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Vase Life of Some Cut Flowers Following Fumigation with Phosphine

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Abstract. **Phosphine (PH_3) is a potential alternative fumigant to methyl bromide for insect disinfestation of cut flowers. King protea (*Protea cynaroides* L.), tulip (*Tulipa gesneriana* 'Apeldoorn'), kangaroo paw (*Anigozanthos manglesii* Hook.), and geraldton wax (*Chamelaucium uncinatum* 'Purple Pride') were fumigated with PH_3 at varying concentrations (100 to 8000 $\mu L \cdot L^{-1}$) for 2, 4, or 6 hours. Vase life was evaluated at 20 °C, 65% relative humidity, and constant illumination with a photosynthetically active radiation of 15 $\mu mol \cdot m^{-2} \cdot s^{-1}$. No significant change in vase life was observed for kangaroo paws after any of the PH_3 fumigations. A 6-hour fumigation at 8000 $\mu L \cdot L^{-1}$ significantly reduced vase life in king protea, tulip, and geraldton wax flower. Geraldton wax flower and tulip were relatively sensitive to PH_3, as they were damaged by 4000 $\mu L \cdot L^{-1}$ for 6 hours and 8000 $\mu L \cdot L^{-1}$ for 4 hours, respectively. Phosphine has potential as an insect disinfestation fumigant for king protea, tulip, and kangaroo paw at 4000 $\mu L \cdot L^{-1}$ for 6 hours without affecting vase life or causing damage.**

A major problem encountered by Australian flower exporters is the rejection of consignments in foreign markets, particularly Japan, due to the presence of insects, most commonly with larval, pupal, and adult stages of aphids, mites, and thrips (Williams, 1986). Estimates of losses due to enforced fumigation of rejected consignments were AUD $700,000 (Australian) in 1993 or 10% of the shipments to Japan (Horticultural Research and Development Corporation, 1994). Fumigation with hydrogen cyanide and methyl bromide (MB) caused severe damage to unspecified *Protea* species (Coetzee and Wright, 1990). Aside from its phytotoxic aspects, MB has also been identified as an ozone-depleting gas under the Montreal Protocol (United Nations Environment Protocol, 1995) and is to be completely phased out by 2010. It is, therefore, necessary to develop alternate methods to MB fumigation for insect disinfestation of cut flowers. Phosphine (PH_3), because of its high toxicity to insects, rapid rate of diffusion and desorption, together with minute residues of phosphites and phosphates, may have an important role as a replacement for MB in the fumigation of many horticultural products (Bond, 1984).

Phosphine is widely used to control insects in stored grain, but effective disinfestation requires varying concentrations and exposure times in the presence of oxygen for individual insect species (Bond et al., 1969). For cut flowers, exposure duration must be minimized to avoid reduced vase life. This research was undertaken to determine the effect of PH_3 on the vase life of four cut-flower species.

Materials and Methods

Export quality king protea, tulip, geraldton wax flower, and kangaroo paw were received from a commercial supplier within 1 d of harvest. A mixture of PH_3 (2%) and N_2 (98%) was prepared by BOC Gases, Sydney, and stored in high-pressure cylinders.

About 1 cm was cut from the stems and two lots of 15 stems were then placed in 66-L plastic containers filled with water at a load factor of 0.22 stems/L. The containers' joints were sealed with silicon and PH_3 gas from the cylinder was fed via a pressure regulator into the top of the containers via plastic tubing, while the displaced water was automatically discharged from the bottom of containers (via plastic tubing), thereby maintaining atmospheric pressure. The appropriate volume of PH_3 to achieve the desired concentration was determined by the volume of water discharged from the containers. A separate control was used for each duration (2, 4, or 6 h). Flowers were aerated in a fume cupboard under air at velocity of 10 $m \cdot min^{-1}$ for 30 min, immediately after fumigation at 24 °C.

After fumigation, 1 cm was again cut from each stem and the stems were placed in separate 1-L glass jars containing distilled water. Vase water was replaced and flowers evaluated daily. Each treatment was tested under five concentrations with two replications per test, each having 15 stems. Vase life was evaluated for flowers held in a constantly illuminated room with a photosynthetically active radiation of 15 $\mu mol \cdot m^{-2} \cdot s^{-1}$ at 20±1 °C and 65% ±5% relative humidity.

Vase life was determined twice daily, and was considered ended according to the following criteria: king protea, first sign of leaf blackening or bract tips turning gray with upper bracts starting to curl; tulip, first sign of petal wilting; geraldton wax, 50% of flowers closed, or abscised, or tip wilting with leaf abscission; kangaroo paw, top flower wilting.

Mean vase life was compared by the Scheffe's test ($P \leq 0.05$) for statistical significance (Gilbert, 1981).

Table 1. The effect of PH_3 fumigation at various concentrations and exposures on mean flower vase life.

Flower	Fumigation duration (h)	Vase life (d) Phosphine concn ($\mu L \cdot L^{-1}$) 0	100	500	4000	8000
King protea	2	6.0	6.0	6.5	6.5	6.5
	4	6.5	6.0	6.5	6.0	6.0
	6	7.0	9.0	8.0	7.5	3.5*
Tulip	2	6.0	6.0	6.0	6.0	5.5
	4	4.0	4.0	4.0	3.5	3.0*
	6	4.5	4.5	4.0	4.0	2.5*
Kangaroo paw	2	5.5	7.0	7.5	5.5	5.0
	6	6.0	6.0	7.0	5.0	6.0
Geraldton wax flower	2	4.5	5.0	5.5	6.0	5.0
	4	11.0	10.5	8.5*	11.0	10.0
	6	8.5	7.0	6.5	4.0*	3.0*

*Significantly different at $P \leq 0.05$ from the control (Scheffe's test).

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Results and Discussion

King protea treated with PH_3 for 2 or 4 h at 100, 500, 4000, or 8000 $\mu L \cdot L^{-1}$ did not differ in vase life from untreated flowers (Table 1). Fumigation with 8000 $\mu L \cdot L^{-1}$ for 6 h, however, caused a significant decrease in vase life, expressed as an increase in damaged flowers (Fig. 1A). Bracts fumigated with 8000 $\mu L \cdot L^{-1}$ started turning gray with the tips slightly curling inwards 1 d after fumigation. As flowers further aged, the gray areas of bracts expanded with further curling along the tips. Leaf blackening commenced 20 to 24 h before the discoloration of bracts and only occurred at 8000 $\mu L \cdot L^{-1}$ for 6 h. With some flowers, leaf blackening was visible immediately (0 h) after fumigation. The blackened spots on leaves rapidly increased in size to cause marked blotches on leaves within 18 to 30 h after fumigation.

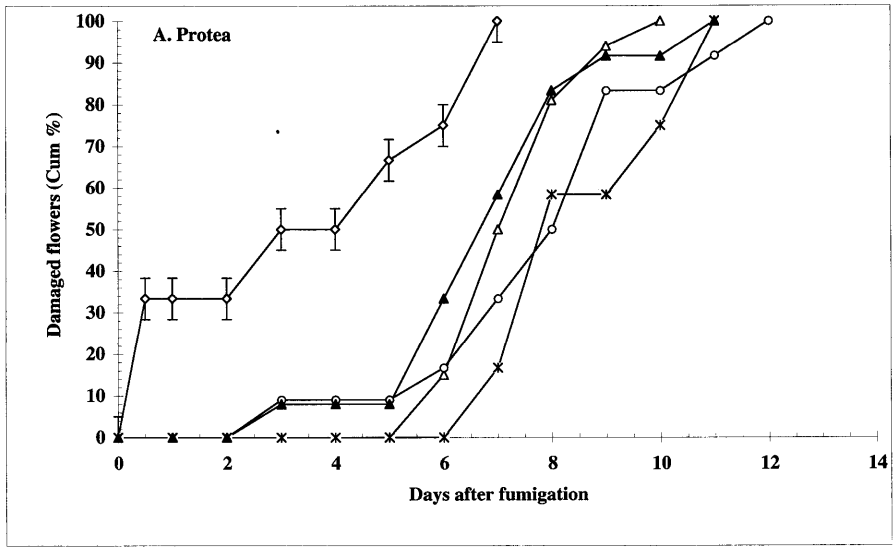
Tulips exposed to PH_3 at any concentration for 2 h showed no significant decrease in vase life compared to untreated flowers. However, when fumigated for 4 h, at 8000 $\mu L \cdot L^{-1}$ vase life was significantly reduced when compared to flowers fumigated at 0, 100, 500, or 4000 $\mu L \cdot L^{-1}$ (Table 1). Flower damage increased after a 6 h fumigation (Fig. 1B), with tulips showing accelerated curling of petal tips. This curling occurred 1 d before a slight wilting and discoloration of petal edges, noted 2.5 to 4 d after fumigation. PH_3 at 4000 or 8000 $\mu L \cdot L^{-1}$ for 6 h also caused rapid opening of tulip petals compared to flowers exposed to <4000 $\mu L \cdot L^{-1}$ or nontreated controls.

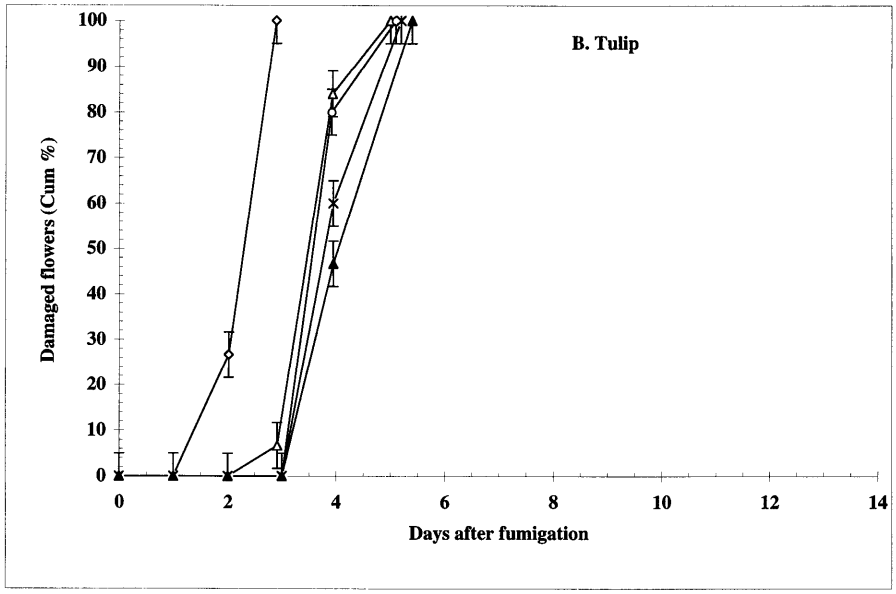
No visible phosphine damage was noticed in kangaroo paws at any concentration or duration when compared to nontreated controls (Table 1). The normal wilting of flowers and drooping of the top flowers with time was uniform in those from all the treatments. In contrast, kangaroo paws exposed to MB at 7500 $\mu L \cdot L^{-1}$ for 2 h showed significant wilting of the top flower (Flower Export Council of Australia, unpublished).

Phosphine at 4000 and 8000 $\mu L \cdot L^{-1}$ for 6 h significantly decreased the vase life of wax flowers by 4 to 5 d (Fig. 1C). No reduction in vase life was noticed after a 2 h fumigation at any PH_3 concentration. Vase life was, however, reduced by 2.5 d with 500 $\mu L \cdot L^{-1}$ for 4 h when compared with the corresponding vase life of 11 d in the control, a result we cannot explain.

Leaf abscission occurred in wax flowers exposed to PH_3 >500 $\mu L \cdot L^{-1}$ at all the durations tested. However, abscission was minimal and the loss of vase life due to this damage was not significantly different from untreated stems. Leaf abscission was normally followed by closing and discoloration of florets, particularly in flowers exposed to longer durations (6 h) of PH_3. Heavy abscission of leaves occurred when the flowers were exposed to 4000 or 8000 $\mu L \cdot L^{-1}$ for 6 h, which was significantly different from the control. Other fumigants such as MB, hydrogen cyanide, and carbonyl sulfide clearly damaged florets and foliage (P. Williams, 1995, pers. comm.).

The PH_3 concentration needed to attain a 100% kill of greenhouse thrips (*Heliothrips*





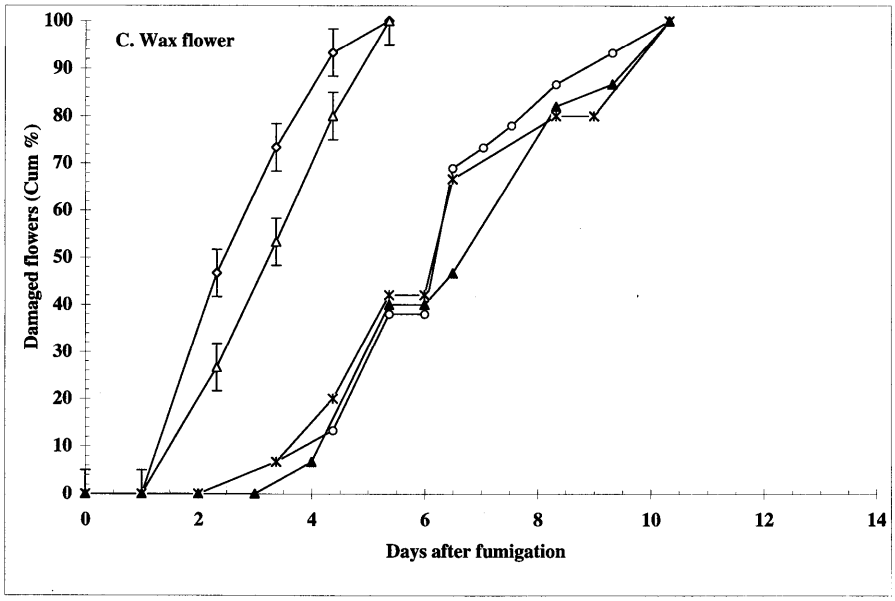


Fig. 1. Cumulative increase in damaged flowers (%) following fumigation with phosphine for 6 h at various concentrations ($\mu L \cdot L^{-1}$). (◊) 8000, (Δ) 4000, (○) 500, (*) 100, (▲) control; (**A**) King protea; (**B**) Tulip; (**C**) Geraldton wax flower.

haemorrohidalis Bouche), adult aphids (*Myzus persicae* Sulzer), and light brown apple moth larvae (*Epiphyas postvittana* Walker) is 300 $\mu L \cdot L^{-1}$ for 2 h, 4000 $\mu L \cdot L^{-1}$ for 6 h, and 2500 $\mu L \cdot L^{-1}$ for 6 h, respectively (Karunaratne et al., 1995). Protea, tulip, and kangaroo paw fumigated with 4000 $\mu L \cdot L^{-1}$ for 6 h showed no significant loss of vase life when compared with the nontreated controls. Hence, PH_3 could be used successfully to kill these three species of insects on king protea, tulip, and kangaroo paw flowers without affecting vase life.

Fumigation of wax flowers with 4000 $\mu L \cdot L^{-1}$ PH_3 led to the loss of vase life, particularly at 6 h (Table 1); thus, concentrations between 500 and 4000 $\mu L \cdot L^{-1}$ need to be tested to determine ideal fumigation conditions for disinfesting wax flower.

Further trials need to determine if concentrations and exposures to phosphine we used are effective under commercial conditions. This step is particularly important in protea, where insect pests are known to be found deep within the flowerhead and might potentially escape fumigation.

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