International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2017; 5(4): 419-424

Received: 15-05-2017
Accepted: 14-06-2017

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Effect of pre-harvest foliar sprays of different chemicals on fruit quality and shelf life of litchi fruits

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Abstract
Present study was conducted to evaluate the effect of different chemicals on fruit quality and shelf life of litchi fruits. Four chemicals were applied viz., calcium nitrate, calcium chloride, boric acid, salicylic acid and humic acid on litchi plants. Physiological loss in weight of fruits (9.36%) was minimum with Salicylic acid (50 µ mol l^{-1}). Higher total soluble solids (20.89 °Brix) were recorded with Calcium nitrate (0.5%). Minimum treatable acidity (0.29%) was recorded in Calcium nitrate (0.5%) and humic acid (0.4%). TSS: Acid ratio (71.56) was maximum with humic acid (0.4%). Browning index (4.97) was minimum with Calcium chloride (0.5%). Spoilage percentage (20.32%) was minimum with Calcium chloride (0.5%).

Keywords: Litchi, fruit quality, shelf life, spoilage percentage, browning index

Introduction
Litchi (*Litchi chinensis* Sonn.) is an important evergreen, subtropical fruit tree native to southern China. It belongs to family Sapindaceace. It was introduced to India at the end of the 17th century [19]. Litchi is a delicious fruit of commercial importance and has high demand as table fruit and processed products. Litchi fruit is highly nutritious. It contains 83.6 g moisture, 0.7 g protein, 0.1 g fat, 15.0 g carbohydrates, 4.0 mg calcium, 32.0 mg phosphorus, 0.7 mg iron, 0.02 mg thiamine, 0.07 mg riboflavin, 1.1 mg niacin, 15 mg ascorbic acid and traces of carotene [5]. It has a strong commercial value in international markets for its bright red skin and sweet, juicy and crisp aril [11]. India is the second largest producer of litchi in the world next after China. Presently in India litchi is cultivated on an area of about 84 thousand hectares with a total production of 585 thousand metric tons [1]. In India, it is mainly grown in Bihar, West Bengal, Uttar Pradesh, Punjab and Uttarakhand.

Litchi being a non-climacteric fruit, does not improve in quality after harvesting, but has to ripen on the tree [3]. Therefore, fruits are harvested ripen and should reach to the ultimate consumers immediately. To extend the availability of fruits storage life of the fruits has to be increased. Pericarp browning, desiccation, loss of quality, post-harvest decays and micro cracking are major constraints affecting commercial quality during storage and transportation [25, 16]. Litchi undergoes deteriorative changes immediately after harvest which makes it otherwise highly potential commercial crop and thus lose its marketability especially in the global context. Rapid desiccation of fruits leads to browning of pericarp which brings about a decline in the consumer's appeal and acceptability although the nutritive quality and taste is still retained. Pre-harvest application of various chemicals have been reported to enhance the shelf life of fruits by reducing physiological loss in weight, decay losses during storage [10, 15] and fruit cracking [23]. Calcium, an essential nutrient maintains the cell wall integrity and is found to inhibit to some extent the senescence of litchi fruits. Pre-harvest treatment of calcium helped in maintenance of fruit quality [24, 4]. The beneficial effects of boron as pre-harvest sprays have been reported to govern several physiological and biochemical plant processes on litchi fruits [6]. calcium is involved in cracking resistance in litchi fruit because trees with lower cracking incidence have higher calcium levels, while, a low exchange able calcium in plants results in high cracking incidence [19]. The present study was under taken to evaluate the influence of plant growth regulators and mineral nutrients on yield and physico-chemical characteristics of litchi CV.

'Rose Scented'. Considering the above points in view, an experiment was designed to study the "Effect of pre-harvest sprays of different chemicals on fruit yield, quality, cracking and shelf life in litchi (*Litchi chinensis* Sonn.) Cv. Rose Scented" at Horticulture Research Centre, Patharchatta and Department of Horticulture, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar (Uttarakhand) with the objective to study the effect of pre-harvest treatments on fruit size, yield and quality of litchi fruits.

Materials and methods

The present investigation was conducted during the year 2015 at Horticultural Research Centre, Patharchatta, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India. Pantnagar is geographically situated in the *Tarai* region at the foot hills of Himalayas at 29° N latitude and 79.3° E longitude and at an altitude of 243.83 meters above mean sea level. The climate of Pantnagar is sub humid, subtropical with hot dry summers and cool winters. The summer temperature rises up to 46 °C, while the winter temperature falls to 2 °C. The mean annual rainfall is 2382 mm and relative humidity fluctuates around 98% during rainy season and remains above 85% in February after which it decreases up to 5% in May. The data on air temperature (maximum and minimum), relative humidity, rainfall, and velocity were recorded at weekly interval during the period of field investigation (Appendix 1). The experiment was conducted with 24 years old bearing litchi (*Litchi chinensis* Sonn.) cv. Rose Scented of uniform vigour and size. All the trees were maintained under uniform cultural practices during the course of investigation. The plants were sprayed with different concentration of calcium nitrate, calcium chloride, boric acid, salicylic acid and humic acid twice with the help of foot sprayer. First application was done on April 24, 2015 and second on May 10, 2015. The experiment was laid out in factorial randomized block design (FRBD) as given by Snedecor and Cochran [26] consisted of eight treatments viz., T_1: Calcium nitrate (0.5%), T_2: Calcium chloride (0.5%), T_3: Boric acid (0.1%), T_4: Salicylic acid (50 µ mol l^{-1}), T_5: Salicylic acid (100 µ mol l^{-1}), T_6: Humic acid (0.2%), T_7: Humic acid (0.4%) and T_8: Control (water spray). All the treatments were replicated thrice and one tree served as a treatment unit in each replication. The overall significance of differences among the treatments was tested, using critical difference (C.D.) at 5% level of significance [7]. Fruits were weighed at regular intervals using an electronic balance. The observations on physiological loss in weight (PLW) of fruits under storage conditions were calculated by per cent loss in fruit weight as compared to the fruit weight at harvesting. Total soluble solids (TSS) of the fruits was measured by using digital hand refractometer at room temperature and expressed in terms of degree Brix (°B). Titratable acidity of litchi fruits was calculated by titrating the pulp extract with 0.1 N NaOH as described by Ranganna [22] using phenolphthalein as an indicator and was expressed in percentage (%). TSS: Acid level was calculated by dividing TSS with acidity and expressed as a ratio of TSS and acidity. Browning index was assessed visually according to the method of Ramma [21], by measuring the total browning areas of the pericarp on each fruit in a packet. In a single packet 10 fruits were taken. The scale was used as; 0 = no browning (excellent quality), 1 = slight browning, 2 = 25% browning, 3 = 25–50% browning, 4 = 50-75% browning and 5= >75% (very poor quality). Decayed fruit resulting from natural infection was assessed by observing visible fungal or bacterial growth on the fruit surface. On the basis of number of spoiled fruits (unfit for human consumption) observed at every day interval, the percentage spoilage was worked out and the spoilt fruits were removed.

Results and discussion

The data physiological loss in weight of fruits (Table 1) showed the effect of different chemicals, ambient storage period and their interactions on physiological loss in weight of fruits under ambient conditions. All treatments showed significant effect on physiological loss in weight (%). The minimum loss in weight was recorded with T_4 (9.36%) followed by T_5 (9.38%) while maximum loss in weight (13.58%) was noted with T_8 (control) followed by T_7 (11.43%). The minimum loss in weight (10.20%) was recorded on the 3rd day of storage while maximum loss in weight (21.27%) was recorded in 6th day of storage. Effect of interaction between treatments and storage periods was found statistically significant. The minimum loss in weight (8.12%) was noticed in T_1 on 3th day of storage while maximum loss in weight (26.60%) was recorded T_8 on 6th day of storage.

The present findings are fully supported with the findings of Jayachandran *et al.* (2005) who reported that the effect of pre harvest sprays of various calcium compounds ($CaCl_2$, $CaNO_3$ and $CaSO_4$ @ 0.5 and 1.0%) on the shelf life and fruit quality of guava cv. Lucknow-49, and found that $CaNO_3$ @ 1.0% showed the lowest physiological loss in weight who reported that (4.24%) as compared to control. Brar *et al.* [2] reported that physiological loss of weight of fruits was significantly reduced with both pre and post-harvest Salicylic acid treatments as compared to control. Gangwar *et al.* [8] observed that 1.0 % calcium nitrate treated fruits significantly reduced the physiological loss in weight of fruits, pathological loss and exhibited better quality by rendering them acceptable upto period of 15 days.

The data on total soluble solids (Table 2) showed that the maximum total soluble solids were recorded in T_1 (20.89%) followed by T_7 (20.51%) while a minimum Total soluble solids were noted with T_3 (18.84%) followed by T_8 (18.93%). The maximum Total soluble solids (21.58%) were recorded on the 6th day of storage while minimum Total soluble solids (17.89%) were recorded in 0 day of storage. Effect of interaction between treatments and storage periods on total soluble solids was found statistically non-significant. The maximum total soluble solids (22.80%) were noticed in T_1 on 6th day of storage while minimum Total soluble solids (17.07%) were recorded in T_3 on 0 day of storage.

The present findings are in agreement with the finding of Kaur and Kumar [12] who reported that the data pertaining to the influence of different post-harvest treatments and storage conditions on TSS. The initial rise in TSS of fruit and its decline later was observed under both the conditions of storage regardless of the post-harvest treatments. Increase in TSS during storage may be due to break down of complex to break down of complex polymers into simpler substances by hydrolytic enzymes which might further be metabolized during respiration and thus the level of TSS decreased during subsequent storage [9]. The rate of increase of TSS was faster at room temperature than in cold storage. Waskar et al. [29] in Pomegranate have reported similar findings. No significant effect on TSS content of Kinnow fruits up to 45 days of storage in cold storage conditions and up to 30 days under ambient conditions were observed under different treatments. However, mean TSS were maximum during ambient storage

(13.23%) and cold storage (12.74%) with $CaCl_2$ (1%) and bavistin (500 ppm), respectively.

The on treatable acidity (Table 3) indicated that the minimum treatable acidity was recorded with treatment T_2 and T_7 (0.29%) followed by T_1, T6 and T_8 (0.30%) while maximum treatable acidity was noted with T_3 (0.32%) followed by T_4 and T_5 (0.31%). The minimum treatable acidity (0.26%) was recorded on the 6th day of storage while maximum treatable acidity (0.33%) was recorded on 0 day of storage. Effect of interaction between treatments and storage periods on treatable acidity was found statistically non-significant. The minimum treatable acidity (0.25%) was noticed in T_2, T_7 and T_8 on 6th day of storage while maximum treatable acidity (0.35%) was recorded T_3 on 0 day of storage.

The present findings are partially supported by Kumari *et al.* [18] who reported that there was no significant effect of treatments on treatable acidity during storage but ascorbic acid content was maintained higher in treated fruits. Thus, combination treatment of 1.0 mM salicylic acid and 2% chitosan can be used to reduce pericarp browning and preserving quality of litchi fruit during postharvest storage. Kaur and Kumar [12] reveal that with an increase in the storage duration, the acidity in fruit juice among the treatments was found to vary non significantly in both ambient and cold storage conditions. The reduction in the acidity of, Kinnow fruit juice during storage has also been noticed earlier by Thakur *et al.* [27] and this might be due to utilization of acids by the respiratory process. The decline in acidity was found to be faster at room temperature as compared to cold storage temperature. This could be associated with the higher rates of respiration since acid forms the necessary respiratory substrate for this catabolic process in fruits. Similar observations were reported by Koksal [14] in pomegranate and by Thakur *et al.* [27] in Kinnow under different storage conditions.

The data in Table 4 with regard to effect of different chemicals, ambient storage period and their interactions on TSS: acidity under ambient conditions. The maximum TSS: acidity was recorded in T_7 (71.56%) followed by T_1 (70.93%) while minimum TSS: acidity was noted with T_3 (60.71%) followed by T_4 (62.70%). The maximum TSS: acidity (82.84%) was recorded on the 6th day of storage while minimum TSS: acidity (53.16%) was recorded on 0 day of storage.

Effect of interaction between treatments and storage periods on TSS: acidity was found statistically non-significant. The maximum TSS: acidity (88.56%) was noticed in T_7 on 6th day of storage while minimum Total soluble solids (48.31%) were recorded in T_3 on 0 day of storage.

The perusal of data in Table 5 with indicate the effect of different chemicals, ambient storage period and their interactions on pericarp browning under ambient conditions. The minimum pericarp browning was recorded with T_2 (4.97%) followed by T_1 (5.05%) while maximum pericarp browning was noted with T_8 (control) (5.53%) followed by T_4 (5.30%). The minimum pericarp browning (6.05%) was recorded on the 3rd day of storage while maximum pericarp browning (9.50%) was recorded on 6th day of storage. Effect of interaction between treatments and storage periods on the pericarp browning was found non-significant. The minimum pericarp browning (5.73%) was noticed in T_2 on 3rd day of storage while maximum pericarp browning (9.89%) was recorded T_8 on 6th day of storage.

The minimum fruit spoilage was recorded with T_2 (20.32%) followed by T_1 (21.33%) while maximum fruit spoilage was noted with T_8 (32.35%) followed by T_6 (25.60%). The minimum fruit spoilage (30.48%) was recorded on the 3rd day of storage while maximum fruit spoilage (45.00%) was recorded in 6th day of storage. Effect of interaction between treatments and storage periods on spoilage (%) was found statistically significant. The minimum fruit spoilage (25.32%) was noticed in T_2 on 3rd day of storage while maximum fruit spoilage (58.56%) was recorded T_8 on 6th day of storage.

The present findings are fully supported with the findings of Kumar *et al.* [17] who reported that the cashew apple treated with 0.5% calcium chloride as calcium recorded minimum of physiological loss in weight (5.62%) and less rotting (10%) during the 4th day of storage. The calcium treated cashew apple maintained a higher level of chemical compound and fruits have good shelf life of 2-4 days compared to the control. Kirmani *et al.* [13] the Plum (*Prunus salicina* L.) cv. Santa Rosa treated with 0.5% calcium chloride ($CaCl_2$) proved to be more efficacious in minimizing these losses. Physiological loss in weight (PLW) and spoilage followed continuously increasing trend with the advancement of storage period. Such fruits exhibited minimum loss in weight, maximum retention in firmness and minimum spoilage on each sampling date. Tsomu *et al.* [28] However, minimum Physiological loss in weight and, total spoilage were noticed under $CaCl_2$ 5000 mg/l and 10000 mg/l treated fruits. The study suggests that calcium chloride (5000 mg/l) as post-harvest dip improves the fruit firmness, shelf life and ripening period of the sapota up to 12 days of storage.

Table 1: Effect of different pre-harvest chemicals on physiological loss in weight of litchi cv. Rose Scented

Treatments	Physiological loss in weight of fruits			Mean
	Storage intervals (days)			
	0	3	6	
T_1: Calcium nitrate @ 0.5%	-	8.12	20.06	9.39
T_2: Calcium chloride @ 0.5%	-	9.25	21.62	10.29
T_3: Boric acid @ 0.1%	-	9.08	19.75	9.61
T_4: Salicylic acid @ 50 µ mol l^{-1}	-	9.45	18.64	9.36
T_5: Salicylic acid @ 100 µ mol l^{-1}	-	9.55	18.58	9.38
T_6: Humic acid @ 0.2%	-	11.30	21.34	10.88
T_7: Humic acid @ 0.4%	-	10.74	23.56	11.43
T_8: Control (water spray)	-	14.13	26.60	13.58
Mean	-	10.20	21.27	
Factors	*C.D. at 5%		SEm ±	
Storage Intervals (S)	0.82		0.29	
Treatments (T)	1.34		0.47	
Interaction (S×T)	2.33		0.82	

*C.D.=Critical difference, SEm±=Standard error of means

Table 2: Effect of different pre-harvest chemicals on Total soluble solids (°B) level of litchi cv. Rose Scented

Treatments	Total soluble solids (°Brix)			Mean
	Storage intervals (days)			
	0	3	6	
T_1: Calcium nitrate @ 0.5%	19.13	20.73	22.80	20.89
T_2: Calcium chloride @ 0.5%	17.73	19.07	21.13	19.31
T_3: Boric acid @ 0.1%	17.07	18.73	20.73	18.84
T_4: Salicylic acid @ 50 µ mol l^{-1}	18.07	19.73	21.73	19.84
T_5: Salicylic acid @ 100 µ mol l^{-1}	18.13	19.87	21.87	19.96
T_6: Humic acid @ 0.2%	17.13	19.00	21.07	19.07
T_7: Humic acid @ 0.4%	18.73	20.40	22.40	20.51
T_8: Control (water spray)	17.13	18.80	20.87	18.93
Mean	17.89	19.54	21.58	
Factors	C.D. at 5%		SEm ±	
Storage Intervals (S)	0.69		0.24	
Treatments (T)	1.13		0.40	
Interaction (S×T)	*N/A		0.69	

*N/A=Not applicable

Table 3: Effect of different pre-harvest chemicals on titratable acidity of litchi cv. Rose Scented

Treatments	Titratable acidity (%)			Mean
	Storage intervals (days)			
	0	3	6	
T_1: Calcium nitrate @ 0.5%	0.33	0.29	0.26	0.30
T_2: Calcium chloride @ 0.5%	0.31	0.28	0.25	0.29
T_3: Boric acid @ 0.1%	0.35	0.33	0.27	0.32
T_4: Salicylic acid @ 50 µ mol l^{-1}	0.34	0.32	0.28	0.31
T_5: Salicylic acid @ 100 µ mol l^{-1}	0.34	0.31	0.27	0.31
T_6: Humic acid @ 0.2%	0.34	0.29	0.26	0.30
T_7: Humic acid @ 0.4%	0.32	0.30	0.25	0.29
T_8: Control (water spray)	0.31	0.33	0.25	0.30
Mean	0.33	0.31	0.26	
Factors	C.D. at 5%			SEm ±
Storage Intervals (S)	0.69			0.243
Treatments (T)	1.13			0.397
Interaction (S×T)	*NS			0.688

*NS=Not significant

Table 4: Effect of different pre-harvest chemicals on TSS: acid level of litchi cv. Rose Scented

Treatments	TSS : acid			Mean
	Storage intervals (days)			
	0	3	6	
T_1: Calcium nitrate @ 0.5%	56.94	68.01	87.84	70.93
T_2: Calcium chloride @ 0.5%	56.67	67.41	85.70	69.93
T_3: Boric acid @ 0.1%	48.31	57.94	75.86	60.71
T_4: Salicylic acid @ 50 µ mol l^{-1}	50.27	59.95	77.88	62.70
T_5: Salicylic acid @ 100 µ mol l^{-1}	53.36	62.25	82.20	65.94
T_6: Humic acid @ 0.2%	50.42	63.52	82.17	65.37
T_7: Humic acid @ 0.4%	57.97	68.15	88.56	71.56
T_8: Control (water spray)	51.35	62.20	82.52	65.36
Mean	53.16	63.68	82.84	
Factors	C.D. at 5%			SEm ±
Storage Intervals (S)	2.24			0.78
Treatments (T)	3.66			1.28
Interaction (S×T)	NS			2.22

Table 5: Effect of different pre-harvest chemicals on Browning index of litchi cv. Rose Scented

Treatments	Browning index			Mean
	Storage intervals (days)			
	0	3	6	
T_1: Calcium nitrate @ 0.5%	-	5.82	9.32	5.05
T_2: Calcium chloride @ 0.5%	-	5.73	9.18	4.97
T_3: Boric acid @ 0.1%	-	5.88	9.37	5.08
T_4: Salicylic acid @ 50 µ mol l^{-1}	-	6.09	9.79	5.30
T_5: Salicylic acid @ 100 µ mol l^{-1}	-	5.99	9.56	5.18
T_6: Humic acid @ 0.2%	-	6.11	9.46	5.19
T_7: Humic acid @ 0.4%	-	6.09	9.44	5.18
T_8: Control (water spray)	-	6.70	9.89	5.53
Mean	-	6.05	9.50	
Factors	C.D. at 5%		SEm ±	
Storage Intervals (S)	0.65		0.23	
Treatments (T)	N/A		0.37	
Interaction (S×T)	N/A		0.64	

Table 6: Effect of different pre-harvest chemicals on spoilage (%) of litchi cv. Rose Scented

Treatments	Spoilage (%)			Mean
	Storage intervals (days)			
	0	3	6	
T_1: Calcium nitrate @ 0.5%	-	26.72	37.28	21.33
T_2: Calcium chloride @ 0.5%	-	25.32	35.64	20.32
T_3: Boric acid @ 0.1%	-	30.34	44.26	24.86
T_4: Salicylic acid @ 50 µ mol l^{-1}	-	31.24	46.33	25.86
T_5: Salicylic acid @ 100 µ mol l^{-1}	-	30.29	45.17	25.15
T_6: Humic acid @ 0.2%	-	30.71	46.99	25.90
T_7: Humic acid @ 0.4%	-	30.77	45.78	25.51
T_8: Control (water spray)	-	38.48	58.56	32.35
Mean	-	30.48	45.00	
Factors	C.D. at 5%		SEm ±	
Storage Intervals (S)	1.20		0.42	
Treatments (T)	1.96		0.69	
Interaction (S×T)	3.4.		1.19	

Apendix 1: The weekly weather data during crop season 2014-2015

Date	Temperature (°C)		Relative Humidity (%)		Rainfall (mm)	Wind Velocity (Km/hr)	Sun shine hours
	Maximum	Minimum	Maximum	Minimum			
24 April	36.8	17.4	67	28	000.0	4.4	11.3
01 May	34.4	16.3	87	33	018.4	11.0	08.7
08 May	38.5	25.5	57	31	000.0	4.7	10.0
15 May	36.2	21.9	74	37	000.0	4.6	12.1
22 May	41.0	18.9	63	29	000.0	7.8	11.8
29 May	40.5	20.9	78	28	000.0	5.5	11.0

Conclusion

On the basis of results summarized above, it can be concluded that physiological loss in weight of fruits, Total soluble solids, Titratable acidity, TSS: Acid ratio and spoilage percentage of litchi fruits were influenced significantly by the pre-harvest application of different treatments. To obtain better quality and increased storage period of litchi fruits, two spray of calcium chloride (0.5%) could be use during the period of fruit growth and development at fortnightly interval.

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