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Packaging technology for export of jasmine (*Jasminum sambac* Ait.) flowers

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ABSTRACT

A study was conducted to standardize packaging technology for export of jasmine flowers. Experiments were laid out in FCRD in three replications, with 12 chemical treatments, and packing with unit packing boxes and thermocol boxes under gel-ice cold condition. Effects of various chemical treatments and their interaction with packaging were studied and observations were recorded on visual quality (freshness index, flower-opening index, colour retention index and fragrance score) of flowers and physiological parameters associated with post harvest quality of flowers. Export suitability of the package was also studied and Cost:Benefit ratio (CBR) worked out. Chemical treatment of flowers with 4% boric acid, packing in aluminum-foil lined boxes and further packaging in thermocol boxes under gel-ice cold condition was found to be significantly superior to Control, and recorded a shelf life of 42.88h. This package also recorded maximum freshness index (70 to 90%), minimum flower-opening index (10.5 to 50%) and maximum colour retention index (77.77 to 88.88%) of flowers. CBR was 1:2.5.

Key words: Jasmine flowers, *J. sambac*, chemical treatment, packing, packaging, export suitability

INTRODUCTION

Jasmine (*Jasminum sambac* Ait.) is the oldest of fragrant flowers cultivated by man. The flowers are used for various purposes, viz., making garlands and bouquets, for religious offerings, etc. These are also used for production of essential oils in the form of 'concrete' and 'absolute' used in cosmetic and perfumery industries. *J. sambac*, called 'Gundumalli/Madurai malli' in Tamil Nadu, has several cultivars, namely, Motia, Single Mogra, Double Mogra, Ramanathapuram Local, Oosimalli, Soojimalli, Ramabanam and Iruvatchi (Abdul Khader and Kumar, 1995). Though cut flowers constituted a major share of flower exports over the past two decades, recently, export of the traditional group of flowers, especially jasmine flowers, has picked up. This is because of increasing demand for these from the Indian population settled in Middle East countries and the United States of America. Strung flowers of *J. sambac* have good export demand in long distance markets like the US. It takes around 36–48h from India to New York market by air. The flowers are very delicate and show signs of wilting with abrupt loss of fragrance within 24 -36 h after harvest. One of the major problems faced by exporters is lack of suitable packaging technology for export. In view of the increasing demand for fresh flowers and the need for developing reliable export packaging technology catering to distant overseas markets, the present study was undertaken. The objective was to standardize export packaging technology in jasmine flowers.

MATERIAL AND METHODS

Unopened, fresh flower-buds of *J. sambac* constituted the experimental material. Investigations on packaging were carried out under gel-ice cold conditions. The design adopted was CRD with 2 factors (chemical treatment and packaging material). Chemical treatments used were based upon earlier, published results (Nirmala and Reddy, 1994; Madhu, 1999; Karruppaiah *et al*, 2006). Details of chemical treatments are: T_1 - Sucrose 2%, T_2 - Sucrose 4%, T_3 - Boric acid 2%, T_4 - Boric acid 4%, T_5 - Salicylic acid 25 ppm, T_6 - Salicylic acid 50 ppm, T_7 - Ascorbic acid 50 ppm, T_8 – Ascorbic acid 100 ppm, T_9 - NAA 50 ppm, T_{10} - NAA 100 ppm, T_{11} - Distilled water, T_{12} - No soaking (Control). Three types of packing boxes were used: Box A – Aluminium-foil lined cardboard boxes of dimensions 14 x 11 x 14cm; Box B - 0.5mm thick polypropylene boxes of dimensions 16 x 11 x 4cm, and Box C - 0.3mm thick Polypropylene boxes of dimension 10 x 7 x 4 cm. Thermocol box of dimension 60 cm x 45 cm x 30 cm capable of holding 50, 40 and 50 Boxes A, B & C, respectively, was used for

packaging. Butter paper was used as the lining material inside boxes A, B and C. Aluminum-foils and butter paper were used for lining between boxes packaged in Thermocol boxes. Ten grams of fresh-flower buds of uniform size were treated with the chemicals, air dried and packed in boxes A, B, and C lined with butter papers. These boxes, in turn, were packed in thermocol boxes with intermittent gel-ice layers, lined with aluminum-foil and butter paper. This package was stored under ambient conditions and observations were recorded at 24h and 36h after storage.

Visual observations like freshness index, flower-opening index, colour retention index, fragrance index and shelf life were recorded based on hedonic scale scoring (1999). Physiological paramaters such as moisture content, physiological loss in weight (PLW), membrane integrity (MI) (Barrs and Weatherley, 1962), relative water content (RWC), peroxidase activity (Srivastava, 1987) and catalase activity (Diby Paul and Sharma, 2005) were analyzed. Shelf life of flowers was recorded as time taken to wilting of 50% of flowers. Export suitability of the best package developed was evaluated for US market (New Jersey) and Cost : Benefit Ration (CBR) was worked out. Standard procedure of Sukhatme and Amble (1985) was adopted for statistical scrutiny of data.

RESULTS AND DISCUSSION

Visual and physiological parameters 24 hours after packaging

Among packing boxes, no significant differences were noticed for freshness index, moisture content, RWC and total carbohydrates 24h after packaging. Flowers packed in Box A (aluminium-foil lined box) recorded the least flower-opening index of 39.69% (Table 1) and maximum colour-retention index of 74.07% (Table 2) as also the lowest PLW of 2.24% (Table 3) and maximum membrane integrity of 58.51% (Table 4). Activity of peroxidase and catalase was found to be non-significant.

With regard to chemical treatments, boric acid at 4% (T_4) recorded maximum freshness index (81.63%), followed by boric acid at 2% (T_2) at 81.41% (Table 1). The same treatments were at par with each other and recorded the least flower-opening index (5%) and maximum colour-retention index (88.88%) (Table 2). In the case of physiological parameters, treatments with boric acid at 4% (T_4) and 2% (T_2) recorded the least PLW (1.83 and 1.85, respectively), maximum moisture content (57.14 and 56.99%) (Table 3), maximum RWC (85.72 and 85.49%) and maximum membrane integrity (47.14 and 47.31% respectively) (Table 4). Activities of enzymes such as peroxidase (17.96 change in OD/g/min.) (Fig. 1) and catalase (40.96µg H_2O_2/g/min.) (Fig. 2) were found to be highest in boric acid 4% treatment.

In the case of B x T (packing box and chemical treatment) interaction, except for flower-opening index and PLW, all other parameters recorded non-significant values. Data on fragrance score indicated that the Control recorded higher fragrance score of '3' (strong) while all other treatments recorded a score of '2' (mild).

Visual and physiological parameters 36 hours after packaging

In the case of chemical treatments, boric acid at 4% (T_4) recorded maximum freshness index (71.75%) (Table 1), lowest flower-opening index (29.17%) and maximum colour-retention index (77.77%) (Table 2). The same treatment also recorded the least PLW (2.83%) and maximum values for moisture content (50.23%), RWC (75.34%) and membrane integrity (53.08%). Highest activity of the enzymes peroxidase (38.21 change in OD/g/min.) and catalase (37.73µg H_2O_2/g/min.) were also recorded in treatment T_4 compared to all other treatments and Control.

Among packing boxes, Box A (aluminium-foil lined boxes) exhibited significance and recorded maximum freshness-index of 52.42% (Table 1) and maximum colour retention index of 57.40% (Table 2). As for physiological parameters, Box A recorded the least PLW of 4.76% (Table 3) and highest values for moisture content (36.69%), RWC (55.04%) and membrane integrity (68.74%) (Table 4). Highest activity of enzymes like peroxidase (26.21 change in OD/g/min.) (Fig. 1) and catalase (39.60µg H_2O_2/g/min.) (Fig. 2) were also registered in flowers packed in Box A.

Among B x T interaction effect, B_1T_4 (packing box A + boric acid 4%) was found to be significantly better for maximum freshness index (74.15%), least flower-opening, highest colour-retention index (88.88%), least PLW (2.59%) along with maximum moisture (51.91%), RWC content (77.86%) and membrane integrity (51.90%) and highest activities of peroxidase (37.08 change in OD/g/min.) and catalase (31.06µg H_2O_2/g/min.). Decrease in fragrance level was noticed in the Control. All treatments recorded a fragrance score of '2' (mild) at 36 hours after packaging.

Shelf-life of jasmine flowers

Among packing boxes, Box A (B_1) exhibited maximum shelf life of 35.63h. Among chemical treatments, boric acid 4% (T_4) recorded higher shelf life of 40.96h

Table 1. Effect of chemical treatment and thermocol packaging on freshness index and flower opening index of *J. sambac*

Packing Treatment	Freshness index								Flower opening index							
	24 hours after packing				36 hours after packing				24 hours after packing				36 hours after packing			
	B_1	B_2	B_3	Mean	B_1	B_2	B_3	Mean	B_1	B_2	B_3	Mean	B_1	B_2	B_3	Mean
T_1	74.21	74.36	70.22	72.93	42.85	41.28	30.22	38.12	53.75	56.25	50.00	53.33	75.15	80.00	75.50	76.88
	(59.58)	(59.68)	(56.99)	(58.75)	(40.88)	(39.97)	(33.33)	(38.06)	(47.15)	(48.60)	(45.00)	(46.92)	(60.21)	(63.62)	(60.44)	(61.42)
T_2	77.81	74.00	71.31	74.37	42.18	42.14	30.14	38.15	41.25	43.75	50.00	45.00	75.00	80.00	75.00	76.67
	(62.04)	(59.44)	(57.68)	(59.72)	(40.49)	(40.47)	(33.28)	(38.08)	(39.95)	(41.40)	(45.00)	(42.12)	(60.11)	(63.62)	(60.11)	(61.28)
T_3	85.17	80.11	78.96	**81.41**	**73.22**	70.41	70.14	**71.26**	**15.00**	**0**	**0**	**5.00**	**42.50**	**45.00**	**15.00**	**34.17**
	(67.72)	(63.70)	(62.86)	(64.76)	(58.92)	(57.11)	(56.94)	(57.66)	(22.77)	(1.65)	(1.65)	(8.69)	(40.68)	(42.12)	(22.77)	(35.19)
T_4	84.32	81.26	79.32	**81.63**	**74.15**	70.82	70.28	**71.75**	**15.00**	**0**	**0**	**5.00**	**36.25**	**38.75**	**12.50**	**29.17**
	(67.00)	(64.57)	(63.12)	(64.90)	(59.54)	(57.37)	(57.03)	(57.98)	(22.77)	(1.65)	(1.65)	(8.69)	(37.01)	(38.49)	(20.69)	(32.06)
T_5	70.82	72.85	73.21	72.29	41.25	40.48	30.77	37.50	48.75	51.25	50.00	50.00	73.12	80.00	15.00	56.04
	(57.37)	(58.68)	(58.92)	(58.32)	(39.95)	(39.50)	(33.68)	(37.71)	(44.28)	(45.71)	(45.00)	(45.00)	(58.86)	(63.62)	(22.77)	(48.42)
T_6	72.31	74.28	72.85	73.15	46.25	37.62	31.28	38.38	45.00	47.50	50.00	47.50	74.15	78.00	75.50	75.88
	(58.33)	(59.62)	(58.68)	(58.88)	(42.84)	(37.82)	(33.99)	(38.22)	(42.12)	(43.56)	(45.00)	(43.56)	(59.54)	(62.18)	(60.44)	(60.72)
T_7	72.84	73.85	71.28	72.66	43.75	33.51	28.14	35.13	41.25	43.75	50.00	45.00	75.00	79.00	75.00	76.33
	(58.67)	(59.34)	(57.66)	(58.56)	(41.40)	(35.36)	(32.02)	(36.26)	(39.95)	(41.40)	(45.00)	(42.12)	(60.11)	(62.89)	(60.11)	(61.03)
T_8	73.22	74.28	73.14	73.55	42.50	32.16	28.24	34.30	42.50	45.00	50.00	45.83	75.00	80.00	75.00	76.67
	(58.92)	(59.62)	(58.87)	(59.14)	(40.68)	(34.53)	(32.09)	(35.76)	(40.68)	(42.12)	(45.00)	(42.60)	(60.11)	(63.62)	(60.11)	(61.28)
T_9	80.12	79.23	74.28	77.88	69.96	32.71	28.14	43.60	33.75	36.25	50.00	40.00	74.50	80.00	80.00	78.17
	(63.71)	(63.06)	(59.62)	(62.13)	(56.82)	(34.87)	(32.02)	(41.24)	(35.50)	(37.01)	(45.00)	(39.17)	(59.77)	(63.62)	(63.62)	(62.34)
T_{10}	80.31	79.14	76.31	78.59	70.12	32.71	28.24	43.69	45.00	47.50	50.00	47.50	73.15	75.00	80.00	76.05
	(63.85)	(62.99)	(61.00)	(62.61)	(56.92)	(34.87)	(32.09)	(41.29)	(42.12)	(43.56)	(45.00)	(43.56)	(58.88)	(60.11)	(63.62)	(60.87)
T_{11}	70.41	70.82	70.11	70.45	41.28	32.71	28.14	34.04	48.75	51.25	50.00	50.00	75.00	79.00	75.00	76.33
	(57.11)	(57.37)	(56.92)	(57.13)	(39.97)	(34.87)	(32.02)	(35.62)	(44.28)	(45.71)	(45.00)	(45.00)	(60.11)	(62.89)	(60.11)	(61.03)
T_{12}	78.52	70.14	70.86	73.17	41.50	34.56	28.28	34.78	46.25	48.75	50.00	48.33	75.00	78.00	75.00	76.00
	(62.55)	(56.94)	(57.40)	(58.96)	(40.09)	(35.99)	(32.11)	(36.07)	(42.84)	(44.28)	(45.00)	(44.04)	(60.11)	(62.18)	(60.11)	(60.80)
Mean	76.67	75.36	73.49	75.17	52.42	41.76	36.00	43.39	39.69	39.87	41.67	40.21	**68.65**	72.73	**60.71**	67.36
	(61.40)	(60.42)	(59.14)	(60.32)	(46.54)	(40.23)	(36.72)	(41.16)	(38.70)	(36.39)	(37.77)	(37.62)	(56.29)	(59.08)	(51.24)	(55.54)

	SED	CD 5%	CD 1%	SED	CD 5%	CD 1%	SED	CD 5%	CD 1%	SED	CD 5%	CD 1%
Packing (B)	0.96	NS	NS	0.53	1.07*	1.42**	0.47	0.94*	1.25**	0.90	1.80*	2.39**
Treatment (T)	1.93	3.86*	5.13**	1.07	2.14*	2.84**	0.94	1.88*	2.50**	1.80	3.60*	4.78**
BXT	3.35	NS	NS	1.86	3.71*	4.93**	1.64	3.27*	4.34**	3.13	6.24*	8.29**

Values in parentheses are arcsine transformed

T_1 - Sucrose 2%
T_2 - Sucrose 4%
T_3 - Boric acid 2%
T_4 - Boric acid 4%
T_5 - Salicylic acid 25 ppm
T_6 - Salicylic acid 50 ppm
T_7 - Ascorbic acid 50 ppm
T_8 - Ascorbic acid 100 ppm
T_9 - NAA 50 ppm
T_{10} - NAA 100 ppm,
T_{11} - Distilled water
T_{12} - Control

B_1 - Box A
B_2 - Box B
B_3 - Box C

Table 2 . Effect of chemical treatment and thermocol packaging on colour retention index and fragrance of *J. sambac*

Packing	Colour Retention Index (%)								Fragrance score					
Treatment	24 hours after packing				36 hours after packing				24 hours after packing			36 hours after packing		
	B_1	B_2	B_3	Mean	B_1	B_2	B_3	Mean	B_1	B_2	B_3	B_1	B_2	B_3
T_1	66.66 (54.77)	55.55 (48.19)	66.60 (54.74)	62.94 (52.57)	44.44 (41.80)	44.44 (41.80)	33.33 (35.25)	40.74 (39.61)	2	2	2	2	2	2
T_2	66.66 (54.77)	66.66 (54.77)	66.66 (54.77)	66.66 (54.77)	44.44 (41.80)	44.44 (41.80)	33.33 (35.25)	40.74 (39.61)	2	2	2	2	2	2
T_3	100 (71.23)	88.88 (71.23)	92.00 (71.23)	88.88 (71.23)	88.88 (62.01)	77.77 (62.01)	77.77 (62.01)	77.77 (62.01)	2	2	2	2	2	2
T_4	100 (71.23)	88.88 (71.23)	92.00 (71.23)	88.88 (71.23)	88.88 (62.01)	77.77 (62.01)	77.77 (62.01)	77.77 (62.01)	2	2	2	2	2	2
T_5	66.66 (54.77)	55.55 (48.19)	66.66 (54.77)	62.96 (52.58)	44.44 (41.80)	44.44 (41.80)	33.33 (35.25)	40.74 (39.61)	2	2	2	2	2	2
T_6	66.66 (54.77)	55.55 (48.19)	55.55 (48.19)	59.25 (50.38)	44.44 (41.80)	44.44 (41.80)	33.33 (35.25)	40.74 (39.61)	2	2	2	2	2	2
T_7	66.66 (54.77)	55.55 (48.19)	66.66 (54.77)	62.96 (52.58)	44.44 (41.80)	44.44 (41.80)	33.33 (35.25)	40.74 (39.61)	2	2	2	2	2	2
T_8	66.66 (54.77)	55.55 (48.19)	66.66 (54.77)	62.96 (52.58)	44.44 (41.80)	44.44 (41.80)	33.33 (35.25)	40.74 (39.61)	2	2	2	2	2	2
T_9	88.88 (71.23)	77.77 (62.01)	77.77 (62.01)	81.47 (65.08)	77.77 (71.23)	66.66 (71.23)	66.66 (54.77)	81.47 (65.74)	2	2	2	2	2	2
T_{10}	88.88 (71.23)	77.77 (62.01)	77.77 (62.01)	81.47 (65.08)	77.77 (71.23)	66.66 (71.23)	66.66 (54.77)	81.47 (65.74)	2	2	2	2	2	2
T_{11}	66.66 (54.77)	55.55 (48.19)	55.55 (48.19)	59.25 (50.38)	44.44 (41.80)	44.44 (41.80)	33.33 (35.25)	40.74 (39.61)	2	2	2	2	2	2
T_{12}	66.66 (54.77)	55.55 (48.19)	55.55 (48.19)	59.25 (53.30)	44.44 (41.80)	44.44 (41.80)	33.33 (35.25)	40.74 (39.61)	3	3	3	2	2	2
Mean	74.07 (60.26)	65.73 (54.88)	69.43 (57.80)	69.74 (57.65)	57.40 (50.07)	57.00 (50.07)	46.29 (44.77)	53.70 (48.31)						

	SED	CD 5%	CD 1%	SED	CD 5%	CD 1%
Packing (B)	1.01	2.03*	2.69**	0.80	1.60*	2.13**
Treatment (T)	2.03	4.06*	5.39**	1.61	3.21*	4.26**
BXT	3.53	NS	NS	2.79	5.57*	7.39**

Fragrance score

- Very strong – 4
- Strong – 3
- Mild – 2
- Least, and undesirable – 1

Values in parentheses are arcsine transformed

Table 3. Effect of chemical treatment and thermocol packaging on physiological loss in weight and moisture content in *J. sambac*

Packing	PLW (%)								Moisture Content (%)							
Treatment	24 hours after packing				36 hours after packing				24 hours after packing				36 hours after packing			
	B_1	B_2	B_3	Mean	B_1	B_2	B_3	Mean	B_1	B_2	B_3	Mean	B_1	B_2	B_3	Mean
T_1	2.59	2.57	2.97	2.71	5.72	5.87	6.98	6.19	51.95	52.05	49.15	51.05	30.00	28.90	21.15	26.68
	(9.25)	(9.22)	(9.91)	(9.46)	(13.82)	(14.01)	(15.31)	(14.38)	(46.11)	(46.18)	(44.51)	(45.60)	(33.19)	(32.50)	(27.37)	(31.02)
T_2	2.21	2.60	2.86	2.56	5.78	5.79	6.99	6.19	54.47	51.80	49.92	52.06	29.53	29.50	21.10	26.71
	(8.54)	(9.27)	(9.73)	(9.18)	(13.90)	(13.91)	(15.31)	(14.37)	(47.56)	(46.03)	(44.95)	(46.18)	(32.90)	(32.88)	(27.33)	(31.04)
T_3	1.48	1.98	2.10	1.85	2.68	2.96	2.99	2.88	59.62	56.08	55.27	56.99	51.25	49.29	49.10	49.88
	(6.98)	(8.08)	(8.32)	(7.79)	(9.41)	(9.90)	(9.94)	(9.75)	(50.56)	(48.50)	(48.03)	(49.03)	(45.71)	(44.59)	(44.48)	(44.93)
T_4	1.56	1.87	2.06	1.83	2.59	2.92	2.97	2.83	59.02	56.88	55.52	57.14	51.91	49.57	49.20	50.23
	(7.17)	(7.85)	(8.24)	(7.75)	(9.25)	(9.82)	(9.91)	(9.66)	(50.21)	(48.96)	(48.18)	(49.12)	(46.09)	(44.75)	(44.54)	(45.13)
T_5	2.91	2.71	2.67	2.76	5.88	5.95	6.92	6.25	49.57	51.00	51.25	50.61	28.88	28.34	21.54	26.25
	(9.81)	(9.47)	(9.39)	(9.56)	(14.02)	(14.11)	(15.24)	(14.46)	(44.75)	(45.57)	(45.71)	(45.34)	(32.49)	(32.15)	(27.64)	(30.76)
T_6	2.76	2.57	2.67	2.67	5.38	6.24	6.87	6.16	50.62	52.00	51.00	51.21	32.38	26.33	21.90	26.87
	(9.55)	(9.22)	(9.39)	(9.39)	(13.40)	(14.45)	(15.18)	(14.35)	(45.35)	(46.15)	(45.57)	(45.69)	(34.67)	(30.86)	(27.88)	(31.14)
T_7	2.71	2.61	2.86	2.73	5.63	6.65	7.19	6.49	50.99	51.70	49.90	50.86	30.63	23.46	19.70	24.60
	(9.47)	(9.28)	(9.73)	(9.49)	(13.71)	(14.93)	(15.54)	(14.72)	(45.56)	(45.97)	(44.94)	(45.49)	(33.59)	(28.95)	(26.33)	(29.62)
T_8	2.67	2.57	2.68	2.64	5.75	6.78	7.18	6.57	51.25	52.00	51.20	51.48	29.75	22.51	19.77	24.01
	(9.39)	(9.22)	(9.41)	(9.34)	(13.86)	(15.08)	(15.53)	(14.82)	(45.71)	(46.15)	(45.68)	(45.85)	(33.04)	(28.31)	(26.38)	(29.24)
T_9	1.98	2.07	2.57	2.21	3.00	6.73	7.19	5.64	56.08	55.46	52.00	54.51	48.97	22.90	19.70	30.52
	(8.08)	(8.26)	(9.22)	(8.52)	(9.96)	(15.02)	(15.54)	(13.51)	(48.50)	(48.14)	(46.15)	(47.60)	(44.40)	(28.57)	(26.33)	(33.10)
T_{10}	1.96	2.08	2.36	2.13	2.99	6.73	7.18	5.63	56.22	55.40	53.42	55.01	49.08	22.90	19.77	30.58
	(8.04)	(8.28)	(8.83)	(8.38)	(9.95)	(15.02)	(15.53)	(13.50)	(48.58)	(48.10)	(46.96)	(47.88)	(44.47)	(28.57)	(26.38)	(33.14)
T_{11}	1.89	2.91	2.98	2.59	5.87	6.73	7.19	6.60	49.29	49.57	49.08	49.31	28.90	22.90	19.70	23.83
	(7.89)	(9.81)	(9.93)	(9.21)	(14.01)	(15.02)	(15.54)	(14.86)	(44.59)	(44.75)	(44.47)	(44.60)	(32.50)	(28.57)	(26.33)	(29.14)
T_{12}	2.14	2.98	2.91	2.68	5.85	6.54	7.17	6.52	54.96	49.10	49.60	51.22	29.05	24.19	19.80	24.35
	(8.40)	(9.93)	(9.81)	(9.38)	(13.99)	(14.81)	(15.52)	(14.77)	(47.85)	(44.48)	(44.77)	(45.70)	(32.60)	(29.45)	(26.40)	(29.48)
Mean	2.24	2.46	2.64	2.45	4.76	5.82	6.40	5.66	53.67	52.75	51.44	52.62	36.69	29.23	25.20	30.38
	(8.55)	(8.99)	(9.33)	(8.96)	(12.44)	(13.84)	(14.51)	(13.60)	(47.11)	(46.58)	(45.83)	(46.51)	(37.14)	(32.51)	(29.78)	(33.14)

	SED	CD 5%	CD 1%	SED	CD 5%	CD 1%		SED	CD 5%	CD 1%		SED	CD 5%	CD 1%		
Packing (B)	0.08	0.17	0.22**	0.13	0.26*	0.35**		0.57	NS	NS		0.37	0.74*	0.99**		
Treatment (T)	0.17	0.34	0.45**	0.26	0.52*	0.70**		1.14	2.28	3.02		0.74	1.49*	1.98**		
BXT	0.29	0.59	0.78**	0.46	0.91*	1.21**		1.98	NS	NS		1.29	2.58*	3.43**		

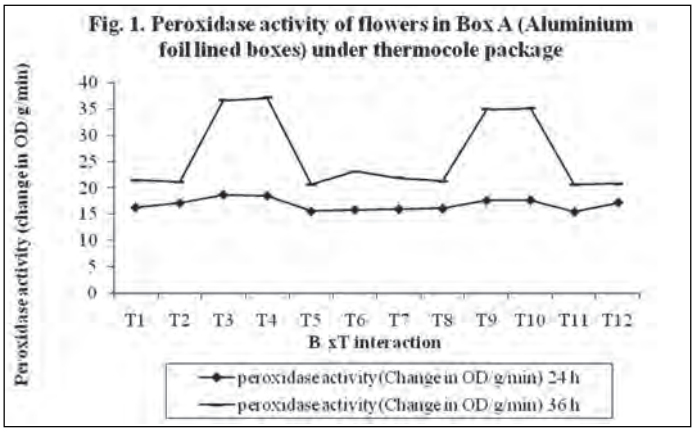
Values in parentheses are arcsine transformed

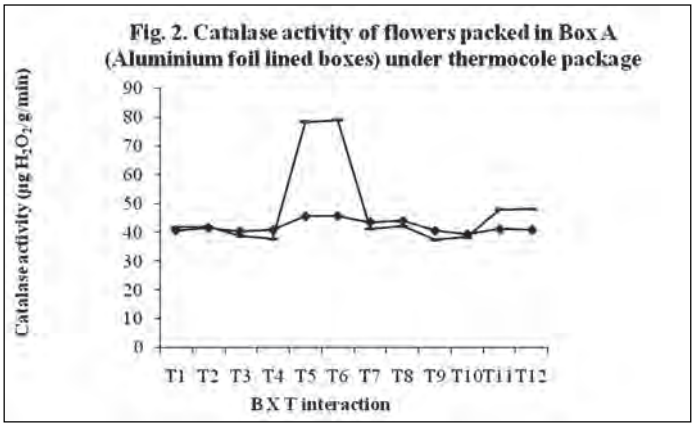
Table 4 . Effect of chemical treatment and thermocol packaging on RWC and MI of *J. sambac* under gel-ice cold condition

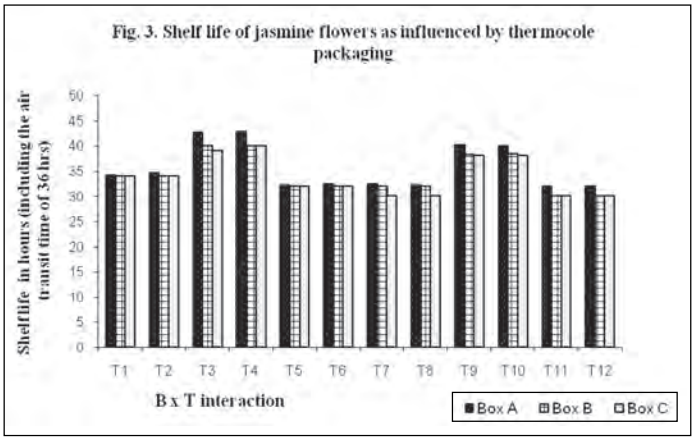
Packing	RWC (%)								Membrane Integrity (% of solute leakage)							
Treatment	24 hours after packing				36 hours after packing				24 hours after packing				36 hours after packing			
	B_1	B_2	B_3	Mean	B_1	B_2	B_3	Mean	B_1	B_2	B_3	Mean	B_1	B_2	B_3	Mean
T_1	77.92	78.08	73.73	76.58	44.99	43.34	31.73	40.02	62.86	62.74	68.99	64.86	77.01	78.21	86.73	80.65
	(62.12)	(62.23)	(59.26)	(61.20)	(42.12)	(41.16)	(34.27)	(39.18)	(52.48)	(52.40)	(56.21)	(53.70)	(61.48)	(62.33)	(69.11)	(64.31)
T_2	81.70	77.70	74.88	78.09	44.29	44.25	31.65	40.06	60.09	63.04	68.09	63.74	77.52	77.55	86.79	80.62
	(64.90)	(61.96)	(60.02)	(62.30)	(41.71)	(41.69)	(34.22)	(39.21)	(50.84)	(52.58)	(56.65)	(53.02)	(61.84)	(61.86)	(69.17)	(64.29)
T_3	89.43	84.12	82.91	**85.49**	76.88	73.93	73.65	**74.82**	**44.42**	48.32	49.20	**47.31**	**50.62**	51.78	55.99	**52.80**
	(71.82)	(66.83)	(65.85)	(68.17)	(61.39)	(59.39)	(59.20)	(60.00)	(41.79)	(44.03)	(44.54)	(43.45)	(45.35)	(46.02)	(48.45)	(46.61)
T_4	88.54	85.32	83.29	**85.72**	77.86	74.36	73.79	**75.34**	**45.07**	47.43	48.92	**47.14**	**51.90**	51.47	55.88	**53.08**
	(70.87)	(67.86)	(66.16)	(68.29)	(62.08)	(59.68)	(59.30)	(60.35)	(42.16)	(43.52)	(44.54)	(43.35)	(46.09)	(45.84)	(48.38)	(46.77)
T_5	74.36	76.49	76.87	75.91	43.31	42.50	32.31	39.37	65.47	63.91	66.48	65.29	78.24	78.83	86.31	81.13
	(59.68)	(61.12)	(61.38)	(60.73)	(41.15)	(40.68)	(34.62)	(38.82)	(54.05)	(53.10)	(54.66)	(53.94)	(62.35)	(62.77)	(68.73)	(64.61)
T_6	75.93	77.99	76.49	76.80	48.56	39.50	32.84	40.30	64.32	62.80	67.43	64.85	74.39	81.03	85.91	80.44
	(60.73)	(62.17)	(61.12)	(61.34)	(44.17)	(38.93)	(34.95)	(39.35)	(53.35)	(52.44)	(55.25)	(53.68)	(59.70)	(64.40)	(68.37)	(64.16)
T_7	76.48	77.54	74.84	76.29	45.94	35.19	29.55	36.89	63.91	63.14	68.11	65.05	76.31	84.20	88.33	82.95
	(61.11)	(61.85)	(60.00)	(60.99)	(42.66)	(36.37)	(32.91)	(37.31)	(53.10)	(52.64)	(55.67)	(53.80)	(61.00)	(66.90)	(70.66)	(66.19)
T_8	76.88	77.99	76.80	77.22	44.63	33.77	29.65	36.02	63.22	62.80	68.68	64.90	77.28	85.24	88.26	83.59
	(61.39)	(62.17)	(61.33)	(61.63)	(41.91)	(35.51)	(32.98)	(36.80)	(52.69)	(52.44)	(56.02)	(53.72)	(61.67)	(67.78)	(70.59)	(66.68)
T_9	84.13	83.19	77.99	81.77	73.46	34.35	29.55	45.79	48.31	48.99	60.80	52.70	52.13	84.81	88.33	75.09
	(66.84)	(66.08)	(62.17)	(65.03)	(59.08)	(35.86)	(32.91)	(42.62)	(44.02)	(44.42)	(51.25)	(46.57)	(46.22)	(67.42)	(70.66)	(61.43)
T_{10}	84.33	83.10	80.13	82.52	73.63	34.35	29.65	45.88	48.16	49.06	62.00	53.07	53.16	84.81	88.26	75.41
	(67.01)	(66.00)	(63.72)	(65.58)	(59.19)	(35.86)	(32.98)	(42.68)	(43.94)	(44.46)	(51.96)	(46.79)	(46.81)	(67.42)	(70.59)	(61.61)
T_{11}	73.93	74.36	73.62	73.97	43.34	34.35	29.55	35.75	65.78	65.47	69.30	66.85	78.21	84.81	88.33	83.78
	(59.39)	(59.68)	(59.18)	(59.42)	(41.16)	(35.83)	(32.91)	(36.65)	(54.23)	(54.05)	(56.41)	(54.90)	(62.33)	(67.42)	(70.66)	(66.80)
T_{12}	82.45	73.65	74.40	76.83	43.58	36.29	29.69	36.52	70.50	65.99	71.22	69.24	78.05	83.39	88.22	83.22
	(65.49)	(59.20)	(59.71)	(61.47)	(41.30)	(37.03)	(33.00)	(37.11)	(57.17)	(54.36)	(56.95)	(56.16)	(62.21)	(66.24)	(56.94)	(61.79)
Mean	80.51	79.13	77.16	78.93	**55.04**	43.85	37.80	45.56	**58.51**	58.64	64.10	60.42	**68.74**	77.18	82.28	76.06
	(64.28)	(63.10)	(63.66)	(63.01)	(48.16)	(41.50)	(37.85)	(42.51)	(49.99)	(50.04)	(56.25)	(51.09)	(56.42)	(62.20)	(65.19)	(61.27)

	SED	CD 5%	CD 1%		SED	CD 5%	CD 1%		SED	CD 5%	CD 1%		SED	CD 5%	CD 1%	
Packing (B)	1.10	NS	NS		0.57	1.15*	1.52**		0.69	1.37*	1.82**		1.13	2.25*	2.99**	
Treatment (T)	2.20	4.39*	5.83**		1.15	2.30*	3.05**		1.38	2.75*	3.65**		2.26	4.51*	5.99**	
BXT	3.81	NS	NS		2.00	3.98*	5.29**		2.39	NS	NS		3.92	7.82*	10.38**	

Values in parentheses are arcsine transformed







Packaging technology adopted for export of jasmine flowers

Loose flower of harvested jasmine

Strung flowers of jasmine

Treating flowers with boric acid 4%

Packing in aluminium-foil lined boxes

Packaging in thermocol boxes with intermittent gel-ice layers

Aluminium-foil lining

Thermocol packages ready for air lifting

Export packages loaded onto reefer vans

[This technology has been filed for patenting (Patent application No.1370/CHE/2010)]

Table 5 . Effect of chemical treatment and thermocol packaging on shelf life (hours) of *J. sambac* under gel-ice cold condition

Packing Treatment	B_1	B_2	B_3	Mean
T_1	34.22	34.00	34.00	34.07
T_2	34.62	34.00	34.00	34.21
T_3	42.60	40.00	39.00	40.53
T_4	42.88	40.00	40.00	40.96
T_5	32.22	32.00	32.00	32.07
T_6	32.26	32.00	32.00	32.09
T_7	32.40	32.00	30.00	31.47
T_8	32.10	32.00	30.00	31.37
T_9	40.20	38.22	38.00	38.81
T_{10}	40.00	38.40	38.00	38.80
T_{11}	32.00	30.00	30.00	30.67
T_{12}	32.00	30.00	30.00	30.67
Mean	35.63	34.39	33.92	34.64
	SED	CD 5%	CD1%	
Packing (B)	0.65	1.31*	1.73**	
Treatment (T)	1.31	2.62*	3.47**	
BXT	2.27	3.54*	5.02**	

Table 6. Economics of export packaging technology per kilogram of *J. sambac* flowers (tested for Long distance market - New Jersey, US)

Particulars of packaging per kg of flowers	Cost (Rs.)
Best Package	
Boric acid 4% + Aluminum foil lined box Packing + Thermocol packaging + gel-ice cold condition	
1. Average cost of flowers/kg	100/-
2. Cost of packaging technology	
2.1. Chemical treatment with 4% boric acid/kg of flowers	20/-
2.2. Packing (Aluminium foil lined boxes)	36/-
2.3. Packaging (Thermocol box)	540/-
2.4. Lining (aluminium foil, gel-ice pads and butter paper)	27/-
2.5. Transport cost (Handling, Clearing & Forwarding and Freight)	153/-
3. Total expenditure (1+2)	876/-
4. Income / kg of flowers (Average: $ 47 per kg of flowers)	2115/-
CBR	1 : 2.5

(Table 5 and Fig. 3). Interaction of B x T indicated that B1T4 (Box A + boric acid 4%) was better, with a shelf life of 42.88h (Table 5, Fig. 3) which was on par with B_1T_3 (42.60h) compared to other treatment interactions and the Control, B_1T_{12} (32.00h).

In the present investigation, it was observed that treatments differed significantly in extending shelf life of *Jasminum sambac* flowers. Among chemical treatments, boric acid proved effective by registering higher levels of moisture, relative water content, lowest rates of PLW, three to six fold increase in activity of peroxidase and catalase, and maximum accumulation of carbohydrates. This, in turn, reduced solute leakage from flowers, indicating increased membrane integrity of flowers. All these factors proved effective in retaining freshness index of flowers, thus delaying wilting. Boric acid was used earlier as a mineral salt that could increase osmotic concentration and pressure potential of petal cells, thus improving their water balance and longevity in cut flowers (Halevy, 1976; Van Meeteren, 1989). In agreement with present findings, the potential of boric acid in prolonging post harvest life of flowers has also been reported in jasmine earlier (Mukhopadhyay *et al*, 1980), *Oncidium* (Tatt, 1982), rose cv. Grussen Teplitz (Kumar and Bhattacharjee, 2002) and carnation (Serrano *et al*, 2006).

In the present study, experiments carried out under gel-ice cold condition in thermocol boxes proved beneficial in maintaining low temperature around the flowers. Among the packaging boxes, aluminium-foil lined boxes proved effective in significantly extending shelf life of jasmine flowers. Cumulative effects of these treatments in thermocol packaging can be summarized as follows:

Treatment	**Beneficial effect**
Chemical treatment (boric acid)	Anti-oxidant effect, improving water balance, delayed ethylene production
Aluminium-foil lined box	Impermeability to water vapor and gases
Gel-ice pads	Creation and maintenance of low temperature in the package; Temperature as measured by hand held hygrometer in the thermocol package: 4.2°C (initial) 16.5°C (final, 36h after packaging)
Thermocol boxes	Thermal insulation, resistance to moisture and weathering

Physiological loss in weight (PLW), moisture content, relative water content (RWC) and membrane integrity of flowers are traits inter-related to each other. Increased PLW leads to decline in fresh weight of flowers, which expresses visually as symptoms of wilting of flowers, as reported in carnation (Nichols, 1966) and *Rosa damascena* (Sharma, 1981). Relative water content of flowers manifests water status of petals. It is obvious that when moisture content is higher and weight loss is lower, relative water content stays high. In the present study, moisture levels of 40 to 50% resulted in 'nil' PLW which, in turn, registered higher relative water content of 70 to 90%. Rapid decline in moisture content of flowers four days after vase-holding was identified as the main cause of flower senescence in *Rosa hybrida*

'Samantha' by Xue and Lin, (1999). Similar reduction in moisture content due to rapid water loss in petals was reported in *Rosa hybrida* too (Carpenter and Rasmussen, 1973) and anthurium cv. Ozaki Red (Paull *et al*, 1985). It has been reported in gladiolus flower senescence that decrease in RWC (Relative Water Content) of tepals caused dehydration of tissues and, in turn, wilting (Zahed Hossain *et al*, 2006).

Catalase (CAT) and peroxidase (POD) activities result in reduced production of H_2O_2 and play a key role in plant antioxidative system (Monk *et al*, 1989). Senescence symptoms are characterized by increased activity of peroxidase enzyme which, in turn, leads to increased production of peroxides and free radicals (Fridovich, 1975). These free radicals are involved in ethylene production (Beauchamp and Fridovich, 1970) and promotion of senescence (Mishra *et al*, 1976). Increased activity of peroxidase and catalase during wilting of florets has been reported earlier in gladiolus (Yamane *et al*, 1999).

Testing suitability of packaging material for export of *J. sambac* and its economics

The best package, B_1T_4, for *J. sambac* was tested for export suitability by M/S Vanguard Exports, located at Coimbatore in Tamil Nadu, India, to the US market and was found to be suitable, with acceptable levels of flower freshness, colour and fragrance. This packaging technology for export to a long-distance market (New Jersey) was also found to be economically feasible, with cost:benefit ratio of 1:2.5 (Table 6).

Conclusion

From the present investigation, it may be concluded that for the export of *J. sambac* flowers, a packaging technology of treatment with 4% boric acid + packing in aluminum-foil lined boxes and, further packaging in Thermocol under gel-ice cold condition, was found to be highly suitable. Flowers in this package recorded shelf life of 42.88h, with a cost:benefit ratio of 1:2.5.

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