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Effect of Planting Density and Gibberellic Acid on Quantitative and Qualitative Characteristics of *Solidago canadensis* "Tara" in Egypt

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ABSTRACT

Demand on *Solidago* has been rising dramatically over the past few years. *Solidago canadensis* L.cv. "Tara" belongs to family Asteraceae and grows as wild flower in North America, Asia and Europe. It is widely used as a landscaping flowering plant, as an excellent cut flower arrangements and bouquets with high post harvest durability and as a dried flower. This study was carried out to determine the response of *S. canadensis* L.cv. "Tara" to five Gibberellic Acid (GA_3) concentrations (control zero, 50, 100, 200 and 400 ppm) as foliar spray and two planting densities (16 and 32 plants m^{-2}) and interactions between them in an attempt to increase its landscape value, its quality as a cut flower production for reaching to maximum export value and increase its offsets production value as a vegetative propagation method under Egyptian conditions. The results revealed that stem height, stem circumference, fresh and dry weight, total leaves area $plant^{-1}$, inflorescence length, percentage inflorescence length $stem^{-1}$, number of flowering branches inflorescencestem $plant^{-1}$, flowering branches length $inflorescence^{-1}$, vase life, total chlorophyll and carotene contents of leaves increased significantly by reducing planting density. While, significant delay from (120 to 125 days) in flowering occurred due to increasing planting density. Application of 200 ppm GA_3 significantly increased stem height, inflorescence length, percentage inflorescence length $stem^{-1}$ and flowering branches length $inflorescence^{-1}$, while GA_3 had no effect on flowering date. Application of 400 ppm GA_3 significantly decreased stem circumference, fresh and dry weight, number of leaves $plant^{-1}$, total leaves area $plant^{-1}$, number of flowering branches inflorescencestem $plant^{-1}$ and total chlorophyll. The plants treated by combination of GA_3 at 100 ppm with 16 plants m^{-2} density recorded the best in terms of almost all characters studied. With respect to almost all characteristics, we can recommend that the best results were recorded in plants treated by combination GA_3 at 100 ppm with 16 plants m^{-2}.

Key words: *Solidago canadensis*, planting density, gibberellic acid

INTRODUCTION

Floriculture has become a profitable sub-sector of agribusiness throughout the world in recent years. The export trade in floriculture has grown substantially to become one of Egypt's major foreign exchange generating ventures. Quality and yield improvement are important aims of florists. These problems can be rectified by optimizing the production conditions and utilization of plant growth regulators (PGRs). *Solidago canadensis* L.cv. "Tara" belongs to family Asteraceae and

is native to North America and Mexico (Walck *et al.*, 2001). It is a wild plant but also appreciated as a landscaping easily managed plant, as an excellent cut flower with high post-harvest durability and as a dried flower. 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. In the Dutch auctions, *Solidago canadensis* L.cv. "Tara" is graded by stem weight stem, length and ripeness (Anonymous, 2009). The high export value of cut flowers in Egypt encourages growers to dramatic increases in quality of production. Good quality of *Solidago canadensis* cut flower, especially for export is usually achieved by manipulating growth factors such as temperature and light. These physical factors are very difficult to control and perhaps expensive in Egypt. Agricultural factors such as spacing have critical effects on quantitative and qualitative characteristics of plants (Badi *et al.*, 2004). Plant growth and flowering depend on PGRs equilibrium and plants quickly respond to change of hormonal balance (Khangoli, 2001). In some species, the application of gibberellic acids (specifically GA3) reduces postproduction losses by preventing leaf senescence (Han, 1997; Ranwala *et al.*, 2003; Ranwala and Miller, 1998). Gibberellins, especially gibberellic acid (GA3) play an important role in the growth and development of plants. Gibberellins are classified as diverse group of plant hormones that enhance some physiological or biochemical pathways in plants. The use of GA3 for boosting the growth and vigor of various horticultural plants is very old known and well documented (Gul *et al.*, 2006). Gibberelic acid 3 improves yield and quality of ornamental plants via plant growth incitation and stem elongation (Fathipour and Esmaellpour, 2000). Gibberelic acid 3 enhances plant growth and internode length by increasing the cell division and enlargement. It also increases cell size, stem height, stem thickness and number of leaves. Other studies on the effect of GA3 on ornamental plants showed that, GA3 accelerated flowering and enhanced plant height (Gul *et al.*, 2006). Plant responses to Plant Growth Regulators (PGRs) are highly variable: therefore, all PGRs must be examined in different species, cultivars and even at various developmental stages before useful recommendations can be developed (Gent and McAvoy, 2000).

The experiment was undertaken to estimate the proper planting density and concentrations of GA_3 for quantitative and qualitative characteristics of *Solidago canadensis* plantlets.

MATERIALS AND METHODS

The experiment was carried out in two successive seasons, started in February 2012 and ended in July of the same year and repeated during the same period of time in 2013, in Meniat bani Mansour village, Etey Ellbaroud, El-Behira Governorate, Egypt (30" 54' 34, 87" N and 30" 42' 33, 78" E) in an open private commercial field provided with drip irrigation fertigation system.

Plant material: Rooted cutting of *Solidago canadensis* L. cv. "Tara" (Fig. 1) of length 5 cm with eight to nine leaves per cutting (Fig. 2) were planted in beds of length 6 m and width 1 m in sand 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. 3). Soil analysis was carried out in the soil testing laboratory, Desert Development Center, American University in Cairo (Table 1).

Five concentrations of (GA_3) Gibberellic Acid were used as a foliar spray application at a concentration of 0, 50, 100, 200 and 400 ppm. Gibberellic Acid 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.

Fig. 1: Inflorescence of *Solidago canadensis* L. cv. "Tara"

Fig. 2: Rooted cutting of *Solidago canadensis* L. cv. "Tara" of length 5 cm with eight to nine leaves per cutting

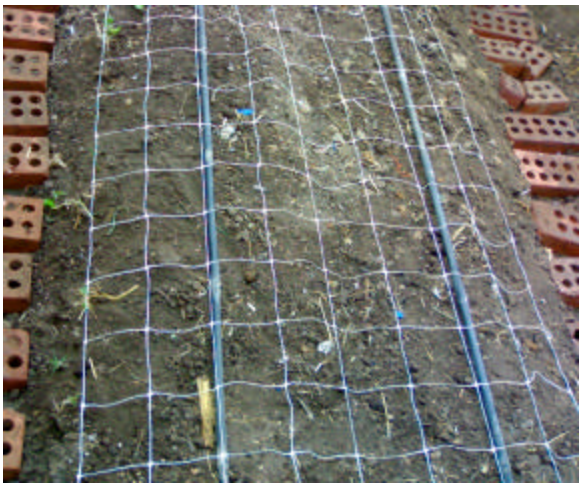

Fig. 3: Net (12.5×12.5 cm) for adapted planting density

Fig. 4: General view of *Solidago canadensis* L. cv. "Tara" plants at open field

Table 1: Soil analysis

Soil texture	ECds (m^{-1})	pH	N mmol (L^{-1})	P mmol (L^{-1})	K (nmol L^{-1})	Organic matter (%)	Na+ (mmol L^{-1})	Ca++ (mmol L^{-1})	Mg++ (mmol L^{-1})
Sand clay loam	7.2	7.8	0.9	0.24	0.41	0.8	40	9	6

Irrigation and lighting systems: Plants were irrigated using drip irrigation system and grown under natural temperature (Fig. 4) 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 2.5 m from soil surface. *Solidago* stays rosette when minimum temperature and day length are less than 15°C and

12 h, the influence of day length over the rosette formation is stronger than the influence of cold temperatures. With the usage of lighting and heating, a program of year round production is possible (Highsun Express Plugs, 2008), also he mentioned that, the application of lighting and heating (temperature over 10°C and light 16 h) after pruning back the plants, *Solidago* keeps producing flower stalks. When the stalks reach to 30-40 cm or your target stem length, stop lighting and then *Solidago* grows generative and forms its flowers.

Fertilizing system: 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}.

Statistical analysis of data: The experimental design was a Randomized Complete Block Design (RCBD) in factorial experiment with three replicates: each replicate contained three samples, the main effect was the planning density and sub effect was the (GA_3) Gibberellic Acid concentrations. Data were subjected to Analysis of Variance (ANOVA) using the SAS program (SAS, 2002) and the mean values were compared using Tukey's test at p=0.05 level (Snedecor and Cochran, 1974).

Stem height, stem circumference, fresh weight, dry weight, number of leaves plant^{-1}, total leaves area plant^{-1}, inflorescence length, percentage of inflorescence length stem^{-1}, number of flowering stem plant^{-1}, number of flowering branches inflorescencestem plant^{-1}, flowering branches length inflorescence^{-1}, days to flowering, vase life, number of offsets, chlorophyll a, chlorophyll b, total chlorophyll and caroten were recorded. In this study the values are means of two seasons, 2012 and 2013 were presented in results part.

Chlorophyll a, chlorophyll b, total chlorophyll and carotene contents of leaves were assayed in the commercial cut stage1/3 open inflorescence according (Wintermans and de Mots, 1965), absorption at 662, 644 and 440 nm were detected using spectrophotometer (UNICO 3200). Vase life, the stem were cut to a uniform length and lower leaves were removed leaving only few upper leaves after that, the stems were put in 250 mL conical flask containing distilled water at (room temperature 30°C±2 and 75% humidity) until wilting.

RESULTS AND DISCUSSION

Vegetative growth: The analysis of variance showed that, the F-values of planting density, GA_3 concentration and interactions between them were significant at level 0.05 of significance. In general, all data on means of *Solidago canadensis* L. cv. "Tara" stem height, stem circumference, fresh weight, dry weight and total leaves area per plant were reduced significantly by increasing planting density from 16-32 plants m^{-2} (Table 2). The reduction in parameters might be due to the excessive competition between plants on nutrients and water and reduction in light intensity and light penetration to lower leaves (Rahnama and Bakhshandeh 2006; Bugbee and Salisbury 1988; Osman *et al*., 2011).

Stem height increased significantly by increasing GA_3 concentration reaching its peak at 200 ppm GA_3 (94.33 cm) and then declined at higher concentration and the highest stem length was achieved at 200 ppm GA_3 combined with 16 plants m^{-2} (101.22 cm). Table 2 same results were reported by Kazaz and Karaguzel (2010), Patil *et al*. (1996) and Pobudkiewicz and Novak (1992) in goldenrod, they reported that the GA_3 treatments increased plant height in goldenrod plants.

Table 2: Effect of planting density (D), GA_3 concentration (ppm) and their interactions (D×GA_3) on vegetative growth of *Solidago canadensis* "Tara"

Treatments	Stem height (cm)	Stem circumference (cm)	Fresh weight (g)	Dry weight (g)	No. of leaves plant^{-1}	Total leaves area plant^{-1} (cm^2)
Main effect of planting density (D)						
16 plants m^{-2}	91.88^a	1.95^a	50.86^a	40.37^a	43.91^a	211.710^a
32 plants m^{-2}	83.15^b	1.81^b	38.08^b	37.15^b	44.62^a	156.150^b
Main effect of GA_3 concentration (GA_3)						
0	80.94^c	1.92^a	50.88^a	43.50^a	60.05^a	343.167^a
50	86.00^b	2.01^a	45.50^{ab}	39.05^b	49.55^b	217.556^b
100	86.55^{bc}	1.93^a	48.44^{ab}	41.94^a	43.72^c	164.000^c
200	94.33^a	1.89^a	42.94^b	37.33^{bc}	36.50^d	117.389^d
400	89.77^{ab}	1.63^b	34.61^c	32.20^c	31.50^e	77.550^e
Main effect of interaction between (D×GA_3) planting density and GA_3 concentration						
Planting density (D)	GA_3 concentration	Stem height (cm)	Stem circumference (cm)	Fresh weight (g)	Dry weight (g)	No. of leaves plant^{-1}	Total leaf area (cm^2)
16 plants (m^{-2})	0	81.55	2.15	59.77	45.44	60.88	426.22
	50	88.88	2.03	50.44	38.11	49.22	283.44
	100	90.66	1.95	53.55	41.88	44.22	186.89
	200	101.22	1.86	47.33	36.88	37.33	96.44
	400	97.11	1.74	43.22	39.55	27.88	65.55
32 plants (m^{-2})	0	80.33	1.70	42.00	41.55	59.22	260.11
	50	83.11	2.00	40.55	40.00	49.88	151.67
	100	82.44	1.91	43.33	42.00	43.22	141.11
	200	87.44	1.92	38.55	37.77	35.66	138.33
	400	82.44	1.52	26.00	25.00	35.11	89.55
L.S.D 0.05 for (D×GA_3)		5.52	0.11	6.43	2.34	3.27	24.18

Values are means of two seasons, 2012 and 2013, L.S.D$_{0.05}$ = Least significant differences at 0.05 probability, Means with the same letter are not significantly different (p = 0.05) according to Tukey

This result might be due to that the Gibberellins (GA_3) play important roles in several processes including shoot elongation, cell division, cell elongation and increase in the internodal length (Roberts *et al*., 1999; Kende and Zeevaart, 1997).

Stem circumference increased by increasing GA_3 concentration compared to control then decreased at higher concentration: which is agreement with Karaguzel and Mansuroglu (2003) in *Consolida orientalis* however, this difference was found not significant except the result at 400 ppm GA_3 was decreased significant. The best Stem circumference (2.03 and 2 cm) was found by combination GA_3 concentration at 50 ppm with 16-32 plants m^{-2}, respectively (Table 2).

Number of leaves per plant and total leaf area decreased significantly by increasing GA_3 concentration. The reduction in total leaf area might be due to the reduction in total number of leaves per plant which due to increase in the internodal length (Roberts *et al*., 1999) in Roses confirmed the effect of GA_3 on increasing of internode length. The best number of leaves per plant after control Table 2 (49.22 and 49.88), were found by combination GA_3 concentration at (50 ppm) with (16 plants m^{-2} and 32 plants m^{-2}), respectively after (44.22 and 43.22) were found by combination GA_3 concentration at (100 ppm) with (16-32 plants m^{-2}), respectively. The best total leaf area after control (283.44 and 186.89 cm^2) were found by combination GA_3 concentration at (50 and 100 ppm) with 16 plants m^{-2}, respectively.

The highest fresh weight after control (53.55 and 50.44 g) Table 2 were found by combination GA_3 concentration at (100 and 50 ppm) with (16 plants m^{-2}), respectively. These results might be due to effect of GA_3 and planting density on vegetative and flowering growth that agreement with Kumar and Singh (2003) they showed spraying of 100 ppm GA_3 increased fresh flower weight in Carnation, GA_3 may be also promote cell growth by causing decrease in the osmotic potential of cells (Attia, 2004) on *Zantedeshia aethopica* that reflected on enhancing leaf bud development as well as blade area and its fresh and dry weight.

The highest dry weight after control (42 and 41.88 g) Table 2 were found by combination GA_3 concentration at (100 ppm) with (32 and 16 plants m^{-2}), respectively. Similar results were obtained by Wakchaure *et al.* (2008) in goldenrod.

Flowering characteristics: The analysis of variance showed that, the F-values of planting density, GA_3 concentration and interactions between them were significant at level 0.05 of significance. Generally, All data on means of *Solidago canadensis* L. inflorescences length, percentage inflorescences length $stem^{-1}$, number of flowering branches inflorescencestem $plant^{-1}$ and flowering branches length $inflorescence^{-1}$ reduced significantly by increasing planting density from 16-32 plants m^{-2} (Table 3). The reduction in parameters might be due to the competition between plants on nutrients and water which led to reduction in vegetative growth then reflected at flowering growth (Bugbee and Salisbury 1988; Osman *et al.*, 2008) in *carthamus tinctorius* while, a significant delay in flowering occurred due to increasing planting density from 120.15-125 days (Table 3). This result might be due to plant response to light intensity due to tight spacing which cause delay in emergence of flowers that agreement with Sloan *et al.* (2003) in sunflower and (Osman *et al.*, 2011) in *solidago*.

Inflorescences length and percentage inflorescences length $stem^{-1}$ increased significantly by increasing GA_3 concentration compared to control reaching its peak at (100 and 200 ppm) GA_3 (56.83 and 59.55 cm) and (57.22 and 54.83%), respectively then declined at higher concentration. The highest inflorescence length (66.88 cm) was achieved at 200 ppm GA_3 combined with 16 plants m^{-2} and the best percentage inflorescences length $stem^{-1}$ (58.44 and 57.11%) were obtained at (100 ppm GA_3 combined with 32 plants m^{-2} and 200 ppm GA_3 combined with 16 plants m^{-2}), respectively (Table 3). These results might be due to GA_3 enhances plant growth by increasing the cell division, cell elongation and cell size which agreement with Gul *et al.* (2006).

Number of flowering stem $plant^{-1}$ increased by increasing GA_3 concentration compared to control however, this difference increased was not significant. The highest number of flowering stem $plant^{-1}$ (3.44, 3.33 and 3) were found by combination GA_3 concentration at (400, 100 and 200 ppm) with 16 plants m^{-2}, respectively (Table 3). This result agreement with Wakchaure *et al.* (2008) he reported that GA_3 treatment improved the yield and flower quality parameters in goldenrod. Number of flowering branches inflorescencestem $plant^{-1}$ decreased significantly by increasing GA_3 concentration. The highest numbers of flowering branches inflorescencestem $plant^{-1}$ after control (31.22 and 28.77). Table 3 were found by combination GA_3 concentration at (50 and 100 ppm) with 16 plants m^{-2}, respectively. These results might be due to the effect of GA_3 on increase in the nternodal length (Roberts *et al.*, 1999) in Roses.

Flowering branches length $inflorescence^{-1}$ increased significantly by increasing GA_3 concentration compared to control then decreased at higher concentration. The highest flowering branches length $inflorescence^{-1}$ (29.55 and 24.66 cm) were found by combination GA_3 concentration at (200 and 100 ppm) with 16 plants m^{-2}, respectively (Table 3) (Roberts *et al.*, 1999).

Table 3: Effect of planting density (D), GA_3 concentration (ppm) and their interactions (D×GA_3) on flowering characteristics of *Solidago canadensis* "Tara"

Treatments	Inflor. length (cm)	Inflo. length stem^{-1}	No. of flowering stem plant^{-1}	No. of flowering branches inflorescence^{-1}	Flowering branches length inflorescence^{-1} (cm)	Days to flowering (days)
Main effect of planting density (D)						
16 plants m^{-2}	57.04^{a}	53.15^{a}	2.91^{a}	29.40^{a}	24.95^{a}	120.15^{b}
32 plants m^{-2}	44.66^{b}	48.35^{b}	2.75^{a}	25.97^{b}	21.60^{b}	125.00^{a}
Main effect of GA_3 concentration (GA_3)						
0	39.77^{c}	39.38^{b}	2.44^{a}	31.10^{a}	20.50^{c}	122.50^{a}
50	49.66^{b}	50.38^{a}	2.72^{a}	29.55^{ab}	22.44^{bc}	123.00^{a}
100	56.83^{a}	57.22^{a}	3.11^{a}	28.16^{ab}	24.00^{ab}	122.72^{a}
200	59.55^{a}	54.83^{a}	2.72^{a}	26.61^{b}	26.38^{a}	122.83^{a}
400	48.44^{b}	51.94^{a}	3.16^{a}	23.00^{c}	23.05^{bc}	122.22^{a}
Main effect of interaction between (D×GA_3) planting density and GA_3 conc.						
Planting density (D)	GA_3 concentration	Inflor. length (cm)	Inflo. length stem^{-1}	No. of flowering stem plant^{-1}	No. of flowering branches inflorescence^{-1}	Flowering branches length inflorescence^{-1} (cm)	Days to flowering (days)
16 plants (m^{-2})	0	46.88	42.22	2.44	34.11	21.44	119.00
	50	58.55	54.00	2.33	31.22	24.55	120.78
	100	54.00	56.00	3.33	28.77	24.66	121.00
	200	66.88	57.11	3.00	27.33	29.55	121.11
	400	58.88	56.44	3.44	25.55	24.55	118.89
32 plants (m^{-2})	0	32.66	36.55	2.44	28.11	19.55	126.00
	50	40.77	46.77	3.11	27.88	20.33	125.22
	100	59.66	58.44	2.88	27.55	23.33	124.44
	200	52.22	52.55	2.44	25.88	23.22	124.56
	400	38.00	47.44	2.88	20.44	21.55	124.56
L.S.D 0.05 for (D×GA_3)		4.94	7.60	0.88	2.60	2.30	1.55

L.S.$D_{0.05}$: Least significant differences at 0.05 probability, Means with the same letter are not significantly different ($p \leq 0.05$) according to Tukey Values are means of two seasons, 2012 and 2013

Increased GA_3 concentration led to delay in flowering however the difference was not significant. This result might be due to the role of GA_3 as a component of flowering stimulus since it can be a substitute of long day or cold requirements needed for flowering (Taiz and Zeiger, 2002) and (Brooking and Cohen, 2002). The earliest flowering (118.89 days) table 3 was found by combination GA_3 concentration at 400 ppm with 16 plants m^{-2}. Similar results were reported by Patil *et al.* (1996) in goldenrod.

Vase life, offset production and chemical analyses: All data on means of *Solidago* vase life, number of offsets plant^{-1}, chlorophyll a, chlorophyll b, total chlorophyll and carotene contents of leaves in reduced significantly by increasing planting density from 16-32 plants m^{-2} and were positively significant affected by GA_3 its peak at 100 ppm GA_3 (11 days, 2.77 offsets plant^{-1}, 8.17, 11.94, 20.11and 2.89 mg L^{-1}), respectively then declined at higher concentration and the highest values of chlorophyll b, total chlorophyll and carotene contents of leaves (12.8, 20.98 and 3.72 mg L^{-1}), respectively were achieved by combination GA_3 concentration at 100 ppm with 16 plants m^{-2} (Table 4). These results could be explained through the role of planting density and GA3 in stimulating the vegetative growth, as mentioned previously and hence high accumulation

Table 4: Effect of planting density (D), GA_3 concentration (ppm) and their interactions (D×GA_3) on vase life, offset production and chemical analyses of *Solidago canadensis* "Tara"

Treatments	Vase life (days)	No. of offsets plant^{-1}	Chlorophyll a (mg L^{-1})	Chlorophyll b (mg L^{-1})	Total chlorophyll (mg L^{-1})	Caroten (mg L^{-1})
Main effect of planting density (D)						
16 plants m^{-2}	10.2^{a}	2.5.0^{a}	8.18^{a}	11.79^{a}	19.98^{a}	2.82^{a}
32 plants m^{-2}	8.2^{b}	2.3.0^{a}	7.81^{b}	10.15^{b}	17.97^{b}	2.27^{b}
Main effect of GA_3 concentration (GA_3)						
Zero	6.0^{d}	1.94^{c}	7.85^{a}	10.82^{b}	18.68^{b}	2.67^{a}
50	10.0^{b}	3.11^{a}	8.06^{a}	11.65^{ab}	19.76^{a}	2.84^{a}
100	11.0^{a}	2.77^{ab}	8.17^{a}	11.94^{a}	20.11^{a}	2.89^{a}
200	10.0^{b}	2.38^{abc}	7.98^{a}	10.91^{b}	18.89^{b}	2.12^{b}
400	9.0^{c}	2.05^{bc}	7.91^{a}	9.52^{c}	17.44^{c}	2.22^{b}

Main effect of interaction between (D×GA_3) planting density and GA_3 concentration

Planting density (d)	GA_3 concentration	Vase life (days)	No. of offsets /plant	Chlorophyll a (mgL^{-1})	Chlorophyll b (mgL^{-1})	Total chlorophyll (mgL^{-1})	Caroten (mgL^{-1})
16 plants (m^{-2})	0	7.00	2.33	8.02	11.71	19.74	2.69
	50	11.00	3.44	8.11	12.43	20.58	3.50
	100	12.00	3.00	8.17	12.80	20.98	3.72
	200	11.00	2.33	8.15	11.46	19.62	1.97
	400	10.00	1.77	8.45	10.54	18.99	2.24
32 plants (m^{-2})	0	5.00	1.55	7.68	9.93	17.61	2.65
	50	9.00	2.77	8.02	10.87	18.94	2.19
	100	10.00	2.55	8.16	11.07	19.24	2.07
	200	9.00	2.44	7.82	10.36	18.16	2.27
	400	8.00	2.33	7.38	8.50	15.88	2.19
L.S.D 0.05 for (D×GA_3)		0.59	0.69	0.29	0.74	0.71	0.23

Values are means of two seasons, 2012 and 2013 , $LSD_{0.05}$: Least significant differences at 0.05 probability, Means with the same letter are not significantly different ($p \leq 0.05$) according to Tukey

rate of metabolic components especially carbohydrates such as chlorophyll and carotene. That result was confirmed with the result obtained by Taiz and Zeiger (2002) and EL-Ashry *et al.* (1998) on *Strelitizia reginae*.

The GA_3 application pre-harvest significantly increased vase life of *Solidago* inflorescence in comparison with the control and the peak at 100 ppm GA_3 (11 days) then declined at higher concentration and the longest vase life was observed (12 days) by combination GA_3 at 100 ppm with 16 plants m^{-2} (Table 4). Improving the postharvest quality of *Solidago* inflorescence by using GA_3 could be explained through the role of GA_3 Improving water balance, fresh weight (EL-Saka *et al.*, 2002) and hence high accumulation of carbohydrates in stem and leaves which consequently increased the vase life (Hassan *et al.*, 2003).

Number of offsets per *Solidago* plant was positively affected by GA_3 application in comparison with the control. GA_3 at (50 and 100 ppm) were more effective (3.11 and 2.77), respectively and the highest number of offsets per plant (3.44 and 3) were found by combination GA_3 at (50 and 100 ppm) with 16 plants m^{-2} (Table 4). These results could be explained through the role of GA_3 and planting density in stimulating the vegetative and flowering growth in *Solidago* plant, as mentioned previously, consequently the plants could produce good plants which can store large

amount of food in produce more number of offsets per plant, in addition the long day condition (Highsun Express Plugs, 2008) which more available in July under open felid in Egypt condition, that led to more vegetative growth translated into more offsets.

CONCLUSION

With respect to almost all characteristics for *Solidago canadensis* "Tara" cut flower, we can recommend that the best results were recorded in plants treated by combination of GA_3 at 100 ppm with 16 plants m^{-2} since it gave stem height (90.66 cm), stem circumference (1.95 cm), fresh and dry weight (53.55 and 41.88 g), respectively, inflorescence length (54 cm), percentage inflorescence length $stem^{-1}$ (56%), number of flowering stem $plant^{-1}$ (3.33), number of flowering branches inflorescencestem $plant^{-1}$ (28.77), flowering branches length $inflorescence^{-1}$ (24.66 cm), days to flowering (121 days), total chlorophyll and carotene contents of leaves (20.98 and 3.72 mg L^{-1}), respectively vase life (12 days) and number of offsets $plant^{-1}$ (3).

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