Effect of Cycocel and Paclobutrazol on the Dwarfing Characteristics of *Chrysanthemum indicum* L.

M. H. Abou Elhassan, H. A. Bosila, M. A. Hamza*, A. A. Elateeq, and A. I. Abdel-Gawad

Horticulture Department, Faculty of Agriculture, Al-Azhar University, Cairo, Egypt.

*Corresponding author E-mail: hamza.plant@azhar.edu.eg (M. Hamza)

ABSTRACT:

Chrysanthemum indicum L. is one of the most important ornamental crops worldwide that can be produced as both potted plants and cut flowers. In this paper, a pot experiment was conducted to study the effects of different levels of cycocel (1500, 3000 and 6000 ppm) and paclobutrazol (25, 50 and 75 ppm) on the dwarfing characteristics of *C. indicum* plant as a potted plant. Spraying the dwarfing agents, cycocel (CCC) and paclobutrazol (PPP) was started 4 weeks after the cuttings were transplanted and repeated 2 weeks later. After applying CCC and PPP, the vegetative and flowering growth characteristics as well as leaf pigments showed significant differences between treatments. Application of the growth retardants had a positive influence on reducing plant height and increasing shoot number, flowering period and flowers number per plant. Moreover, chlorophyll and carotenoids contents were enhanced in plants sprayed with CCC and PPP at all concentrations. In sum, moderate and low levels of CCC (1500 and 3000 ppm) and PPP (25 and 50 ppm) had the desired effects in manipulating growth parameters of *C. indicum*, thus enhancing dwarfing and the commercial value of *C. indicum* for the industry of potted ornamental flowering plants.

Keywords: Chrysanthemum; Cycocel; Paclobutrazol; Growth Retardants; Dwarfing; Chlorophyll.

INTRODUCTION

Floricultural cut flowers and pot plants occupy a major share in the human interesting and accordingly the demand for pot plants has increased (Renu and Srivastava, 2013). The genus *Chrysanthemum* L. (*Dendranthema* (DC.)) belongs to the family Asteraceae and includes about 40 species, widely distributed in China, Mongolia, Japan, and Eastern Europe. Nowadays, most of *Chrysanthemum* plants are cultivated as ornamentals in the whole world (Mabberley, 2008; Youssef *et al.*, 2020). *Chrysanthemum indicum* L. is one of the most important ornamental crops worldwide that can be produced both as pot plant and cut flower.

A major problem with chrysanthemums which are grown as pot plants is its plant height is greater than desired and its irregular growth habit. The fastest and the cheapest way to induce compactness and to reduce the height of chrysanthemums is application of growth retardants. *C. indicum* demands a short day until flowering and pot plants are used for house decoration. Its use in amenity horticulture has steadily increased not only for their outstanding aesthetic beauty and a long-lasting quality but also because of their good prospect of marketing as cut flowers and potted plants for many countries in the world (Erler and Sigmund, 1986). Many researchers have shown that there is a great variation in sensitivity of chrysanthemum cultivars to application of growth retardants (Pobudkiewicz, 2014).

Plant growth retardants can be an economical option for controlling growth, and to improve the quality and overall appearance of many plants (Asrar *et al.*, 2014; Toaima *et al.*, 2017). Among various plant growth retardants, paclobutrazol and cycocel are well known for producing qualified dwarfed plants. Paclobutrazol, a triazole plant growth regulator, is effective in controlling vegetative growth and promoting compactness in the production of a number of ornamental plants including *C. morifolium* (Zalewska, 1989). Paclobutrazol operates by inhibiting cytochrome P-450, which mediates oxidative dimethylation reactions, including those which are necessary for the synthesis of ergosterol and the conversion of kaurene to kaurenoic acid in the gibberellins biosynthetic pathway (Fletcher *et al.*, 2000). Cycocel is a synthetic plant growth inhibitor used in ornamental plants to cause dwarfing in plants and shorter green stems and leaves. It is also used in order to produce potted and bedding plants, enhance the green color of foliage, strengthen the flower stem and raise the foliage's resistance to environmental stresses (Ghatas, 2016). The present work aims to produce a potted chrysanthemum plant by studying the effect of spraying growth retardants, cycocel and paclobutrazol, on the dwarf characteristics of *C. indicum* L. to improve the quality of the product enough to meet market quality standards.

MATERIALS AND METHODS

The experiment was conducted in a private field at El-Qurin, Sharkia, Egypt during the two successive seasons 2018/2019 and 2019/ 2020 to investigate the effect of applying growth retardants paclobutrazol (PPP) and cycocel (CCC) on growth and flowering of *Chrysanthemum indicum* L. cv. Pink Zamble.

Plant materials

C. indicum L. cv. Pink Zamble cuttings were obtained from a private farm at El-Qanater El-Khayreya, Qalyubia, Egypt. Terminal cuttings (8-10 cm long) were treated with indole 3-butyric acid (IBA) powder at 2000 ppm. The cuttings were then planted in a mixed medium of sand and peat-moss in a ratio of 1:1 (V/V) and incubated under long day conditions and fairly high humidity for 10-15 days until fully rooted.

Soil and water used

A commercial mixture substrate composed of 20% perlite and 80% peat moss v/v were prepared homogeneity before cultivation. The soil pH was adjusted to 6.2 with calcium carbonate. Irrigation water and soil mixture were chemically analyzed at National Research Centre, Dokki, Cairo, Egypt and the results were presented in Table (1) and (2), respectively.

Cultivation

Pots of 14 cm diameters were filled with the previous prepared mixture. The pots were arranged into groups of 15 pots for each treatment which contains 3 replicates of 5 pots each. The different groups of the prepared pots were placed on benches in spacing of 30 cm x 30 cm. Uniform rooted cuttings, 15 days old, were planted on February 1st in both seasons. The planted containers (one plant per pot) were placed on top of bricks for easy of drainage water and were grown under Maltispan covered with plastic thickness of 120 microns. After transplanting, artificial light for 4 hours (3 meters between lamps and 1.75 meter between plant and lamp) were employed to prolong the day to become more than 16 hours for all treatments for 28 days. After that, covering black plastic was applied from 5 PM to 7 AM until color appeared in the flower buds. Pinching was carried out 2 weeks after planting. Plants were watered by drip irrigation to control the irrigation management with a frequency depending on weather and plants conditions.

Treatments

Cycocel (CCC) (chlormequat chloride or 2-chloro ethyl trimethyl ammonium chloride) at rates of 1500, 3000, 6000 ppm and paclobutrazol (PPP) at rates of 25, 50 and 75 ppm were applied in the present study. CCC and PPP treatments started 4 weeks after the cuttings were transplanted (2 weeks after pinching) and repeated again 2 weeks later. The spraying soaks both leaves and stems using 2-liter hand pump sprayer to wet foliage and stems. Control plants were sprayed with tap water. Treatments are applied in the afternoon (4.00 pm) when the temperature is at the lowest level, evaporation is reduced and absorption is easier.

Measurements

Vegetative parameters:

Plant height (cm) from the pot surface to stem apex, number of branches per plant, and number of leaves per plant were measured at the beginning of flowering. Fresh weight of aerial organs including flowers (g/plant) was recorded at the stage of complete flowering opening. Dry weight (g/plant) was determined after drying in an oven at 65^{o}C for 48 h until the weight became constant.

Flowering parameters:

Flowering start was considered at the first bud sprouting since the cuttings were planted. Flowers number per plant was calculated for both open and unopened flowers. Flower diameter (cm) was measured for opened flowers, and flowering period was recorded from the first opened flower until the end of experiment.

Leaf pigments determination:

Chlorophyll a, b, total chlorophyll and carotenoid contents (mg/g FW) were determined spectrophotometry (JENWAY 6800 UV/Vis. spectrophotometer) in leaf extracts according to Lichtenthaler (1987)

Statistical analysis

The experiment design was arranged in a randomized complete block design during the two seasons. Each treatment contained three replicates and each replicate consisted of 5 potted plants. The statistical analysis of data was subjected to Analysis of Variance (ANOVA) followed by Duncan's Multiple Range Test (DMRT) (Duncan, 1955) at $P<0.05$

using COSTAT package ver. 6.4 (CoHort software Monterey, USA).

RESULTS AND DISCUSSION

Effect of CCC and PPP on vegetative growth characteristics

When producing potted plants, height control is often necessary to achieve the desired size and shape of the plant. As shown in Table (3), application of CCC and PPP each alone caused a significant inhibition in plant height compared to control treatment in both seasons. Plant height was decreased linearly in relation to the increase in the concentration of CCC and PPP. The tallest plants in both seasons were recorded from untreated plants (control). The treated plants had different growth rates due to the concentration application of plant growth retardants. The plant heights through the first and second growing seasons were 49.33, 20.20 and 14.10 cm/plant, and 50.33, 22.00 and 14.10 cm/plant, respectively, for CCC concentrations (1500, 3000 and 6000 ppm, respectively), while they were 55.50, 23.00 and 14.67 cm/ plant, and 70.30, 25.13 and 14.66 cm/ plant, for first and second seasons, respectively, for PPP concentrations (25, 50 and 75 ppm, respectively) compared to control (74.67 and 77.33 cm/plant, respectively). The mechanism of reduction occurred in plant height due to the growth retardant application appears to be related to slowing down of cell division and reducing cell expansion (Magnitskiy *et al*., 2006). Karunananda and Peiris (2010) suggested that reduction in stem height of pot poinsettia under CCC application probably was caused by restriction of cell elongation rather than cell division. It is known that cycocel completely inhibits the biosynthesis of gibberellins (GA) (Carvalho *et al*., 2008); the main phytohormone responsible for cell elongation (Latimer *et al*., 2001).

With respect to branching, the results in Table (3) show that using CCC and PPP gave a significantly different response in number of branches. Number of branches increased by spraying CCC at low and moderate doses in both seasons, while PPP only stimulate branching at moderate concentration. The highest branch number (4.00 branches per plant) was counted for plants treated with 1500 ppm of cycocel in first season compared to control (3.00 branches per plant). Higher levels of CCC and PPP led to a severe reduction in the number of branches due to the toxic effect on the plant cell. Promotion of branching due to low and moderate levels of CCC and PPP is mainly attributed to the inhibitory effect of these growth regulators on the cell division in the apical bud, which subsequently might have stopped the growth of the main axis and resulted in more laterals production (Prashanth *et al*., 2006; Di Benedetto and Molinari, 2007). Moreover, plant growth retardants activated lateral buds to grow and fill in with a greater number of branches (Benjawan *et al*., 2007). The increase in number of branches could be due to inhibition in the auxin activity in the apical bud because of the application of growth inhibitor since they act as anti-auxin. These treatments intern suppressed the apical dominance, thereby diverting the polar transport of auxins towards the basal nodes leading to increase branching rate (Dole and Wilkins, 1999 and Reddy, 2005). Hence, special care is needed to establish bushy and dwarfed chrysanthemum plants to suit market specifications mainly in terms of plant height and number of branches, mostly 20 to 50 cm and 3-4 branches per plant.

In contrast to branches number, leaves number per plant was decreased with all concentrations of CCC and PPP in both seasons (Table 3). This decrease in leaf number may be attributed to the resulting inhibition on stem height under the influence of the growth inhibitors. The negative effect on the number of leaves increased with the increase in the concentration of the growth inhibitors. However, fresh and dry weights recorded higher values for plants treated with low and moderate doses of PPP, implying that plants may have absorbed more water and nutrients. Similar observation was reported by Liu *et al*. (2012) on *Vallisneria natans*. In this concern, 25 ppm of PPP recorded the highest fresh weight (93.00 and 93.67 g/plant) in first and second seasons, respectively. Same level of PPP enhanced dry weight without significant differences with control. All treats of CCC reduced fresh and dry weights of plants compared to untreated ones. North *et al*. (2010) on *Dombeya burgessiae* reported the same observation where the fresh and dry weights of plants were severely reduced with the increase in CCC concentrations. Lodeta *et al*. (2010) studied the effect of different combinations of cycocel (500, 1500 and 3000 ppm) and alar (2500 and 5000 ppm) on *Euphorbia pulcherrima*. They found that minimum dry weight was recorded with cycocel/alar at 3000/5000 ppm compared to other concentrations and control.

Effect of CCC and PPP on flowering growth characteristics

Data tabulated in Table (4) show that there is a clear considerable significant difference in the number of days from cutting cultivation time until the first flowering start due to spraying the plants with the different levels of cycocel or paclobutrazol in both seasons. The earliest flowering was achieved at the moderate treatments of CCC and PPP. Here, the first bud was noticed after 82.33 days in 1st season in plants treated with 50 ppm of PPP followed by CCC at 300 ppm (85.33 days). In the second season, the CCC was two days earlier than the PPP (82.33 and 84.33 days, respectively). The last time of the first flowering was occurred with PPP at 75 ppm (105.33 and 102.33 days) followed by control (100 and 101 days) in first and second seasons, respectively. The promoter effect of cycocel on time of the first bract coloring in *Euphorbia pulcherrima* was reported by Karunananda and Peiris (2010). They observed an early appearance of bracts color as a result of applying pinching followed by 1500 ppm cycocel. Contrary to our results, Ghatas (2016) found that cycocel (1000, 2000 and 3000 ppm) and paclobutrazol (20, 40 and 60 ppm) treatments delayed the flowering of *C. frutescence* plants as compared with untreated control plants, which indicates that the effect of these growth retardants depends on many factors, including the plant species.

The flowering period is one of the important characteristics that potted plant producers seek to enhance. Application of plant growth retardants on chrysanthemum plants in the current study increased the flowering period. All tested concentrations of PPP prolonged the flowering period from 18.33 days to 21.00 days in first season and from 19.00 days to 21.67 days in second season, compared to control one (15.67 and 16.00 days, respectively). Treating plants with CCC also enhanced the flowering period except for 3000 ppm CCC which decreased the period to only 11.33 and 12.00 days in first and second seasons, respectively. The longest periods of flowering (23.67 and 24.67 days) were observed for 3000 ppm of cycocel in first and second seasons, respectively. However, cycocel at 1500 ppm appears to be more suitable because stem height and branching have high values under this treatment.

Significant differences in flower number per plant were recorded between treatments (Table 4). Flowers number was stimulated by low and moderate concentrations of CCC (3000 and 6000 ppm) and by moderate levels of PPP (50 ppm). The highest significant number of flowers (12.10 and 12.90 flowers/plant for 1st and 2nd seasons, respectively) was counted for plants sprayed with CCC at 3000 ppm followed by PPP at 50 ppm which recorded 10.93 and 11.93 flowers/plant versus control (9.47 and 10.03 flowers/plant) for 1st and 2nd seasons, respectively. Ghatas (2016) found that the highest number of flowers per plant was recorded for *C. frutescens* plants sprayed with 60 ppm PPP. Higher levels of both growth inhibitors significantly reduced the number of flowers to less than 3 flowers per plant and also reduced the flower diameter to less than 3 cm. The diameter of the flower reached its maximum values (4.47 and 4.57 cm) when the plants were treated with 3000 ppm of CCC as well as untreated plants (control; 4.40 and 4.43 cm) in 1st and 2nd seasons, respectively, without significant differences between them. Similar results were recorded in *Primula forbesii* plants treated with CCC (Zhang *et al*., 2020).

Effect of CCC and PPP on chlorophyll and carotenoids contents

Data presented in Figure (1-4) displayed the effect of various levels of cycocel and paclobutrazol on chlorophyll a, b and carotenoids in chrysanthemum leaves (mg/g FW). Cycocel and paclobutrazol at all levels increased the contents of chlorophyll and carotenoids compared with control in both seasons. The gradual increase in both dwarfing factors was accompanied by a gradual increase in the content of chlorophyll, which also reported by Araghi *et al*. (2013) and Abbas (2017) on poinsettia plants. In 1st season, the highest values of chlorophyll a, chlorophyll b and total chlorophyll contents (1.01, 0.39 and 1.40 mg/g FW, respectively) were recorded with 75 ppm PPP, while the lowest value was recorded for control plants (0.51, 0.20 and 0.71 mg/g FW, respectively). In the second season, the same trend was observed (Figure 1-3). The content of total chlorophyll was increased by the application of CCC and PPP compared to the control. This may be due to the inhibitor effect of growth retardant that produced smaller cells and thus resulted in more concentrated chlorophyll content inside the reduced cell volume (Thakur *et al*., 2006). In addition, Tsegaw *et al*. (2005) suggested that higher pigment content in potato leaves was due to enhancement of chlorophyll synthesis by paclobutrazol application and for more densely spaced chloroplasts per leaf area unit. These findings are agreed with Sridhar (2006) who found that application of cycocel (500 and 1000 ppm) and ethephon (100 and 200 ppm) increased the chlorophyll content in *Jasminum* *auriculatum* compared to the control. Also, the increase in chlorophyll content due to growth retardants treatments has been confirmed in *C. frutescens* plants (Ghatas, 2016).

It was reported that the treatment with cycocel and paclobutrazol led to an increase in the content of chlorophyll and the rate of photosynthesis, and consequently, an increase in the accumulation of sucrose and carbohydrates in plant leaves (Zheng *et al*., 2012). Thus, this may be the reason for the increase in plant biomass, flowers number, and the prolongation of the flowering period in some treatments compared to the control.

The carotenoids content reached the highest value in plants sprayed with CCC at concentration of 1500 ppm (0.57 mg/g FW). However, the increase in CCC levels above 1500 ppm caused a decrease in the carotenoids content but it still higher than that of the non-sprayed plants. In contrast, rising PPP levels enhanced the content of carotenoids. The stimulatory effects of the growth retardants on enhancing the biosynthesis of carotenoids have been confirmed by Lodeta *et al*. (2010) and Abbas (2017) on poinsettia plants, and Abdel-Moniem *et al*. (2016) on sunflower.

CONCLUSIONS

This study has produced findings suggesting that cycocel (CCC) and paclobutrazol (PPP) could be used well to control the containerized herbaceous perennial plant *C. indicum*, to improve its commercial viability in the flowering potted plant market. The application of the growth retardants, cycocel and paclobutrazol, had a positive influence on reducing plant height and increasing shoot number, flowering period and flowers number per plant. Moreover, chlorophyll and carotenoids contents were enhanced in plants sprayed with CCC and PPP at all concentrations. Overall, moderate and low levels of CCC and PPP had the desired effects in manipulating the parameters of vegetative and flowering growth in *C. indicum*, thus enhancing dwarfing and the commercial value of *C. indicum* in the potted flower industry. The interaction between plant inhibitors such as cycocel and paclobutrazol, and growth-stimulating nutrients is a necessary future requirement to achieve the desired plant height with high dwarfing qualities suitable for commercial production of chrysanthemums as a potted plant, and also to overcome the toxicity that may be caused by plant growth retardants used for dwarfing.

REFERENCES

Abbas, M.N. 2017: Effect of some cultural treatments on the vegetative growth and flowering in *Euphorbia pulcherrima* plant. M.Sc. Thesis. Faculty of Agriculture, Al-Azhar University, Cairo, Egypt.

Abdel-Moniem, A.M. 2016: Effect of some growth retardants on growth and flowering of *Helianthus annuus* l. cv. sunrich orange summer 981v plants b- application of ancymidol, daminozide and ethephon in combinations. Sci. J. Flowers Ornam. Plants, 3 (2), 119-134.

Araghi, A.M., Naderi, R., Babalar, M., Taheri, M. 2013: Effect of different spraying levels of cycocel on vegetative growth and flowering of poinsettia pot plant. J Sci. Technol. Greenhouse Cult., 5 (17), 73-84.

Asrar, A.W., Elhindi, E., Abdel-Salam, E. 2014: Growth and flowering response of chrysanthemum cultivars to Alar and slow-release fertilizer in an outdoor environment. J. Food, Agric. Environ.,12 (2), 963-971.

Benjawan, C., Chutichudet, P., Chanaboon, T. 2007: Effect of chemical paclobutrazol on growth, yield and quality of okra (*Abelmoschus esculentus* L.) Har lium cultivar in northeast Thailand. Pak. J. Biol.Sci., 10 (3), 433-438.

Carvalho, S.M.P., Van Noort, F., Postma, R., Heuvelink, E.P., 2008: Possibilities for producing compact floricultural crops. Wageningen. Report, p. 173.

Di Benedetto, A., Molinari, J. 2007: Influence of river waste-based media on efficacy of paclobutrazol in inhibiting growth of *Petunia* x *hybrida*. Int. J. Agric. Res., 2 (3), 289-295.

Dole, J.M., Wilkins, H.F. 1999: Plant growth regulation. In: Dole, J.M., Wilkins, H.F. (Eds). Floriculture: Principles and Species. Prentice-Hall, Eaglewood Cliffs, NJ, p. 90-104.

Duncan, D.B. 1955: Multiple range and multiple F tests. Biometrics, 11 (1), 1-42.

Erler, R., Sigmund, I. 1986: Year book of the international horticultural statistics. USA. P44.

Fletcher, R.A., Gill, A., Davis, T.D., Sankhla, N., 2000: Triazoles as plant growth regulators and stress protectants. Hortic. Rev., 24, 55-138.

Ghatas, Y.A.A. 2016: Influence of paclobutrazol and cycocel sprays on the growth, flowering and chemical composition of potted *Chrysanthemum frutescens* plant. Ann. Agric. Sci., Moshtohor. 54 (2), 355-364.

Karunananda, D.P., Peiris, S.E. 2010: Effects of pinching, cycocel and b-nine treatments on branching habit of pot poinsettia (*Euphobia pulcherrima* Willd). Trop. Agric. Res. 21 (3), 284 -292.

Latimer, J.G., Scoggins, H.L., Banko, T.J. 2001: Using plant growth regulators on containerized herbaceous perennials. Virginia Cooperative Ext. 430: 103.

Lichtenthaler, H.K. 1987: Cholorophylls and carotenoids: pigments of photosynthetic biomembranes. Methods Enzymol. 148, 350-382.

Liu, X., Zhang, Y., Li, Y., Dong, Y., Wen, X., Yi, M., He, P., Li, J. 2012: Effects of cycocel on the dwarfing characteristics and physiological indices of *Vallisneria natans*. Chin. J. Ecol., 31 (10), 2561-2567.

Lodeta, K.B., Ban, S.G., Perica, S., Dumičić, G., Bućan, L. 2010: Response of poinsettia to drench application of growth regulators. J. Food Agric. Environ. 8 (1), 297-301.

Mabberley, D.J. 2008: Mabberley's Plant-Book: A Portable Dictionary of Plants, Their Classification and Uses, 3rd ed.; Cambridge University Press: New York, NY, USA, p. 1021.

Magnitskiy, S.V., Pasian, C.C., Bennett, M.A., Metzger, J.D. 2006: Controlling plug height of *Verbena*, *Celosia*, and *Pansy* by treating seeds with paclobutrazol. HortSci. 41 (1), 158-161.

North, J.J., Laubscher, C.P., Ndakidemi, P.A. 2010: Effect of the growth retardant Cycocel® in controlling the growth of *Dombeya burgessiae*. Afr. J. Biotechnol. 9 (29), 4529-4533.

Pobudkiewicz, A. 2014: Effect of growth retardant on some morphological and physiological traits of Chrysanthemum. Pol. J. Nat. Sci., 29 (4), 291-306.

Prashanth, P., Reddy, S.A., Srihari, D. 2006: Studies on the effect of certain plant growth regulators on growth of Floribunda Roses (*Rosa hybrida* L.). Orissa J. Hort., 34 (2), 78-82.

Reddy, P. 2005: Effect of growth retardants and nipping on growth and yield parameters in cowpea (*Vigna unguiculata* L.) B. Sc. Thesis, Fac. Agric., Dharwad.

Renu, Srivastava, R. 2013: Effect of cycocel and alar on the growth and flowering of poinsettia cv. Single. Asian J. Hortic., 8 (1), 313-316.

Sridhar, P. 2006: Hormonal regulation of growth and yield in jasmine (*Jasminum auriculatum* Vahl). B. Sc. Thesis, Dept. Fac. Agric., University of Agricultural Sciences, Dharwad.

Thakur, R., Sood, A., Nagar, P.K., Pandey, S., Soboti, R.C., Ahuja, P.S. 2006: Regulation of growth of Lilium plantlets in liquid medium by application of paclobutrazol or ancymidol, for its amenability in a bioreactor system: Growth parameters. Plant Cell Rep. 25 (5), 382-391.

Toaima, N., Mahmoud, S., Hamza, M., Nour el deen, M.A. 2017: Influence of different levels of Ethephon on the growth and flowering of *Euphorbia pulcherrima* var. 'Freedom Red' plant. J. Biol. Chem. Environ. Sci., 12 (4), 79-92.

Tsegaw, T., Hammes, S., Robbertse, J. 2005: Paclobutrazol-induced leaf, stem, and root anatomical modifications in potato. HortSci. 40 (5), 1343-1346.

Youssef, F.S., Eid, S.Y., Alshammari, E., Ashour, M.L., Wink, M., El-Readi, M.Z. 2020: *Chrysanthemum indicum* and *Chrysanthemum morifolium*: chemical composition of their essential oils and their potential use as natural preservatives with antimicrobial and antioxidant activities. Foods, 9, 1460.

Zalewska, M. 1989: Growth regulators in pot culture of chrysanthemum cultivars 'Paloma', 'Poranek' and 'Promyk'. Acta Hort. 251, 335-340.

Zhang, M., Yang, J., Pan, H., Pearson, B.J. 2020: Dwarfing effects of chlormequat chloride and uniconazole on potted baby primrose. HorTechnol. 30 (5), 536-543.

Zheng, R., Wu, Y., Xia, Y. 2012: Chlorocholine chloride and paclobutrazol treatments promote carbohydrate accumulation in bulbs of *Lilium* Oriental hybrids 'Sorbonne'. J. Zhejiang Univ-Sci. B (Biomed. Biotechnol.), 13 (2), 136-144.

Table 1: Chemical analysis of irrigation water used in this investigation

Chemical analysis of irrigation water								
K	Na	Mg	Ca	SO4	Cl	HCO3	PH	E.C
0.2	2.65	1.00	1.50	0.65	1.50	3.2	6.78	0.54

Table 2: Physical and chemical properties of the experimental soil

Items	1st season	2nd season
Moisture %	38	43
Ash%	51.61	63
Organic Matter%	10.39	9.00
PH	7	6.3
E.C	0.35	0.38
CaCO3%	2.85	2.60
Available Macronutrients		
Available N mg/kg soil	50	51
Available P mg/kg soil	11	13
Available K mg/kg soil	78	80
Available Ca mg/kg soil	1200	1142
Available Mg mg/kg soil	162	170
Available Na mg/kg soil	144	139
Available Micronutrients		
Available Fe mg/kg soil	4.3	4.1
Available Mn mg/kg soil	4.4	4
Available Zn mg/kg soil	4.5	4.1
Available Cu mg/kg soil	0.8	0.6

mg/kg soil = ppm ,Source: National Research Centre, Dokki, Cairo, Egypt

Table 3: Effect of different concentrations of cycocel (CCC) and paclobutrazol (PPP) on vegetative growth characteristics in *Chrysanthemum indicum* L. cv. Pink Zamble during two seasons of 2018 and 2019.

Treatments		Plant height (cm)		Number of branches /plant		Leaves number /plant		Fresh weight (g/plant)		Dry weight (g/plant)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control		74.67 a	77.33 a	3.00 c	3.37 b	63.33 a	65.00 a	70.30 c	71.03 c	11.17 a	11.13 b
CCC (ppm)	1500	49.33 c	50.33 c	4.00 a	3.67 a	42.00 b	45.00 b	69.50 c	69.83 cd	10.30 c	10.60 c
	3000	20.20 e	22.00 e	3.67 b	3.67 a	35.33 c	34.33 c	67.00 d	67.87 d	9.50 d	9.70 d
	6000	12.11 g	14.10 f	1.33 f	1.27 e	12.00 e	11.33 e	56.33 e	57.67 e	8.60 e	8.80 e
PPP (ppm)	25	55.50 b	70.30 b	2.67 d	2.33 c	42.00 b	44.00 b	93.00 a	93.67 a	11.73 a	11.77 a
	50	23.00 d	25.13 d	3.67 b	3.67 a	28.33 d	26.00 d	76.27 b	78.27 b	10.90 b	10.97 bc
	75	14.67 f	14.66 f	1.67 e	1.77 d	9.33 f	11.00 e	46.33 f	47.00 f	9.61 d	9.81 d

Mean values with different letters in the column are statistically different according to DMRT (*P*<0.05)

Table 4: Effect of different concentrations of cycocel (CCC) and paclobutrazol (PPP) on flowering growth characteristics in *Chrysanthemum indicum* L. cv. Pink Zamble during two seasons of 2018 and 2019.

Treatments		Flowering start (days)		Flowering period (days)		Flowers number /plant		Flower diameter (cm)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control		100.00 b	101.00 a	15.67 e	16.00 e	9.47 d	10.03 c	4.40 a	4.43 ab
CCC (ppm)	1500	98.33 c	88.67 c	18.67 cd	18.33 d	10.10 c	9.10 d	3.71 c	3.80 d
	3000	85.33 f	82.33 e	11.33 f	12.00 f	12.10 a	12.90 a	4.47 a	4.57 a
	6000	95.33 d	92.00 b	23.67 a	24.67 a	2.97 f	2.10 f	1.60 e	1.63 f
PPP (ppm)	25	92.67 e	90.00 c	18.33 d	19.00 cd	8.00 e	8.90 e	4.10 b	4.13 c
	50	82.33 g	84.33 d	19.67 c	20.00 c	10.93 b	11.93 b	4.17 b	4.27 bc
	75	105.33 a	102.33 a	21.00 b	21.67 b	2.57 g	2.10 f	3.00 d	2.93 e

Mean values with different letters in the column are statistically different according to DMRT (*P*<0.05)

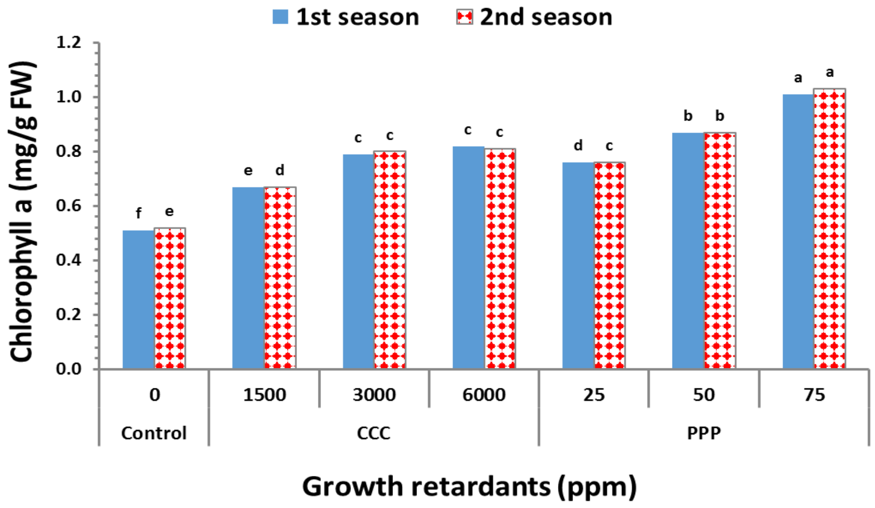

Figure 1: Effect of different concentrations of cycocel (CCC) and paclobutrazol (PPP) on chlorophyll a content (mg/g FW) in *Chrysanthemum indicum* L. cv. Pink Zamble during two seasons of 2018 and 2019. Columns annotated with different letters are statistically different according to DMRT (*P*<0.05)

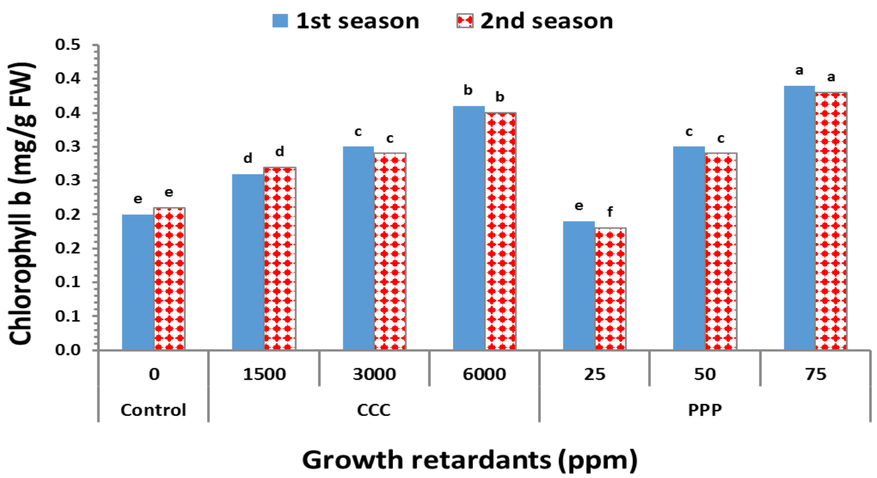

Figure 2: Effect of different concentrations of cycocel (CCC) and paclobutrazol (PPP) on chlorophyll b content (mg/g FW) in *Chrysanthemum indicum* L. cv. Pink Zamble during two seasons of 2018 and 2019. Columns annotated with different letters are statistically different according to DMRT (*P*<0.05)

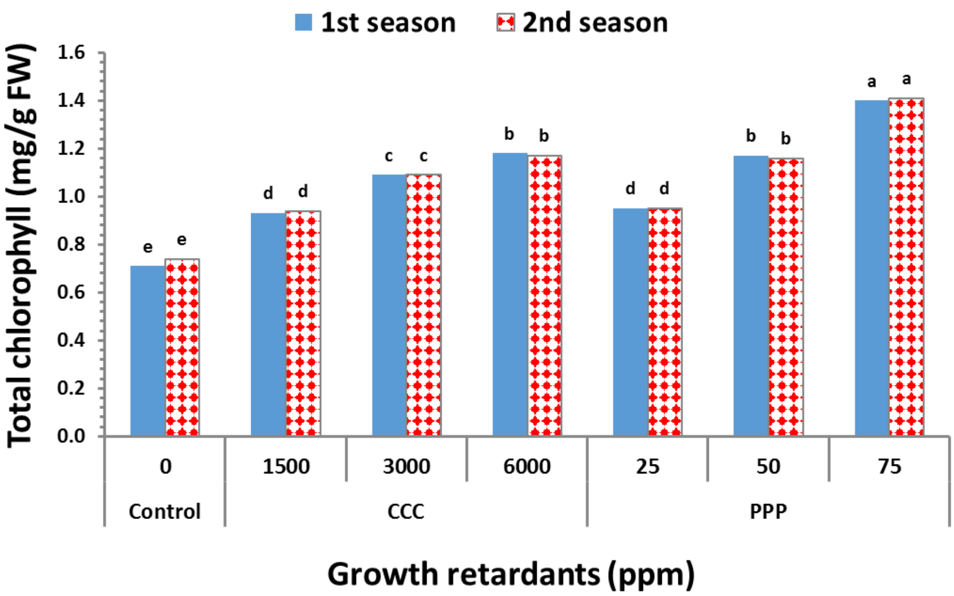

Figure 3: Effect of different concentrations of cycocel (CCC) and paclobutrazol (PPP) on total chlorophyll content (mg/g FW) in *Chrysanthemum indicum* L. cv. Pink Zamble during two seasons of 2018 and 2019. Columns annotated with different letters are statistically different according to DMRT (P<0.05)

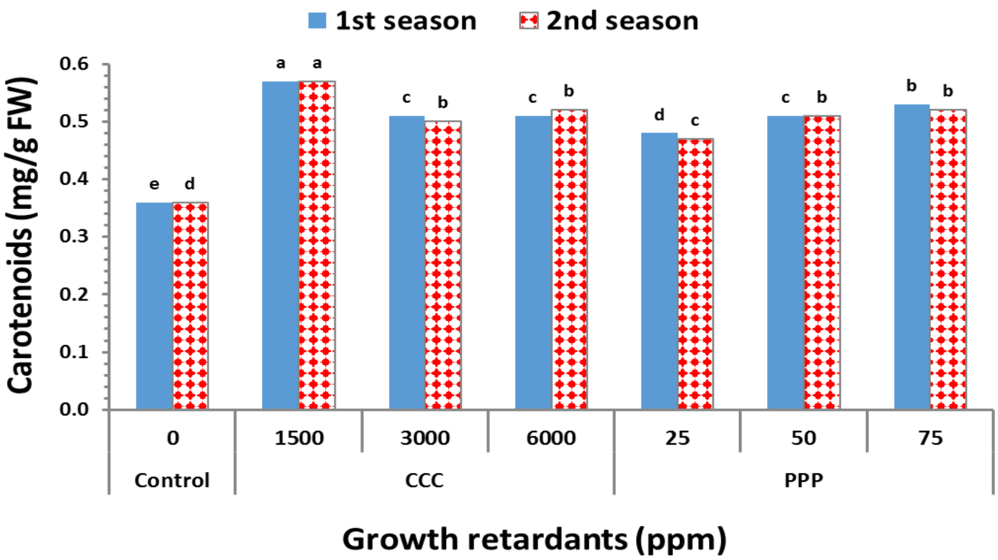

Figure 4: Effect of different concentrations of cycocel (CCC) and paclobutrazol (PPP) on carotenoids content (mg/g FW) in *Chrysanthemum indicum* L. cv. Pink Zamble during two seasons of 2018 and 2019. Columns annotated with different letters are statistically different according to DMRT (P<0.05)

تأثير السيكوسيل والباكلوبترازول على خصائص التقزم لنبات الأراولا

محمود حامد محمود أبو الحسن، حسينى عبدالحق بصيلة، محمد عبدالفتاح حمزة*، أحمد عبدالفتاح العتيق، علاء إبراهيم محمد عبدالجواد

قسم البساتين، كلية الزراعة، جامعة الأزهر ، القاهرة، مصر.

*البريد الإلكتروني للباحث الرئيسي: hamza.plant@azhar.edu.eg

الملخص العربي:

يعتبر نبات الأراولا *Chrysanthemum indicum* L. أحد محاصيل الزينة الهامة عالمياً والذي يمكن إنتاجه كنبات أصص أو كأزهار قطف. في هذا البحث تم إجراء تجربة لدراسة تأثير المستويات المختلفة من السيكوسيل (1500 ، 3000 ، 6000 جزء في المليون) و الباكلوبترازول (25 ، 50 ، 75 جزء في المليون) على خصائص التقزم لنبات الأراولا كنبات أصيص. بدأ رش عوامل التقزم السيكوسيل و الباكلوبترازول بعد 4 أسابيع من زرع العقل وتم تكرار الرش مرة أخرى بعدها بأسبوعين. بعد تطبيق السيكوسيل و الباكلوبترازول، أظهرت خصائص النمو الخضري والزهري بالإضافة إلى الصبغات النباتية في الأوراق اختلافات معنوية بين المعاملات. كان لتطبيق مثبطات النمو تأثير إيجابي في تقصير طول النبات وزيادة كل من عدد الفروع وفترة التزهير وعدد الأزهار لكل نبات. علاوة على ذلك ، تم تحسين محتويات الكلوروفيل والكاروتينات في النباتات التي تم رشها بالسيكوسيل و الباكلوبترازول بجميع التركيزات. بشكل عام، كان للمستويات المعتدلة والمنخفضة من السيكوسيل (1500 و 3000 جزء فى المليون) و الباكلوبترازول (25 و 50 جزء فى المليون) التأثيرات المرغوبة في تعديل وتحسين مؤشرات النمو في نبات الأراولا، وبالتالي تعزيز التقزم والقيمة التجارية له في مجال إنتاج نباتات الزينة المزهرة النامية فى أصص.

الكلمات الاسترشادية: كريزانثمم، سيكوسيل، باكلوبترازول، مثبطات النمو ، التقزيم، الكلوروفيل.