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Influence of Growth regulators on Physiology and Senescence of Cut Stems of Chrysanthemum (*Chrysanthemum morifolium* Ramat) Var. Thai Ching Queen

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Abstract - The present study was conducted on cut stems of standard chrysanthemum var. Thai Ching Queen to assess the effect of ethrel, STS, 6-BAP and TDZ on post harvest senescence of florets and yellowing of leaves. The stems were harvested when ¾th outer florets were fully expanded and treated with ethrel (50 and 100 µM), STS (0.1 and 0.2 mM), 6-BAP (50 and 100µM) and TDZ (5 and 10 µM) for 24 h. After the treatments, the stems were placed in distilled water. One set of stems were similarly treated with water represented control. The stems treated with ethrel exhibited early senescence of florets and yellowing of leaves which was associated with decrease in MSI, loss of chlorophyll and respiratory metabolites (total soluble and reducing sugars), accumulation of H_2O_2 content, increase in lipid peroxidation and loss in activity of antioxidant enzymes viz. peroxidase (POD), superoxide dismutase (SOD) and catalase (CAT). BAP and TDZ treatments prolonged post harvest longevity of florets as well as leaves. This effect was associated with increased activities of antioxidant enzymes. BAP and TDZ treatments, also reduced the production of H_2O_2, minimized lipid peroxidation, maintained respirable substrates and improved water uptake of the stems. TDZ was found to be most effective for delaying floret senescence as well as yellowing of leaves in cut stems of chrysanthemum.

Key words: Chrysanthemum, ethrel, floret senescence, leaf yellowing, pulsing, thidiazuron, vase-life.

I. INTRODUCTION

Maintaining good quality of cut flowers and extending the vase life are considered vital and practical for having acceptable products for the market. The three main factors which affect vase life of cut flowers are plant hormone ethylene which accelerates the senescence of many flowers, depletion of sugars and microorganisms which cause vascular blockage and thus reduce the vase life of cut flowers (Zencirkiran 2010). Numerous studies have been undertaken with the objective to evaluate treatments with various chemicals to extend vase life of various cut flower species (Redman et al. 2002; Macnish et al. 2008; Zencirkiran 2010; Mashhadian et al. 2012).

Chrysanthemum is ranked as the second most economically important cut flower in the world, after rose (Kafi and Ghahsareh 2009). The cut stems of chrysanthemum are highly prone to loss of water through stomata and cavitation of xylem vessels (Meeteren 1989; Nowak and Rudnicki 1990; Singh and Moore 1992). The stems of chrysanthemum varieties also exhibit pre-mature yellowing of leaves which adversely affects vase life. Therefore, finding methods to increase longevity of the cut stem is of great importance. Using preservatives in vase solutions is one of the most common methods for prolonging cut flowers' vase life. Physiology of flower senescence has predominantly been studied in some plant families such as Carophyllacaeae, Malvaceae and Orchidaceae in which petal senescence is regulated by ethylene (Trobacher 2009, Shahri and Tahir; 2011). The evolution of ethylene was not observed in chrysanthemum (Singh and Moore, 1992). Relatively few studies have been made on flower senescence in ethylene-insensitive flowers. The mechanism of floret and leaf senescence in chrysanthemum is not fully understood. The present study was aimed at the physiological and biochemical basis of petal and leaf senescence in chrysanthemum.

II. MATERIALS AND METHODS

Plants of standard chrysanthemum var. Thai Ching Queen were raised through the rooting of terminal cuttings. The rooted cuttings were planted 30×30 cm apart on 6 inch raised beds, at the Research Farm of the Department of Floriculture and Landscaping, PAU, Ludhiana. Recommended agronomical practices were followed to raise the plants to flowering stage. The stems were harvested when ¾th outer florets were fully expanded. Leaves from lower one-third portion of the stem were removed and uniform number of leaves were retained on each stem. The stems were pre-treated with 1000 mg l^{-1} silver nitrate solution by dipping basal 2-3 cm portion for one min to prevent microbial growth on the cut surface of the stem. Thereafter, the stems were treated with the solution containing ethrel (50 and 100 µM), silver thiosulphate (STS) (0.1 and 0.2 mM), 6-benzylaminopurine (BAP) (50 and 100 µM) and thidiazuron (TDZ) (5 and 10 µM), for 24 h in an air-conditioned laboratory (22±3°C; 60-70% R.H. under continuous illumination of 18 µ mol m^{-2} s^{-1} intensity provided by 40 W fluorescent tubes). Following the treatments, the stems were placed in distilled water. Keeping quality of the stems was evaluated under laboratory conditions mentioned above. The freshly-harvested stems placed in distilled water served as control. The experiment was set up in randomized block design with three replications and three stems in each replication. Observations were recorded for days to the initiation and complete senescence of florets and 50% yellowing of leaves. The amount of water uptake by stems was calculated by measuring the volume of water at the termination of vase life and subtracting it from the initial quantity of distilled water in jars. For biochemical estimations, samples of the florets were taken from outer, middle as well as inner whorls and pooled together where as leaves were collected from middle portion of the stem after 6 and 12 days in vase. Biochemical estimations were carried out for leaf chlorophyll content (Hiscox and Israelstam 1979), membrane stability index (Singh et al. 2007), total soluble sugars (Dubois et al. 1956), reducing sugars (Nelson 1944), H_2O_2 content (Brenan and Frenkel 1977), lipid peroxidation (Heath and Packer 1968) and activities of antioxidant enzymes viz. peroxidase (POD) (Shannon et al. 1966), superoxide dismutase (SOD) (Marklund and Marklund 1974) and catalase (CAT) (Teranishi et al. 1974).

Statistical analysis: Each value represents the mean of three independent replicates. The data has been analyzed statistically and CD computed at p=0.05 using CPCS1 software.

III. RESULTS AND DISCUSSION

Floret senescence and yellowing of leaves: Results presented in Table I show that the initiation of floret senescence occurred earliest of all in stems treated with 100 µM ethrel, followed by those treated with 50 µM of ethrel which indicates that ethylene plays role in inducing floret senescence in chrysanthemum. Silver thiosulphate (STS) at 0.1 and 0.2 mM concentration did not affect days to the initiation or complete senescence of florets. STS is an inhibitor of ethylene action and is reported to

improve vase life of ethylene-sensitive flowers such as sweet pea (Mor et al. 1984), some varieties of rose (Chamani 2006), carnation (Karimi et al. 2013) etc. Singh and Moore (1992) have earlier reported that the flowers of chrysanthemum cv. Snow Don produced minute quantities of ethylene and exogenously-applied ethylene also did not affect floret longevity. Ethrel-induced floret senescence in var. Thai Ching Queen indicates that ethylene induces floret senescence of some chrysanthemum cultivars. . Pardha Saradi and Mohan Ram (1989) reported that cobalt chloride, an inhibitor of ethylene biosynthesis extended vase life of chrysanthemum in cv. Jyotsna. IAA, which enhances the activity of ACC synthase (Yang 1980), antagonized the effect of cobalt chloride which indicates that ethylene might induce senescence of florets in some cultivars of chrysanthemum. STS did not significantly affect days to the initiation or complete senescence of florets. It could be because STS treatment was below the threshold level required to delay senescence of florets. Both BAP and TDZ delayed the initiation as well as complete senescence of florets. TDZ was more effective than BAP in this respect. Ethrel treatment significantly hastened the yellowing of leaves. Yellowing of leaves was initiated in 4.00 and 3.33 days in stems treated with ethrel, 50 and 100 µM as compared to 8.67 days in control. Reyes-Arribas et al. (2000) have also reported that exogenous ethylene accelerated decline in chlorophyll content in detached leaves of 'Tara', a yellowing cultivar of chrysanthemum. Doi et al. (2004) also reported that ethylene promoted leaf yellowing in chrysanthemum cultivar 'Shuho-no-chikara' and the sensitivity of the leaves to ethylene gradually increased with time. Both BAP and TDZ delayed the appearance of symptoms of yellowing in the leaves. TDZ was more effective in this respect. The stems treated with TDZ at 5 and 10 µM concentrations exhibited the initiation of leaf senescence in 14.33 and 14.78 days respectively, as compared to 8.67 days in control. Similar trends were observed on the effect of treatments on 50% yellowing of leaves which occurred at the earliest in 100 µM ethrel-treated stems. Maximum delay in 50% yellowing of leaves was observed in stems treated with 10 µM of TDZ followed by the treatment with 5 µM TDZ. Some cut flowers such as stock, *Lilium*, *Alstromeria* and chrysanthemum are sensitive to post harvest yellowing of leaves (Ferrante et al. 2012). One of the main factors causing leaf yellowing could be ascribed to the degradation of chlorophyll caused by lack of cytokinins. BAP has been reported to extend vase life of 3 species of *Draceana* viz. *D. marginata* 'bicolor', *D. sanderiana* 'white' and *D. deremensis* whereas STS had no effect (Subhashini et al. 2011). Thidiazuron (TDZ), a substituted phenyl urea with cytokinin activity is reported to delay leaf yellowing as well as flower senescence in freesia, geranium, *Ornithogalum*, *Euphorbia fulgens* (Jiang et al. 2009), cut stock flowers and *Matthiola incana* (Ferrante et al. 2012).

Water absorption: Stems treated with ethrel (50 and 100 µM) recorded the minimum water absorption. Ethrel-induced decrease in water absorption was apparently due to early senescence of leaves. Treatments with STS did not significantly affect water absorption by the stem over the control. BAP and TDZ improved water absorption and the effects were more pronounced in case of TDZ-treated stems. Improved water absorption in BAP and TDZ-treated stems was apparently due to delayed senescence of leaves and florets with these treatments. It has also been reported that treatment with TDZ in chrysanthemum prevented weight loss and improved hydraulic conductance of the stem (Ferrante 2012). It may be noted that in the present study though BAP and TDZ both delayed senescence of florets and leaves, TDZ was more effective at much lower concentrations i.e. at 5 and 10 µM than BAP at 50 and 100 µM. Jiang et al. (2009) have suggested that TDZ is a good substitute for BAP, zeatin and other cytokinins because of its high activity and non metabolizable nature.

Chlorophyll content: Chlorophyll content showed decline with increase in duration in vase (Figure I). The minimum chlorophyll content was observed in treatment with 100 µM ethrel after 12 days in vase. STS treatment did not significantly affect chlorophyll content of the leaves. On the other hand, both BAP and TDZ maintained significantly higher chlorophyll content than the control. Effect of TDZ in this respect was more pronounced than that of BAP. After 12 days in vase, the maximum chlorophyll content was observed in leaves of stems treated with10 µM TDZ. These results support the observations discussed earlier that TDZ treatment delayed number of days taken for yellowing of leaves.

Membrane stability index (MSI)*:* Cut stems showed progressive decline in MSI in both florets and leaves with increase in number of days in vase (Figure II). The maximum MSI was observed on 0 day i.e. immediately after the treatment but declined to the lowest level after 12 days in vase. Treatment with ethrel significantly decreased where as BAP and TDZ substantially improved MSI of both florets and the leaves. MSI is an indicator of functional properties of the membrane. Membrane deterioration is characteristic feature of petal senescence in which an increase in membrane fluidity is observed and membranes lose selective permeability (Singh et al. 2007). Increase in membrane permeability and electrolyte leakage has also been reported earlier in senescing petals (Elanchezian and Srivastava 2001, Gulzar et al. 2005, Chakrabarty et al. 2009). Membrane stabilizing effect of BAP and TDZ indicates that both these bioregulators curtailed the deteriorative processes that bring about loss of membrane permeability in florets and leaves.

Total soluble sugar and reducing sugar content: Total soluble sugar and reducing sugar content of florets showed decline as number of days progressed in vase (Table II). Leaves recorded significantly lower total soluble as well as reducing sugar contents than florets. Florets from the stems treated with ethrel exhibited significant decrease in total soluble sugar content. The stems treated with both the concentrations of STS did not significantly influence total soluble sugar content over the control. Treatment with BAP and TDZ slowed down the reduction in total soluble sugar content as only slight decrease was observed after 6 and 12 days with these treatments. It was observed that BAP and TDZ treatments maintained high total soluble sugar contents even after 12 days. Exogenous ethylene treatment is reported to increase activities of hydrolytic enzymes which lead to rapid depletion of sugars and other metabolites consequently negatively affecting vase life of cut flowers (van Doorn and Woltering 2008). In the present study, STS treated stems did not exhibit significant change in total soluble and reducing sugar contents over the control. These treatments also did not prolong longevity of the florets or leaves. Cytokinins are reported to maintain high carbohydrate levels by regulating assimilate partitioning (Roitsch and Ehness 2000). Cytokinins also affect invertase activity responsible for sugar metabolism in florets and leaves (Lara et al. 2004). This may explain the maintenance of high soluble sugars of florets and leaves in stems treated with BAP and TDZ.

MDA and H_2O_2 content: Florets and leaves exhibited low content of MDA and H_2O_2 initially but both continued to increase till 12 days in vase (Table III). The contents were very high in ethrel-treated stems and maximum in treatment with 100 µM ethrel after 12 days in vase. STS treatment did not much affect MDA and H_2O_2 content of the florets and leaves over the control. Both BAP and TDZ significantly reduced MDA content in the florets and leaves. It may, thus appear that BAP and TDZ helped in stabilizing membranes by reducing peroxidation of membrane fatty acids.

Activity of antioxidant enzymes: SOD activity of the florets showed slight increase till 6 days of storage but showed subsequent decline after that (Table 4). Treatment with ethrel was found to decrease enzyme activity where as STS had no significant effect. Treatment with BAP and TDZ increased SOD activity of florets with maximum activity (127.8 U min^{-1} g^{-1} FW) was observed in 10 µM TDZ treated stems. Similar trends were observed in leaves. The activity showed increase with progress of storage duration. Ethrel suppressed SOD activity where as BAP and TDZ enhanced it. POD activity of florets showed increase in storage duration (Table 4). As a consequence, the activity reached the maximum level after 12 days of storage. Treatment with ethrel inhibited POD activity. As a consequence, high ethrel concentration (100 µM) led to maximum decline in activity as compared to control. BAP and TDZ significantly enhanced POD activity over the control. As a consequence, the maximum activity was observed in 10 µM TDZ treatment. The leaves exhibited lesser POD activity than the florets. The activity exhibited similar trends as observed in florets. The activity increased with increasing storage duration. The activity was minimum in leaves of ethrel-treated stems but was higher in stems treated with BAP as well as TDZ. The maximum activity was observed in stems treated with 10 µM TDZ. Catalase activity in florets also showed increase during storage of the stems (Table 4). The activity decreased slightly in ethrel-treated stems where as

BAP and TDZ enhanced the same. Leaves showed continuous increase in CAT activity during storage. The activity was high in BAP and TDZ treated stems. The maximum activity was observed in leaves from stems treated with TDZ (10 µM).

It has been suggested that metabolic processes related to senescence continue during refrigerated storage, though at a slow pace (Bhattacharjee and De 2006; Singh et al. 2012). Present studies also illustrate that with the progress of storage duration, the cut stems exhibited loss of floret longevity and early yellowing of leaves. The increase in SOD activity, which neutralizes superoxide radicals, during storage is indicative of production of ROS in florets and leaves during storage. Similarly, high activity of peroxidase and catalase during storage indicates that these enzymes play a role in removal of H_2O_2 produced in florets and leaves during storage. It has also been suggested earlier that damage induced by low temperatures could be due to generation of ROS (Campos et al. 2003; Wongshree et al. 2009; Yang et al. 2011). This may also account for increase in antioxidant enzyme activities during storage of stems.

IV. References

1. Brenan T, Frenkel C (1977) Involvement of hydrogen peroxide in the regulation of senescence in pear. Plant Physiology 59:411-416

2. Chakrabarty D, Verma AK, Dutta SK (2009) Oxidative stress and antioxidant activity as the basis of senescence in *Hemerocallis* (day lily) flowers. J Hort Forestry 1:113-119

3. Chamani E (2006) Effect of TDZ, 1-MCP, NO_2, STS and ethylene on physiochemical characteristic of cut rose first red. Ph.D. Thesis, University Of Tehran, Iran.

4. Doi M., Aoe K, Watabe S, Inamoto K, Imanishi H (2004) Leaf yellowing of cut standard chrysanthemum (*Dendranthema grandiflora kitamura*) 'shuho-no-chikara' induced by ethylene and the postharvest increase in ethylene sensitivity. J Japanese Soc Hort Sci 73:229-234

5. Dubois M, Giles KA, Hamilton JK, Rebers PA, Smith F (1956) Colorimetric method for the determination of sugars and related substances. Ann Chem 28:350-356

6. Elanchezhian R, Srivastava GC (2001) Effect of growth regulators on senescence of chrysanthemum flowers. Indian J Plant Physiol 6:233-243

7. Evans AC, Burge GK, Litlejohn RP, Douclas MH, Bicknell RA, Lill RE (2002) Mount cook lily (*Ranunculus lyalli*) a potential cut flower? New Zealand J Crop Hort Sci 30:323-28

8. Ferrante A, Trivellani A, Sodi AM (2012) Interaction of 1-methylcyclopropene and thidiazuron on cut stock flowers vase life. The Open Hort J 5:1-5

9. Gulzar S, Tahir I, Amin I, Farooq S(2005) Flower development and senescence in petunia hybrida vilm cv. Tint cascade. J Plant Biol 32:53-56

10. Heath RL, Packer L (1968) Photoperoxidation in isolated chloroplast. i. kinetics and stoichiometry of fatty acid peroxidation. Archives Biochem Biophysics 125:189-198

11. Hiscox JD, Israelstam GF (1979) A method for extraction of chlorophyll from leaf tissue without maceration. Hort Res 9:26-36

12. Jiang CZ, Wu L, Macnish AJ, King A, Yi M, Reid MS (2009) Thidiazuron, a non-metabolized cytokinin, shows promise in extending the life of potted plants. Acta Hort 847:59- 65

13. Kafi M, Ghahserah M (2009) Floriculture. 4th Edition, Vol I, Pp 108-18. Jahad Press, Tehran.

14. Karimi M, Asil MH, Nematzadeh G, Zakizadeh H (2013) Effects of anti ethylene treatments on ethylene production and antioxidant activites on cut spray carnation. J Fruit Orn Plant Res 20:173-182

15. kumar n, singh rk (2007) Effect of sulphosalicylic acid on antioxidant activity of cut gladiolus spikes of different genotypes. Asian J Hort 2:37-43

16. Lara MEB, Garcia MCG, Fatima T, Ehness R, Lee TK, Proels R (2004) Extracellular invertase is an essential component of cytokinin mediated delay of senescence. Plant Cell 16:1276-1287

17. Macnish AJ, Jiang CZ, Reid MS (2010) Treatment with thidiazuron improves opening and vase life of iris flowers. Postharvest Biol Technol 56:77-84

18. Marklund S, Marklund G (1974) Involvement of superoxide anion radical in autooxidation of pyrogallol as a convenient assay for superoxide dismutase. European J Biochem 47:469-474

19. Mashhadian NV, Tehranfar HB, Seleahvarzi Y (2012) Salicylic and citric acid treatments improve the vase life of cut chrysanthemum flowers. J Agric Sci Tech 14:879-887

20. Mor Y, Reid MS, Kofranek AM (1984) Pulse treatment with silver thiosulphate and sucrose improve the vase life of sweet peas. J Amer Soc Hort Sci 109:866-868

21. Nelson N (1944) A photometric adaptation of the somogyi method for the determination of glucose. J Biol Chem 153:375-380

22. Nowak J, Rudnicki RM (1990) Postharvest handling and storage of cut flowers, florist greens and potted plants. Pp 209.Chapman and Hall, London
.
23. Redman P B, Dole JM, Maness NO, Anderson JA (2002) Post harvest handling of nine speciality cut flower species. Sci Hort 92:203-303

24. Reid MS (1989) The role of ethylene in flower senescence. Acta Hort 261:157-169

25. Reyes-Arribas T, Barett JE, Nell TA, Clark DG (2000) Effect of ethylene and benzyl adenine on leaf senescence of two chrysanthemum cultivars ′tara′ and ′boaldi′. Acta Hort 518:125-129

26. Roitsch T, Ehness ER (2000) Regulation of source sink relation by cytokinins. Plant Growth Regul 32:359-367

27. Shahri W,Tahir I (2011) Flower senescence-strategies and some associated events. Bot Rev 77:152-184

28. Shannon LM, Kay E, Lew JY (1966) Peroxidase isozymes from horse radish roots: isolation and physical properties. J Biol Chem 241:2166-2172

29. Singh A, Kumar J, Kumar P, Singh VP (2007) Membrane stability and post harvest keeping quality of gladiolus cut spikes as influenced by certain chemicals with sucrose in vase solution. J Orn Hort 12:63-71

30. Singh K, Moore KG (1992) Water relations of cut chrysanthemum flowers. Adv Hort Sci 6:121-124

31. Subhashini RMB, Amarathunga NLK, Krishnarajah SA, Eeswara JP (2011) Effect of benzylaminopurine, gibberellic acid, silver nitrate and silver thiosulphate, on postharvest longevity of cut leaves of dracaena. Ceylon J Sci (Biol Sci) 40:157-162

32. Teranishi Y, Tanaka A, Osaumi M, Fukui S (1974) Catalase activity of hydrocarbon utilizing candida yeast. Agric Biochem 38:1213-1216

33. Trippi V, Paulin A (1984) The senescence of cut carnations: a phasic phenomenon. Physiol Plantarum 20:221-226

34. Trobacher CP (2009) Ethylene and programmed cell death in plants. Botany 87:757-769

35. van Doorn WG, Woltering EJ (2008) Physiology and molecular biology of petal senescence. J Exp Bot 59:453-480

36. Zencirkiran M (2010) Effects of 1-MCP (1-methylcyclopropene) and STS (silver thiosulphate) on vase life of cut freesia flowers. Scientific Res Essays 5:2409-2412

37. Zhou Y, Wang CY, Cheng ZW (2008) Effect of exogenous ethylene and ethylene inhibitors on longevity and petal senescence of sweet osmanthus. Acta Hort 768:487-493

Table I: Effect of ethrel, STS, 6-BAP and Thidiazuron (TDZ) on days to floret senescence, yellowing of leaves and water absorption per stem in chrysanthemum var. Thai Ching Queen					
Treatments	**Days to initiation of floret senescence**	**Days to complete floret senescence**	**Days to initiation of leaf yellowing**	**Days to 50% leaf yellowing**	**Total water absorbed per stem (ml)**
Control	7.33	16.67	8.67	14.67	36.7
Ethrel, 50 µM	6.67	14.33	4.00	11.33	31.7
Ethrel, 100 µM	5.56	10.78	3.33	10.00	30.6
STS, 0.1 mM	7.44	16.33	7.67	14.67	33.8
STS, 0.2 mM	8.45	16.78	8.56	15.45	35.3
BAP, 50 µM	11.00	17.00	10.89	17.67	41.5
BAP, 100 µM	11.56	19.67	11.67	19.00	44.7
TDZ, 5 µM	14.89	22.44	14.33	22.78	49.7
TDZ, 10 µM	15.22	23.56	14.78	23.56	51.5
Mean	9.79	17.51	9.32	16.57	39.5
CD at p=0.05	0.71	0.96	0.74	0.84	1.49

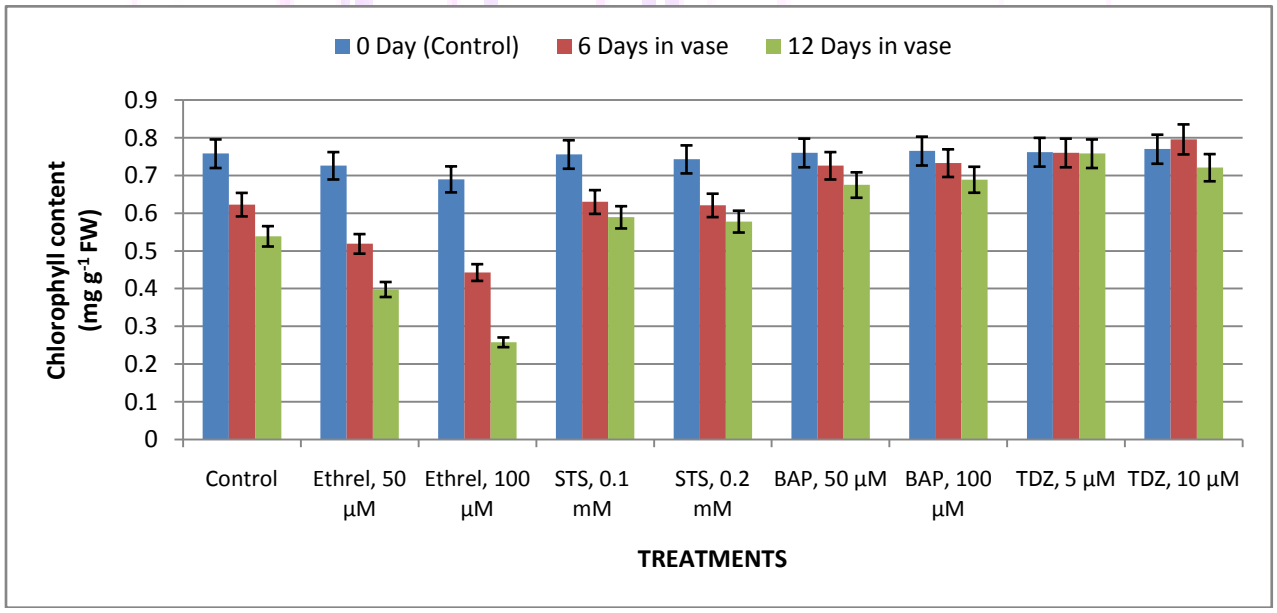

Figure I: Effect of ethrel, silver thiosulphate (STS), 6-benzyl aminopurine (BAP) and thidiazuron (TDZ) on chlorophyll content (mg g^{-1} FW) in leaves of chrysanthemum variety Thai Ching Queen after varying durations in vase (Vertical bars represent SE of mean)

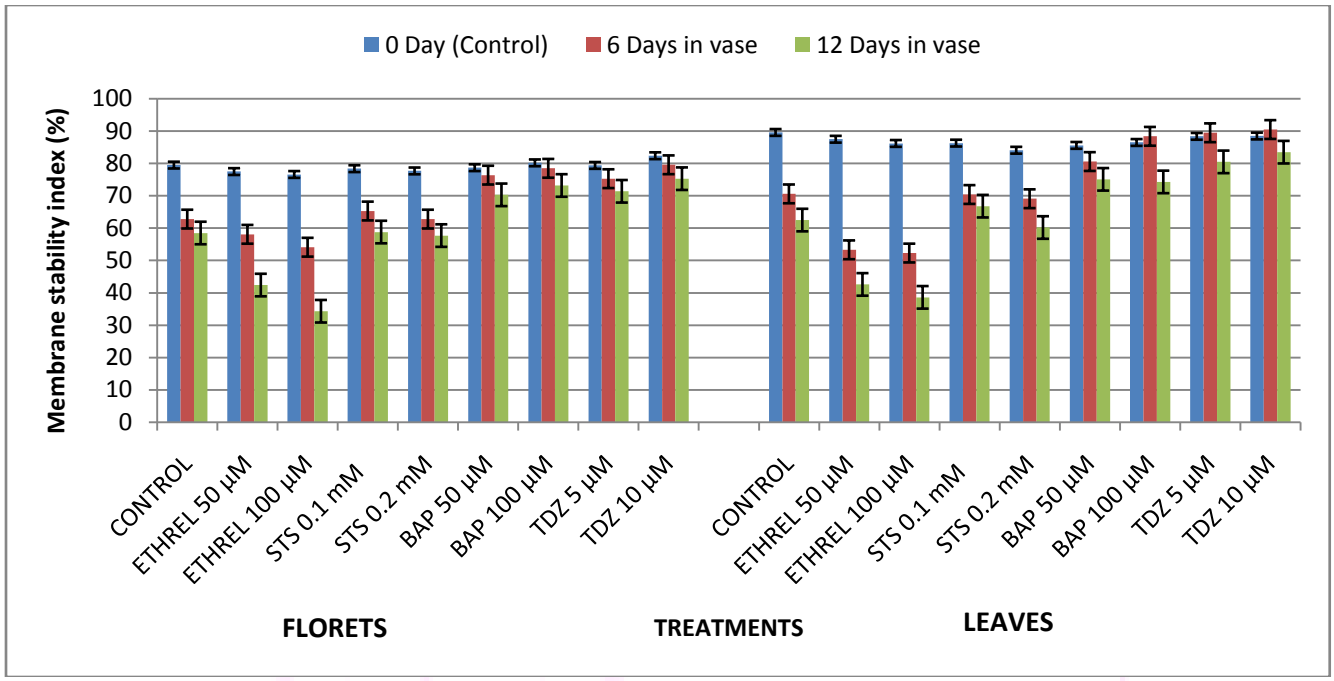

Figure II: Effect of ethrel, STS, 6-BAP and TDZ on membrane stability index (%) in florets and leaves of chrysanthemum variety Thai Ching Queen after varying durations in vase (Vertical bars represent SE of mean)

Table II: Effect of ethrel, silver thiosulphate, 6-benzyl aminopurine and thidiazuron on total soluble and reducing sugar (µg mg^{-1} DW) content in florets and leaves of cut stems of chrysanthemum variety Thai Ching Queen after varying durations in vase																
Treatments	**TOTAL SOLUBLE SUGAR content**								**REDUCING SUGAR content**							
	FLORETS				**LEAVES**				**FLORETS**				**LEAVES**			
	0	**6**	**12**	**M**	**0**	**6**	**12**	**M**	**0**	**6**	**12**	**M**	**0**	**6**	**12**	**M**
Control	522.1	355.6	264.9	380.9	148.7	116.8	81.9	115.8	48.6	24.5	18.3	30.5	6.7	4.9	3.3	5.0
Ethrel, 50 µM	508.4	331.8	207.3	349.2	150.1	108.4	79.4	112.7	40.2	19.1	10.5	23.3	6.5	3.8	2.3	4.2
Ethrel, 100 µM	505.5	334.8	211.3	350.5	148.9	98.2	70.2	105.8	39.6	17.5	8.9	22.0	5.9	2.8	1.2	3.3
STS, 0.1 mM	507.7	347.6	248.5	367.9	152.3	106.6	80.8	113.2	40.9	26.7	17.6	28.4	6.6	4.2	3.4	4.7
STS, 0.2 mM	501.3	354.3	310.2	388.6	147.8	119.8	81.7	116.4	44.4	29.5	18.7	30.9	7.0	6.6	4.6	6.1
BAP, 50 µM	494.5	362.4	254.5	370.5	147.0	123.8	85.3	118.7	41.9	25.9	25.1	31.0	6.6	5.8	4.5	5.6
BAP, 100 µM	493.9	371.8	274.9	380.2	151.7	133.4	90.8	125.3	47.5	31.6	28.9	36.0	8.5	6.4	6.0	7.0
TDZ, 5 µM	502.3	370.9	263.8	379.0	153.9	125.2	91.5	123.5	44.5	42.8	39.3	42.2	7.0	7.3	7.6	7.3
TDZ, 10 µM	507.7	364.3	283.9	385.0	151.6	135.9	107.7	131.7	45.7	47.5	40.4	44.5	8.5	10.0	10.4	9.6
CD at p=0.05	Treatments (A)=34.21; Days in vase (B)=19.49; AXB=59.21				Treatments (A)=11.50; Days in vase (B)=6.62; AXB=NS				Treatments (A)=3.35; Days in vase (B)=1.92; AXB=5.80				Treatments (A)=0.53; Days in vase (B)=0.36; AXB=0.87			

Table III: Effect of ethrel, silver thiosulphate, 6-benzyl aminopurine and thidiazuron on H_2O_2 (mM g^{-1} FW) and MDA content (n mol g^{-1} FW) in florets and leaves of cut stems of chrysanthemum variety Thai Ching Queen after varying durations in vase																
Treatments	**H_2O_2 CONTENT**								**MDA CONTENT (lipid peroxidation)**							
	FLORETS				**LEAVES**				**FLORETS**				**LEAVES**			
	0	**6**	**12**	**M**	**0**	**6**	**12**	**M**	**0**	**6**	**12**	**M**	**0**	**6**	**12**	**M**
Control	0.543	0.673	0.865	0.693	0.507	0.754	0.853	0.705	1.643	1.993	2.353	1.996	1.130	1.357	1.933	1.473
Ethrel, 50 µM	0.682	0.752	1.345	0.926	0.590	0.939	1.049	0.859	1.753	2.232	3.333	2.439	1.257	1.740	2.040	1.679
Ethrel, 100 µM	0.652	1.259	1.650	1.187	0.663	1.049	1.145	0.952	1.750	2.543	3.933	2.742	1.250	2.300	2.413	1.988
STS, 0.1 mM	0.511	0.561	0.843	0.638	0.554	0.675	0.834	0.688	1.752	2.271	2.343	2.122	1.227	1.541	2.067	1.612
STS, 0.2 mM	0.438	0.546	0.789	0.591	0.559	0.645	0.754	0.653	1.630	2.030	2.380	2.013	1.223	1.430	1.947	1.533
BAP, 50 µM	0.381	0.447	0.427	0.418	0.419	0.491	0.663	0.524	1.463	1.857	2.147	1.822	1.187	1.360	1.597	1.381
BAP, 100 µM	0.334	0.433	0.574	0.447	0.389	0.473	0.642	0.501	1.400	1.637	1.837	1.624	0.977	1.150	1.213	1.113
TDZ, 5 µM	0.353	0.452	0.558	0.454	0.403	0.539	0.724	0.555	1.033	1.315	1.453	1.267	1.160	1.2057	1.373	1.246
TDZ, 10 µM	0.324	0.486	0.543	0.451	0.410	0.474	0.633	0.506	1.093	1.309	1.467	1.289	1.047	1.113	1.260	1.140
CD at p=0.05	Treatments (A)=0.07; Days in vase (B)=0.04; AXB=0.13				Treatments (A)=0.07; Days in vase (B)=0.04; AXB=NS				Treatments (A)=0.12; Days in vase (B)=0.07; AXB=0.21				Treatments (A)=0.13; Days in vase (B)=0.08; AXB=0.23			

Table IV: Effect of ethrel, silver thiosulphate, 6-benzyl aminopurine and thidiazuron on enzyme activities in florets and leaves of chrysanthemum variety Thai Ching Queen after varying durations in vase																								
Treatments	**Superoxide dismutase (SOD) activity (U min^{-1} g^{-1} FW)**								**Peroxidase (POD) activity (change in absorbance min^{-1} g^{-1} FW)**								**Catalase (CAT) activity (mM H_2O_2 hydrolysed g_{-1} FW)**							
	FLORETS				**LEAVES**				**FLORETS**				**LEAVES**				**FLORETS**				**LEAVES**			
	0	**6**	**12**	**M**	**0**	**6**	**12**	**M**	**0**	**6**	**12**	**M**	**0**	**6**	**12**	**M**	**0**	**6**	**12**	**M**	**0**	**6**	**12**	**M**
Control	98.5	83.6	72.6	84.9	54.4	48.9	42.4	48.6	94.7	120.4	71.9	95.7	123.8	95.5	77.8	90.0	0.546	0.476	0.435	0.485	0.981	0.873	0.753	0.869
Ethrel, 50µM	93.2	70.6	43.8	69.2	53.9	45.3	36.6	45.3	90.5	113.6	65.5	89.9	118.5	96.5	78.1	97.7	0.526	0.466	0.392	0.461	0.942	0.864	0.820	0.875
Ethrel, 100µM	90.5	68.9	36.3	65.2	51.8	38.9	32.8	41.2	88.5	110.6	60.5	86.5	112.5	97.8	66.1	105.5	0.516	0.443	0.365	0.441	0.893	0.810	0.752	0.818
STS, 0.1mM	96.8	90.3	70.3	85.8	52.3	48.4	41.7	47.5	93.4	107.8	87.3	96.2	123.4	107.8	75.5	102.2	0.544	0.488	0.443	0.491	0.973	0.846	0.821	0.880
STS, 0.2 mM	97.6	85.3	75.0	86.0	53.7	50.3	48.7	50.9	95.0	116.6	81.2	97.6	120.3	102.3	82.5	101.7	0.556	0.500	0.452	0.502	0.987	0.862	0.830	0.893

BAP, 50µM	100.5	95.3	81.8	92.5	52.5	58.5	54.8	55.3	95.8	131.4	114.2	113.8	125.5	112.4	101.5	113.1	0.542	0.513	0.483	0.512	0.981	0.892	0.800	0.891
BAP, 100µM	103.2	98.0	85.3	95.5	56.7	58.2	54.6	56.5	92.1	135.6	120.1	115.9	130.6	117.6	110.4	119.5	0.541	0.524	0.490	0.518	0.900	0.901	0.856	0.885
TDZ, 5µM	97.9	97.9	90.5	95.4	57.1	62.6	64.9	61.5	87.7	127.4	114.6	109.9	125.6	128.4	116.3	123.4	0.550	0.540	0.514	0.534	0.874	0.842	0.800	0.838
TDZ, 10µM	99.5	91.7	88.9	93.4	58.6	61.9	65.6	62.0	94.3	130.4	120.4	115.0	128.9	135.7	120.8	128.4	0.557	0.595	0.524	0.558	0.892	0.863	0.745	0.833
CD at p=0.05	Treatments (A)=5.65; Days in vase (B)=3.25; AXB=9.64				Treatments (A)=5.24; Days in vase (B)=2.92; AXB=8.90				Treatments (A)=7.37; Days in vase (B)=4.23; AXB=12.73				Treatments (A)=6.03; Days in vase (B)=3.57; AXB=8.90				Treatments (A)=0.008; Days in vase (B)=0.005; AXB=0.010				Treatments (A)=0.020; Days in vase (B)=0.009; AXB=0.020			