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SYNERGISTIC EFFECTS OF BORIC ACID AND COLD STORAGE ON POST-HARVEST QUALITY AND SHELF LIFE OF *Tabernaemontana divaricata* FLOWER BUDS

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ABSTRACT

The post-harvest longevity of loose flowers is critically influenced by physiological deterioration, limiting their commercial utility. *Tabernaemontana divaricata* (L.), an emerging ornamental species with year-round flowering potential, remains underexploited due to insufficient understanding of its post-harvest behaviour. The present study was undertaken to evaluate the interactive effects of boron application and storage temperature on quality retention in flower buds. Out of twelve accessions collected the best performing four accessions were subjected to six treatment combinations involving boric acid (2% and 4%) under ambient and refrigerated (5°C) storage conditions in a factorial completely randomized design. Post-harvest attributes, including freshness index and moisture content, were assessed at 3, 6, and 9 days of storage. Notable differences occurred between the treatment types, accession types, and interaction effects. Flower buds treated with 2% boric acid and stored at 5°C maintained high-quality levels, with the best index of freshness (78.17%) and water content (67.91%) measured on the ninth day. This was due to the role of boron in stabilizing cellular membranes, facilitating carbohydrate transport, and preventing the aging process induced by ethylene. The low temperature also helped to slow down the metabolic activities. Accession differences showed that there were variations in genetic factors affecting post-harvest behaviour. Overall, the experiment demonstrated a viable approach to increasing the storage period and improving marketing prospects for *T. divaricata* as a loose flower variety.

Keywords **:** *Tabernaemontana divaricata*, post-harvest quality, shelf life, boric acid, cold storage, moisture retention, flower senescence.

Introduction

Floriculture has grown to be a highly profitable sector within the horticultural industry with a significant contribution in terms of earnings, employment, and exports. In countries like India, loose flowers make up a huge proportion of floriculture production owing to its extensive use in religious, cultural, and decorative activities. The perishable nature of flowers contributes to large post-harvest loss that may go up to 30 to 40 per cent because of quick senescence and poor post-harvest handling methods (Halevy and Mayak, 1981; Wills *et al.*, 1998). Proper post-harvest management is thus important for maintaining quality and increasing shelf-life.

Tabernaemontana divaricata (L.) commonly referred to as crepe jasmine or pinwheel flower is an evergreen ornamental plant belonging to the family Apocynaceae. The plant produces beautiful white flowers and continuous flowering during all times of the year. This plant has recently received much attention as a possible alternative loose flower crop owing to the fact that it shares physical resemblance with jasmine flower buds and the ability to bloom during off season. It is also less prone to pest infestation and disease development, hence can easily be grown under low input conditions. The crop has not been exploited commercially because of lack of knowledge on how to handle it after harvest.

Postharvest deterioration of the flower occurs through various physiological and biochemical processes like respiration, transpiration, membrane deterioration, and hormones among others. Ethylene is one of the significant elements which hasten the process of senescence in flowers through petal wilting, colour change, and flower drop (Rani & Singh, 2014). As a result of enhanced levels of ethylene formation, the quality of the flower deteriorates quickly. Transpiration loss causes the turgor pressure in flowers to fall leading to wilting. Boron is one of the micronutrients required for the proper functioning of plant cells. Its involvement in cell wall formation, membrane stabilization, and carbohydrate transport is well established (Nason and McElroy, 1963). Boric acid assists in the formation of borate-sugar complex to facilitate sugar transportation and metabolic functions in storage. Post-harvest treatment with boric acid has been found effective in slowing down the process of senescence by ensuring membrane stabilization and reducing leakage of solutes from cells, along with inhibition of ethylene production (Aarts, 1958; Serrano *et al.*, 1991). In loose flowers like jasmine, boric acid treatment increases freshness, decreases physiological loss in weight, and improves shelf life. Temperature is another vital parameter that influences the post-harvest life of flowers. Lowering the temperature leads to reduction in the respiration rate, enzyme action, and moisture loss, thus retarding the process of senescence (Rudnicki *et al.*, 1991; Wills *et al.*, 1998). This in turn leads to enhanced freshness of flowers. Cold temperatures not only inhibit the production of ethylene and microbial action but also improve the shelf life. Studies have been carried out in relation to the interaction of chemicals with refrigeration showing synergism in post-harvest improvement of ornamentals.

Although numerous studies have been conducted on conventional loose flowers like jasmine and rose in relation to post-harvest management, very few scientific investigations have been done regarding *Tabernaemontana divaricata*. With the current rising demand and growing importance for commercial purposes, it becomes imperative to devise scientifically proven post-harvest procedures for this plant. Hence the present study was initiated with the aim of evaluating the interactive effect of boric acid application and storage temperature on post-harvest quality of *Tabernaemontana divaricata* flower buds.

Materials and Methods

The current study was carried out in 2022-2023 in the Post-Harvest Laboratory of the Department of Floriculture and Landscape Architecture, Tamil Nadu Agricultural University, Coimbatore, India. Ambient conditions in the laboratory were maintained at a temperature of 28 ± 2 °C, and relative humidity of 70–80 per cent, whereas cold storage conditions were maintained at 5 ± 1 °C, and relative humidity of 85–90 per cent. From the four selected accessions, fresh intact flower buds of *Tabernaemontana divaricata* (L.) with uniform size and physiological maturity without any mechanical injuries were harvested during early morning and taken to laboratory.

A factorial completely randomized design (FCRD) was followed with two factors *viz.*, accessions and post-harvest treatment. Factor A included four accessions, and Factor B included six post-harvest treatments. The post-harvest treatments were (1) ambient storage (control), (2) refrigeration (5 °C), (3) application of 2 per cent boric acid in ambient conditions, (4) application of 2 per cent boric acid in refrigeration conditions, (5) application of 4 per cent boric acid in ambient conditions, and (6) application of 4 per cent boric acid in refrigeration conditions. Experimental units consisted of 10 g of flower buds. The freshly picked buds were subjected to chemical treatments where each batch of buds were dipped in boric acid solution for five minutes so that an even distribution of the treatment could take place. After the treatment, the buds were dried superficially under shade for the drying of the extra solution. Treated buds were placed in polyethylene bags, of 200-gauge thickness and 15 × 9 cm size.

Following the treatment, post-harvest observations were made on the third, sixth and ninth days. The observation included

(i) Determination of the freshness index of the flowers based on visual inspection of their turgidity and colour. This was done using a percentage index formula:

$$\text{Freshness Index (\%)} = \frac{\text{Score obtained}}{\text{Maximum score}} \times 100$$

(ii) Colour retention index was evaluated based on the degree of retention of original colour of the buds and expressed as percentage using the following formula:

$$\text{Colour Retention Index (\%)} = \frac{\text{Number of buds retaining original colour}}{\text{Total number of buds}} \times 100$$

(iii) Flower opening index was determined by recording the number of buds that opened during storage and expressed as percentage:

$$\text{Flower Opening Index (\%)} = \frac{\text{Number of opened buds}}{\text{Total number of buds}} \times 100$$

(iv) Moisture content was estimated using the gravimetric method by drying the samples in a hot air oven at 70 °C until constant weight was achieved, and calculated as:

$$\text{Moisture Content (\%)} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Fresh weight}} \times 100$$

(v) Relative water content was determined following standard procedures using fresh weight (FW), turgid weight (TW), and dry weight (DW), and expressed as:

$$\text{Relative Water Content (\%)} = \frac{\text{FW} - \text{DW}}{\text{TW} - \text{DW}} \times 100$$

(vi) Physiological loss in weight was calculated by recording the reduction in weight of the samples during storage and expressed as percentage:

$$\text{Physiological Loss in Weight (\%)} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

(vii) Shelf life was determined based on the period (hours) during which the flower buds maintained their acceptability in terms of appearance, freshness, and marketability. The termination of shelf life occurred when the buds became commercially unacceptable through wilting, discolouration, or too much opening.

The results generated were analysed statistically using analysis of variance (ANOVA) suitable for the factorial completely randomized design recommended by Gomez and Gomez (1984). Treatment differences were determined statistically at the 5 per cent probability level, with critical difference (CD) being used to determine treatment mean differences. The statistical analyses were done using AGRES software.

Results and Discussion

The post-harvest response of flower buds of *T. divaricata* was evidently influenced by boric acid treatments, storage temperature, accessions and their interaction. From each parameter studied, there was a consistent drop in quality with increase in storage time, although the rate of deterioration differed between the various treatments, signifying that chemical and temperature manipulation are effective strategies for senescence retardation.

Freshness index dropped progressively from the third to the ninth day of storage in all the treatments (Figure 1a). Treatment effects and accession effects on freshness index at varying storage times are shown in Table 1. However, buds subjected to 2 percent boric acid and stored at 5°C had significantly high freshness index across all days during storage. At the ninth day, buds of the above treatment group had the highest freshness index (78.17%) while the control treatment showed a marked decline. This improvement in freshness was due to greater membrane stability and resistance to ethylene damage leading to senescence delay (Serrano *et al.*, 1991). The cold storage temperature further helped in maintaining cell integrity and freshness through reduction in respiratory rates and metabolic activities (Wills *et al.*, 1998). Accession 1 buds had significantly high values for freshness index compared to the other accession treatments.

The variation in colour retention index due to treatment, accession, and interaction between treatment and accession is shown in Table 2. Like the freshness index, the colour retention index showed a pattern of decline. The highest value for the colour retention index was obtained from a combination of 2 per cent boric acid treatment and refrigeration, which implies that the white coloration of the buds was effectively maintained. This loss of colour in untreated samples can be attributed to pigment breakdown and oxidation during senescence. The use of boric acid treatment probably facilitated the maintenance of cell structure and reduced oxidative stress. Such findings were also seen in jasmine flowers (Jawaharlal *et al.*, 2012).

From the flower opening index, there was a negative correlation with freshness, as more bud openings occurred quickly. The control treatment had the highest flower opening index, showing that the flowers progressed to senescence very fast. On the other hand, boric acid-treated buds, especially those refrigerated, had a lower flower opening index, indicating delay in physiological development. Flower opening suppression may result from decreased ethylene formation and slower metabolism at low temperatures (Rani & Singh, 2014). Delaying bud opening is advantageous for loose flower trade since it increases the duration of marketability. Table 3 illustrates the effects of postharvest treatments on the flower opening index. There was a gradual reduction in moisture content throughout storage in all treatment conditions (Fig. 1b), showing that there was a consistent loss of moisture through transpiration. Nevertheless, moisture content was significantly higher in buds exposed to 2 per cent boric acid in a refrigerated environment on day nine at 67.91 per cent moisture content. This could be due to increased membrane integrity and impermeability, resulting in minimized loss of water. Boron has been shown to provide stability to cell membranes and minimize the release of cellular materials, hence ensuring moisture balance (Nason & McElroy, 1963). Refrigeration reduced the transpiration rate by minimizing vapor pressure difference, hence conserving moisture content (Table 4).

Relative water content also exhibited a decreasing trend, implying that there was a steady reduction in the hydration of the cells. Relative water content was highest in samples exposed to 2 per cent boric acid and refrigeration treatment, validating its efficacy in retaining moisture levels in the tissues. Higher retention of relative water content is important in maintaining tissue firmness and rigidity in flower buds. These results are supported by previous studies conducted on ornamentals, wherein a combination of chemicals and refrigeration increased their shelf life due to better water relationships (Rudnicki *et al.*, 1991). Results concerning relative water content are presented in Table 5.

Loss of physiological weight increased with the increase in the period of storage due to loss of moisture through water and weight loss due to respiratory activities. Minimum physiological weight loss was achieved under refrigerated conditions with 2 per cent boric acid, showing that there was minimization of loss of moisture and metabolism. On the other hand, the highest loss of weight occurred in the control test, which hastened the deterioration process. Loss of physiological weight in boric acid treatment could be due to stabilization of the cell membranes and minimization of transpiration, whereas refrigeration contributed to minimal losses of respiration and evaporation (Wills *et al.*, 1998). Effect of post-harvest treatments on physiological loss in weight of *T. divaricata* accessions during the storage period is shown in Table 6. However, the shelf life of the flower buds was affected significantly by treatments (Fig. 1c), with the highest value for 2 per cent boric acid solution with cooling temperature. Shelf life of the flower buds treated with 2 per cent boric acid solution with cooling was higher by 168.34 h compared to other treatments. Extended shelf life may be due to delay in senescence, less ethylene emission, proper water balance, and lower metabolic rate. The present result correlates well with previous studies on jasmine and tuberose, in which the combination of boric acid application with cooling increased shelf life significantly (Jawaharlal *et al.*, 2012; Manimaran *et al.*, 2018). Effect of treatments on shelf life of *T. divaricata* flower buds is shown in Table 7.

The interaction effect of accession and treatment was found to be significant in all traits, implying variation in response to the genetic background of the plant material. Accession 1 was found to be superior in all traits compared to other accessions, indicating the possibility of using accession 1 commercially. In summary, the above findings clearly illustrate how boric acid treatment in conjunction with cold storage of *Tabernaemontana divaricata* flower buds at 5°C is an effective strategy for delaying senescence, physiological integrity, and improving post-harvest quality of flower buds by stabilizing cellular membranes, inhibiting action of ethylene, maintaining optimum water status, and slowing down metabolic rate. The superior effects of 2 per cent boric acid solution on post-harvest quality of *T. divaricata* flower buds have been validated through the use of multiple parameter analysis to establish that combination of boric acid and refrigeration was significantly better than other combinations (Fig. 2). The synergistic effect of boric acid and low temperatures in preserving post-harvest quality of flower buds can be explained based on mechanisms involving membrane stabilization, inhibition of respiration, and reduced water loss (Fig. 3). It is clear from the analysis that treatment T_4 was the best performer, followed by T_2 and T_3, while T_1 performed poorly.

Conclusion

The results obtained from the current experiment indicate that the quality and longevity of *T. divaricat*a flower buds after harvest are greatly affected by the influence of chemical treatments and temperature conditions. In comparing the effectiveness of different combinations of treatments applied to the flower buds, it can be seen that treatment with 2 per cent boric acid solution and further storage in a refrigerator at 5 °C was found to be the most efficient method of maintaining the fresh state of the buds, their coloration, moisture content, and physiological properties. The enhanced post-harvest performance in response to boric acid treatment is due to the ability of the chemical to stabilize the membranes, increase carbohydrate transport, and lower ethylene-induced senescence, whereas the cooling treatment effectively minimized respiration rate and water loss. This considerable difference seen in the accessions also supports the contribution of genetic variations in post-harvest behaviour, with Accession 1 exhibiting exceptional performance for all attributes. In summary, the application of both boric acid treatment and low temperature storage is deemed to be a feasible and economical solution that could prolong the shelf life of the *T. divaricata* flowers and maximize their market potential. These results obtained from this study offer valuable information for optimizing post-harvest techniques in *T. divaricata*, which could pave the way for this species to become an established loose flower commodity.

Table 1 : Effect of post-harvest treatments on freshness index of *T. divaricata* accessions during the storage period

S. No.	Factors	Freshness Index (%)														
	Acc. / Trt.	3rd day					6th day					9th day				
		A_2	A_6	A_{10}	A_{11}	Mean	A_2	A_6	A_{10}	A_{11}	Mean	A_2	A_6	A_{10}	A_{11}	Mean
1	T_1	91.07	81.83	86.15	82.85	**85.47**	80.47	80.00	75.38	70.00	**70.46**	74.28	60.90	57.50	63.00	**63.92**
2	T_2	94.84	94.80	92.00	85.25	**91.72**	88.82	78.00	72.33	84.28	**80.85**	67.14	76.19	69.23	81.40	**73.49**
3	T_3	94.75	81.83	90.76	87.13	**88.61**	83.46	73.00	67.60	74.73	**74.69**	67.50	60.90	64.61	64.80	**64.45**
4	T_4	96.79	92.80	95.37	94.66	**94.90**	91.50	85.45	87.38	76.66	**85.24**	81.41	78.25	82.00	71.04	**78.17**
5	T_5	95.58	88.43	87.50	86.25	**89.44**	75.14	83.16	71.25	81.16	**77.67**	62.85	79.80	61.53	56.47	**65.16**
6	T_6	96.45	91.30	92.00	92.00	**92.93**	80.00	80.00	80.00	83.75	**80.93**	78.46	70.00	76.66	79.04	**76.04**
	Mean	**94.91**	**88.49**	**90.63**	**88.02**		**83.23**	**79.93**	**80.65**	**78.43**		**71.94**	**71.00**	**68.58**	**69.29**	
	Treatments	**A**	**T**	**A×T**			**A**	**T**	**A×T**			**A**	**T**	**A×T**		
	SE (d)	0.724	0.887	1.775			0.634	0.776	1.562			0.607	0.744	1.488		
	CD (0.05)	1.457	1.784	3.56			1.275	1.562	4.168			1.221	1.496	2.993		

T1 –Control T2- Refrigeration @ 5°C T3- Boric acid 2% + Room temperature
T4-Boric acid 2% + Refrigeration @ 5°C T5-Boric acid 4% + Room temperature T6-Boric acid 4% + Refrigeration @ 5°C

Table 2 : Effect of post-harvest treatments on colour retention index of *T. divaricata* accessions during the storage period.

S. No.	Factors	Colour Retention Index (%)														
	Acc. / Trt.	3rd day					6th day					9th day				
		A_2	A_6	A_{10}	A_{11}	Mean	A_2	A_6	A_{10}	A_{11}	Mean	A_2	A_6	A_{10}	A_{11}	Mean
1	T_1	93.99	73.14	90.59	93.33	**87.76**	79.43	69.82	78.63	75.38	**75.81**	56.06	54.44	76.23	68.13	**63.71**
2	T_2	98.36	94.40	93.33	92.36	**94.61**	90.79	89.89	85.71	86.80	**88.29**	83.74	88.88	77.76	82.50	**84.22**
3	T_3	96.99	88.71	92.30	92.06	**92.51**	89.33	86.11	75.21	86.27	**84.23**	76.88	58.44	72.64	73.61	**70.39**
4	T_4	98.20	95.55	98.30	94.44	**96.62**	95.73	91.91	85.46	85.47	**89.64**	93.91	88.35	79.48	70.74	**83.12**
5	T_5	97.54	97.60	88.14	88.19	**92.86**	86.63	90.82	84.02	88.88	**87.58**	71.92	58.18	70.83	84.92	**71.46**
6	T_6	97.18	95.16	95.55	94.44	**95.58**	93.69	90.55	85.18	88.00	**89.35**	89.93	80.29	81.48	80.34	**83.01**
	Mean	**97.04**	**90.76**	**93.03**	**92.47**		**89.26**	**86.51**	**82.36**	**85.13**		**78.74**	**71.43**	**76.40**	**76.69**	
	Treatments	**A**	**T**	**A×T**			**A**	**T**	**A×T**			**A**	**T**	**A×T**		
	SE (d)	0.965	1.182	2.365			0.696	0.853	1.706			0.564	0.691	1.382		
	CD (0.05)	1.941	2.378	4.756			1.400	1.715	3.431			1.134	1.389	2.779		

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