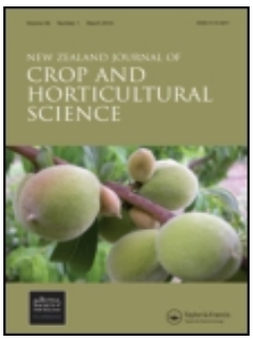

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Normal and modified atmosphere packaging storage of lisianthus (*Lisianthus grandiflorum*) grown in saline conditions

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Abstract In this study, sodium chloride (NaC1) (0, 2, 4, and 8 dS m^{-1}) was applied to 'Pure White' and 'Pink Picotee' lisianthus (*Lisianthus grandiflorum*) at two different stages (vegetative and generative) with drip irrigation. The flowers subjected to NaC1 were stored under normal atmosphere (NA) and modified atmosphere packaging (MAP) conditions with 5 ± 0.5°C and 80 ± 5% relative humidity (RH). At the end of the study, the best results for the quality criteria determined in the research were obtained from the 4 dS m^{-1} treatment under NA and the 2 dS m^{-1} treatment under MAP in 'Pure White'. Considering the same quality criteria, the 2 dS m^{-1} treatment gave the best result in 'Pink Picotee' at the end of NA, whereas 4 dS m^{-1} treatment was found more effective compared with the other treatments in MAP. Moreover, it was determined that the flowers of 'Pure White' could be stored successfully for 2–3 weeks in NA and 5 weeks in MAP, whereas the flowers of 'Pink Picotee' could be stored successfully for 2 weeks in NA and 3–4 weeks in MAP.

Keywords *Lisianthus grandiflorum*; NaC1; preharvest treatment; quality parameters; storage

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INTRODUCTION

Sodium chloride (NaC1) is effective in almost all physiological processes related to plant growth and development. Different physiological processes begin in plant growth and development as a result of NaC1 treatment (Hale & Orcutt 1987). Leaf areas reduce with increasing NaC1 concentrations (Jimenez et al. 1997; Morales et al. 1998). Shillo et al. (2002) also investigated the effects of 2–6 dS m^{-1} NaC1 treatments on morphological parameters in lisianthus (*Lisianthus grandiflorum* Raf. Shinn). The researchers determined that low NaC1 concentrations caused increases in stem weight and number of flowers per stem.

Low temperature is recognised as the most important factor in the successful storage of cut flowers by reducing plant metabolic processes. Modified atmosphere packaging (MAP) is supplemental to refrigeration, thus increasing the efficiency of refrigeration in extending the storage life of cut flowers. Ranges of non-damaging O_2 and CO_2 levels have been studied for a number of flowers and ornamentals (Seaton & Joyce 1993; Meir et al. 1995; Nagaraja et al. 2000; Redman et al. 2002).

In this study, we aimed to investigate the effects of MAP and NaC1 applied at different concentrations during the preharvest period on the postharvest quality and vase life of 'Pure White' and 'Pink Picotee' lisianthus in terms of physiological and morphological changes. In this way, postharvest endurance and vase life of lisianthus plants in response to growing in salty regions or to irrigation with saline water would be determined.

MATERIALS AND METHODS

In the study, 'Pure White' and 'Pink Picotee' lisianthus cultivars were used. Pelleted F_1 hybrid seeds of these cultivars were supplied from Sakata Seed Company. 'Pure White' has double white flowers, whereas 'Pink Picotee' has double white flowers with pink margins. Both cultivars have a stem length of 60–70 cm (Anon. 1998).

The seeds were sown into sterile seed-sowing peat (pH 5.5) and covered with a thin layer of vermiculite. The resulting seedlings were transplanted into pots (3.5 cm diam.) (Tanigawa et al. 2001) at the 2–4-leaf-stage, and to their final places (14 cm diam.) 1 month later. The seedlings were kept there for 8 weeks. Peat:perlite (1:1 (v:v)) was used as the potting mixture. Cultural practices were applied regularly according to Roh & Lawson (1984).

Irrigation (during vegetation) and NaC1 treatments (0: control (EC of greenhouse irrigation water = 0.5 ± 0.1 dS m^{-1}), 2, 4, and 8 dS m^{-1} at two stages (vegetative and generative)) during the growth stage were carried out with drip irrigation.

At the end of the 8-week growing period, the flowers were harvested and brought into the Cold Storage Research and Application Unit of the Department of Horticulture. The flowers below standard were removed and the initial analyses were carried out. The remaining cut flowers were dry stored under normal atmosphere (NA) (in plastic vases without treatment for 3 weeks) and MAP (in plastic trays (38 × 56 × 18 cm) with a sealed plastic cover material for 5 weeks) conditions with 5 ± 0.5°C and 80 ± 5% relative humidity (RH). MAP studies were carried out by using 35 µ polypropylene whose O_2 permeability was 431.10 ml m^{-2} day^{-1} atm^{-1}, and CO_2 permeability was 1381.50 ml m^{-2} day^{-1} atm^{-1} at 5°C.

The flowers were covered with polypropylene using a Petra FS 500 plastic covering machine (all flowers in a replicate together) to form the MAP. The temperature and humidity conditions during storage were determined with a TES-1310 digital thermometer and hygrometer as well as with a Sato thermohygrograph. Changes in quality criteria such as weight loss (%), respiration rate (mg CO_2 kg^{-1} h^{-1}), total leaf chlorophyll (g 100^{-1} g^{-1}), MAP O_2 and CO_2 rate (%), and vase life (day) were determined in samples taken at 1-week intervals during storage.

Weight losses that occurred during storage were determined using a Sartorius precision balance (0.01 g precision), considering initial weight values. Changes in respiration rates were calculated according to Claypool & Keefer (1942) based on CO_2 absorption. The respiration rates of the flowers in MAP were determined following the removal of flowers from the plastic cover material. The flowers in each replicate were sealed in a 5-litre glass container. The respiration rate measurements were determined by calculating the absorbancy values at 615 nm in the spectrophotometer (Shimadzu UV-120-01). Total leaf chlorophyll was determined by subjecting the samples taken from the middle petals of flowers forming the replicate to extraction with acetone (90%) and then reading and calculating the absorbancy values at 652 nm in the spectrophotometer (Holden 1976). A Dräger Multiwarn II gas analyser was used to determine the O_2 and CO_2 concentrations in MAP. Vase life of lisianthus cultivars after each storage period was determined by making cuts at the basal parts of flowers and keeping them in water at room conditions (20 ± 1°C, 60 ± 5% RH). Flower vigour, leaf colour and quality, and stem colour and freshness were taken into consideration when determining the vase life. The flowers were assessed daily for visual appeal. Vase life was judged to have ended when 50% or more of flowers on an inflorescence were rated unattractive. Moreover, lisianthus inflorescences were evaluated on: a senescence scale—0, no senescence symptoms, to 4, more than 50% of total bract area showed browning and an inflorescence wilted scale—0, no wilting symptoms, to 4, the inflorescence had lost turgor and dropped from the vertical axis by more than 90°. Flowers were discarded when more than 50% of the total area showed yellowing or was dried out. Stems were discarded when the stem had lost turgor and more than 50% of the stems showed drooping.

The research was established according to the randomised plots factorial experimental design. The analyses were made in three replicates, with five plants (uniform by flower quality and with 4–5 flowers per plant) in each replicate. The results obtained from the study were analysed using ANOVA and means were compared using the LSD test.

RESULTS AND DISCUSSION

Weight loss

Increases occurred in the weight losses of 'Pure White' and 'Pink Picotee' lisianthus with prolonged storage periods. MAP significantly slowed down weight loss during storage. Weight losses up to 20–30% were observed in lisianthus flowers that could be stored in NA, whereas this rate was no higher than 7–8% in MAP (Fig. 1 and 2). Weight loss that occurred as a result of moisture loss could have been caused by the smaller vapour pressure gradient between flowers and environment in the direction of flowers. Moreover, MAP reduced water loss by minimising the contact of flowers with the surrounding air or by inhibiting the diffusion of water vapour.

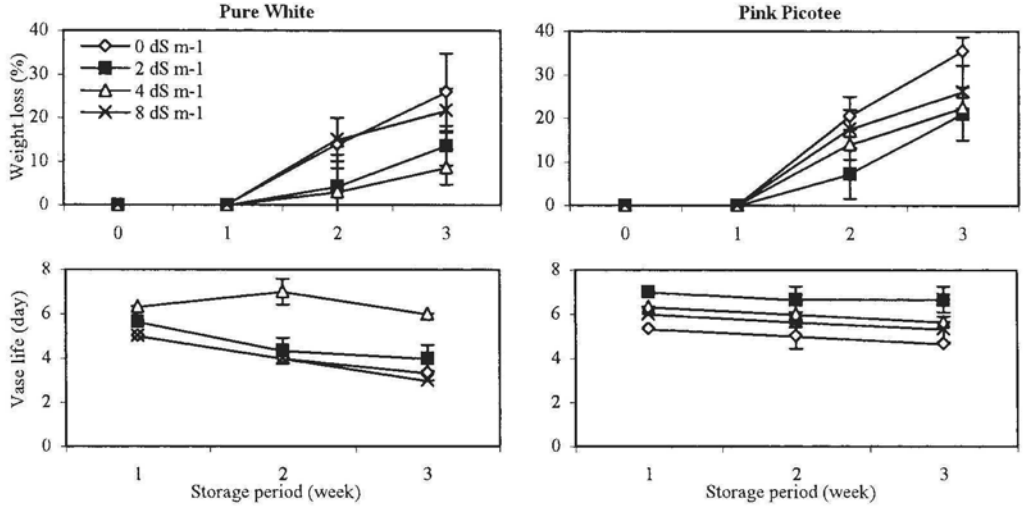

Fig. 1 Changes related to weight loss and vase life values of lisianthus (*Lisianthus grandiflorum*) cultivars during normal atmosphere.

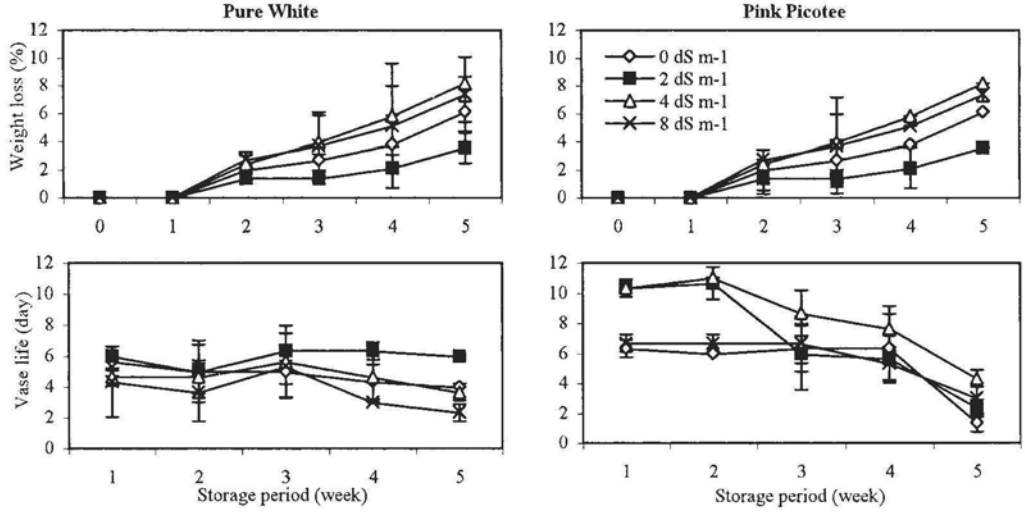

Fig. 2 Changes related to weight loss and vase life values of lisianthus (*Lisianthus grandiflorum*) cultivars during modified atmosphere packaging.

Different weight loss values, which were detected at the treatment level, were concluded to change depending on the increase in osmotic potential in the flower tissues. Nagaraja et al. (2000) examined the changes in weight loss during the storage of *Polianthes tuberosa* in NA and MAP (200, 300, and 400 gauge polyethylene) and determined that the weight loss of 38.56% in the control group changed between 0.68% and 4.12% in MAP, similar to our study.

Respiration rate

The respiration rates, which were high initially, declined towards the end of storage. The lowest respiration rate in 'Pure White' stored in NA was determined in the 4 dS m^{-1} treatment, although a statistically significant difference was not observed between treatments at the end of storage (Table 1). The lowest respiration rates in MAP of the same cultivar during the same period were determined in

Table 1 Respiration rate and total leaf chlorophyll changes of lisianthus (*Lisianthus grandiflorum*) cultivars during normal atmosphere storage. (Means with same letter in a column were not significantly different by LSD at $P < 0.05$.)

Storage period (week)	NaCl (dS m^{-1})	Respiration rate (mg CO_2 kg^{-1} h^{-1})		Total leaf chloropyll (g 100^{-1} g^{-1})	
		Pure White	Pink Picotee	Pure White	Pink Picotee
0	0	271.42 a	249.01 a	22.74 efg	58.37 a
	2	262.20 a	135.24 d	53.56 a	55.34 a
	4	180.03 b	201.17 b	28.13 d	53.29 a
	8	166.65 bc	202.73 b	25.76 def	28.94 b
1	0	148.14 d	132.62 d	21.07 fgh	48.21 a
	2	145.82 d	133.68 d	51.86 a	53.45 a
	4	121.92 e	155.67 c	27.12 de	51.39 a
	8	158.40 cd	121.87 de	24.32 d-g	27.25 b
2	0	120.40 e	106.73 e-h	19.62 gh	47.05 a
	2	127.60 e	94.20 hi	50.19 a	51.48 a
	4	99.88 f	112.22 efg	25.62 def	49.35 a
	8	127.14 e	115.73 ef	24.48 d-g	25.62 b
3	0	96.21 f	94.93 hi	16.97 h	45.24 a
	2	92.43 f	80.96 i	44.51 b	49.90 a
	4	88.76 f	100.46 fgh	33.69 c	45.90 a
	8	90.79 f	97.14 gh	17.49 h	28.82 b
LSD		17.01	15.81	5.05	13.72

Table 2 Respiration rate and total leaf chlorophyll changes of lisianthus (*Lisianthus grandiflorum*) cultivars during modified atmosphere packaging. (Means with same letter in a column were not significantly different by LSD at $P < 0.05$.)

Storage period (week)	NaCl (dS m^{-1})	Respiration rate (mg CO_2 kg^{-1} h^{-1})		Total leaf chloropyll (g 100^{-1} g^{-1})	
		Pure White	Pink Picotee	Pure White	Pink Picotee
0	0	183.85 bc	236.85 a	45.22 ab	54.23 a
	2	183.85 bc	202.06 c	41.18 bc	44.73 bc
	4	195.24 b	145.86 d	38.32 bcd	50.92 ab
	8	146.05 cde	221.00 b	54.34 a	31.63 e
1	0	339.54 a	63.62 l	31.87 d-i	42.03 cd
	2	118.57 d-h	73.23 k	39.90 bcd	44.61 bc
	4	113.75 d-i	79.44 i	33.30 c-i	35.52 de
	8	104.53 e-i	88.05 h	35.43 a-e	23.95 fg
2	0	135.12 def	63.40 mn	33.50 c-h	33.22 e
	2	150.76 bcd	72.32 k	39.29 bcd	29.99 ef
	4	95.68 f-i	53.96 q	32.27 c-i	29.36 ef
	8	114.40 d-i	78.06 j	35.00 c-g	18.73 gh
3	0	130.27 d-g	80.43 i	27.85 e-j	32.77 e
	2	106.11 d-i	62.44 no	36.93 a-d	19.36 gh
	4	187.68 bc	51.11 r	31.42 d-i	29.14 ef
	8	110.77 d-i	63.85 m	24.24 ij	18.39 gh
4	0	107.17 d-i	95.68 g	26.43 f-j	31.44 e
	2	88.68 ghi	51.11 r	31.14 d-i	16.94 h
	4	87.14 ghi	54.13 q	21.07 jk	28.80 ef
	8	72.17 i	80.19 i	20.46 jk	18.23 gh
5	0	97.08 f-i	123.48 e	26.06 g-j	31.24 e
	2	74.21 hi	112.33 f	25.45 hij	14.90 hi
	4	68.92 i	56.42 p	12.87 k	17.01 h
	8	81.86 hi	61.68 o	12.69 k	9.84 i
LSD		45.85	1.37	9.18	6.78

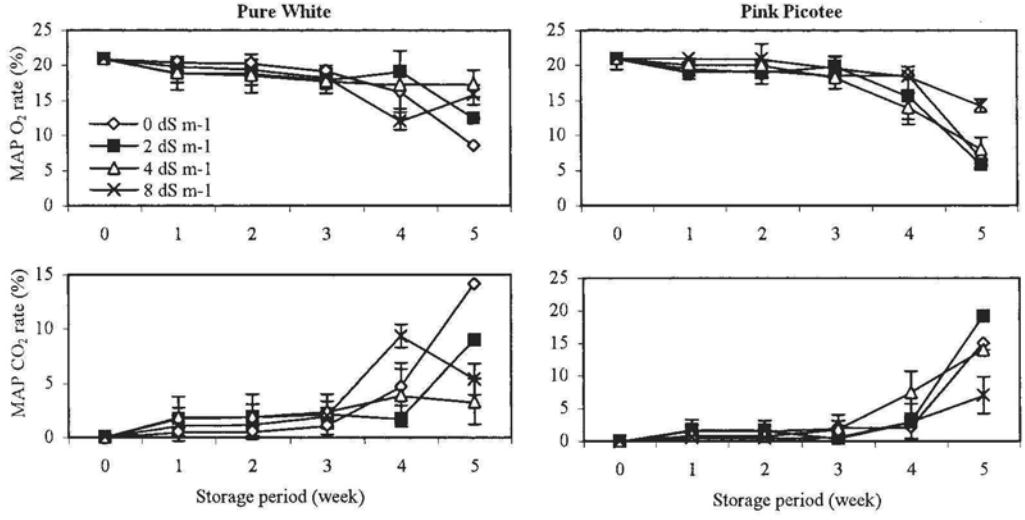

Fig. 3 Changes related to O_2 and CO_2 ratios of lisianthus (*Lisianthus grandiflorum*) cultivars during modified atmosphere packaging (MAP).

the 4 and 2 dS m^{-1} treatments. Similar declines in respiration rate were determined also in 'Pink Picotee' with both storage methods (Table 2). The lowest respiration rate, especially in MAP, was obtained from the 4 dS m^{-1} treatment. Joyce et al. (2000) determined that cut flowers of *Grevillea* hybrid 'Sylvia' produce low levels of CO_2 at low temperatures. Also, in our study, the respiration rates of lisianthus flowers subjected to NaC1 at different concentrations decreased with prolonged storage periods. Moreover, low O_2 and high CO_2 slowed down the respiration rate. However, it should be considered that ultra low O_2 conditions could lead to anaerobic respiration.

Total leaf chlorophyll

In general, reductions were observed in the total chlorophyll of lisianthus leaves in NA and MAP. Chlorophyll loss results in a reduction of quality for many flowers. In this study, lower levels of chlorophyll observed in higher concentrations of NaC1 at the end of storage in NA and MAP was noted as a remarkable result. The lowest total leaf chlorophyll was obtained from the 0 and 8 dS m^{-1} treatments in 'Pure White' and from the 8 dS m^{-1} treatment in 'Pink Picotee' during NA storage (Table 1). A similar situation was also observed during MAP (Table 2). Philosoph-Hadas et al. (1996) investigated the effects of silver thiosulphate (STS), naphthalene acetic acid (NAA), gibberellin (GA_3), and benzyladenine (BA) to maintain the quality characteristics of golden rod (*Solidago canadensis*) and prevent leaf yellowing. In the study, it was determined that STS and BA, in particular, markedly inhibited leaf yellowing during vase life. In our study, leaf yellowing increased at high concentrations of NaC1. Yellowing was observed in the leaf tips of flowers, especially with 8 dS m^{-1} treatment in the later stages of storage in both methods.

MAP O_2 and CO_2 rate

Reductions in O_2 and increases in CO_2 occurred following the transfer of lisianthus into MAP. The lowest O_2 and the highest CO_2 in 'Pure White' at the end of storage was determined with the 0 and 2 dS m^{-1} treatment; whereas in 'Pink Picotee', the best results after 4 weeks of storage, with similar criteria, were obtained from the 4 dS m^{-1} treatment (Fig. 3). Hence, the quantities of O_2 consumed and CO_2 produced by the cultivars in relation to treatments confirms the results obtained from these treatments for respiration rates, because changes in respiration during senescence can be reduced by eliminating ethylene action through the use of low O_2 and high CO_2 atmospheres. Meir et al. (1995) stored gladiolus (*Gladiolus* hybr. 'Adi') for 14 days at 2°C in polyethylene bags with the inner atmosphere combination of 10–14% O_2 and 4–7% CO_2. The researchers determined that leaf senescence was retarded in the gladioli stored under these conditions

because of high CO_2. Also in our study, MAP conditions consisting of optimum low O_2 and high CO_2 were found to give quite good results.

Vase life

Reductions were observed in vase life during storage. The longest vase life in 'Pure White' was determined with 4 and 2 dS m^{-1} treatments in NA and MAP, respectively (Fig. 1 and 2). In 'Pink Picotee', the longest vase life was determined with 2 dS m^{-1} treatment in NA and with 4 dS m^{-1} treatment in MAP (Fig. 1 and 2). Different research conducted on storage of cut flowers investigated different treatments to prolong vase life. In this research, the vase solutions containing silver thiosulphate, sodium thiosulphate, sucrose, benzyladenine, 8-hydroxyquinoline, and citric acid increased the vase life of most cut flowers (Jaroenkit & Paull 2003; Bunya-atichart et al. 2004). In another study, anthuriums were routinely packed in a carton for 2 days. In another study, when anthuriums were packed and held in the carton for up to 12 days at 22°C, there was only a slight decline in vase life after 4 days packed in the carton (Paull & Chantrachit 2001). Seaton & Joyce (1993) also noted that vase lives of Geraldton wax (*Chamelaucium uncinatum*) and red kangaroo paw (*Anigozanthos rufus*) were not reduced following 7 days of storage at 1°C in low CO_2 (up to 15%), compared with controls stored in air. However, vase life of Geraldton wax and red kangaroo paw were shortened and flower colour was altered after storage for 7 days in high CO_2 (>15%). In research on postharvest physiology of *Curcuma alismatifolia* flowers, the stems were wrapped with polyethylene bags. This treatment prevented excessive water loss and flowers held at 10°C had a normal vase life (Bunya-atichart et al. 2004). Also in our study, the vase life of flowers subjected to preharvest NaC1 at low concentrations was determined to be longer than with the other treatments. Thus, NaC1 at low concentrations had a positive effect on the vase life of lisianthus. In this effect the combinations of high CO_2 and low O_2 within a certain range had an important role.

CONCLUSION

As a general evaluation, salt treatments, especially at low concentrations, had some positive effect on the postharvest physiology of lisianthus flowers. It is notable that salt treatment reduced weight loss and respiration rate compared with the control in NA and MAP in both cultivars. This reduction, especially in weight loss, may because of increased osmotic potential of the flower tissues. The retention of chlorophyll and the extension of vase life resulting from the 2 and 4 dS m^{-1} treatments are noteworthy. In the study, certain treatments caused some physiological developments in the flowers to proceed faster in the later stages of storage. In both cultivars, it was observed that flower diameter enlarged and yellowing occurred in leaves more rapidly after the first weeks of the storage period especially with the 0 dS m^{-1} treatment, whereas severe drying and wilting occurred in leaves with the 8 dS m^{-1} treatment. Therefore, postharvest quality losses occur in lisianthus grown under extremely saline conditions and the storage period of flowers becomes shortened. However, low quantities of salt have a promoting effect on the postharvest quality and life of lisianthus. Atmosphere combinations also partially affected flower quality. Development of the pink colour proceeded more rapidly, especially in the treatments with a very high CO_2 rate in 'Pink Picotee'. According to these explanations, the best results, on the basis of the treatments in the study, were obtained from 4 and 2 dS m^{-1} in NA and MAP, respectively in 'Pure White'. The 2 dS m^{-1} treatment gave the best result at the end of NA storage of 'Pink Picotee', whereas the 4 dS m^{-1} treatment was found more effective than the other treatments in MAP. It was determined that 'Pure White' could be stored for 2–3 weeks in NA and for 5 weeks in MAP; whereas 'Pink Picotee' could be stored for 2 weeks and 3–4 weeks in NA and MAP, respectively, under these conditions, without major changes in their flower, flower stem, and leaf qualities.

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