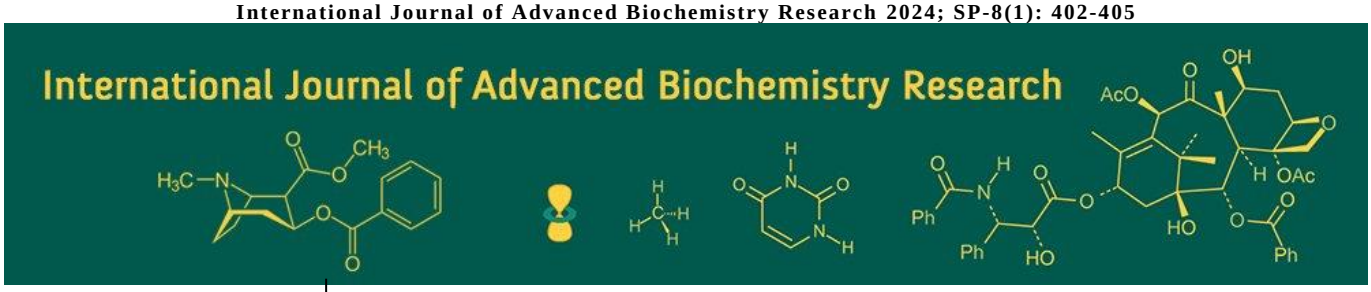

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Cold stored cut spikes influenced by different storage techniques in rose CVs. Bordeaux, poison and avalanche

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Abstract
To evaluate best storage technology, an experiment was conducted on post-harvest studies in rose cv. Bordeaux, Poison and Avalanche. Rose cut flowers were cold stored (at 2°C) techniques comprising of seal packaging of cut spikes with HDPE, LDPE, PP (polypropylene) and without packaging and rose flower cut stems kept in water, $Al_2(SO_4)_3$ 200 ppm and citric acid 200 ppm solutions to study flower quality and vase life Cvs., Bordeaux, Poison and Avalanche for the storage period of 10 days. The 10 days cold stored rose cut flowers were compared with fresh flowers during vase life for different parameters. All three packaging films *viz*., HDPE, LDPE and PP showed promising results in maintaining flower quality and recorded significantly higher water uptake after 10 days of cold storage at 2 °C compared to other storage techniques and fresh flowers. Rose cut spikes packed with PP packaging and stored at 2 °C recorded higher retention of fresh weight, membrane stability index, total soluble sugar content, protein content, anthocyanin content, CAT activity and POX activity during vase life as compared to other storage techniques in the study. Rose cut spikes held in different vase solution during low temperature storage showed advanced flower stage with decrease in vase life upon removal from low temperature storage after 10 days of storage. Thus PP packed cold stored rose flowers retained best flower quality as well as showed higher vase life as compared to the rose flowers stored with other treatments.

Keywords: Rose, polypropylene, low temperature storage, vase life, dry storage and wet storage

Introduction
Roses (*Rosa hybrida* L.) are the most important cut flower grown around the world. Roses called "The Queen of Flowers" are important ornamental crops because of theirs high commercial value and widespread cultivation. Rose is the most popular ornamental flower all over the world, which is used as garden plants and cut flowers (Hong *et al.,* 2021) [12]. Nearly, 30-50 percent of cut flowers loss due to improper postharvest handling during entire market chain (Singh *et al.*, 2007) [24]. However, export of roses via sea shipment is limited due its shorter vase life and deterioration in flower quality (Mor *et al.*, 1989, van Doorn and d' Hont, 1994) and chilling injury (Pompodakis *et al.*, 2010) [17, 28, 22] at low temperature storage. Moreover, it may promote ethylene production that further promotes senescence in rose (Faragher *et al.*, 1986, Devechhi *et al.*, 2003) [8, 6]. Plant growth regulators plays and important role in quality of flower and extending storage life of rose cut flowers (Sharma, 2023). Seal packaging of cut flowers with polyfilms at low temperature helps to create modified atmospheric conditions (Farber *et al*., 2003) [9] that has been found beneficial in retaining flower quality, improving opening ability, reducing water loss during post storage phase in stored flowers like rose (Singh *et al*., 2012 and Makwana *et al*., 2015) gladiolus (Grover *et al*., 2005, Singh *et al*., 2007) [25, 15, 24, 11], Solidago Canadensis (Zeltzer *et al*., 2001) [29] and in Lisianthus (Akbudak *et al*., 2005) [2]. Stated that higher CO_2 and lower O_2 during storage period decrease the production of ethylene and extended the life of fresh produce. Such beneficial conditions in orchid flowers showed promising results and maintained flower quality after completing of storage duration. A strategic research on flower quality and storage aspects with respect to development best storage technology is much needed to meet the domestic as well as overseas market demand, hence this experiment was laid out to evaluate best low temperature storage technique along with packing material for rose cut flower.

Materials and Methods

Location and pant material: Fresh rose cut spikes of cvs. Bordeaux, Poison and Avalanche were cut and taken from greenhouse, Navsari Agricultural University, Navsari and were brought to the Floriculture Laboratory, College of Horticulture and Forestry, NAU Navsari at an ambient room temperature (18-21 °C). The experiment was laid down in completely randomized block with factorial design.

Packaging and storage of flowers: There were total eight treatments of which each treatment was repeated three times. Cut roses at uniform bud size, fresh weight (10±2 g) and stem length (50±5 cm) were selected and divided into seven groups each having 30 flowers (10 in each replications) and are subjected to different storage treatments. As per the storage treatments these bunches were seal packaged with High Density Poly Ethylene (HDPE), Low Density Poly Ethylene (LDPE), Polypropylene (PP) and without any packaging for dry storage whereas for wet storage there bunches of thirty flowers for each were dipped in Alluminium Sulphate 200 mg/l [$Al_2(SO_4)_3$], citric acid 200 mg/l and water. All bunches *viz*., wet and dry storage were moved to cold storage for 10 days at 2 °C temperature. After 10 days of storage duration, the flowers were taken out from cold storage, re-cut of 2 cm from the base was given and flowers were kept in distilled water at room temperature for taking observations and recording data. Fresh flowers of cultivars Bordeaux, Poison and Avalanche as control bought from the same greenhouse and held in distilled water in order to compare with treated and stored flowers.

Observations: Different postharvest parameters regarding quality of flowers were recorded at different intervals during vase life. Observations on post-harvest parameters like Change in fresh weight (%), water uptake (ml) and membrane stability index (MSI) were recorded 2nd day after storage. Total soluble sugar, Protein content in petals, anthocyanin content, CAT and POX activity of petals at 4th DAS during vase life. MSI was calculated on the basis of electrolyte leakage (ion leakage) of petals. One ml of water was used to measure the TSS of the petals from the solution prepared for electrolyte leakage as per the method given by Franscistt *et al.*, (1971) [10]. Protein concentration of each enzyme extract and seed protein was estimated by method of Lowry *et al.* (1951) [14]. Anthocyanins were extracted from the petals and determined by following the method described by Lees and Francis (1972) [13]. Total catalase activity was determined in the homogenates by measuring the decrease in absorption in 3ml mixture at 240nm as H_2O_2 (ε = 39.4 mM^{-1} cm^{-1}) was consumed according the method of Aebi (1984) [1] and enzyme activity expressed as µmol H_2O_2 oxidized min^{-1} g^{-1} protein. POD activity was determined in the homogenates by measuring the increase in absorption at 470nm due to the formation of tetraguaiacol (ε = 26.6 mM^{-1} cm^{-1}) in a reaction mixture containing 50mM sodium phosphate buffer pH 7.0, 0.1mM EDTA, 0.1ml enzyme extract, 10mM guaiacol and 10mM H_2O_2 (Costa *et al*., 2002) [5].

Results and Discussion

Polyfilm packed rose cut flowers were effective in retaining post-harvest physiology that lead to improved post storage flowers quality and vase life compared to other storage techniques after 10 days of low temperature storage. Storage techniques significantly influence change in fresh weight, water uptake and MSI at 2nd DAS (Table 1). After completion of 10 day of storage duration at 2 ^{0}C, stored flower were compared with fresh flowers and fresh flowers recorded highest retention of fresh weight (12.57%) and MSI (75.36%) which was at par with rose cut spikes wrapped with PP packaging retention of fresh weight (12.37%) and MSI (75.22%) at 2nd DAS compared to other storage techniques while cut flowers kept cold stored without any packaging suffered severe physiological loss of weight with lower MSI during same course of storage time. In terms of varieties cv. Bordeaux showed promising results amongst all three varieties in the study for change in fresh weight and MSI. Interaction of rose cv. Bordeaux cut spikes packed with polypropylene and cold stored at 2^0C temperature recorded higher retention of fresh weight (13.39%) and MSI (75.22%) after 10 days of cold storage. Among all the treatments, cut spikes stored with all three packaging films *viz*., HDPE, LDPE and PP recorded significantly higher total water uptake (ml) at 2nd DAS (67.50 ml, 67.62 ml and 67.82 ml) whereas wet stored spikes and without any packaging recorded significantly lower water uptake while, in case of varieties cv. Bordeaux recorded significantly higher water uptake (48.17ml). The interaction of all three varieties wrapped with HDPE, LDPE and polypropylene and cold stored measured significantly higher water uptake compared with other storage techniques as well as control.

Seal packed fresh produce in poly films is known to create modified internal gaseous components passively (Farber *et al*.,), that helps in minimizing metabolic activities during storage and retains fresh produce in normal condition (Zeltzer *et al*., 2001) [29]. Thus, PP, HDPE and LDPE packaging contributed in maintaining higher water uptake as well as maintained fresh weight and higher MSI in stored cut flowers during vase life. Packaging with poly films have been earlier known to enhance water uptake after cold storage as well as retain fresh weight in gladiolus cut spikes (Singh *et al*., and Grover *et al*.,), gerbera (Patel and Singh, 2009) [20] and Solidago (Zeltzer *et al*., 2001) [29] and rose (Makwana *et al*., 2015) [15].

Data depicted in Table 2 showed significant influence of storage techniques and varieties on flower parameters like total soluble sugar (mg/g fresh weight), Protein content (mg/g fresh weight) and Anthocyanin content of petals (mg/g fresh weight) at 4th DAS. Fresh flowers recorded significantly higher total soluble sugar (51.38 mg/g fresh weight), Protein content (16.49 mg/g fresh weight), Anthocyanin content of petals (10.24 mg/g fresh weight) which was at par with cut spikes packed with polypropylene in total soluble sugar (50.83 mg/g fresh weight), Protein content (16.14 mg/g fresh weight), Anthocyanin content of petals (10.13 mg/g fresh weight) in cold stored rose cut spikes for 10 days. In case of varieties, cv. Bordeaux recorded significantly higher total soluble sugar (43.95 mg/g fresh weight), Protein content (16.32 mg/g fresh weight), Anthocyanin content of petals (12.75 mg/g fresh weight). In case of interaction effect PP packaged rose cut flowers cv. Bordeaux recorded significantly higher total soluble sugar (53.63 mg/g fresh weight), Protein content (18.07 mg/g fresh weight), Anthocyanin content of petals (14.10 mg/g fresh weight) amongst all the storage techniques which was at par with fresh flowers. According to Oloo-Abucheli *et al.*, (2017) [18] anthocyaninc content is highly affected by environmental conditions in rose. Higher Anthocyanin content can be attributed to better environmental conditions within the packaging and retention of higher fresh weight

and petal tissue integrity as evidenced from retained MSI level. The enhanced water uptake by fresh rose cut flowers and in cut roses that were PP packaged might have increased the cell-turgidity and cell enlargement leading to petal expansion as also observed earlier in gladiolus (Grover *et al.*, 2009) [11], gerbera (Patel and Singh, 2009) [20] and rose (Makwana *et al.*, 2015) [15].

Significant influence of storage techniques was observed on CAT/ POD activity and vase life. Fresh flowers recorded significantly higher CAT activity (16.34), POD activity (37.52) and vase life (4.86 days) which was at par with PP packed cut flowers and stored for 10 days (16.05, 37.31 and 4.77 days) respectively (Table III). While in case of varieties cv. Bordeaux recorded significantly higher CAT activity (11.62), POD activity (24.33) and vase life (3.63 days). Amongst all the storage techniques cut spikes packaged with PP cv. Bordeaux recorded higher CAT activity (18.63), POD activity (35.90) and vase life (5.17 days). High activity with progressive decrease in catalase and peroxidase activity and protein content was observed in control as compared to all other treatments. Catalase and peroxidase enzymatic activities play protective role on membrane structure due to oxidative stress in plant cells (Droillard *et al.*, 1987) [21]. These enzymatic activities are known to be maintained higher in the initial phase and gradually decline with approaching senescence as reported in pea leaves (Pastori and Del Rio, 1997) [19] and sunflower (Bailly *et al.*, 1996) [3]. Oxidative stress in petal cells leads to the formation of H_2O_2 and hydroxyl radical that are toxic to the membranous structure of cellular components by catalyse while peroxidase liberates free radical by Catylising H_2O_2. Catalase Peroxidase activity is considered to be detoxification process for high H_2O_2 levels (Paulin and Droillard, 1989) [7]. The condition (similar to fresh flowers) might have contributed in maintenance of membranous bract structure of cell organelles. The maintained higher fresh weight, higher water uptake, TSS, MSI and cell structure contributed to the retained higher CAT and POD activities and protein content and ultimately longer vase life in cold stored rose cut flowers.

Table 1: Effect of different storage techniques on Change in fresh weight (%), Water uptake (ml) and Membrane stability index (%) at 2nd DAS in rose (cv. Bordeaux, Poison and Avalanche)

Treatment	Change in fresh weight (%) at 2nd DAS				Water uptake (ml) at 2nd DAS				Membrane stability index (%) at 2nd DAS			
	V_1	V_2	V_3	MEAN	V_1	V_2	V_3	MEAN	V_1	V_2	V_3	MEAN
T_0 (Control)	13.44	12.41	11.88	12.57	62.13	60.93	59.63	60.90	78.82	74.88	72.37	75.36
T_1 (HDPE)	12.84	11.47	10.94	11.75	68.02	67.82	66.67	67.50	78.28	74.39	71.89	74.85
T_2 (LDPE)	13.03	11.66	11.13	11.94	68.72	67.77	66.37	67.62	78.64	74.28	71.91	74.94
T_3 (Polypropylene)	13.39	12.12	11.59	12.37	68.97	67.88	66.60	67.82	78.78	74.64	72.25	75.22
T_4 (Water)	9.74	8.37	8.51	8.87	33.18	31.68	28.63	31.17	64.84	58.15	51.42	58.13
T_5 (200 mg/l $Al_2(SO_4)_3$)	11.01	10.63	9.90	10.51	37.05	32.67	36.73	35.48	69.67	65.02	65.55	66.74
T_6 (200 mg/l Citric acid)	11.50	10.94	10.74	11.06	34.27	33.02	34.32	33.87	67.52	66.41	63.00	65.64
T_7 (Without any packaging)	-27.41	-25.78	-29.14	-27.44	13.02	11.62	10.18	11.61	28.10	22.46	25.06	25.21
Mean	7.19	6.48	5.69		48.17	46.67	46.14		68.08	63.78	61.68	
	T	V	T x V		T	V	T x V		T	V	T x V	
CD (p=0.05)	0.38	0.23	0.47		1.14	0.70	1.39		2.11	1.29	2.58	

*DAS: Days after storage

Table 2: Effect of different storage techniques on Total soluble sugar, Protein content (mg/g fresh weight), Anthocyanin content of petals (mg/g fresh weight) at 4th DAS in rose (cv. Bordeaux, Poison and Avalanche)

Treatment	Total soluble sugar				Protein content (mg/g fresh weight)				Anthocyanin content of petals (mg/g fresh weight)		
	V_1	V_2	V_3	Mean	V_1	V_2	V_3	Mean	V_1	V_2	Mean
T_0 (Control)	54.18	50.94	49.02	51.38	18.60	16.43	14.45	16.49	14.21	6.27	10.24
T_1 (HDPE)	52.38	49.14	47.22	49.58	17.15	15.12	13.33	15.20	13.52	5.54	9.53
T_2 (LDPE)	52.58	49.34	47.42	49.78	17.44	15.70	13.49	15.55	13.22	5.38	9.30
T_3 (Polypropylene)	53.63	50.39	48.47	50.83	18.07	16.18	14.18	16.14	14.10	6.17	10.13
T_4 (Water)	35.73	35.63	34.43	35.27	14.97	12.65	11.63	13.09	12.54	4.58	8.56
T_5 (200 mg/l $Al_2(SO_4)_3$)	41.08	38.90	34.64	38.21	15.84	13.38	12.50	13.91	12.92	4.82	8.87
T_6 (200 mg/l Citric acid)	39.24	36.69	34.75	36.89	15.99	13.81	12.80	14.20	12.84	4.75	8.79
T_7 (Without any packaging)	22.77	19.53	17.61	19.97	12.49	10.28	10.81	11.19	8.62	3.32	5.97
MEAN	43.95	41.32	39.20		16.32	14.19	12.90		12.75	5.10	
	T	V	T x V		T	V	T x V		T	V	T x V
CD (p=0.05)	1.00	0.61	1.23		0.35	0.22	0.43		0.27	0.09	0.27

Table 3: Effect of different storage techniques on Catalase activity (µ mol H_2O_2 min^{-1} g^{-1} protein), Peroxidation activity (µ mol H_2O_2 min^{-1} g^{-1} protein) and vase life in rose (cv. Bordeaux, Poison and Avalanche)

Treatment	Catalase activity (µ mol H_2O_2 min^{-1} g^{-1} protein)				Peroxidation activity (µ mol H_2O_2 min^{-1} g^{-1} protein)				Vase life			
	V_1	V_2	V_3	Mean	V_1	V_2	V_3	mean	V_1	V_2	V_3	mean
T_0 (Control)	19.01	15.64	14.39	16.34	38.60	36.48	37.48	37.52	5.30	4.97	4.30	4.86
T_1 (HDPE)	18.63	14.91	13.51	15.68	35.90	33.25	34.12	34.42	5.07	4.57	4.00	4.55
T_2 (LDPE)	18.53	15.18	13.36	15.69	36.20	34.41	35.46	35.36	4.97	4.37	3.90	4.42
T_3 (Polypropylene)	18.83	15.22	14.10	16.05	38.22	36.31	37.41	37.31	5.17	4.87	4.27	4.77
T_4 (Water)	5.42	4.73	5.30	5.15	12.94	14.30	8.60	11.95	2.10	1.97	2.00	2.03
T_5 (200 mg/l $Al_2(SO_4)_3$)	5.70	5.27	5.30	5.42	14.77	16.21	13.24	14.74	2.57	2.40	2.27	2.42

T_6 (200 mg/l Citric acid)	5.54	5.22	5.48	5.41	14.30	15.99	12.21	14.17	2.37	2.17	2.31	2.38
T_7 (Without any packaging)	1.30	1.57	0.96	1.28	3.75	7.66	2.98	4.80	1.50	1.30	1.40	1.40
MEAN	11.62	9.72	9.05		24.33	24.33	22.69		3.63	3.33	3.09	
	T	V	T x V		T	V	T x V		T	V	T x V	
CD (p=0.05)	0.45	0.28	0.55		0.29	0.12	0.24		0.11	0.07	0.13	

Conclusion

PP (polypropylene) as packing film for rose cut spikes (cv. Bordeaux, Poison and Avlanche) and cold stored at 2ºC temperature for duration of 10 days helps in maintaining flower quality equivalent to fresh flowers with maintained visual appearance, qualitative and quantitative parameters.

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