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Influence of different pre-harvest sprays on physical and physiological parameters of banana cv Rajapuri (AAB) fruits

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Abstract
The present study was conducted to recognize the influence of different pre-harvest sprays on the physical and physiological parameters of the banana cv. Rajapuri fruits during the year 2019-20 and 2020- 2021. The chemicals *viz.*, calcium chloride (1 and 2.0%), hexanal (2 and 3.0%), salicylic acid (0.40 and 0.60%) and potassium silicate (0.40 and 0.60%) were sprayed at two concentration levels before one month of the harvesting during both the years. Later they were harvested and brought to laboratory for studying their physical and physiological behaviors during ambient storage. Among different pre-harvest sprays, fruits sprayed with potassium silicate at 0.60 per cent has showed the better physical and physiological behaviors with enhanced shelf life compared to other treatments.

Keywords: Banana, pre-harvest, potassium silicate and physiological parameters

Introduction
Banana is one of the most important tropical fruit crop of the world. It is well-known and popular among Indians and its culture dates back to Indian civilization. It is the inexpensive fruit grown in the country with high energy, nutritional quality, affordability and year round availability as opposed to other seasonal fruits.

Bananas are typical climacteric fruits, which ripen with an increasing rate of respiration coupled with ethylene production. The perishability of the fruit is attributed to the adverse physiological changes, loss of weight due to respiration and transpiration, softening of flesh and loss of resistance to microbial attack during storage. Fruit shelf life can be effectively extended if these physiological changes that occur during post-harvest storage of bananas are delayed or postponed. As a consequence, efforts to prolong the shelf life of banana fruits should focus on decelerating the metabolic rate, ethylene biosynthesis and its action in the harvested fruits. Extending the shelf life of the banana cv. Rajapuri fruits by various methods not only reduce post-harvest loss but also increase per capita availability of the fruits and pave the way for the export of the famous indigenous varieties to the rest of the world without compromising their quality or flavour. Exporting fruits to domestic and international markets not only expands the area of cultivation but also tends to increase banana growers' interest in large-scale cultivation of banana cv. Rajapuri. The objective of the present study was to study the influence of different chemicals applied as pre-harvest sprays on the physical and physiological behavior of the banana cv. Rajapuri fruits.

Material and Methods
Uniformly matured and even-sized, blemish, pest and disease free banana cv. Rajapuri bunches were selected, tagged and used for the pre-harvest sprays treatments in the field of ICAR-AICRP on Fruits, Kittur Rani Channamma College of Horticulture, Arabhavi during both the years (2019- 20 and 2020- 21). The experiment was laid out in a completely randomized design with nine treatments in three replications. Spray of calcium chloride (1 and 2.0%), hexanal (2 and 3.0%), salicylic acid (0.40 and 0.60%) and potassium silicate (0.40 and 0.60%) was taken one month before harvesting. The fruit bunches of uniform size, shape and are at 80 per cent maturity stage were harvested in the early morning hours and immediately brought to the Department of Post-Harvest Technology laboratory with utmost care for further study. The cultural operations were conducted regularly and uniformly to all experimental plants.

The physical parameters *viz*., bunch weight (kg), number of hands per bunch (No's), weight of the third hand (kg), number of fingers in third hand (No's), finger weight (g), finger length (cm), finger girth (cm), pulp weight (g), peel weight (g) and pulp to peel ratio were recorded manually at the initial day of experiment using electronic weighing balance and vernier calipers. Physiological parameters *viz*., physiological loss in weight and respiration rate were taken at initial and also at three days interval up to the end of the storage. To determine the physiological loss in weight, the banana hands in each treatment were weighed at beginning of storage which was recorded as initial weight and in subsequent intervals during storage as final weight. The fruits were weighed again and recorded as final weight on each day of observation. At three days interval, the cumulative loss in weight was then calculated and the PLW was expressed in per cent on a fresh weight basis using the below formula.

$$\text{Physiological loss in weight (\%)} = \frac{[P_0 - P_1 \text{ or } P_2 \text{ or } P_3 \text{ or } P_4 \text{ or } P_5]}{P_0} \times 100$$

Where,

P_0 - Initial weight and P_1, P_2, P_3, P_4 and P_5 -weight after regular intervals.

The rate of respiration was measured by a static method using a gas analyzer (PBI, DANSENSOR, CHECKMATE 2). The known quantity of banana fruits was sealed hermetically in a 650 ml plastic container having a provision for a hole and the hole was closed with a septum for 30 min at ambient temperature. The syringe was inserted into the headspace of the container to estimate the CO_2 released by the fruits. The change in the concentration of CO_2 was recorded as per cent. The rate of respiration was calculated using the below formula.

$$\text{Respiration rate (ml } CO_2\text{/kg/h)} = \frac{CO_2 \text{ concentration x Volume of the container}}{100 \text{ x weight of the fruit (Kg) x Time (h)}}$$

The data recorded on the physical and physiological parameters of the banana cv. Rajapuri fruits were analysed using Web Agri. Stat. Package 2 developed by ICAR research complex, Goa. Interpretation of the data was carried out in accordance with Panse and Sukhatme (1985) [19]. The data on the physical and physiological parameters of the banana cv. Rajapuri fruits taken during two consecutive years (2019-2020 and 2020-2021) were pooled and the results are presented here.

Results and Discussion

According to pooled data, statistically higher bunch weight (15.63 kg) was recorded in T_9 (Potassium silicate-0.60%), which was on par (15.34 kg) with T_8 (Potassium silicate-0.40%), T_3 (15.07 kg) and T_2 (14.93 kg), whereas lowest bunch weight was noticed in control (14.03 kg). The maximum weight of the third hand (2.09 kg) was recorded in T_9 (potassium silicate 0.60%) bunches and it was statistically on par (1.88 kg) with T_8 (Potassium silicate-0.40%) and T_3 (1.82 kg). At the same time, the minimum hand weight was observed in control (1.49 kg). Whereas statistically, a non-significant difference was observed in the number of hands per bunch and number of fingers in the third hand of the banana cv Rajapuri bunches among treatments. The bunches sprayed with the potassium silicate (0.40 and 0.60%) had shown the highest weight of the bunch and third hand. This may be attributed to the potassium and silicon supplied to the bunches before 30 days of harvest increased the fruit weight and fruit quality (Table 1). According to Smith (2011) [23], the application of silicon helped to stimulate plants nutrients uptake and more photosynthesis. The increase in fruit weight was mainly due to cell division in the initial stages and later due to cell expansion associated with the movement of water and other metabolites into the cell leading to an increase in the overall weight of the fruit (Young *et al.*, 1996) [27]. Similar findings have been reported by Nesreen *et al.* (2011) [18] in pod weight of beans; Mustaffa *et al.* (2004) [17] in banana; Bhavya (2010) [5] in grapes; Ravishankar (2016) [21] in banana and Jaishankar (2018) [8] in custard apple.

Table 1: Influence of pre-harvest sprays on bunch weight, number of hands per bunch, weight of third hand and number of fingers in third hand (at mature stage) of banana cv Rajapuri

Treatments	Bunch weight (kg)	Number of hands/ bunch	Weight of third hand (kg)	Number of fingers in third hand
T_1 - Control	14.03	7.08	1.49	14.69
T_2 - $CaCl_2$ (1.0%)	14.93	7.31	1.69	14.84
T_3 - $CaCl_2$ (2.0%)	15.07	7.34	1.82	14.86
T_4 - Hexanal (2.0%)	14.60	7.25	1.63	14.81
T_5 - Hexanal (3.0%)	14.74	7.27	1.67	14.82
T_6 - Salicylic acid (0.40%)	14.37	7.24	1.56	14.79
T_7 - Salicylic acid (0.60%)	14.44	7.18	1.60	14.78
T_8 - Potassium silicate (0.40%)	15.34	7.38	1.88	14.89
T_9 - Potassium silicate (0.60%)	15.63	7.39	2.09	14.92
Mean	14.79	7.27	1.71	14.82
S.Em±	0.17	0.07	0.09	0.04
C.D. @ 1%	0.68	NS	0.38	NS

*NS: Non significant

The number of hands per bunch and number of fingers in the third hand was not affected significantly by the different pre-harvest treatments indicating that, the application of pre-harvest chemicals before 30 days of harvest had no effect on the number of hands or number of fingers but it did effect on the quality, weight and other physiological parameters of the fruits.

Table 2: Influence of pre-harvest sprays on finger weight, finger length, finger girth, pulp weight, peel weight and pulp to peel ratio (at mature stage) of banana cv Rajapuri

Treatments	Finger weight (g)	Finger length (cm)	Finger girth (cm)	Pulp weight (g)	Peel weight (g)	Pulp to peel ratio
T_1 - Control	101.08	14.91	13.08	72.18	28.90	2.50
T_2 - $CaCl_2$ (1.0%)	114.75	15.44	14.12	84.36	30.39	2.78
T_3 - $CaCl_2$ (2.0%)	122.18	15.53	14.17	90.72	31.46	2.88
T_4 - Hexanal (2.0%)	109.72	15.23	13.68	79.44	30.27	2.62
T_5 - Hexanal (3.0%)	112.72	15.34	13.66	82.40	30.32	2.72
T_6 - Salicylic acid (0.40%)	103.97	15.09	13.28	74.65	29.32	2.55
T_7 - Salicylic acid (0.60%)	108.25	15.17	13.44	78.21	30.04	2.60
T_8 - Potassium silicate (0.40%)	125.96	15.62	14.28	94.16	31.80	2.96
T_9 - Potassium silicate (0.60%)	139.74	15.76	14.64	106.34	33.39	3.18
Mean	115.37	15.34	13.81	84.72	30.65	2.75
S.Em±	4.50	0.08	0.18	3.92	0.50	0.08
C.D. @ 1%	18.05	0.32	0.72	15.70	2.00	0.32

The statistics suggest a highly significant variation in finger weight, finger length, finger girth, pulp weight, peel weight and pulp to peel ratio between pre-harvest sprayed treatments and control (Table 2). The more finger weight was recorded in T_9 (139.74 g), which was at parity with T_8 (125.96 g) and T_3 (122.18 g). In comparison, lower finger weight was in control fruits (101.08 g). The highest finger length was observed in T_9 (15.76 cm), which was on par with T_8 (15.62 cm), T_3 (15.53 cm) and T_2 (15.44 cm). The lowest finger length was recorded in T_1 (14.91 cm). Finger girth was maximum in the case of T_9 (14.64 cm), which was statistically on par with the T_8 (14.28 cm), T_3 (14.17 cm) and T_2 (14.12 cm). While the minimum finger girth was in control fruits (13.08 cm). The highest pulp weight was in T_9 (106.34 g), it was at parity with T_8 (94.16 g) and T_3 (90.72 g) respectively. Whereas, the lowest was recorded in control (72.18 g). The peel weight was maximum in T_9 (33.39 g), which was on par with T_8 (31.80 g) and T_3 (31.46 g). However, the minimum peel weight was in control (28.90 g). The highest pulp to peel ratio was noticed in T_9 (3.18), it was on par with T_8 (2.96) and T_3 (2.88). Conversely, the low pulp to peel ratio was in control fruits (2.50).

The maximum pooled finger weight, finger length and finger girth (139.74 g, 15.76 cm, 14.64 cm and 125.96 g, 15.62 cm, 14.28 cm) were recorded in T_9 (Spray of potassium silicate- 0.60%) and T_8 (Spray of potassium silicate- 0.40%) respectively. Similarly, the highest pooled pulp weight, peel weight and pulp to peel ratio (106.34 g, 33.39 g, 3.18 and 94.16 g, 31.80 g, 2.96) was also recorded in bunches sprayed with potassium silicate (0.60%) and potassium silicate (0.40%) respectively (Table 2). Whereas significantly minimum pooled finger weight, finger length, finger girth, pulp weight, peel weight and pulp to peel ratio was recorded in the untreated fruits (101.08 g, 14.91 cm, 13.08 cm, 72.18 g, 28.90 g and 2.50 respectively). The increase in fruit size might be due to higher photosynthetic activity and biomass production in the plant which might have resulted in more metabolites in the fruits (Young *et al.*, 1996) [27]. As the growth and development of the fruits advances, a large amount of water and other metabolites translocated into the fruits resulting in improvement in the growth and quality of fruits.

The next best treatments for maximum pooled bunch weight, weight of the third hand, finger weight, finger length and girth, pulp and peel weight and the pulp to peel ratio was T_3 (Spray of $CaCl_2$ 2.0%) and T_2 (Spray of $CaCl_2$ 1.0%) sprayed bunches. The application of the calcium chloride to bunches 30 days before the harvest was proved to enhance the quality parameters of the banana cv. Rajapuri fruits. Calcium maintains the cell wall structure in fruit by interacting with the pectic acid in the cell walls to form calcium pectate. Ca^{2+} forms cross-links between pairs of negatively charged homo galacturonans, thus tightening the cell wall (Picchioni *et al.*, 1998) [20]. Calcium helps to bind polygalactonic acid to each other and make the membrane strong and rigid. Calcium treatments have been commercially applied in apples to increase the shelf life and reduce post-harvest disorders (Sharma *et al.*, 1991) [22]. An increase in fruit parameters was also noticed by Karemera and Habimana (2014a and 2014b) [11, 12] in mango due to calcium chloride sprays. This may be due to its effects in the formation and changes of carbohydrates and carbohydrate enzymes, others reasons might be the reduction of abscission and the calcium influence in maintaining the middle lamella cells and improved vegetative developments may increase the weight of the banana bunch (Karemara and Habimana, 2014a). Calcium was known to have a profound influence on fruit maturation (Ferguson, 1984) [7]. Foliar feeding of calcium was beneficial for accelerating the development of growth characters, quality and shelf life of fruits (Bhatt *et al.*, 2012) [4]. Similar findings were reported by Manasa (2015) [15] in mango and Jaishankar (2018) [8] in custard apple.

Weight loss is a major predictor of the post-harvest shelf life of fresh produce. Water loss during metabolic processes such as respiration and transpiration is the chief cause of weight loss during storage. Transpiration results in direct moisture loss and the cellular breakdowns in the fruit tissue hasten the rate of transpiration (Woods, 1990) [26]. PLW of the banana cv. Rajapuri fruits showed an increasing trend throughout the storage period irrespective of the treatments with significant differences (Table 3). At 3 and 6 DAS significantly minimum PLW was recorded in T_9 (1.47 and 2.70%) which was on par with T_8 (1.68 and 3.12%), T_3 (2.16 and 3.33%) and T_2 (2.30 and 3.47%) whereas, maximum PLW was noticed in the control (5.10 and 12.61%). After seven days of storage control fruits lost their keeping quality, so at 9 DAS statistical analysis was not done because of less degrees of freedom. Among remaining treatments, minimum PLW was recorded in T_9 (4.12%) followed by T_8 (4.61%), whereas the maximum was in T_6 (13.19%), which was followed by T_7 (13.02%). Banana cv. Rajapuri fruits of treatment 6 and 7 lost their keeping quality after the 9th day. So after 12 days of storage, minimum PLW was noticed in T_9 (7.73%) followed by T_8 (7.93%), whereas the maximum was in the case of T_4 (14.31%) which was followed by T_5 (13.96%). At 15 DAS, all the treatments lost their keeping quality except T_2 (spray of 1.0% $CaCl_2$), T_3 (spray of 2.0% $CaCl_2$), T_8 (spray of 0.40% potassium silicate) and T_9 (spray of 0.60% potassium silicate).

Among these four treatments, minimum PLW was recorded in T_9 (12.10%) and maximum was in T_2 (13.60%).

Table 3: Influence of pre-harvest sprays on physiological loss in weight (%) of banana cv. Rajapuri under ambient storage

Treatments	Days after storage				
	3	6	9	12	15
T_1 - Control	5.10	12.61	*	*	*
T_2 - $CaCl_2$ (1.0%)	2.30	3.47	5.23	8.88	13.60
T_3 - $CaCl_2$ (2.0%)	2.16	3.33	4.91	8.45	13.08
T_4 - Hexanal (2.0%)	3.24	6.03	11.80	14.31	*
T_5 - Hexanal (3.0%)	2.82	5.71	11.04	13.96	*
T_6 - Salicylic acid (0.40%)	3.86	9.54	13.19	*	*
T_7 - Salicylic acid (0.60%)	3.63	9.02	13.02	*	*
T_8 - Potassium silicate (0.40%)	1.68	3.12	4.61	7.93	12.63
T_9 - Potassium silicate (0.60%)	1.47	2.70	4.12	7.73	12.10
Mean	2.92	6.17	8.49	10.21	12.85
S.Em±	0.22	0.20	-	-	-
C.D. @ 1%	0.88	0.82	-	-	-

* No observation was recorded as the fruits lost their keeping quality

Respiration, a catabolic process, leads to the consumption of preserved foods. Weight loss due to respiration occurs when a carbon dioxide molecule is produced from an absorbed oxygen molecule and a corresponding carbon atom is lost from the fruit and released into the atmosphere. Data reveals that as the storage period progressed, the respiration rate increased until it reached the climacteric peak and declined later, indicating the initiation of the senescence (Table 4). Initially, fruits showed respiration rates of 21.80 and 26.43 ml CO_2/kg/h in 2020 and 2021, respectively. Significantly, lower respiration rate was recorded in T_9 (28.16 and 74.65 ml CO_2/kg/h) which was at parity with T_8 (31.74 and 82.11 ml CO_2/kg/h), T_3 (33.72 and 87.30 ml CO_2/kg/h) and T_2 (38.09 and 99.35 ml CO_2/kg/h) whereas, highest was noticed in T_1 (87.51 and 265.82 ml CO_2/kg/h) at 3 and 6 days after storage respectively. After nine days of storage, the respiration rate was minimum in T_9 (134.04 ml CO_2/kg/h), it was followed by T_8 (150.34 ml CO_2/kg/h) and the maximum respiration rate was in T_4 (260.92 ml CO_2/kg/h) which was followed by T_5 (249.89 ml CO_2/kg/h). Minimum respiration rate was noticed in T_9 (218.28 ml CO_2/kg/h) followed by T_8 (232.68 ml CO_2/kg/h) and the maximum was in T_2 (276.02 ml CO_2/kg/h) followed by T_3 (249.61 ml CO_2/kg/h) at 12 days after storage respectively. The minimum respiration rate at 15 days of storage was recorded in T_2 (226.16 ml CO_2/kg/h), indicating initiation of senescence and the maximum was in T_9 (268.16 ml CO_2/kg/h).

Table 4: Influence of pre-harvest sprays on respiration rate (ml CO_2/kg/h) of banana cv. Rajapuri under ambient storage

Treatments	Days after storage				
	3	6	9	12	15
T_1 - Control	87.51	265.82	*	*	*
T_2 - $CaCl_2$ (1.0%)	38.09	99.35	164.08	276.02	226.16
T_3 - $CaCl_2$ (2.0%)	33.72	87.30	149.50	249.61	240.97
T_4 - Hexanal (2.0%)	46.50	109.13	260.92	233.39	*
T_5 - Hexanal (3.0%)	43.45	103.73	249.89	242.05	*
T_6 - Salicylic acid (0.40%)	73.73	257.34	237.54	*	*
T_7 - Salicylic acid (0.60%)	66.97	249.71	243.17	*	*
T_8 - Potassium silicate (0.40%)	31.74	82.11	150.34	232.68	259.96
T_9 - Potassium silicate (0.60%)	28.16	74.65	134.04	218.28	268.16
Mean	49.99	147.68	198.68	242.01	248.81
S.Em±	2.59	6.45	-	-	-
C.D. @ 1%	10.53	25.20	-	-	-

* No observation was recorded as the fruits lost their keeping quality

In the present study, the minimum physiological loss in weight and respiration rate was achieved in the T_9 (Spray of potassium silicate- 0.60%) and T_8 (Spray of potassium silicate- 0.40%) treated fruits. While maximum PLW and respiration rate was noticed in the control fruits (T_1). The two potassium treatments were on par with each other throughout the course of the study. The minimum respiration rate in potassium silicate (0.60 and 0.40%) sprayed banana fruits was mainly due to its anti-senescence nature of the chemical which caused the inhibition of ethylene biosynthesis (Babak and Majid, 2011) [1] or because of the reduced rate of metabolism in the treated fruits. The results of the study were in harmony with the work of Barbang *et al.* (2002) [2]; Stamatakis *et al.* (2003) [24]; Kaluwa *et al.* (2010) [10] in tomato; Ravishankar (2016) [21] in banana and Jaishankar (2018) [8] in custard apple.

The minimum PLW and respiration rate was also noticed in the calcium chloride (2 and 1.00%) treated fruits (Table 3 and 4). This was due to the action of calcium applied to the banana bunches before one month of harvest, which lowered the phospholipid, protein and ion leakage losses in calcium chloride treated fruits with maintaining the membrane functionality and integrity. So, lower weight loss was seen in these treatments. Similar findings were found in muskmelons (Lester and Grusak, 1999) [13]. A similar effect of calcium was reported by Sharma *et al.* (1991) [22]; Picchioni *et al.* (1998) [20]; Benavides *et al.* (2002) [3]; Vali *et al.* (2011) [25] and Casero *et al.* (2004) [6] in apple, Mahmad *et al.* (2008) [14] in papaya, Monica *et al.* (2013) [16] in litchi, Jaishankar (2015) [9] in sapota and Manasa (2015) [15] in mango.

Conclusion

Among different pre-harvest spray treatments, T_9 (Spray of potassium silicate- 0.60%) and T_8 (Spray of potassium silicate- 0.40%) treated fruits recorded maximum enhanced shelf life with better physical and physiological behaviour compared to other treatments during the storage under ambient conditions.

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