylic acid (DNS) method (Miller, 1959). Total carbohydrate was estimated by Anthrone method. Green life was estimated by counting number of days from harvesting till the fruits start to turn yellow. Yellow life was estimated by counting the number of days from yellow till the fruits start rotting. Shelf life of fruits was decided based on the appearance of the fruits. When the fruits attained beyond edible ripe stage, then those fruits were considered to have reached the end of their shelf life. Sensory evaluation of banana fruit with respect to taste, flavour, colour, appearance, firmness as well as overall acceptability were examined on a 10 point scale by a panel of 10 judges.The data in respect of all the above parameters were tabulated and subjected to the statistical analysis (ANOVA) for Complete Randomized Design and results were tested at 1 per cent level of significance by using Fischer method of analysis of variance as suggested by Cochran and Cox (1957).

RESULTS AND DISCUSSION

Banana fruit contains around 75 per cent water (Pruthi *et al.*,

Table 1: Effect of phytohormones and signal molecules on physiological loss in weight

Treatments	Days After Storage	Physiological weight loss (%)					
		4	8	12	16	20	24
T_1	IAA 25ppm	5.53	8.43	14.67	17.57	22.10	27.97
T_2	IBA 100ppm	5.73	8.63	15.00	18.10	24.63	NA
T_3	GA_3 150ppm	4.58	7.12	13.60	17.23	19.10	24.07
T_4	Kinetin 0.5mg/L	5.40	6.79	14.50	17.43	21.97	26.39
T_5	ABA 10μM	6.53	9.43	16.93	21.20	28.57	NA
T_6	SNP 1mM	4.97	6.79	12.73	16.83	18.83	25.17
T_7	SNP 0.5mM	5.87	8.77	15.30	18.30	25.97	NA
T_8	Chitosan 0.1% for 10 min	6.03	9.03	16.07	18.43	27.10	NA
T_9	Chitosan 0.1% for 1 hr	5.30	8.50	15.47	17.70	21.07	NA
T_{10}	Chitosan 0.1% for 3 hr	5.73	9.03	16.63	20.33	27.43	NA
T_{11}	Salicylic acid 100μM	5.40	8.27	14.40	17.47	21.40	27.10
T_{12}	Ethrel 1ml/L	9.93	14.87	NA	NA	NA	NA
T_{13}	Control	7.53	10.13	17.97	21.17	NA	NA
F test		**	**	**	**	**	**
S. Em ±		0.22	0.23	0.24	0.32	0.64	0.40
CD at 1%		0.87	0.93	0.95	1.29	2.54	1.61

(NA in the table indicates the completion of shelf life and no fruits were available for recording observation); ** Significant at 1% and 5% level of significance

Table 2: Effect of phytohormones and signal molecules on firmness

Treatments	Days After Storage	Firmness (N)					
		4	8	12	16	20	24
T_1	IAA 25ppm	55.10	50.15	40.21	36.28	27.60	14.71
T_2	IBA 100ppm	53.04	46.15	38.25	30.40	17.66	NA
T_3	GA_3 150ppm	60.33	55.00	46.09	41.18	29.66	18.63
T_4	Kinetin 0.5mg/L	55.12	50.13	42.10	35.20	28.34	16.67
T_5	ABA 10μM	49.07	42.00	35.30	19.61	12.67	NA
T_6	SNP 1mM	60.00	53.00	42.17	38.24	29.16	17.65
T_7	SNP 0.5mM	50.99	47.33	33.34	28.90	19.28	NA
T_8	Chitosan 0.1% for 10 min	50.20	45.03	31.38	25.49	16.83	NA
T_9	Chitosan 0.1% for 1 hr	52.79	49.00	39.80	29.42	17.90	NA
T_{10}	Chitosan 0.1% for 3 hr	50.18	45.00	34.34	25.13	26.22	NA
T_{11}	Salicylic acid 100μM	54.14	50.07	41.30	37.27	27.75	12.75
T_{12}	Ethrel 1ml/L	29.49	18.64	NA	NA	NA	NA
T_{13}	Control	48.24	42.00	28.12	17.65	NA	NA
F test		**	**	**	**	**	**
S. Em ±		0.40	0.43	0.18	0.08	0.09	0.02
CD at 1%		1.60	1.70	0.73	0.36	0.37	0.04

(NA in the table indicates the completion of shelf life and no fruits were available for recording observations)

Table 3: Effect of phytohormones and signal molecules on per cent reducing sugar

Treatments		Reducing Sugar (%)					
	Days After Storage						
		4	8	12	16	20	24
T_1	IAA 25ppm	2.93	4.33	6.00	7.86	11.56	9.77
T_2	IBA 100ppm	3.53	4.53	6.60	10.53	9.88	NA
T_3	GA_3 150ppm	2.70	3.77	4.80	7.50	8.30	11.77
T_4	Kinetin 0.5mg/L	2.80	4.00	5.93	8.01	11.53	9.57
T_5	ABA 10μM	3.73	5.60	8.53	11.33	8.67	NA
T_6	SNP 1mM	2.80	3.87	5.33	7.63	8.07	11.63
T_7	SNP 0.5mM	3.43	5.26	6.77	10.17	9.60	NA
T_8	Chitosan 0.1% for 10 min	3.47	5.23	6.23	9.27	9.17	NA
T_9	Chitosan 0.1% for 1 hr	3.33	4.75	6.04	8.20	10.73	NA
T_{10}	Chitosan 0.1% for 3 hr	3.73	5.25	6.27	10.63	9.73	NA
T_{11}	Salicylic acid 100μM	3.13	4.53	6.10	8.57	11.07	10.00
T_{12}	Ethrel 1ml/L	7.23	11.98	NA	NA	NA	NA
T_{13}	Control	3.77	5.76	8.60	11.89	NA	NA
F test		**	**	**	**	**	**
S. Em $\pm$		0.14	0.01	0.15	0.03	0.17	0.14
CD at 1%		0.57	0.025	0.63	0.09	0. 69	0. 56

(NA in the table indicates the completion of shelf life and no fruits were available for recording observations)

Table 4: Effect of phytohormones and signal molecules on total carbohydrate

Treatments		Total carbohydrate (g/100g)					
	Days After Storage						
		4	8	12	16	20	24
T_1	IAA 25ppm	29.00	27.16	25.00	18.00	12.00	3.00
T_2	IBA 100ppm	28.00	27.00	22.00	15.00	9.00	NA
T_3	GA_3 150ppm	30.00	29.00	27.00	25.00	15.00	5.00
T_4	Kinetin 0.5mg/L	30.00	28.00	25.50	17.00	10.00	2.00
T_5	ABA 10μM	26.00	21.66	15.50	11.00	3.50	NA
T_6	SNP 1mM	29.50	28.00	26.00	24.00	13.00	3.50
T_7	SNP 0.5mM	26.00	23.00	16.00	12.00	4.00	NA
T_8	Chitosan 0.1% for 10 min	27.00	24.33	20.33	14.00	5.00	NA
T_9	Chitosan 0.1% for 1 hr	28.00	26.16	21.00	16.00	7.00	NA
T_{10}	Chitosan 0.1% for 3 hr	27.00	25.00	18.00	10.00	3.00	NA
T_{11}	Salicylic acid 100μM	30.00	28.00	25.20	19.00	13.50	2.50
T_{12}	Ethrel 1ml/L	20.66	14.00	NA	NA	NA	NA
T_{13}	Control	25.00	21.16	15.00	8.50	NA	NA
F test		**	**	**	**	**	**
S. Em $\pm$		0.24	0.21	0.11	0.16	0.42	0.16
CD at 1%		0.96	0.87	0.42	0.62	1.60	0.62

(NA in the table indicates the completion of shelf life and no fruits were available for recording observations)

1977). Under normal atmospheric conditions, fruits loose moisture causing shrinkage and loss of turgidity. Freshly harvested fruits are living entities wherein several metabolic activities are occurring viz., respiration, ripening, etc., which lead to physiological loss in weight (PLW) of fruits. This loss in weight is attributed to loss in moisture and gaseous exchange. If this is retarded then shelf life could be extended. Table 1 represents the PLW of banana fruit as affected by phytohormones and signal molecules treatment. There was increase in PLW irrespective of the treatment with the progress of ripening, similar findings were observed by Gohlani and Bisen (2012) in custard apple coated with different coating materials. The minimum PLW was recorded in the fruits treated with GA_3 (150ppm) at 4th and 24th days after storage and in SNP (1mM) treated fruits at 8th, 12th, 16th and 20th days after storage.The reduction in weight loss was due to the retardation of transpiration and respiration process and reduced moisture loss lead to maintain the turgidity of the cells. The results are in conformity with the findings of Kramchote *et al*. (2008) where nitric oxide treatment was reported to reduce the rapidity of weight loss in litchi. Similar results with use of GA_3 were also observed by Banik *et al*. (1988) in sapota, Khadar (1989) in mango Singh and Singh (1992) in mango and Choudhary and Dhaka (2005) in Kinnow mandarin fruits.

There was decrease in the fruit firmness with the advancement of ripening (Table 2) and the fruits treated with GA_3 (150ppm) significantly recorded the maximum fruit firmness during the course of storage, this might be due to slow break down of insoluble pro pectin into soluble pectin or by less cellular disintegration leading to high membrane permeability (Brinston *et al.*, 1988). Similar findings were obtained by Desai and Deshpande (1978) in banana. The fruits with lesser firmness documented the enhanced ripening and minimum shelf life. The highest percentage of reducing sugar (11.98%) was recorded in treatment with ethrel 1mlL^{-1} on 8th day after storage and the treatments with GA_3 150ppm, SNP 1mM, kinetin 0.5mg

Table 5: Effect of phytohormones and signal molecules on overall acceptance of banana fruit

Treatments	Colour and appearance	Fruit firmness	Taste and flavour	Overall acceptance
T_1- IAA 25ppm	6.00	5.00	8.00	8.00
T_2 - IBA 100ppm	5.00	5.00	7.00	6.00
T_3 - GA_3 150ppm	7.00	7.00	9.00	9.00
T_4 - Kinetin 0.5mg/L	6.00	6.00	8.00	8.00
T_5- ABA 10μM	6.00	5.67	7.00	6.00
T_6- SNP 1mM	6.00	6.00	8.50	8.67
T_7- SNP 0.5mM	5.00	5.00	7.00	6.00
T_8 - Chitosan 0.1% for 10 min	5.00	5.00	7.00	6.00
T_9 - Chitosan 0.1% for 1 hr	6.00	5.00	8.00	6.67
T_{10} - Chitosan 0.1% for 3 hr	5.00	5.00	7.00	6.00
T_{11} - Salicylic acid 100μM	6.00	6.00	8.00	8.00
T_{12}- Ethrel 1ml/L	6.00	5.00	8.67	7.00
T_{13}- Control	6.00	5.00	7.33	6.33
F test	**	**	**	**
S. Em $\pm$	0.22	0.18	0.15	0.22
CD at 1%	0.88	0.78	0.60	0.88

Table 6: Effect of phytohormones and signal molecules on shelf life of banana fruit

Treatments	Green life(days)	Yellow life(days)	Shelf life (days)
T_1- IAA 25ppm	14.33	7.00	21.33
T_2 - IBA 100ppm	12.00	7.00	19.00
T_3 - GA_3 150ppm	17.00	7.33	24.33
T_4 - Kinetin 0.5mg/L	15.00	6.00	21.00
T_5- ABA 10μM	11.33	5.00	16.33
T_6- SNP 1mM	15.33	7.67	23.00
T_7- SNP 0.5mM	12.67	5.67	18.33
T_8 – Chitosan 0.1% for 10 min	13.00	5.00	18.00
T_9 - Chitosan 0.1% for 1 hr	13.67	6.33	20.00
T_{10} - Chitosan 0.1% for 3 hr	11.33	5.67	17.00
T_{11} - Salicylic acid 100μM	14.00	6.33	20.33
T_{12}- Ethrel 1ml/L	3.00	5.00	08.00
T_{13}- Control	10.00	6.00	16.00
F test	**	**	**
S. Em $\pm$	0.29	0.28	0.20
CD at 1%	1.09	1.09	0.81

L^{-1}, Salicylic acid 100μM and IAA 25ppm showed less percentage of reducing sugar during the initial days of storage (Table 3)because of slow conversion of starch into sugars and delay in climacteric peak of respiration, however, in ethrel treated fruits there was rapid break down of starch into sugars due to rapid induction of pre climacteric and climacteric phases and onset of climacteric peak in respiratory metabolic pathway in starch hydrolysis resulted in accumulation of sugars in early days of storage and enhanced ripening (Marriot, 1980). GA_3(150ppm) treated fruits attained the maximum per cent reducing sugar on 24th day after storage and significantly showed extended shelf life. Similar findings were observed by Osman *et al.* (2008).

Treatment with GA_3 (150ppm) and SNP (1mM) exhibited slow decline in the total carbohydrate due to slow hydrolysis of carbohydrates into simple sugars. Similar findings were observed by Desai *et al.* (1978) in banana. Yadav *et al.* (2013) found that GA_3 200ppm treatment recorded the highest total soluble solids, reducing sugars and carbohydrates in sapota. Fruits treated with GA_3 (150ppm) recorded the highest score (7.00) for colour and appearance compared to others at their full ripe stage. Similarly, the maximum score for fruit firmness (7.00), taste and flavour (9.00). Looking into all the parameters the maximum score value for overall acceptance of the fruit (9.00) was given to the fruits treated with GA_3 (150ppm) which is represented in the table 5 Present findings are in conformity with Yadav *et al.* (2013).

Significant differences were observed among the different treatments with respect to shelf life of the fruit (Table 6). Fruits treated with GA3 (150ppm) recorded the maximum green life (17.00 days) due to slowing down in the ripening process, delayed senescence and reduced chlorophylase activity. Similar findings were reported by Porat *et al.* (2001) in citrus wherein GA_3 application effectively retained the green colour of 'Oroblanco'citrus fruit stored at 2ºC and in banana (Sultana *et al.*, 2012).

Ethrel 1mlL-1 treated fruits recorded the minimum green life (3.00 days) followed by control fruits (10.00 days). Treatment with SNP 1mM recorded the maximum yellow life (7.67 days), it might be due to delayed ripening, retardation of respiration, suppression of ethylene production and climacteric peak during ripening. The present findings are in conformity with Zhang *et al.* (2008) in plum and Flores *et al.* (2008) in pear.The treatment $GA_3$150ppm recorded significantly the highest shelf life of 24.33 days; however, SNP 1mM was statistically on par (23.00 days). The lowest shelf life (8.00 days) was noticed in ethrel 1mlL^{-1} followed by control (16.00 days). Extended shelf life over control was due to more green life, enhanced yellow life, delayed respiration, suppression of ethylene production, and maintenance of turgidity with less PLW, high fruit firmness and delay in colour development. Pinaki *et al.* (1997) reported that mature and fully developed banana fruits dipped into GA_3 (150ppm) was most effective treatments for prolonging the shelf life of banana. Similar results were noticed by Kahlon and Uppal (2005), Gangwar *et al.* (2008), Osman *et al.* (2008), Bhalerao *et al.* (2010), Lokesh *et al.* (2012) in banana and Yadav *et al.* (2013) in sapota.

It was established that for extended shelf life of banana, NO alters endogenous ethylene levels at various levels by modifying many pathways changing post climacteric biochemical changes which are linked to fruit quality (Manjunatha *et al.*, 2012). NO represses precursors of ethylene

and also affects the ethylene accumulation by stoichiometric reactions contributing for enhanced shelf life of fruits (Xue *et al.*, 2012). NO antagonise ethylene at various levels through transcriptional modification of 1-Aminocyclopropane 1-carboxylic acid oxidase (ACO) genes, post translational modification of methionine adenosyltransferase (MAT), inhibition of hydrogenation of ethane to ethylene and stoichiometric reduction of 1- malonylaminocyclopropane 1-carboxylic acid (MACC) with co-ordination of other signal molecules such as salicylic acid, polyamines and cytokinin thus, helps in extending the shelf life of fruits (Manjunatha *et al.*, 2012).

From the present investigation it was reported that phytohormones and signal molecules have significant effect on shelf life improvement of banana fruit. GA_3 treatment resulted in minimum loss of fruit weight, maximum firmness, high score for colour, taste and flavour, overall acceptance and showed slow decline in total carbohydrate. The results also revealed that among the growth regulator treatments GA_3appeared to be more suitable for extending the shelf life as well as other quality attributes of banana fruits. 1mM SNP followed by 25ppm IAA and 0.5gL^{-1} kinetin were also found the best next to GA_3 for extending shelf life of banana fruit. The phytohormones role in extended shelf life with enhanced fruit attributes, clearly suggesting the ways for manipulating them into formulations for pre-treatment. However, its stoichiometry is needed to be understood for its exploitation commercially and validated using different treatment conditions and varieties.

REFERENCES

Anonymous 2012. Indian Horticulture Data Base. *National Horticulture Board, September*. pp. 36-43.

Banik, D., Dhua, R. S., Ghosh, S. K. and Sen, S. K. 1988. Study on extension of storage life of sapota (*Achrazzapota* L.). *Indian J. Hort.* **45:** 241-248.

Bhalerao, P. P., Bhaleraom, R. R., Patil, S. J., Gaikwad, S. S. and Patel, C. M. 2010. Effect of growth regulators on shelf life of banana fruits cultivar Grand Naine. *Green Farming*. **1**: 55-58.

Brinston, K., Dey, P. M., John, M. A. and Pridhan, J. B. 1998. Post-harvest changes in *Mangiferaindica* mesocarp walls and cytoplasmic polysaccharides. *Phytochem*. **27:** 719-723.

Breen, W. M. 1975. Application of texture profile analysis to instrumental food texture evaluation. *J. Texture Stud.* **6:** 53-82.

Choudhary, M. R. and Dhaka, R. S. 2005. Effect of post-harvest treatments on quality of Kinnow mandarin fruits during storage. *Haryana J. Hort. Sci.* **34(1-2):** 39-41.

Cochran and Cox. 1957. Experimental design procedure for the behavioural sciences. *Cole Publ. Co.* pp. 319-380.

Desai, B. B. and Deshapande, P. B. 1978. Chemical control of ripening in banana. *Pl. Physiol.* **44:** 238-240.

Flores, B., Sanchez bel, P., Monika, V., Felix, R., Maria and Isabel, E. M. 2008. Effects of a pre-treatment with nitric oxide on peach (*Prunuspersica* L.) storage at room temperature.*Euro Food Res. Tech.* **227:** 1599-1611.

Gangwar, D., Katiyar, J. P., Singh and Singh, P. C. 2008. Effect of post-harvest chemical treatments on shelf life and physico-chemical quality of banana cv. Harichal. *The Asian J. Hort.* **3(2):** 386-388.

Gohlani, S. and Bisen, B. P. 2012. Effect of different coating material on the storage behavior of custard apple (*Annonasquamosa* L.). *The Bioscan.* **7(4):** 637-640.

Kahlon, P. S. and Uppal, R. S. 2005. Effect of post-harvest treatments on shelf life of mango cv. Chausa. *Haryana J. Hort. Sci.* **34(1-2):** 51-53.

Khader, S. E. S. A. 1989. Delaying ripening by post-harvest treatments of GA_3 in mango.*Indian J. Hort.* **46(4):** 444-448.

Lokesh, V., Manjunatha, G. and Bhagyalakhmi, N. 2012. Effect of phytohormones on the expression of ripening related genes in banana (*Musa acuminate* AAB cultivar NanjanaguduRasabale). Parer presented in Lenoia International Convention Centre, Hyderabad, India.

Manjunatha, G., Guptha, K. J., Lokesh, V., Luis Aj Mur and Bhagyalakhmi, N. 2012. Nitric oxide counters ethylene effects on ripening fruits. *Plant Signalling Behaviour.* **7:** 476-483.

Manjunatha, G., Lokesh, V. and Bhagyalakshmi, N. 2012. Nitric oxide induced enhancement of banana fruit attributes and keeping quality. *Acta. Hort.* **934:** 799-806.

Marriot, J. 1980. Banana-physiology and biochemistry of storage and ripening for optimum quality. *Critical Reviews in Food Science and Nutrition*.**13:** 41-88.

Miller, G. L. 1959. Use of dinitrosalicylic acid reagent for determination of reducing sugar. *Anal. Chem.* **31:** 426-428.

Osman, H. E., Abu Bakr Ali and Abu Goukh. 2008. Effect of polythene film lining and gibberellic acid on quality and shelf life of banana fruits. *J. Agric. Sci.***16:** 242-261.

Pinaki, A. K., Rajput, C. B. S., Acharya, P. and Kumar, D. 1997. Effect of gibberellic acid, calcium chloride and bavistinon the post-harvest life of banana fruits. *Recent Hort.* **4:** 30-31.

Porat, R. 2001. Gibberellic acid slows post-harvest de-greening of 'Oroblanco' citrus fruits. *Hort. Sci.* **36(5):** 937-940.

Pruthi, J. S., Bhat, A. V., Kutty, S. K., Gopalkrishna, M. and Verkay, A. G. 1977. Varietal trials for banana grown in kerala for processing. *Indian Food Packer* (May- August). pp. 8-17.

Singh, B. K. and Singh, T. P. 1992. Effect of certain post-harvest treatments on the storage life and quality of mango cv. Zardalu.*Indian Food Packer* (Nov- Dec). pp. 55-61.

Singh, H. P. 2002. Indian banana issues and strategies, Global Conference on Banana and Plantain. Oct 28-31. Bangalore, India, abstracts. pp. 1-2.

Sultana, M. S., Islam, M. Z., Shamim, A. H. M. and Mondal, M. F. 2012. Effect of growth regulators on physical changes and shelf life of banana during storage. *Int. J. Sustainable Crop Prod.* **7(3):** 31-35.

Xue Ping Li, Bin Wu, Qin Guo, Ji De Wang, Pin Zhang and Wei Xin Chen. 2012. Effect of nitric oxide on post-harvest quality and soluble sugar content in papaya fruit during ripening. *J. Food Processing and Preservation*. ISSN. pp. 1745-4549.

Yadav, N. K. K., Bharathi, N., Ramana, C. V. and Goud, P. V. 2013. Efffect of growth regulators on quality of sapota (*Manilkaraachraz*) cv. Kalipatti. *Pl. Archieves*. **13(2):** 893-896.

Zhang, D. D., Cheng, G. P., Li, J., Yi, C., Yang, E. and Qu, H. X. 2008. Effect of nitric oxide on disorder development and quality maintenance of plum stored at low temperature. *Acta Hort.* **804:** 549-554.

Zhu, S., Liu, M. and Lhou, H. 2006. Inhibition by nitric oxide of ethylene biosynthesis and lipoxygenase activity in peach fruit during storage. *Post harvest Biol. Tech.* **42:** 41-48.