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Vegetative Growth and Flowering of *Russelia equisetiformis* Affected by Different Growth Regulators

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ABSTRACT

This study examined the effects of different growth regulators, such as Cycocel (CCC) at 1000 and 1500 ppm, Ethephon at 300 and 450 ppm, and Daminozide at 2000 and 4000 ppm on the growth and flowering of *Russelia equisetiformis* as a potted plant. The results showed that CCC treatments significantly reduced plant height and root length, while Daminozide treatments increased them. CCC treatments also promoted the highest number of main and secondary shoots, whereas Ethephon treatments resulted in the lowest flower and root numbers. Flower production showed no significant difference between CCC and Daminozide treatments, but was lowest for Ethephon treatments. Fresh and dry weights were highest for Daminozide treatments and lowest for Ethephon and the control treatment. The study recommends using specific plant growth regulators to enhance the growth of *Russelia equisetiformis* in pots.

Keywords: CCC, Daminozide, Ethephon, growth, plant growth regulators, *Russelia equisetiformis*

Introduction

Consumed by mammals, is catabolized into the two chemical components (a non-toxic general intermediate) as succinic acid in a primary metabolism, and 1, 1-dimethylhydrazine is a component with carcinogenic *Russelia equisetiformis*, commonly known as coral plant, firecracker plant, fountainbush and fountain plant belong to family Scrophulariacaea, is ornamental plants native in Mexico, North America, and Guatemala, it's have tubular red flowers and usually blooms round the year, used as versatile, plenty, ground cover plant outdoors, hanging flower pots in window, as well as unclipped hedge (Awe *et al*., 2009), many substances and treatments were used for increasing flowers and stem stunted of *Russelia equisetiformis*, these substances are growth retardants as CCC (chlormequat (Cycocel) it's used as prevention of stem elongation., Ethephon (2-chloroethylphosphonic acid) as growth regulators it's found as gaseous form only, its converted into ethylene for helping plants to reach ripening more than its promotes senescence. Daminozide (B-Nine (2,2-dimethyl hydrazide) Butanedioic acid mono it's used for controlling the height plant by inhibit the synthesis of GA3 and also used as fungicide, in addition to known as aminozide, used as plant growth regulators, daminozide can be affects flow-bud initiation on fruit trees, fruit-set maturity, fruit firmness also coloring, pre-harvest as a drop and marketing quality, under storage, but when daminozide activity in animal models relevant to humans). The scission also occurs when the sprayed chemical residue remains on fruit when stored, increasing with the highest temperatures degree and longer period; meanwhile, the EPA outlawed daminozide on U.S. food crops, but still allowed it for non-food crops as ornamental plants. The daminozide showed as severely restricted in its exports on the list of pesticides, all these previous substances were used to affect the growth of *Russelia equisetiformis* and *Eustoma grandiflorum* by different scientists as, Cycocel and daminozide at different concentrations were significant affected stem height, flowers numbers of 'Revert' chrysanthemum (Karloviae *et al.,* 2004 and Ramírez *et al.*, 2022), increasing shoots numbers of Carnation (*Dianthus caryophyllus*) and maximum number of flowers, when treated with higher level

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1000 mgL-1of cycocel (Ahmad *et al.,* 2007), the main goal of usage of growth retardants in large scale of agriculture field for produce the compact growth, increasing number of healthy branches, and dwarfness plants (Banon *et al*., 2002), Chlorocholine chloride (2chloroethyl) trimethyl ammonium chloride (CCC) which is the anti-gibberellin for growth regulator that can be inhibition the conversion from geranylgeranyl pyrophosphate (GGPP) to ent-kaurene, that is the first step in gibberellic acid (GA) biosynthesis, adionally improved starch content (Wang *et al*., 2009), GA lead to reduction adenosine diphosphate-glucose pyrophosphorylase (AGPase) which is enzyme of starch synthesis (Mares *et al*., 1981) meanwhile, CCC can be reduced in starch synthesis and inhibit the synthesis of GA, furthermore CCC caused changed the endogenous hormone as decreasing activity synthesis of GA and (ABA) abscisic acid (Wang and Xiao 2009 and Sharma *et al*., 1998a), (Karaguzel 1999) who found the application as foliage spray of Paclobutrazol at 0 (control), 125, 250, 500 and 1000 ppm caused decreased the length of shoots, number of flowers/ plant and increased the number of shoots, highest contents of chlorophyll, total carbohydrate % and N P K% when the *Murraya exotica* L. and *Duranta repens* L. treated with PP333 at 70 ppm and CCC at 4000 ppm (Eisa 2014), shoot height, root number of *Zinnia elegans* and lateral shoot length were reduced with CCC from 1000 to 2000 ppm,Cycocel 2000 ppm produced most lateral shoot and flower number and weak quantities the fresh and dry weight of root, shoot carbohydrate (Hojati *et al*., 2009), 500 mg/L CCC caused decreasing of plant height, while increasing number of flowers per plant, the highest number of leaves of *Calendula officinalis* L., also produced the highest amount of essential oils, (Hashemabadi, *et al*., 2012), the application of Ray Florets of Bronze Chrysanthemum (*Chrysanthemum morifolium* Ramat.) with 22–50 % daminozide can be increasing the flavones apigenin, acacetin rutinoside, diosmetin rutinoside, and eupatorin, and increasing in the flavonol quercetin (Roepke *et al*., 2013), Pbz inhibited the biosynthesis of GA_3 so it caused the inhibition of growth, its caused oxidative reaction between kauren and kaurenoic acid in GA_3 synthesis which resulted in stem suppression, inhibit the aging phase and extending harvest life while pbz can be promoted the flowering, pigments formation, furthermore its prevent the etiolation, (Soumya *et al.,* 2017), Ethephon at 1000 mg l^{-1} three times as spraying were tardiness flowering of *Echinacea purpurea* Moench 'Bravad, *Monarda didyma* L. *and Physostegia virginiana* Bentham 'Summer Snow and reduced height of *Achillea millefolium* L. 'Weser River Sandstone' Leucanthemum × superbum Bergmans ex. J. Ingram 'Thomas Killen, *Monarda didyma* L. 'Blue Stocking', *Phlox paniculata* L. 'Mt. Fuji', and *Physostegia virginiana* Bentham 'Summer Snow (Hayashi et al., 2001), ethephon enhancing development the axillary shoots even any loses of apical meristem. In large scale ethephon is used to developing the branches on crop species like azalea, chrysanthemum, Fuchsia, geranium, New Guinea impatiens, Lantana, and Verbena (Dole and Wilkins, 1999), 60 ppm pbz and 200 ppm cycocel induced maximum number of bulbs plants and flower and bulb weight diameter (Malik *et al*., 2021), Pbz at 100 pp caused increase the chlorophyll a, b and chl a+ chl b in addition to increasing activity of SPAD enzyme., also stimulated diameter and fresh weight of flower- bud- stage of (*Paeonia lactiflora* Pall) Herbaceous peony (Yanqing *et al.,* 2022), PBZ at 50 ppm produced increasing of leaves chlorophyll, anthocyanins, early flowering time, flower diameter of *Chrysanthemum* (Lailaty, and Nugroho, 2022), foliar application of pbz from 50 to 200 ppm and soil drenching from 50 to 200 ppm improved lateral branches numbers and increasing the Calendula *Calendula officinalis* L. flower . This work is based on the hypothesis that the spraying with different treatments which playing as growth regulators on the aerial parts of *Russelia equisetiformis* can be provides increasing development and upon this the maximum numbers of flowers.

2. Materials and Methods

This study was carried out at Ornamental Plants and Landscape Gardening Res. Dept., Hort. Res. Inst., Giza, Egypt, during the two successive seasons of (2021 and 2022) to investigate the effects of different spraying treatments of Cycocel (CCC), Ethiphon and Daminozide on pot plants of *Russelia equisetiformis*

2.1. Plant materials

Russelia equisetiformis pot plants were one year old, 30-35 cm in height and bearing 10 to 12 branches on the plant. Pot plants of *Russelia equisetiformis* were cultivated in plastic pots about 20cm in diameter and 25cm in depth. The pots were filled with a mixture of clay and sand 2:1 and these

plants were kept in the nursery and fertilized with NPK 20-20-20 once a week at 5 g/l, this study included foliar spraying treatments once a week for two seasons (6 months) for each one with different concentrations as plants haven't sprayed for the control treatment.

Cycocel, CCC Fig 1. at 0, 1000 and 1500 ppm
Ethephon, Fig 2. at 0, 300 and 450 ppm
Daminozide, Fig 3. at 0, 2000 and 4000 ppm

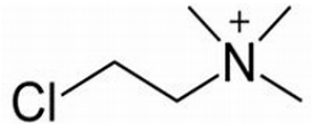


Fig. 1: Chlormequat chloride ($C_5H_{13}C_{l2}N$)

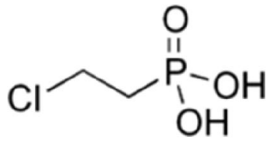
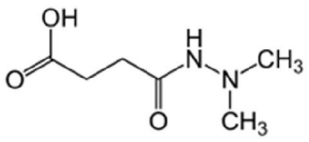


Fig. 2: Ethiphon (2- Chloroethyl phosphonic acid)



$C_6H_{12}N_2O_3$

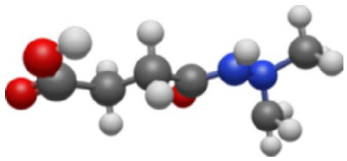


Fig. 3: Daminozide 4-(2,2-Dimethylhydrazin-1-yl)-4-oxobutanoic acid

2.2. Data Recorded:

2.2.1. Vegetative growth estimation: was measured after the end experiment of seasons as follows: Plant height (cm), shoots numbers/plant, number of second shoots/plant, flowers numbers/plant, fresh and dry weights of shoots (g).

2.2.2. Leaves chemical contents as:

Indoles mg/g f.w. as described by Salim *et al*. (1978).
Phenols contents according to A.O.A.C. (1990).
Chlorophyll contents a, b and carotenoids (mg/g f.w.) according to Lichtentaler and Wellburn (1985).

2.2.3. Experimental design

The obtained data were analyzed as randomized complete block design (RCBD), 3 concentrations for each treatment X 3 replicates x 3 pot plants for replicate, the data were subjected to variance analysis using a statistical package for social science ("MSTAT-C", Gomez and Gomez ,1984), the means significant differences were compared using one-way ANOVA T tests at a probability of 5%.

3. Results

The data in (Table 1) indicates significant differences between spraying treatments. Daminozide at 4000 ppm had the least impact on stem reduction, followed by 2000 ppm. Conversely, spraying with CCC at 1500 ppm and 1000 ppm effectively controlled stem elongation, resulting in shorter plants in both seasons. Additionally, the highest number of main shoots was observed with CCC at 1000 and 1500 ppm in both seasons, while daminozide at 4000 ppm had the most significant effect on shoot numbers in the second season. The control treatment resulted in the lowest number of main shoots.

The best results for the number of second main shoots were achieved with CCC at 1500 ppm, while other treatments had minimal effects and showed no significant differences. Growth retardants like CCC suppressed internode elongation, increased lateral shoots, and reduced vegetative shoots below flowers, leading to more inflorescences. The highest flower numbers were observed with CCC at 1500 ppm and daminozide at 4000 ppm, while ethephon at both tested levels resulted in fewer flowers.

Table 1: Effect of different growth regulators spray treatments on vegetative growth of *Russelia equisetiformis* during seasons of 2021 and 2022.

Growth characters		Plant height cm		Number of main shoots		Number of second shoots		Number of flowers	
Spraying treatments		1st	2nd	1st	2nd	1st	2nd	1st	2nd
Con.		59.0	62.8	17.0	19.0	40.3	45.2	30	33.7
CCC	**1000**	35.2	31.2	20.7	23.9	45.3	49.2	32	35.7
CCC	**1500**	32.2	29.5	22.4	25.0	54.0	56.6	40	43.3
Mean		**33.7**	**30.4**	**21.6**	**24.5**	**49.7**	**52.9**	**36.0**	**39.5**
Ethephon	**300**	38.9	40.5	16.4	18.2	37.3	40.2	22.7	25.0
Ethephon	**400**	42.1	43.9	17.7	20.0	45.0	45.6	29.7	30.7
Mean		**40.5**	**42.2**	**17.1**	**19.1**	**41.2**	**42.9**	**26.2**	**27.9**
Daminozide	**2000**	65.2	68.4	18.5	21.1	41.7	45.1	32	35.3
Daminozide	**4000**	63.8	66.9	20.6	23.0	41.3	47.9	39.7	42.7
Mean		**64.5**	**67.7**	**19.6**	**22.1**	**41.5**	**46.5**	**35.9**	**39.0**
L.S.D. 0.05		3.5	3.1	1.3	1.2	5.5	5.5	5.7	5.4

Data in Table (2) reported that regarding root growth in *Russelia equisetiformis*, daminozide at both levels enhanced root length, CCC increased root numbers, and ethephon led to fewer roots.

In general *Russelia equisetiformis* treated with daminozide at both concentrations showed significantly higher shoot fresh and dry weights compared to ethephon and CCC, which resulted in the lowest values in both seasons as indicated in Table (2).

Table 2: Effect of different growth regulators spray treatments on root length (cm), root numbers, fresh weight and dry weight (g) f *Russelia equisetiformis* during seasons of 2021 and 2022.

Growth characters		Root length (cm)		Roots numbers		Shoot fresh weight (g)		Shoot dry weights (g)	
Spraying treatments		1st	2nd	1st	2nd	1st	2nd	1st	2nd
Con		20.5	23.3	13.5	13.9	16.0	16.8	7.5	7.6
CCC	**1000**	16.0	17.2	13.0	13.3	16.3	18.3	7.4	8.5
CCC	**1500**	14.9	16.6	15.0	15.7	15.0	16.1	6.8	7.8
Mean		**15.5**	**16.9**	**14.0**	**14.5**	**15.7**	**17.2**	**7.1**	**8.2**
Ethephon	**300**	22.2	24.1	11.6	12.3	16.0	18.2	7.5	8.3
Ethephon	**400**	23.3	25.2	11.0	12.0	14.0	16.6	6.5	7.5
Mean		**22.8**	**24.7**	**11.3**	**12.2**	**15.0**	**17.4**	**7.0**	**7.9**
Daminozide	**2000**	24.3	26.4	12.3	14.0	18.0	20.8	8.0	9.4
Daminozide	**4000**	25.3	27.2	13.0	15.0	18.3	21.7	8.4	10.2
Mean		**24.8**	**26.8**	**12.7**	**14.5**	**18.2**	**21.3**	**8.2**	**9.8**
L.S.D 0.05		0.9	0.8	1.5	1.6	3.0	2.9	1.4	1.2

Regarding shoot chemical composition (Fig. 4) treated plants with daminozide had the highest indole content, while ethephon resulted in the lowest. Conversely, phenol content (Fig 5) was highest in plants treated with CCC at both levels, followed by ethephon and daminozide in both seasons.

In (Fig. 6) the study found that chlorophyll a content increased with higher concentrations of CCC, followed by 400 mg/L ethephon and 4000 mg/L daminozide. Chlorophyll b showed a more significant increase at the second concentration across all treatments. The lowest pigment content was observed in the control group. Regarding carotenoids (mg/g fresh weight), daminozide at both tested levels resulted in the highest content, while CCC led to the lowest carotenoid levels.

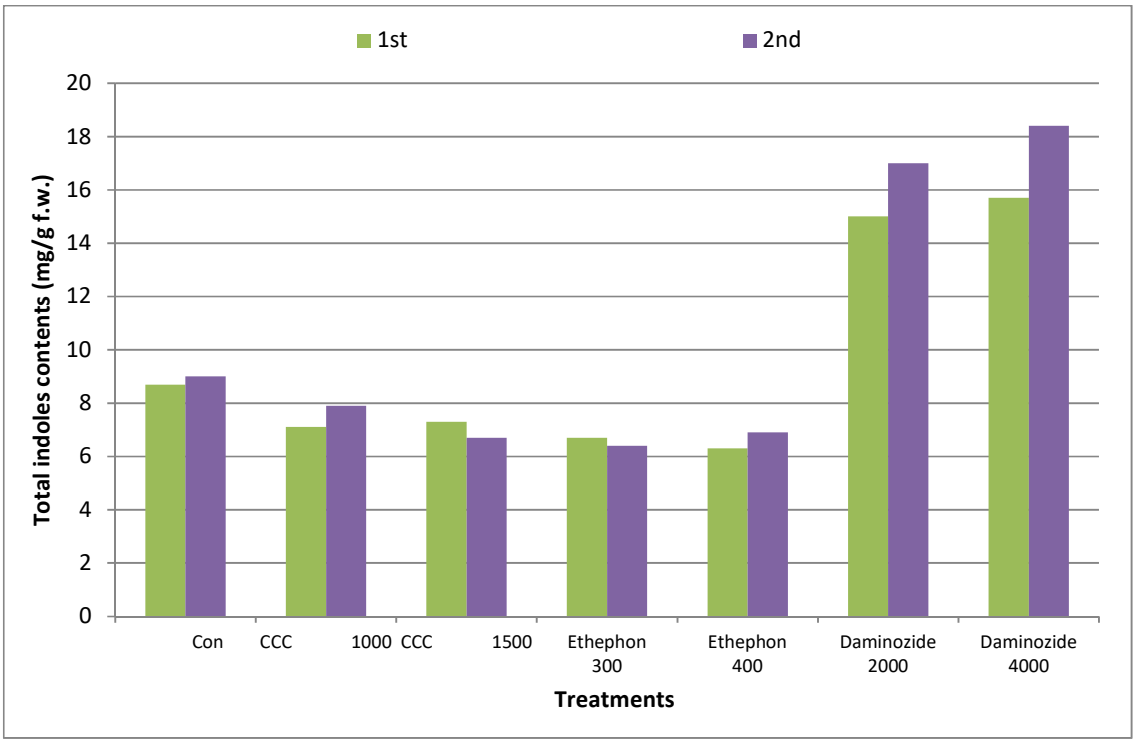


Fig. 4: Effect of different growth regulators spray treatments on total indoles contents (mg/g f.w.) of *Russelia equisetiformis* during seasons of 2021 and 2022.

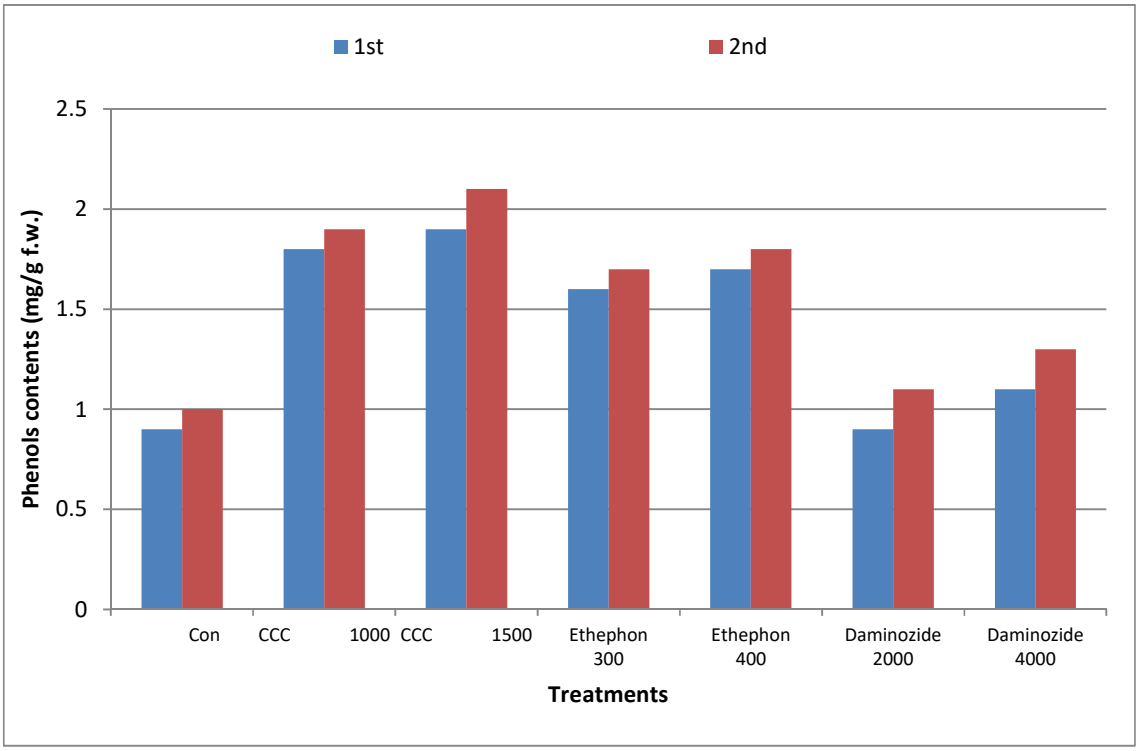


Fig. 5: Effect of different growth regulators spray treatments on Phenols contents (mg/g f.w.) of *Russelia equisetiformis* during seasons of 2021 and 2022.

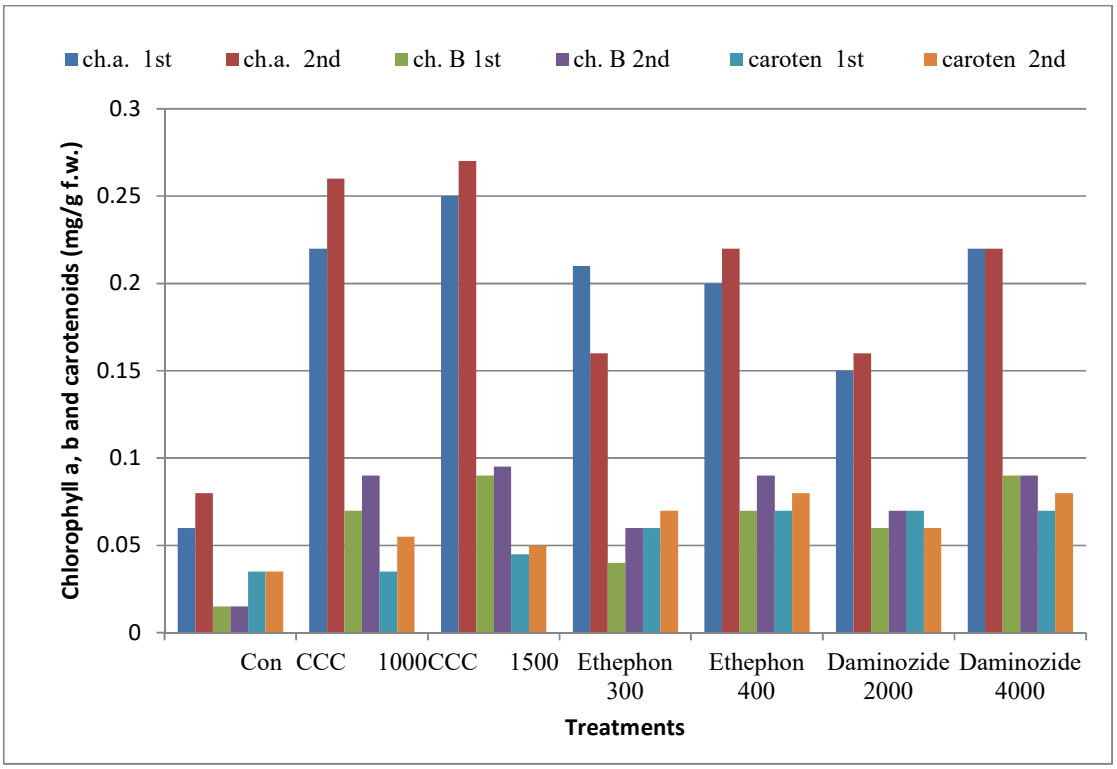


Fig. 6: Effect of different growth regulators spray treatments on chlorophyll a, b and carotenoids (mg/g f.w.) of *Russelia equisetiformis* during seasons of 2021 and 2022.

4.Discussion

The obtained results revealed that spraying of CCC and ethephon were successfully for reduced stem height and root length, more umbers of main and second shoots and flowers also fresh and dry weights of shoots, these results were in harmony according to found by the other scientists as, the highest reduction of shoots and highest shoots number of Poinsettia (*Euphorbia pulcherrima* Willd) were get when the plants were spraying by 1500 ppm cycocel application, these reduction for plant height when spraying by CCC it might be due to the retarding effect on apical growth that can be encourage lateral shoot growth (Karunananda and Peiris 2010 and Ahmad *et al*., 2007), maximum numbers of flowers of *Zinnia elegans* flower diameter, flower fresh and dry weight and flower vase life under 2000 mg/l CCC and pbz 400 mg/l in addition to increasing chlorophyll contents and carbohydrates %, N and P % contents (El- Shanhorey and Adam 2022), 10 ppm pbz produced maximum total dry mass and storage root dry mass of sweet potato variety VitAto (Rashid 2018), Cycocel foliar spray at 200 ppm led to decreasing length, highest fresh and dry weight of Lawn Grass and increasing proline contents. Cycocel caused lowest fresh and dry weight of grass and act as reducing the plants auxin levels, paclobutrazol (40 mg/pot^{-1}) as drench application caused a reduced shoot mass of (Borrichia frutescens L. DC., sea marigold) and root mass, paclobutrazol (40 mg / pot^{-1}) and uniconazole (2 mg / pot^{-1}) lead to reduce of leaf number and plant height (Carver *et al*., 2014), meanwhile the spraying application of uniconazole at 10–40 mg L^{-1} and daminozide at 2,500–7,500 mg L^{-1} reduced shoot height (Burnett *et al*., 2000), the maximum reduction of (*Nerium odorum* L.) was to be found with 2500 ppm CCC, meanwhile the level 2000 ppm can be produce the highest numbers of primary also secondary branches and number of flowers per plant (Kumar *et al.,* 2019), the obtained results proved that the number of flowers were affected by different spraying treatment which were increased with CCC and Daminozide followed by ethephon, ethephon at 3000 mg/L increased production flowering early spring (Zhang *et al*., 2022), flurprimidol at 40 mg l^{-1} has effective to highest reduction of plant height, The tepal size, leaf size the length of pedicel oriental lily 'Mona Lisa' and slightly delayed of flowering time, but vice versa the daminozide was ineffective for reduced the plant height (Pobudkiewicz and Treder 2006), 'Rocha' pear tree shoots and fruit size and fruits numbers of apple trees were had been decreased when using

300 - 750 mg/l ethephonm (Eth) and paclobutrazol (pbz) whilst return bloom and yield components increased (Meland and Sekse 2011), chemical shoots contents showed different impact as, different used spraying treatments also can affected the chemical estimated contents as, foliar spray of CCC or PBZ at 300 mg/L led to increasing of chlorophyll contents and accumulated total carbohydrates (Zheng *et al.,* 2012; (Shekoofa and Emam 2008; Pirasteh *et al*., 2016 and Rani *et al*., 2020), proline and chlorophyll content index of wheat, barley, maize and sunflower were increasing with 3.5 g/l CCC (Pirasteh-Anosheh *et al*., 2014), ethephon at 250 ppm help to improving the lateral buds/stem mean number, maximum total phenols content when treated by ancymidol, followed by the ethephon (Abdel-Moniem, 2016), daminozide at 5000 and 1000 mg/l exhibited an insignificant influence on fresh weight and chlorophyll a and b content (Kofidis *et al*., 2008), all of these effects of vegetative growth and chemical contents by usage these treatments were produced by different ways as, containing daminozide and maleic hydrazide that can be controlling the height and morphological characteristics, branch numbers and also can improve the flowering by inhibited the GA_3 biosynthesis (Lodeta *et al*., 2010 and Hayashi *et al*., 2019), same trend was found as, this results illustrated that CCC can be work as restrict the formation of GA_3 and cell elongation (Adel- kader and Abdalla, 2003), in addition to ethephon treatment was affected the estimations by different way as, ethephon as plant growth regulators which yielded ethylene gaseous, that used in industry for leaf abscission, delay flowering, selective flower abortion, stem reduction and increasing stem strength (Basra, 2000), Ethephin at 50 times the recommended agriculture rates was stimulated ethylene production strongly in shoots and roots differences in elongation response were related to differences in sensitivity to ethylene released by ethephon (Rajala *et al*., 2002).

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