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The Effect of Cycocel and Pot Size on Vegetative Growth and Flowering of Zinnia (*Zinnia elegans*)

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Abstract

Zinnia is a very attractive and beautiful ornamental plant due to the diversity of color and flowering period. The effect of cycocel and pot size was studied on growth and flowering of zinnia in a factorial experiment based on a randomized complete design with two factors: cycocel at 3 levels (0, 1000 and 2000 ppm) and pot size at 4 levels (10, 12, 14 and 16 cm) with 12 treatments and 3 replications. The interaction results showed that cycocel and pot size had a significant effect on all studied traits, that 2000 ppm cycocel in 12 cm pots produced the minimum height and that 16 cm pots treated with 1000 ppm cycocel or without cycocel treatment produced the maximum plant height. Maximum flowering period was related to 14 cm pots × 1000 ppm cycocel that had no significant difference with plants in 16 cm pot size in all three concentrations of cycocel. Minimum flowering period was related to 10 cm pot size at all three concentrations of cycocel. Zinnias planted in 10 cm pot size without cycocel treatment exhibited the minimum fresh weight and in 14 cm pot size without cycocel treatment exhibited the maximum root fresh weight. Overall, flowers in 14 and 16 cm pot sizes treated with 1000 ppm cycocel were found to be the best treatments.

Keywords: Cycocel, Leaf area, Plant height, Pot size, Zinnia.

INTRODUTION

Today, urban development and increasing environmental pollution has given the plants a more important role in urban areas. Plants with longer flowering period and shorter height are more valuable. Zinnia (*Zinnia elegans*) is one of the cold sensitive flowers from the Asteraceae family that has tallest height between seasonal bedding plants (Hojjati *et al*., 2009). Zinnia is so valuable in terms of green space because of its long flowering period, i.e. from late spring to mid-fall, and its tolerance to drought and heat (Ebrahimzadeh and Seifi, 1999). Cultivation of pot plants, in addition to attractiveness and marketing, is another advantage of zinnia. The control of vegetative growth and the reduction of plant height are very important factors in pot production (Hadizadeh *et al*., 2010). Therefore, it is essential to reduce plant height and at the same time, to keep the quality at a desirable level.

One of the important effects of plant growth retardants is the control of plant height. These compounds prevent cell division and growth in the area below the apex but they have no effect on meristem. The size of these plants remains short. The advantage of the use of growth retardants in crop production is the improvement of the appearance of the plant by maintaining the shape and size of the plant in accordance with the size of the pot (Whipker and Mc Call, 2000). Cycocel is a plant growth retardant that is widely used in reducing the growth of a large number of plants. In the "Red Elite" geranium, cycocel can reduce the height of flowering branch (Olivera and Browing, 1993). Wanderley *et al.* (2014) reported that treatment with cycocel at concentrations of 2000, 4000 and 6000 ppm had no effect on the final height of Arundina graminifolia.

It should be noted that the size of the pot changes different physiological and morphological traits in plants through influences the volume of planting bed and that the imbalance between roots and shoots can cause short-term or long-term effects on plant growth. In addition, container size reduces the volume of aerial parts by reducing root volume. A study on Salvia splendens showed that root biomass was increased linearly with increasing pot volume (Van Iersel, 1997). In general, root and shoot growth, biomass accumulation, photosynthesis and chlorophyll content, plant water relations, uptake of elements, respiration, flowering and yield are some features affected by the pot and root restriction (NeSmith and Duval, 1998). The aim of the present study was to investigate the effect of different concentrations of cycocel and pot size on some vegetative and flowering features of zinnia to produce zinnia potted plants with shorter height and more flowers with significant improvement of marketability and quality characteristics.

MATERIALS AND METHODS

In April 2015, the seeds of zinnia (*Zinnia elegans*) were planted in the tray seedlings with cocopeat substrate in plastic greenhouse. After about two weeks, the seedlings were transferred to pots filled with a mixture of garden soil, farmyard manure and cocopeat (2:1:1 v/v). Following the complete establishment of plants, while seedlings averagely had 4 to 6 leaves, the leaves were sprayed with cycocel at the concentrations of 1000 and 2000 ppm. One week later, the plants were taken out of greenhouse.

The experiment was carried out as a factorial experiment based on a RCD with two factors including cycocel at 3 levels (0, 1000 and 2000 ppm) and the size of the pot at 4 levels (10, 12, 14 and 16 cm) with 12 treatments, 3 replications and 36 plots, and each plot included 5 pots. In total, 180 pots were used in this experiment.

Characteristics evaluated were plant height, flowering period, flower diameter, leaf chlorophyll, fresh and dry weight of root, root volume, surface of leaf and petal carotenoids. Height of the plants was measured by a ruler before CCC spray at the end of the experiment. The flower diameter was determined using a digital caliper with precision of 0.01 mm. In order to measure the fresh and dry weight of root at the end of the experiment, fresh weight was measured after cutting the roots and their rinsing. Dry weight was measured after drying roots at 75°C for 48 hours. In all cases, the weight measurements were performed using a digital scale with 0.001 g precision. Root volume was measured with graduated glass after entering the washed roots into that (based

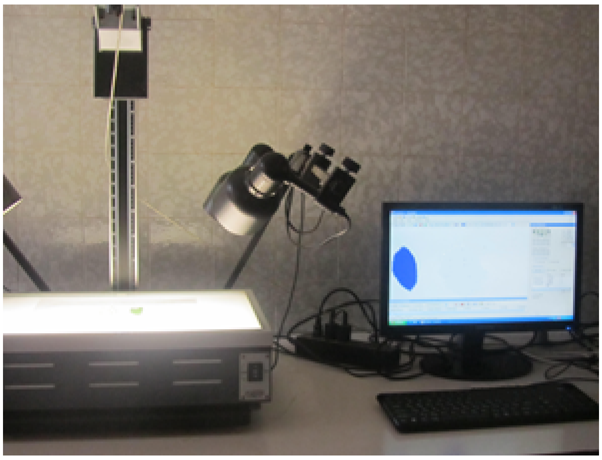

Fig.1. Leaf area meter.

on the Archimedes law). Flowering periods were also recorded during the growth. Leaves chlorophyll and petals carotenoid were measured using Mazumdar and Majumder (2003)'s method at the end of the experiment. To measure the leaf area, a number of leaves were selected from each plant at the end of the experiment and their leaf area was measured by the Leaf Area Meter device, model A3 Light box gCL Bubble Etch Tanks (Fig. 1).

Data were analyzed by SAS software package and the means were compared by the LSD test.

RESULTS AND DISCUSSION

Leaf area

The results of ANOVA (Table 1) indicated that the effects of pot size, different levels of cycocel and their interaction were significant for leaf area at the 1% probability level. According to the results, 16 cm pot size × 1000 ppm cycocel produced the highest leaf area of 933.3 cm2. The minimum leaf area was related with 10 cm pot size × 2000 ppm cycocel (Table 2).

Leaf area is a key feature in plant growth affected by growth retardants. In fact, photosynthesis is increased by the increase in the amount of leaf area. In this study, leaf area was increased by the treatment of cycocel and was decreased by the increase in cycocel concentration. It is suggested that the reducing effect of growth retardents on leaf area is associated with the prevention of the synthesis of GA, the enhancement of ABA and the prevention of cell elongation (Gopi *et al*., 2005; Nazardin *et al.,* 2007). Hojjati *et al*. (2011) stated that cycocel reduced leaf area of *Rudbeckia hirta* as compared to control. Moshrefi Araghi *et al*. (2014) reported that the use of 1500 ppm cycocel had a positive effect on increasing poinsettia leaf area. In this study, leaf area was increased by increasing pot size. Ne Smith and Duval (1992) and van Iersel (1997) stated that the decrease in root size reduces the leaf area of salvia and pepper. The researchers state that the reason for lower leaf area is the production of less and smaller leaves in smaller pots.

Table 1. Analysis of variance (ANOVA) for the effect of different concentrations of cycocel and pot size on leaf area, total chlorophyll, petal carotenoid, root fresh weight, root dry weight, root volume, plant height, flower diameter and flowering period of *Zinnia elegans* L.

S.O.V.	df	Leaf area	Total chlorophyll	Petal carotenoid	Root fresh weight	Root dry weight	Root volume	Plant height	Flower diameter	Flowering period
Pot size (P)	3	709190**	3.71**	2.48**	26.59**	1.586**	137.49**	60.30**	7.68**	230.97**
Cycocel (C)	2	29813**	1.87**	1.014**	4.942**	0.08ns	7.34ns	31.45**	0.083ns	0.208ns
P*C	6	27287**	0.969**	0.332**	10.74**	0.231*	23.05**	44.71**	2.214*	21.79*
Error	22	1797	0.027	0.0008	0.71	0.07	3.95	3.74	0.43	5.93
CV (%)		8.32	5.19	0.43	14.87	24.98	24.44	5.98	11.01	6.29

ns: Non significant, *: Significant at 5%, **: Significant at 1%

Table 1. Analysis of variance (ANOVA) for the effect of different concentrations of cycocel and pot size on leaf area, total chlorophyll, petal carotenoid, root fresh weight, root dry weight, root volume, plant height, flower diameter and flowering period of *Zinnia elegans* L.

Treatments	Leaf area (cm^2)	Total chlorophyll ($mg\ g^{-1}$ FW)	Petal carotenoid ($\mu g\ g^{-1}$FW)	Root fresh weight (g)	Root dry weight (g)	Root volume (ml)	Plant height (cm)	Flower diameter (mm)	Flowering period (day)
P_1	195.0 c	2.27 c	6.54 c	3.80 d	0.63 c	5.55 b	30.31 b	4.74 c	31.80 c
P_2	350.1 b	3.27 b	7.10 b	4.87 c	0.94 b	4.05 b	29.94 b	5.87 b	38.55 b
P_3	745.6 a	3.41 b	6.45 d	7.78 a	1.47 a	11.83 a	34.52 a	6.61 a	40.86 b
P_4	746.8 a	3.78 a	7.57 a	6.20 b	1.48 a	11.11 a	34.68 a	6.77 a	43.66 a
C_0	479.0 b	3.47 a	6.62 c	5.15 b	1.17 a	8.83 a	34.02 a	6.08 a	38.60 a
C_1	566.0 a	2.73 b	7.20 a	6.38 a	1.18 a	8.29 a	32.27 b	5.92 a	38.69 a
C_2	481.0 b	3.34 a	6.93 b	5.46 b	1.03 a	7.29 a	30.79 b	5.99 a	38.86 a
$P_1 \times C_0$	204.7 g	2.42 de	6.00 k	2.81 f	0.62 d	5.16 d	29.44 cd	4.93 cd	31.66 ef
$P_1 \times C_1$	197.8 g	2.04 f	7.15 e	2.95 f	0.59 d	4.83 d	26.50 de	4.36 d	28.60 f
$P_1 \times C_2$	182.4 g	2.35 e	6.47 i	5.64 cd	0.66 d	6.66 cd	35.00 a	4.93 cd	35.13 de
$P_2 \times C_0$	340.0 ef	3.10 c	6.88 g	3.46 ef	1.02 cd	3.33 d	34.50 ab	5.96 abc	40.30 abc
$P_2 \times C_1$	410.9 e	2.52 de	6.99 f	7.82 ab	1.03 cd	5.00 d	29.83 c	5.69 bc	38.33 cd
$P_2 \times C_2$	299.4 f	4.19 a	7.42 b	3.31 ef	0.76 d	3.83 d	25.50 e	5.95 abc	37.00 cd
$P_3 \times C_0$	796.2 b	3.90 b	6.25 j	8.51 a	1.42 abc	13.33 a	35.83 a	6.67 ab	38.76 cd
$P_3 \times C_1$	725.7 bc	2.67 d	6.52 h	6.80 bc	1.27 bc	9.50 bc	36.05 a	6.90 a	44.16 a
$P_3 \times C_2$	714.9 c	3.65 b	6.57 h	8.03 ab	1.72 ab	12.66 ab	31.69 bc	6.25 ab	39.66 bc
$P_4 \times C_0$	576.9 d	4.46 a	7.34 c	5.80 cd	1.61 ab	13.50 a	36.33 a	6.77 ab	43.66 ab
$P_4 \times C_1$	933.3 a	3.68 b	8.12 a	7.95 ab	1.82 a	13.83 a	36.72 a	6.73 ab	43.66 ab
$P_4 \times C_2$	730.2 bc	3.18 c	7.27 d	4.87 de	1.00 cd	6.00 d	30.98 c	6.81 a	43.66 ab

*Similar letter(s) in each column indicates insignificant difference at the 1% and 5% level (LSD test)

P_1: pot size 10 cm
P_2: pot size 12 cm
P_3: pot size 14 cm
P_4: pot size 16 cm

C_0: Without cycocel
C_1: 1000 ppm cycocel
C_2: 2000 ppm cycocel

Total chlorophyll

Analysis of variance (Table 1) showed that the effects of pot size, different levels of cycocel and interaction of pots size × cycocel were significant for total chlorophyll content at the 1% probability level. Their interaction (Table 2) showed that the highest chlorophyll was related to plants grown in 16 cm pot size × no cycocel (4.46 mg g^{-1} FW) and the lowest total chlorophyll was related to plants grown in 10 cm pot size × 1000 ppm cycocel) 2.04 mg g^{-1} FW).

Studies show that leaf chlorophyll content is increased at higher concentrations of growth retardents relating it to the impact of growth retardants on the synthesis of cytokinins that stimulates the synthesis of chlorophyll (Davis *et al.*, 1988; Rossini Pinto *et al.*, 2005; Fletcher *et al.,* 2000). Moshrefi Araghi *et al.*, (2014) confirmed the effect of spraying different levels of cycocel on poinsettia and stated that the use of 2000 ppm cycocel significantly increased the relative amount of chlorophyll in the leaves, which is in agreement with our results. Ne Smith and Duval (1998) believed that the leaf chlorophyll content was one of the features affected by the pot size and limitation of rooting space. In fact, higher pot size results in higher vegetative growth, leaf area, chlorophyll content and its exposure to light by providing more mineral elements, water and adequate space for root growth. Arp (1991) reported a positive correlation between the size of the pot and leaf chlorophyll content.

Petal carotenoid

The results of ANOVA (Table 1) indicated that the effect of pot size, different levels of cycocel and interaction of pot size × cycocel were significant for petal carotenoid content at the 1% probability level. Maximum carotenoid (8.12 µg g^{-1} FW) was obtained from plants of 16 cm pot size × 1000 ppm cycocel and minimum carotenoid obtained from plants of 10 cm pot size × no cycocel (Table 2). Shoa Kazemi *et al.* (2014) reported that growth retardants increased pigmentation of marigold petals. They observed that the maximum amount of carotenoids were obtained from the treatment of 1000 ppm cycocel + 4500 ppm daminozide. Gliozeris *et al*. (2007) reported that the use of growth retardants (daminozide, paclobutrazol and cycocel) on the violets increased the levels of carotenoids as compared to the control.

Root fresh weight

Analysis of variance (Table 1) showed that the effect of pot size, different levels of cycocel and their interaction were significant for root fresh weight at the 1% probability level. The mean comparison of data in different treatments (Table 2) showed that plants grown in 10 cm pot size × no cycocel (2.81 g) produced the minimum fresh weight and plants grown in 14 cm pot size × no cycocel produced the maximum fresh weight (8.31g).

Root dry weight

Analysis of variance (Table 1) showed that the effect of pot size was significant on root dry weight at the 1% probability level. However, no significant difference was observed in root dry weight among different levels of cycocel. The interaction pot size × cycocel was significant at the 5% level of probability. The mean comparison of data in different treatments (Table 2) showed that maximum root dry weight was related to the plants grown in 16 cm pot size × 1000 ppm cycocel (1.82 g) and the lowest root dry weight was related to those grown in 10 cm pot size × 1000 ppm (0.59 g).

Root volume

The effect of pot size and interaction pot size × cycocel were significant for root volume at the 1% probability level. The effect of different levels of cycocel was insignificant on the root volume (Table 1). Results showed that the maximum root volume was related to the plants grown in 16 cm pot size × 1000 ppm (13.83 ml) and the minimum root volume was related to those grown in 12 cm pot size × no cycocel (Table 2).

Researchers believe that although the growth retardants reduce plant height by inhibiting the synthesis of gibberellins, their impact on the root is less intensive. However, they state that the inhibition and stimulation effects of plant growth regulators depend on the type and concentration of these compounds (Latimer, 1991; Lecain *et al*., 1986). Bhat *et al*. (2011) reported that spraying the plants with cycocel reduced root dry weight. The reduction of root dry weight of marigold (Latimer, 1991) has been reported as a result of the use of growth retardant. It is also believed that the root growth is one of the features that are affected by pot size or bed volume (Ne Smith and Duval, 1998). Therefore, an increase in dry weight, fresh weight and volume of root is justified considering the increase in pot size. Kazeroonian *et al.* (2012) conducted a study on roses in a hydroponic system and found that the dry and fresh weights of root in 8 liter pots were significantly increased as compared to 5 liter pots.

Plant height

Analysis of variance (Table 1) showed that the effects of pot size, different levels of cycocel and their interaction were significant for plant height at the 1% probability level. The mean comparison of data in different treatments (Table 2) showed that plants grown in 12 cm pot size × 2000 ppm of cycocel had the lowest height (25.50 cm). The maximum height of zinnia was obtained in 16 cm pot size × 1000 ppm CCC (36.72 cm). Plant height was reduced as cycocel was applied and the pot size was decreased.

Barret (2001) reported that cycocel was an effective growth retardant in controlling the height of poinsettia, azalea, geranium and okra. Cycocel caused the decrease in plant height in ornamental cabbage and kale (*Brassica oleracea*) cultivars 'Kamome White' and 'Nagoya Red' (Gholampour *et al.*, 2015). Dole and Wilkins (1999) believed that the application of growth retardant prevented the division and growth of cells in the area below the terminal meristem of the branch, there by limits plant growth and causes the plant does not grow with normal size and as cultivated plants in small pots have less access to nutrition and water source during the growing season compared with plants in larger pots, thus the reduction in vegetative growth and height is expected for these plants (Poorter, 2002).

Flower diameter

Analysis of variance (Table 1) showed that the effect of pot size was significant on flower diameter at the 1% probability level. However, no significant differences were observed in flower diameter among different levels of cycocel. The interaction pot size × cycocel was also significant at the 5% level of probability. The mean comparison of data in different treatments (Table 2) showed that 14 and 16 cm pot sizes had more flower diameter as compared to 10 and 12 cm pot sizes at all three levels of cycocel. Although there was no statistically significant difference in flower diameter among different levels of cycocel, results showed that the use of cycocel reduced flower diameter as compared to the control. Gilbertsz (1992) reported the reduction of cut chrysanthemum diameter as a result of spraying of the plants by growth retardant. Nakhaei (2011) reported that the use of cycocel decreased narcissus flower diameter as compared to the control that is in agreement with the results of the present study. It is believed that the impact of growth retardant on flower diameters depends on the frequency of the use of growth retardant, environment condition, species sensitivity to growth retardants, and methods (Rossini Pinto *et al*., 2005). Flower diameter was increased with pot size. Favorable conditions were expected in larger pots in terms of nutrition, water, light and photosynthesis in plants. In a study on the yield and quality of two varieties of roses in a hydroponic system, Kazeroonian *et al.* (2012) showed that the diameter of the flower was increased with pot size. However, they revealed that the difference in flower diameter between plants grown in 8 and 5 liter pots was not significant.

Flowering period

Analysis of variance (Table 1) showed that the effect of pot size was significant at 1% probability level on flowering period. However, no significant differences were observed among the different levels of cycocel in flowering period. The interaction pot size × cycocel were also significant at the 5% level of probability. The mean comparison of data in different treatments (Table 2) showed that the maximum flowering period of 44.16 days was related to the plants grown in 14 cm pot size × 1000 ppm cycocel with no significant difference with plants grown in 16 cm pot size in all three concentrations of cycocel. The minimum flowering period of zinnia was related to 10 cm pot size × 1000 ppm cycocel.

In this study, flowering period was not affected by the cycocel (Table 2). In one study, it was found that black iris flowering period was not affected by cycocel (AL-Khassawneh *et al.*, 2006) which is consistent with our results. Flowering period was increased with pot size. Considering that plants grown in small pots has less root volume than those grown in larger pots, they recieved limited water and nutrients. Therefore, it is expected that vegetative and reproductive growth of these plants be less than plants grown in the bigger space. Van Iersel (1997) reported that the use of larger pots and increasing plant rooting space increased salvia flowering period that is consistent with our results.

CONCLUSION

According to the results of the present study, cycocel reduces the height of zinnia. In most studied traits, the treatment of 1000 ppm cycocel was superior. Among various pots, 14 and 16 cm pot sizes improved the recorded traits. Among the interaction treatments, 10 cm pot size in all 3 levels of cycocel was not suitable treatment for most studied traits. But as the size of the pot was increased, the studied traits were improved, so that 14 and 16 cm pot sizes treated with cycocel (especially 1000 ppm) were the best treatments. Finally, according to the results obtained in this study, the use of pot sizes of 14 and 16 cm treated with 1000 ppm cycocel is recommended for growing zinnia.

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