Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2020; 9(1): 1812-1819
Received: 07-11-2019
Accepted: 09-12-2019

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Effect of pre harvest fruit bagging on the physico-chemical properties of litchi (*Litchi chinensis* Sonn.) CV. rose scented

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Abstract
The present investigation was undertaken at Horticulture Research Centre, Pattharchatta, G. B. Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand to see the effect of different bagging materials (white polypropylene and pink polypropylene bags) with varied perforations (0, 5 and 10%) and bagging dates (45, 35 and 30 days before harvest) on the physico-chemical properties of litchi during the year 2018. Among the various bagging materials of different perforations used, white polypropylene bag with 5% perforation had most effectively improved the physical and the chemical attributes of litchi *viz.* fruit retention, fruit cracking, fruit weight, fruit volume, pulp weight, pulp to seed ratio, TSS, total sugars, reducing sugars, non-reducing sugars, ascorbic acid and fruit peel anthocyanin content. However, higher fruit diameter and TSS: Acidity ratio with lower sun burn were obtained in fruits bagged with white polypropylene bags without any perforation. On the other hand, fruits bagged 30 days before harvest gave significant results for all the parameters. The economics calculated for all the treatments showed that bagging of fruits 30 days before harvest with white polypropylene bags having five per cent perforation showed feasibility in litchi cultivation as the net return per rupee was Rs. 2.88.

Keywords: Fruit bagging, litchi, physico-chemical properties, anthocyanin

Introduction
Litchi (*Litchi chinensis* Sonn.) is one of the most important sub-tropical fruit of India.It is highly specific for climatic requirements,which limits its cultivation only to few countries. Generally, it flourishes in moist atmosphere having abundant rainfall and frost free environment. It has a strong commercial value in international market for its bright red skin and sweet, juicy and crisp aril (Jiang *et al.*, 2006) [13]. In India, it is mainly grown in Bihar, West Bengal, Uttar Pradesh, Punjab and Uttarakhand. In Uttarakhand, major litchi producing districts are Dehradun, Haridwar, Nainital and U S Nagar. The total area under litchi in Uttarakhand during 2017-18 stands at 10,500.3 ha and production is 24,271.02 MT. Usually litchi fruits come in the market right from the month of May till early part of July.Considering the importance of litchi in Uttarakhand, efforts are being made to provide technological support through research and developmental programmes for the promotion of production and improved marketing as well as export. The major problems responsible for low economic potential of litchi cultivation are poor fruit set and inferior fruit qualityas well as other factors like irregular flowering, heavy fruit drop, poor fruit retention, alternate bearing, fruit cracking, small fruit size, low and erratic yields are reported wherever litchi is grown, hampering its development as a major commercial crop.Among several such alternatives, pre-harvest fruit bagginghas emerged as an effective approach in different parts of the World. In this technique, individual fruit or fruit bunches are bagged on the tree for a specific period.

Materials and Methods
Uniform aged trees of litchi cv. 'Rose Scented', planted in a square system with the spacing of 10×10 m^2 were selected. The 21 treatment combinations comprised of two different coloured bagging materials with varied per cent perforations (white polypropylene bags + 0% perforation, white polypropylene bags + 5% perforation, white polypropylene bags + 10% perforation, pink polypropylene bags + 0% perforation, pink polypropylene bags + 5% perforation, pink polypropylene bags + 10% perforation) with one unbagged and three bagging dates (45 days before harvest, 35 days before harvest, 30 days before harvest). Bagging for each treatment was distributed equally in four directions and different height of tree canopy to

avoid possible influence on treatment effects. Fruits bagged and non-bagged(control) fruits were harvested at commercial mature stage. Parameters like fruit retention, pericarp sun-burn and fruit cracking percentage were also evaluated along with various physical attributes of fruit i.e., weight, diameter, volume, pulp weight, peel weight, seed weight, pulp to peel ratio, pulp to seed ratio were recorded. Quality attributes like TSS, acidity, TSS: acidity ratio,ascorbic acid, total sugars, reducing sugars, non-reducing sugars and anthocyanin content were estimated as per methods described by Ranganna (1986) [18]. Data were analysed statistically by adopting RBD. The level of significance for different variables was tested at 5% value of significance.

Results and Discussion

The highest fruit retention per panicle was recorded in panicle bagged with white polypropylene bags with 10% perforation (49.66%). However, minimum fruit retention per panicle was recorded in unbagged treatments (42.97%). Among the bagging dates, maximum fruit retention per panicle (51.36%) was observed in panicles bagged 30 days before harvest (51.36%) while the lowest fruit retention per panicle was observed in panicles bagged 45 days before harvest (41.51%). The interaction effects due to bagging dates and bagging materials on fruit retention per panicle was found maximum in fruits bagged 30 days before harvest with white polypropylene bags having 5% perforation (54.13%) whereas, the minimum fruit retention per panicle was found in fruits bagged 45 days before harvest with white polypropylene bags without any perforation(Table 1).Debnath and Mitra (2008) [6] observed that fruit retention per panicle was increased significantly when litchi fruits were bagged one week after fruit set and Yang *et al*. (2009) [23] also reported that white adhesive fabric bag increased the fruit retention rate in cross-winter off-season longan (Dimocarpus longan Lour.) cv. Chuliang.

Least pericarp sunburn (13.59%) was observed in fruits bagged with white polypropylene bags (no perforation) whereas maximum pericarp sun-burn (18.20%) was observed in unbagged fruits. Observations with regards to the date of bagging showed that fruits bagged 30 days before harvesting resulted in minimum pericarp sun-burn 14.36% which was closely followed by fruits bagged 35 days before harvest (14.70%). Observations on interaction effects showed that minimum sun-burn was recorded in fruits bagged with white polypropylene bags (no perforation) 30 days before harvest (Table 1).

Table 1: Effect of bagging dates and bagging materials on fruit retention (%) and pericarp sunburn (%) of litchi cv. Rose Scented

Bagging materials (M)	Fruit retention (%)				Pericarp sun-burn (%)			
	Bagging days before harvest (D)			Mean	Bagging days before harvest (D)			Mean
	45 D	35 D	30 D		45 D	35 D	30 D	
White polypropylene+ 0% perforation	37.09	46.9	52.27	45.42	14.57	13.53	12.66	13.59
White polypropylene+ 5% perforation	40.28	48.94	54.13	47.78	14.88	14.13	13.71	14.24
White polypropylene+ 10% perforation	46.56	48.84	53.58	49.66	15.96	14.29	14.54	14.93
Pink polypropylene+ 0% perforation	37.42	46.02	51.26	44.9	14.62	13.54	12.95	13.70
Pink polypropylene+ 5% perforation	41.16	46.67	51.83	46.56	15.22	14.22	13.76	14.4
Pink polypropylene+ 10% perforation	45.72	46.98	53.28	48.66	15.59	14.99	14.78	15.12
Unbagged	42.33	43.42	43.17	42.97	18.26	18.17	18.16	18.20
Mean	41.51	46.82	51.36		15.59	14.70	14.36	
		C.D. at 5%				C.D. at 5%		
Materials (M)			0.943			0.234		
Days (D)			0.617			0.153		
Interaction (M X D)			1.633			0.405		

Minimum fruit cracking (7.69%) was noticed in fruits bagged with white polypropylene (5% perforation) which was closely followed by fruits bagged with white polypropylene (no perforation) and it was highest (12.79%) in unbagged fruits. Among the bagging dates, minimum fruit cracking (8%) was observed in fruits bagged 30 days before harvest. Among the interaction, fruits bagged 30 days prior to harvest with white polypropylene (no perforation) had least fruit cracking (7.04%) and it was found to be maximum (12.80%) in unbagged fruits tagged 45 days before harvest (Table 2). Similar trends in fruit cracking have been reported by Yang *et al*. (2009) [23] in fruit bagging of longan.

The maximum fruit diameter (3.45 cm) was observed with the fruits bagged with pink polypropylene bags (10% perforation). Among the bagging dates, highest fruit diameter (3.47 cm) was observed in fruits bagged 30 days before harvest. Interaction effect showed that maximum fruit diameter (3.68 cm) was found in fruits bagged 30 days before harvest with pink polypropylene bags without perforation (Table 2). Earlier studies made by several workers also have similar findings like Ghalib *et al*. (1998) [10], El-Kassas *et al*. (1995) [7] in date palm and Daniells *et al*. (2005) [5] in banana fruit.

Table 2: Effect of bagging dates and bagging materials on fruit cracking (%) and fruit diameter (cm) of litchi cv. Rose Scented

Bagging materials (M)	Fruit cracking (%)				Fruit diameter (cm)			
	Bagging days before harvest (D)			Mean	Bagging days before harvest (D)			Mean
	45 D	35 D	30 D		45 D	35 D	30 D	
White polypropylene+ 0% perforation	9.01	7.15	7.04	7.73	3.18	3.45	3.62	3.42
White polypropylene+ 5% perforation	8.87	7.08	7.12	7.69	3.10	3.27	3.49	3.29
White polypropylene+ 10% perforation	8.87	7.27	7.26	7.80	2.85	3.17	3.45	3.16
Pink polypropylene+ 0% perforation	9.16	7.19	7.15	7.83	3.17	3.47	3.68	3.44
Pink polypropylene+ 5% perforation	8.64	7.31	7.30	7.75	3.14	3.40	3.60	3.38
Pink polypropylene+ 10% perforation	9.01	7.33	7.33	7.89	3.32	3.41	3.62	3.45
Unbagged	12.80	12.79	12.79	12.79	2.80	2.81	2.82	2.81
Mean	9.48	8.02	8.00		3.08	3.28	3.47	
			C.D. at 5%			C.D. at 5%		
Materials (M)			0.060			0.047		
Days (D)			0.039			0.031		
Interaction (M X D)			0.103			0.081		

The maximum fruit weight (21.53 g) was recorded when fruits were bagged with white polypropylene bags with 5% perforation whereas the minimum fruit weight (19.95 g) was noticed when fruits were not bagged. Higher fruit weight (21.81 g) was recorded when bags were bagged 30 days before the harvest. Among the interaction effects, maximum fruit weight (22.22 g) was found in fruits bagged 30 days before harvest with white polypropylene bags (5% perforation) while it was found minimum (19.87 g) in unbagged fruits tagged 35 days before harvest (Table 3). similar findings were observed by Fumuro and Gamo (2001) [9] in persimmon and Debnath and Mitra (2008) [6] in litchi fruits. This trend in fruit weight might be attributed due to the favourable microclimate created inside the bags which increased accumulation of assimilates leading to maximum fruit weight.

The data presented in Table 3, shows that fruits bagged with pink polypropylene bags (5% perforation) had higher fruit volume (20.75 ml) while it was found lowest (19.42 ml) in unbagged fruits. The maximum fruit volume (20.89 ml) was observed in fruits bagged 30 days before the harvest. In the interaction, maximum fruit volume (21.25 ml) was recorded in three treatments bagged 30 days prior to harvest with white polypropylene bags (no perforation), white polypropylene bags (5% perforation) and pink polypropylene bags (5% perforations), respectively. Similar results have been obtained by Daniells *et al*. (2005) [5] who reported that the higher fruit volume in banana fruits might be due to higher humidity and appropriate microclimate inside the bags, which results in proper growth and development of fruits.

Table 3: Effect of bagging dates and bagging materials on fruit weight (g) and fruit volume (ml) of litchi cv. Rose Scented

Bagging materials (M)	Fruit weight (g)				Fruit volume (ml)			
	Bagging days before harvest (D)			Mean	Bagging days before harvest (D)			Mean
	45 D	35 D	30 D		45 D	35 D	30 D	
White polypropylene+ 0% perforation	20.59	21.09	22.18	21.29	20.08	20.37	21.25	20.57
White polypropylene+ 5% perforation	21.12	21.26	22.22	21.53	20.56	20.4	21.25	20.74
White polypropylene+ 10% perforation	21.08	21.09	22.11	21.43	20.5	20.26	21.06	20.61
Pink polypropylene+ 0% perforation	20.58	21.07	22.15	21.27	20.17	20.29	21.22	20.56
Pink polypropylene+ 5% perforation	20.97	21.19	22.18	21.44	20.49	20.51	21.25	20.75
Pink polypropylene+ 10% perforation	20.95	21.16	21.83	21.31	20.45	20.31	20.95	20.57
Unbagged	19.97	19.87	19.99	19.95	19.68	19.29	19.28	19.42
Mean	20.75	20.96	21.81		20.28	20.20	20.89	
		C.D. at 5%				C.D. at 5%		
Materials (M)		0.263				0.256		
Days (D)		0.172				0.168		
Interaction (M X D)		0.455				0.443		

The data presented in Table 4, specified that the minimum peel weight (2.58 g) was observed when the fruits were bagged with pink polypropylene (5% perforation) white it was maximum (2.83 g) in unbagged fruits. The minimum peel weight (2.34 g) was observed when the fruits were bagged 30 days before harvest. Among the interaction, minimum peel weight (2.10 g) was noticed in fruits bagged 30 days before harvest with white polypropylene bags (no perforation).

Maximum value (18.59 g) of fruit pulp weight was obtained when fruits were bagged with white polypropylene bags (5% perforation) while the minimum fruit pulp weight (19.42 g) was observed in unbagged fruits. With respect to bagging dates, maximum fruit pulp weight (19.44 g) was observed in fruits bagged 30 days before harvesting. Interaction effect showed that fruits bagged 30 days before the harvest with white polypropylene bags (5% perforation) had the highest (19.96 g) pulp weight (Table 4). Similar results were obtained by Zhou *et al*. (2012) [25] in Canarium album, El-Kassas *et al*. (1995) [7], El-Shazly (1999) [8] and Moustafa (1993) [16] in date palm fruits. The increase in pulp may be due to more moisture levels and temperature inside the bags which promotes better development of fruits.

Table 4: Effect of bagging dates and bagging materials on peel weight (g) and pulp weight (g) of litchi cv. Rose Scented

		Peel weight (g)				Pulp weight (g)		
Bagging materials (M)	**Bagging days before harvest (D)**			**Mean**	**Bagging days before harvest (D)**			**Mean**
	45 D	**35 D**	**30 D**		**45 D**	**35 D**	**30 D**	
White polypropylene+ 0% perforation	3.38	2.73	2.1	2.74	17.27	17.97	19.86	18.37
White polypropylene+ 5% perforation	3.12	2.71	2.25	2.69	17.57	18.26	19.96	18.59
White polypropylene+ 10% perforation	3.29	2.72	2.37	2.79	16.69	17.8	19.75	18.08
Pink polypropylene+ 0% perforation	3.45	2.58	2.15	2.73	16.87	17.74	19.79	18.14
Pink polypropylene+ 5% perforation	2.98	2.43	2.34	2.58	17.21	17.76	19.82	18.26
Pink polypropylene+ 10% perforation	2.98	2.73	2.38	2.7	16.65	17.53	19.69	17.96
Unbagged	2.87	2.82	2.81	2.83	16.64	17.12	17.16	16.97
Mean	3.16	2.68	2.34		16.99	17.74	19.44	
		C.D. at 5%				C.D. at 5%		
Materials (M)		0.137				0.29		
Days (D)		0.09				0.19		
Interaction (M X D)		0.238				0.502		

According to the table 5, least seed weight (3.43 g) was obtained when fruits were bagged with white polypropylene bags (5% perforation) while maximum (3.85 g) fruit seed weight was obtained in unbagged fruits. The fruits bagged 30 days prior to harvest exhibited least (3.44 g) fruit stone weight. Interaction effect due to both the factors showed that minimum (3.04 g) seed weight was found in fruits bagged 30 days before the harvest with white polypropylene bags (5% perforation). The results are in conformity with the findings of several workers like Al-Obeed and Harhash (2010) [1], Rabeh and Kassem (2003) [17] and Awad (2012) [3] in date palm.

The data displayed in table 5, showed that Maximum pulp/peel ratio (7.97) was found in control (unbagged) treatments and with respect to the effect of bagging dates, fruits bagged 30 days before harvest had significantly higher (8.23) pulp/peel ratio while the interaction effect was found to be non-significant. The possible reasons might be the increased fruit pulp weight inside the bags due to favourable microclimate which ultimately resulted in higher pulp/peel ratio of the fruits.

Table 5: Effect of bagging dates and bagging materials on fruit seed weight (g) and fruit pulp/peel ratio of litchi cv. Rose Scented

	Fruit seed weight (g)					Pulp: peel ratio		
Bagging materials(M)	**Bagging days before harvest (D)**			**Mean**	**Bagging days before harvest (D)**			**Mean**
	45 D	**35 D**	**30 D**		**45 D**	**35 D**	**30 D**	
White polypropylene+ 0% perforation	3.82	3.46	3.23	3.51	7.95	6.23	8.45	7.54
White polypropylene+ 5% perforation	3.79	3.47	3.04	3.43	6.01	6.7	8.26	6.99
White polypropylene+ 10% perforation	3.89	3.64	3.51	3.68	5.92	6.4	8.06	6.79
Pink polypropylene+ 0% perforation	3.84	3.74	3.52	3.69	5.98	6.91	8.49	7.13
Pink polypropylene+ 5% perforation	3.65	3.48	3.37	3.49	6.97	7.65	8.58	7.74
Pink polypropylene+ 10% perforation	3.80	3.66	3.64	3.70	5.65	6.37	7.67	6.56
Unbagged	3.96	3.84	3.76	3.85	7.97	7.83	8.11	7.97
Mean	3.82	3.61	3.44		6.64	6.87	8.23	
		C.D. at 5%				C.D. at 5%		
Materials (M)		0.093				0.762		
Days (D)		0.061				0.499		
Interaction (M X D)		0.161				NS		

Maximum pulp: seed ratio (5.49) was obtained in fruits bagged with white polypropylene (5% perforation) while minimum pulp: seed ratio (4.41) was noticed in fruits that were not bagged. Among bagging dates, fruits that were bagged 30 days prior to harvest had higher (5.69) pulp/seed ratio. Interaction effect as shown in Table 6 showed that maximum fruit pulp: seed ratio (6.58) was recorded in fruits bagged with white polypropylene bags (5% perforation) 30 days prior to harvest. The most possible reason behind the significant variation among bagging dates may be due to more pulp weight of the bagged fruits.

According to Table 6, among the bagging materials, the maximum TSS (18.76° Brix) was recorded in fruits that were bagged with white polypropylene bags (10% perforation) and minimum TSS (17.72° Brix) was recorded in fruits that were bagged with pink polypropylene bags (no perforation). The maximum TSS (18.63° Brix) was noticed when the fruits were bagged 30 days before harvest. The interaction effect showed that maximum TSS (20.20° Brix) was reported in bags bagged with white polypropylene bags (5% perforation) 30 days before the harvest. Same results have been reported by several workers *viz*., Debnath and Mitra (2008) [6] in litchi fruit, Wanichkul and Subrungroeng (2011) [21] in carambola, Jakhar and Pathak (2014) [12] in mango. The covered panicles had more TSS than the control one, probably because the higher temperature under the bags favoured the conversion of starch into sugars.

Table 6: Effect of bagging dates and bagging materials on the fruit pulp: seed ratio and TSS (° Brix) of litchi cv. Rose Scented

Bagging materials (M)	Pulp: seed ratio				TSS (° Brix)			
	Bagging days before harvest (D)			Mean	Bagging days before harvest (D)			Mean
	45 D	35 D	30 D		45 D	35 D	30 D	
White polypropylene+ 0% perforation	4.52	5.19	6.15	5.29	17.40	17.93	18.03	17.79
White polypropylene+ 5% perforation	4.65	5.27	6.58	5.49	17.47	18.13	20.20	18.60
White polypropylene+ 10% perforation	4.29	4.89	5.63	4.94	17.97	18.57	19.73	18.76
Pink polypropylene+ 0% perforation	4.39	4.75	5.63	4.92	17.37	17.9	17.90	17.72
Pink polypropylene+ 5% perforation	4.72	5.11	5.89	5.24	18.00	18.07	18.50	18.19
Pink polypropylene+ 10% perforation	4.38	4.79	5.42	4.86	18.07	18.37	18.47	18.30
Unbagged	4.20	4.46	4.58	4.41	17.93	17.80	17.57	17.77
Mean	4.45	4.92	5.69		17.74	18.11	18.63	
		C.D. at 5%				C.D. at 5%		
Materials (M)		0.157				0.377		
Days (D)		0.103				0.247		
Interaction (M X D)		0.272				0.653		

Among the bagging materials, minimum acidity (0.38%) was found in fruits bagged with white polypropylene bags (no perforation) whereas maximum acidity (0.53%) was found in unbagged fruits. Regarding the bagging dates, minimum acidity (0.42%) was found in fruits bagged 35 days prior to harvest. Interaction effect depicted that minimum acidity (0.29%) was noticed in fruits bagged with white polypropylene bags (no perforation) 30 days before harvest. These findings are in accordance with the findings of Ming *et al*. (2005) in litchi and Jakhar and Pathak (2014) [12] in mango. This can be explained as the harvesting of bagged as well as unbagged fruits was taken at the same date and bagging resulted in early maturation of fruits due to improved microclimate (Table 7).

According to Table 7, maximum TSS: acid ratio (48.84) was found in fruits bagged with white polypropylene bags (no perforation) while the minimum (33.12) TSS: acid ratio was reported in the unbagged fruits. Among the bagging dates, maximum TSS: acid ratio (44.05) was noticed in fruits bagged 35 days before the harvest. In the interaction effect, fruits bagged 30 days before harvesting with white polypropylene (no perforation) had highest (58.17) TSS/acid ratio. The TSS: acid ratio higher in bagged fruit might be due to higher total soluble solids and lower rate of acidity. These results are in conformity with the results of Wanichkul and Subrungroeng (2011) [21] in carambola and Ma *et al*. (2009) [15] in peach.

Table 7: Effect of bagging dates and bagging materials on fruit acidity (%) and TSS/acid ratio of litchi cv. Rose Scented

Bagging materials (M)	Fruit acidity (%)				TSS: acidity			
	Bagging days before harvest (D)			Mean	Bagging days before harvest (D)			Mean
	45 D	35 D	30 D		45 D	35 D	30 D	
White polypropylene+ 0% perforation	0.52	0.33	0.29	0.38	33.75	54.6	58.17	48.84
White polypropylene+ 5% perforation	0.41	0.48	0.41	0.43	43.75	38.29	49.02	43.69
White polypropylene+ 10% perforation	0.48	0.46	0.54	0.49	38.78	41.88	36.83	39.16
Pink polypropylene+ 0% perforation	0.52	0.37	0.33	0.41	33.71	49.08	54.46	45.75
Pink polypropylene+	0.48	0.39	0.48	0.45	38.31	46.19	39.04	41.18

5% perforation								
Pink polypropylene+ 10% perforation	0.52	0.41	0.52	0.48	35.06	45.16	36.22	38.81
Unbagged	0.56	0.52	0.52	0.53	32.13	33.17	34.07	33.12
Mean	0.5	0.42	0.44		36.5	44.05	43.97	
		C.D. at 5%			C.D. at 5%			
Materials (M)		0.053			4.544			
Days (D)		0.035			2.975			
Interaction (M X D)		0.092			7.871			

Data recorded in Table 8, summarized that fruits bagged with white polypropylene bags (5% perforation) had increased levels of total sugars (13.25%) while the minimum total sugar (11.92%) was observed in unbagged fruits. Among bagging dates, maximum total sugars (13.37%) in the fruits bagged 30 days before harvest. The interaction showed that the maximum value of total sugars (14.19%) occurred in fruits bagged with white polypropylene bags (no perforation) 30 days before the harvest. The increase in level of total sugars inside the bagged fruits might be due to enzymatic activity of sucrose synthase (SS) and sucrose-phosphate synthase (SPS), SS is an enzyme that plays a key role in sucrose decomposition. These results are in conformity with the results of Al-Obeed and Harhash (2010) [1].

in date palm, Jakhar and Pathak (2014) [12] in mango and Wu *et al*. (2010) [22] in mango.

According to Table 8, maximum (11.41%) amount of reducing sugars was found in fruits bagged with white polypropylene bags (5% perforation) while maximum (11.53%) reducing sugars were observed in fruits bagged 30 days prior to harvest. The interaction effect displayed that it was maximum (12.29%) in fruits that were bagged 30 days prior to harvest with white polypropylene bags (no perforation). The higher reducing sugars might be due to the conversion of sucrose into glucose inside the bag (more sucrose synthase and sucrose-phosphate synthase activity inside the bag). The results presented in the present study are well supported with the findings of Al-Obeed and Harhash (2010) [1] in date palm.

Table 8: Effect of bagging dates and bagging materials on total sugars (%) and reducing sugars (%) of litchi cv. Rose Scented

Bagging materials (M)	Total sugars (%)				Reducing sugars (%)			
	Bagging days before harvest (D)			Mean	Bagging days before harvest (D)			Mean
	45 D	35 D	30 D		45 D	35 D	30 D	
White polypropylene+ 0% perforation	12.29	13.08	14.19	13.19	10.49	11.28	12.29	11.35
White polypropylene+ 5% perforation	12.99	12.84	13.91	13.25	11.19	11.03	11.99	11.41
White polypropylene+ 10% perforation	11.87	12.51	13.58	12.65	10.09	10.72	11.72	10.84
Pink polypropylene+ 0% perforation	11.88	12.60	13.59	12.69	10.07	10.80	11.72	10.86
Pink polypropylene+ 5% perforation	12.53	12.99	13.34	12.95	10.72	11.19	11.46	11.12
Pink polypropylene+ 10% perforation	12.12	12.74	13.18	12.68	10.35	10.95	11.54	10.95
Unbagged	11.96	12.00	11.79	11.92	10.20	10.22	10.00	10.14
Mean	12.24	12.68	13.37		10.45	10.88	11.53	
		C.D. at 5%			C.D. at 5%			
Materials (M)		0.258			0.269			
Days (D)		0.169			0.176			
Interaction (M X D)		0.446			0.466			

The highest amount (1.84%) of non-reducing sugars was noticed in fruits bagged with white polypropylene bags (5% perforation) and among bagging dates, highest per cent (1.86%) of non-reducing sugars were reported in fruits bagged 30 days before the harvest (Table 9). In interaction effect, it was found maximum (1.91%) in the fruits bagged 30 days before the harvest with white polypropylene bags (5% perforation). The results are in accordance with the findings of Al-Obeed and Harhash (2010) [1] in date palm and Wu *et al*. (2010) [22] in mango.

Among bagging materials, ascorbic acid was recorded maximum (22.59 mg/100 g) in fruits bagged with white polypropylene bags (5% perforation) and minimum (20.76 mg/100 g) in unbagged fruits. Among the bagging dates, maximum ascorbic acid (22.54 mg/100 g) was recorded in fruits bagged 30 days before harvest. Interaction effect depicted that fruits bagged 30 days prior to harvest with white polypropylene bags (5% perforation) showed highest (22.99 mg/100 g) ascorbic acid content (Table 9). It might be due to the fact that there is more temperature inside the bags which helped in more activation of phytochemicals and their synergistic effect therefore, increasing the levels of ascorbic acid inside the bags. Similar findings have also been achieved by Chen *et al*. (2015) [4] in longan fruit and by Zhao *et al*. (2012) in Canarium album fruits.

Table 9: Effect of bagging dates and bagging materials on non-reducing sugars (%) and ascorbic acid (mg/100g) of litchi cv. Rose Scented

Bagging materials (M)	Non-reducing sugars (%)				Ascorbic acid (mg/100g)			
	Bagging days before harvest (D)			Mean	Bagging days before harvest (D)			Mean
	45 D	35 D	30 D		45 D	35 D	30 D	
White polypropylene+ 0% perforation	1.79	1.8	1.89	1.83	21.39	22.55	22.89	22.28
White polypropylene+ 5% perforation	1.8	1.81	1.91	1.84	21.89	22.91	22.99	22.59
White polypropylene+ 10% perforation	1.79	1.79	1.86	1.81	21.25	22.42	22.73	22.13
Pink polypropylene+ 0% perforation	1.81	1.8	1.87	1.83	21.49	22.54	22.82	22.29
Pink polypropylene+ 5% perforation	1.81	1.8	1.88	1.83	21.58	22.58	22.87	22.34
Pink polypropylene+ 10% perforation	1.78	1.79	1.82	1.79	21.44	22.57	22.69	22.24
Unbagged	1.76	1.78	1.79	1.78	20.78	20.75	20.77	20.76
Mean	1.79	1.79	1.86		21.4	22.33	22.54	
		C.D. at 5%				C.D. at 5%		
Materials (M)		0.011				0.02		
Days (D)		0.007				0.013		
Interaction (M X D)		0.018				0.034		

Highest anthocyanin content (23.66 mg/100 g) in the peel was reported in fruits bagged with white polypropylene bags (5% perforation) while it was lowest (21.59 mg/100 g) in unbagged fruits. Among the bagging dates, maximum content (24.72 mg/100 g) of anthocyanin in peel was recorded in fruits that were bagged 30 days prior to the harvest. The interaction effects showed that highest (26.17 mg/100 g) amount of anthocyanin content was noticed in the fruits that were 30 days prior to harvest with white polypropylene bags (5% perforation). The results are in conformity with the findings of Guibing *et al*. (2001) [11] in litchi, Tyasa *et al*. (1998) [20] in litchi, Debnath and Mitra (2008) [6] in litchi, Ju (1998) [14] in apple, Wu *et al*. (2013) [22] in mango and Wanichkul and Subrungroeng (2011) [21] in carambola fruit. The reason might be that due to increase in temperature inside the bags the anthocyanin synthesis might have got hastened and at maturity during harvesting, bagged treatments accumulated higher anthocyanin content than the unbagged ones.

The data presented in Table 10, showed that bagging of 100 kg fruits was found significant and feasible with benefit: cost ratio of 3.23, when bagged 30 days before the harvest. Among the interaction effects highest (3.88) benefit: cost ratio was obtained when the fruits were bagged 30 days before the harvest with white polypropylene bags having five per cent perforation. All the fruits that were bagged 30 days before the harvest were feasible. These results are in conformity with the findings of Amarante *et al*. (2002) [2] in pear and as per Sharma *et al*. (2016) [19], bagging is a physical protection method which not only improves the visual appearance of fruit by promoting colouration and reducing blemishes but it also modifies the micro-environment for fruit development, which results in multiple beneficial effects on internal fruit quality to increase market value of fruit.

Table 10: Effect of bagging dates and bagging materials on fruit peel anthocyanin content (mg/100 g) and Benefit: Cost ratio of bagging for 100 Kg produce of litchi cv. Rose

Bagging materials (M)	Anthocyanin (mg/100g)				Benefit: cost ratio			
	Bagging days before harvest (D)			Mean	Bagging days before harvest (D)			Mean
	45 D	35 D	30 D		45 D	35 D	30 D	
White polypropylene+ 0% perforation	21.15	22.91	25.66	23.24	0.95	2.82	3.52	2.43
White polypropylene+ 5% perforation	21.48	23.32	26.17	23.66	0.98	2.82	3.88	2.56
White polypropylene+ 10% perforation	21.69	22.19	24.54	22.81	0.97	2.47	2.82	2.09
Pink polypropylene+ 0% perforation	20.98	22.51	24.85	22.78	0.95	2.12	3.17	2.08
Pink polypropylene+ 5% perforation	21.38	22.71	25.15	23.08	0.97	2.47	3.17	2.20
Pink polypropylene+ 10% perforation	21.59	21.89	24.24	22.57	1.00	1.41	2.82	1.74
Unbagged	20.98	21.38	22.41	21.59				
Mean	21.32	22.42	24.72		0.97	2.35	3.23	
		C.D. at 5%				C.D. at 5%		
Materials (M)		0.214				NS		
Days (D)		0.14				0.456		
Interaction (M X D)		0.37				0.998		

Conclusion

On the basis of present study, it is concluded that bagging of litchi fruits 30 days before the harvest with white polypropylene bags having five per cent perforation may be recommended to enhance the physical as well as biochemical parameters of litchi to obtain good quality litchi fruit for remunerative litchi cultivation in Tarai region of Uttarakhand.

Acknowledgements

We cordially acknowledge the assistance extended by Department of Horticulture, G. B Pant University of Agriculture and Technology, Pantnagar.

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