American-Eurasian J. Agric. & Environ. Sci., 11 (1): 104-110, 2011
ISSN 1818-6769

Solidago Canadensis "Tara" in Response to Spacing and Cycocel

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Abstract: *Solidago canadensis* L.cv."Tara" belongs to family Asteraceae and grows as a wildflower in North America, Asia and Europe. It is widely used as a landscaping flowering plant, an excellent cut flower with high post harvest durability. Demand on *Solidago* has been rising dramatically over the past few years. This study was carried out for the assessment of the response of *S. Canadensis* "Tara" to the treatment with cycocel (CCC) as foliar spray and planting density in attempt to increase its landscape value and its quality as a cut flower. Six CCC concentrations and two planting densities were used (0, 500, 1000, 2000, 3000 and 4000 ppm) and (16 and 32 plants m^{-2}), respectively. Application of 3000 ppm CCC significantly decreased plant height, leaf area, fresh weight and inflorescence length, while application of 4000 ppm CCC increased stem diameter, fresh weight, inflorescence length, leaf area and number of leaves, while CCC had no effect on flowering date. Increasing planting density caused a significant delay in flowering and increased number of offsets. On the other hand, increasing planting density reduced plant and inflorescence length, stem diameter, fresh weight, number of leaves and leaf area. It was concluded that the best CCC concentration for cut flower *Solidago* was 4000 ppm, while the best planting density was 16 plants m^{-2}.

Key words: *Solidago canadensis* · Planting density · Cycocel

INTRODUCTION

Solidago canadensis L.cv."Tara" belongs to family Asteraceae and is native to North America and Mexico [1]. It is a wild plant but also appreciated as a landscaping easily managed plant and as an excellent cut flower with high post-harvest durability. Cultivation is preferably done under cool climate conditions, during the vegetative growing period a 14°C night temperature and a 16°C day temperature are best, though production has proven to be satisfactory under much higher temperatures.

Demand on *Solidago* has been rising dramatically over the past few years. Plant growth retardants are generally used in floriculture industry for height control, lateral branching and increase flowering [2]. Most plant growth retardants, such as paclobutrazol, daminozide and chlormequat chloride, are applied successfully to control height, branching and flowering in many plant species [3, 4].

The retarding effect of CCC is due to its opposing effect to gibberellin biosynthesis (anti-gibberllin dwarfing effect) which leads to the deficiency of gibberellin and blocking the conversion of geranyl pyrophosphate to capalyl prophosphate in gibberellin synthesis causing reduction in cell division and cell elongation [5-8]. Also CCC affects the sub apical meristem by prohibiting cell division [9, 10].

MATERIALS AND METHODS

The experiment was carried out in two successive seasons, started February 2009 and ended in July of the same year and repeated during the same period of time in 2010, in an open private commercial field provided with drip fertigation system in Meniat bani Mansour village, Etay Elbaroud, El-Behira Governorate, Egypt (30" 54' 34, 87" N and 30" 42' 33, 78" E).

Rooted cuttings of *Solidago canadensis* L. cv. "Tara" of length 5 cm with eight to nine leaves per cutting were bought from "3H" commercial nursery Cairo- Egypt. Cuttings were planted in beds of length 6 m and width 1 m in a sandy clay loam soil composed of Sand: Clay: Silt at 65:25:10 v/v, respectively, two planting densities were used 16 and 32 plants m^{-2} (Fig. 1).

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16 plants m^{-2}

32 plants m^{-2}

Fig. 1: Rooted cuttings planted at two planting densities, 16 and 32 plants m^{-2} and irrigated using dripping irrigation system

Table 1: Soil analysis

Soil texture	pH	EC dS m^{-1}	N mmol l^{-1}	P mmol l^{-1}	K mmol l^{-1}	Organic matter (%)	Na+ mmol l^{-1}	Ca++ mmol l^{-1}	Mg++ mmol l^{-1}
Sandy clay loam	7.7	7	0.8	0.22	0.4	0.7	40	9	6

Plants were irrigated using drip irrigation system and grown under natural temperature and controlled day lengths of (16 – 18 lighting hours per day) using Tungsten lamps for extending day length from 9 PM to 3 AM (at a rate of 15 watts m^{-2}) with cyclic lighting of 15 min. on and 15 min. off, the lamps were fixed at 2.5m from soil surface.

Soil analysis was carried out in the soil testing laboratory, Desert Development Center, American University in Cairo (Table 1).

Two weeks after planting, ammonium nitrate at a rate of 0.5 g L^{-1} was added to the irrigation water to all treatments for one month then substituted by calcium nitrate at 0.5 g L^{-1}, when the plants height reached 25 cm a compound fertilizer of N: P_2O_5:K_2O (13: 3: 42) was used at the rate of 0.5 g L^{-1}.

Six concentrations of (CCC) were used as a foliar spray application at a concentration of 0, 500, 1000, 2000, 3000 and 4000 ppm. Cycocel was applied four times in the morning till running off point; the first spray was applied 45 days after planting, then three applications one week apart.

The experimental design was a Randomized Complete Block Design (RCBD) in a factorial experiment with three replicates; each replicate contained three samples, the main effect was the planting density and sub effect was the CCC concentrations.

Plant height, stem diameter, leaf number and area, days to flowering, fresh weight, number of offsets, number of flowering branches, inflorescence length and chlorophyll content were recorded in this study.

Chlorophyll concentration was assayed in the commercial cut stage. It was determined according to [11], absorption at 644 and 662 nm was detected using spectrophotometer (UNICO 3200).

Data were subjected to analysis of variance (ANOVA) using the SAS program and the mean values were compared using Tukey's test at P=0.05 level.

RESULTS AND DISCUSSION

A significant delay in flowering occurred due to increasing planting density from 120 to 126 days (Table 2). The delay in flowering might be due to plant response to light stress due to tight spacing which cause delay in emergence of flowers and fruit ripening [12]. Similar results were obtained by Sloan *et al.* [13] on sunflower, Rahnama and Bakhshandeh [14] and Kazaz *et al.* [15] on carnations.

Number of offsets was increased significantly by increasing planting density from 16 plants m^{-2} to 32 plants m^{-2} which is in consistent with the results reported by Bugbee and Salisbury [16]. On the other hand, increasing planting density caused a reduction in plant

Table 2: Effect of treatments on stem height, stem diameter, Fresh weight, number of offsets, inflorescence length and number of days to flowering

Planting density	Stem height cm	Stem diameter cm	Fresh weight g	no of offsets	Inflor. length	Days to flowering
16 plants m^{-2}						ns
C1	84.7	0.35	57.0	2.4	44.2	120.6
C2	83.5	0.36	69.3	2.0	46.7	122.6
C3	85.2	0.38	82.8*	1.8	47.2	119.8
C4	83.6	0.40*	87.3*	1.6*	43.2	118.1
C5	77.6*	0.41*	57.0	2.0	37.5	120.2
C6	81.6	0.43*	96.0*	2.7	57.1*	120.6
mean	82.75 a	0.39 a	74.93 a	2.13 b	46.02 a	120.37 b
32 plants m^{-2}					ns	ns
C1	82.1	0.28	53.0	1.8	34.7	125.8
C2	77.6	0.32	39.5	2.2	27.4	126.5
C3	75.7*	0.32	45.4	3.0*	28.7	126.5
C4	76.2	0.32	43.5	2.0	30.0	126.3
C5	74.8*	0.35*	41.7*	3.2*	32.6	126.3
C6	73.5*	0.37*	61.3	3.0*	36.1	126.2
mean	76.70 b	0.33 b	47.44 b	2.55 a	31.63 b	126.31 a

Where C1, C2, C3, C4, C5, C6 represents 0,500,1000,2000,3000 and 4000 ppm CCC

*: means that there is a significant difference between treatments and control at $P<0.05$

ns: no significance between treatments

Different letter at each column means there is a significant difference between means.

Table 3: Effect of treatments on number of leaves, total leaf area, number of flowering branches, chlorophyll a, b and total chlorophyll

Planting density	No of leaves	Total Leaf area cm^2	No of flowering branches	Chlorophyll a (mg l^{-1})	Chlorophyll b (mg l^{-1})	Total Chlorophyll (mg l^{-1})
16 plants m^{-2}			ns	ns	ns	ns
C1	62.6	426.2	2.4	7.6	12.3	19.2
C2	64.2	444.5	2.5	7.5	11.8	19.8
C3	69.1	533.8*	2.5	7.3	10.8	18.7
C4	61.0	524.0*	2.1	7.9	11.1	19.1
C5	65.5	326.6*	3.0	6.4	14.1	20.5
C6	74.0*	640.5*	2.6	7.9	14.5	22.4
mean	66.09 a	482.65 a	2.55 a	7.72 a	12.45 a	20.37 a
32 plants m^{-2}	ns	ns	ns	ns	ns	ns
C1	59.0	420.3	2.4	7.8	10.3	18.2
C2	61.8	400.6	2.3	8.1	11.0	19.1
C3	60.5	341.2	2.5	7.8	12.9	20.8
C4	62.1	345.1	3.0	8.1	11.0	19.1
C5	63.0	362.7	1.8	8.1	11.8	19.9
C6	62.5	379.6	2.2	7.5	12.6	19.9
mean	61.52 b	374.96 b	2.41 a	7.92 a	11.63 b	19.10 b

Where C1, C2, C3, C4, C5, C6 represents 0,500,1000,2000,3000 and 4000 ppm CCC

*: means that there is a significant difference between treatments and control at $P<0.05$

ns: no significance between treatments

Different letter at each column means there is a significant difference between means.

height and a significant decreased inflorescence length and stem diameter (Table 2). These results are in agreement with those obtained by Rahnama and Bakhshandeh [14] and Sloan *et al.* [13] on sesame and Kazaz *et al.* [15] on carnations.

Number of leaves and the leaf area were reduced significantly by increasing planting density, the reduction in leaf area might be due to the reduction in total number of leaves per plant (Table 3). Similar results were obtained by Yeh and Chiang [17].

Fresh weight was decreased with increasing planting density. Similar results were reported by …..[15] and …..[18]. The reduction in parameters (plant height, stem diameter, inflorescence length, fresh weight, number of leaves, leaf area and chlorophyll content) due to increasing planting density might be due to the excessive competition between plants on water and nutrients and due to the reduction in light intensity and light penetration to the lower leaves [14, 17].

Cycocel application caused a significant reduction in plant height, the height was reduced by increasing CCC concentration up to 3000 ppm and there was no differences between 500, 1000 and 2000 ppm, the results show that CCC application has a significant effect on depressing stem elongation at 3000 ppm reaching 76.3 cm compared with the control 83.4 cm (Fig. 2 A).

The retarding effect of CCC is due to its opposing effect to gibberellin biosynthesis and the reduction of cell division and cell elongation [5, 6, 8]. Also CCC affects the sub apical meristem by prohibiting cell division; same results were obtained by……. [9] and …… [10].

The reduction in height might be due to the anti-gibberllin dwarfing effect of CCC, which lead to the deficiency of gibberllin and finally blocking the conversion of geranyl pyrophosphate to capalyl prophosphate which is the first step in gibberllin synthesis [7].

Increasing cycocel application caused a significant increase in stem diameter, stem diameter was increased by increasing CCC concentration up to 4000 ppm (Fig. 2 B). The increase in *Solidago* diameter by increasing CCC concentration is in consistent with the results of …….[19], ……..[20] on chrysanthemum and………. [21] on *Vigna unguiculata*.

There were no significant differences between leaf areas due to CCC application between control, 500, 1000 and 2000 ppm, while leaf area was reduced significantly at 3000 ppm CCC and increased at 4000 ppm (Fig. 2 C), the increase in leaf area might be mainly due to the increase in number of leaves per plant at high CCC concentration [22, 23] or might be due to the ability of growth retardants to delay senescence of leaf, arresting chlorophyll degradation and promoting the synthesis of soluble proteins and enzymes resulting in more assimilation surface area. ………….[24] and…………. [25] on *Jasminum auriculatum* found that the leaf area was increased due to CCC application from 500 to 1000 ppm.

Even CCC at 2000 ppm caused an early flowering which is in consistent with……… [26] on *Nerium odorum*, the effect of CCC on date to flowering was not significant in both studies(Fig. 2 D).

Fresh weight was reduced significantly at 3000 ppm and increased at the highest concentration 4000 ppm, while there were no significant differences between control, 500, 1000 and 2000 ppm CCC (Fig. 2 E). Similar results were reported by………… [27] on black iris and………. [21], the increase in fresh weight might be due to the increase in number of offsets, number of leaves, leaf area and stem diameter at high CCC concentrations.

There were no significant differences in number of offsets between control, 500 and 1000 ppm CCC, while number of offsets increased significantly at 3000 and 4000 ppm. (Fig. 2 F). The significant increase in offsets could be due to inhibition in the auxin activity in the plant due to application of CCC which acts as anti-auxin [21]. High CCC concentration could have also suppressed the apical dominance, thereby diverting the polar transport of auxins towards the basal nodes leading to increase in branching [7, 21]. Similar results were obtained by……. [26].

Inflorescence length was reduced with increasing CCC concentration while it increased significantly at the highest CCC concentration (4000 ppm) (Fig. 2G). The increase in inflorescence length at high CCC concentration might be due to the promotion of flowering in response to treatments with CCC and related compounds [28].

………..[26] found that number of flowers per plant and the flower yield in grams increased by increasing CCC concentrations. …………….[29] mentioned that the application of CCC at 3000 ppm increased head diameter of sunflower. The highest number of flowers with better size, weight and ultimate yield might be due to the production and accumulation of more photosynthates that were diverted to the sink (flower) with better translocation in response to the suppression of apical dominance and the increase in number of branches, leaves and leaf area due to retardants [26, 29, 30].

There were no significant difference between number of leaves at 500, 1000, 2000 and 3000 ppm CCC, while number of leaves increased significantly at 4000 ppm (Fig. 2 H). The increase in number of leaves due to CCC application at high concentrations might be due to the effect of growth retardants to delay senescence of leaves by arresting chlorophyll degradation [25]. Similar results were obtained by …..[26] and ……[21]. ……..[31] found that the application of CCC increased the number of leaves significantly and the increase was more at higher concentration.

There were no significant differences in chlorophyll concentration between the control, 500, 1000, 2000 and 3000 ppm CCC while the chlorophyll concentration increased significantly at 4000 ppm (Fig. 2 I).

The increase in chlorophyll b and total chlorophyll at high CCC concentration might be due to leaf senescence delay causing a reduction in chlorophyll degradation [24] also CCC cause induction of greening and initiate the development of chloroplasts [32], similar increase in total chlorophyll content was reported in sunflower by…… [31] and………… [33].

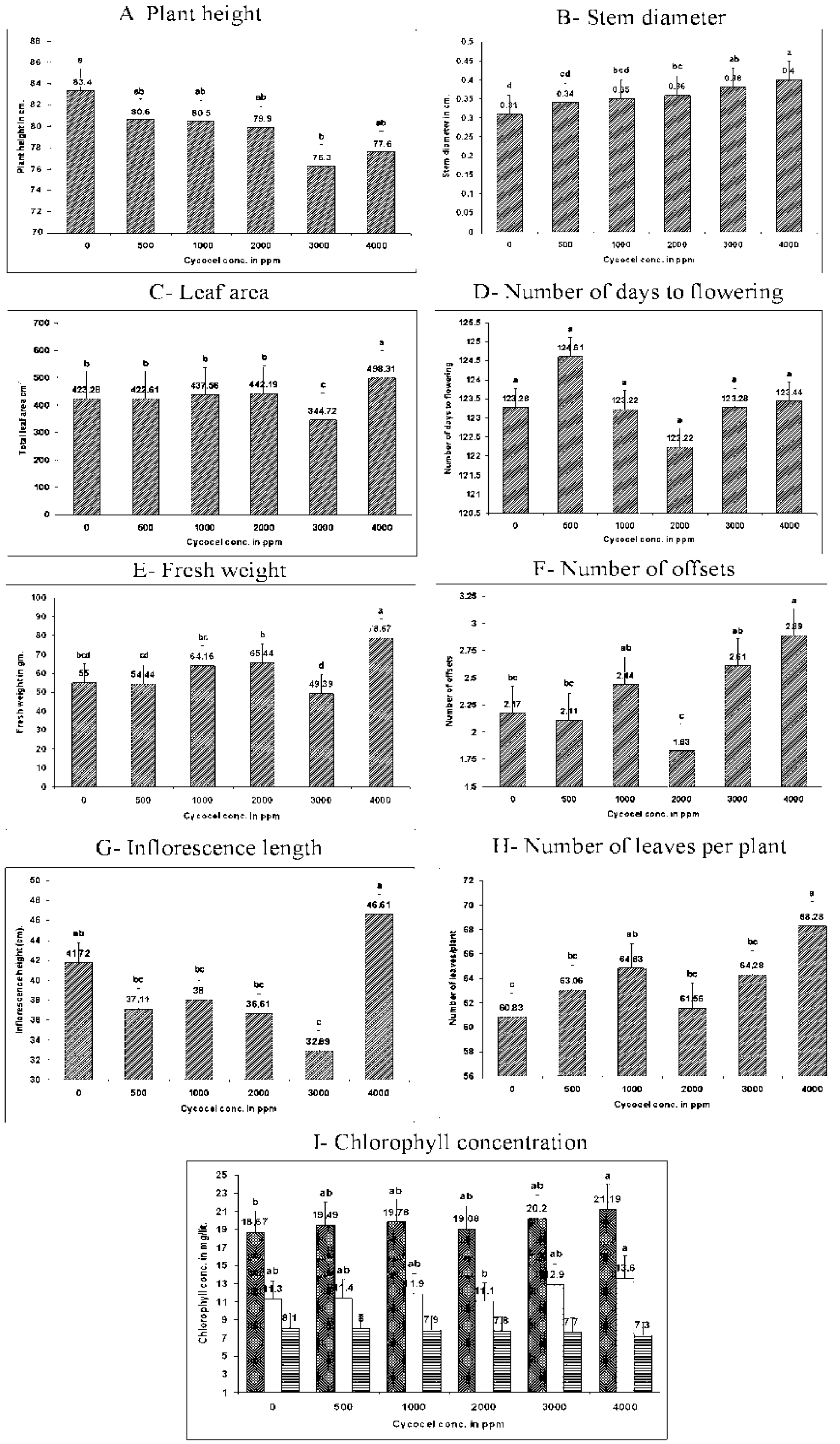

Fig. 1: Same letters in each graph means that there are no significant difference between treatments at P<0.05.
The effect of CCC concentrations on plant height, stem diameter, leaf area, number of days to flowering, fresh weight, number of offsets, inflorescence length, number of leaves per plant and chlorophyll concentration.

CONCLUSION

From the previous results it was concluded that the best CCC concentration for cut flower *Solidago* was the 4000 ppm since it gave the largest stem diameter, leaf area, fresh weight, inflorescence length and chlorophyll content also it reduced the plant height significantly, while the best planting density for cut flower *Solidago* was 16 plants m^{-2} which gave the highest stem diameter, fresh weight, stem and inflorescence height, total chlorophyll, number of leaves and leaf area also caused an early flowering. High planting density 32 plants m^{-2} can be used in landscaping purposes specially if combined with CCC as foliar spray at 4000 ppm as it gave the highest number of offsets and the shortest stem length (shrubby plant), which also can be used for giving a new cycle of cuttings used in propagation purposes.

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