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Evaluating the Efficacy of Some Growth Regulators, Essential Oils and Chemical Materials in Preserving the *Solidago canadensis* L. Cut Inflorescences Postharvest

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Abstract

An investigation was conducted to evaluate the ability of some preservatives in the holding solution to preserve *Solidago canadensis* L. cut inflorescences. The used preservatives were Distilled Water (D.W.) as control, STS (150 mgL^{-1}); BA (25 mgl^{-1}); GA_3 (25 mgl^{-1}); STS (150 mgL^{-1}) + GA_3 (25 mgL^{-1}); STS (150 mgL^{-1}) + BA (25 mgL^{-1}); BA (25 mgL^{-1}) + GA_3 (25 mgl^{-1}); bleach 1 tps /L; distilled water + tween-20 (0.5 μlL^{-1}), thyme oil (250 μlL^{-1}); cumin oil (250 μlL^{-1}); cinnamon (250 μlL^{-1}); clove oil (250 μlL^{-1}); a mixture of the four used essential oils (EOs). The least vase life was obtained with the control and tween-20, while the highest vase life (15 days) was achieved by using GA_3 and bleach in both years. Bleach was recorded the highest values of the water uptake and the water loss, while GA_3 and thyme oil were the most efficient in maintaining the water balance. Bleach could raise the fresh weight of the cut inflorescences till the 7th day, and recorded the highest values of relative fresh weight (R.F.W. %) as well as GA_3. GA_3 +BA and EOs raised the total carotenoid content in the inflorescences. Cinnamon oil was the most efficient preservative in reducing the decomposition of chlorophyll a and b. The highest values of total flavonoid content were obtained by using tween-20 and STS. Vase solution containing clove oil obtained the highest amount of total sugar content. All applied presevative significantly reduced the total plate count of microorganisms with superiority to EOs.

Keywords: *Solidago canadensis* L.; preservatives; holding solutions; GA_3; BA; STS, sodium hypochlorite; bleach; essential oils.

Full length article **Corresponding Author*, e-mail: nhhegazi@yahoo.com

1- Introduction

Solidago canadensis L., known as Canada Goldenrod or Canadian Goldenrod, is an herbaceous perennial plant of the family Asteraceae. It is native to north-eastern and north-central North America [1]. It is also known as 'Sun medicine' for its shinny colour and its medicinal uses. This plant is a genus of 120 species approximately, of flowering plants. The majority of them are herbaceous perennial species located in open areas such as meadows, prairies, and savannahs. The plant is erect forming colonies of small florets. Flowers are small yellow heads held above the foliage on branching inflorescences. Solidago is a marvellous cut flower for vases and bowls of interior decoration and as a dried flower [2]. The growing of Solidago cut flowers has been dramatically increased over the past three years. Moreover, it is a new crop among the top 25 most popular cut flowers around the world. This favourable crop could be adapted to be produced under the natural Egyptian conditions, with low environmental control, to incorporate the export to the European markets during the fall, winter, and early spring seasons according to (Flower Council of Holland, 1999). One of the main reasons that affect the vase life of cut flowers is the microbial contamination [3]. The longevity of the cut flowers in vases after harvesting is mostly affected by microbes, physiological occlusion, or stem occlusion by air [4]. Plant vessel blockage prevents the water absorption also extracellular enzymes secrete, so it can damage the vascular tube cell walls [5]. This physical blockage from the cells and its products makes emboli stimulating in the xylem, leading to cellular malfunction through toxic metabolite productions and enzyme action with degraded cell walls; moreover, there could be an endogenous ethylene production [6].

Essential oils (EOs) are natural organic products derived from aromatic and medicinal plants, used as preservative solutions to control bacterial and fungal pathogens [7]. Most of the essential oils have antioxidants and

antimicrobial characteristics. Essential oils inhibit DNA, RNA, protein, and polysaccharide synthesis [8]. Moreover, essential oils' phenolic compounds such as carvacrol, thymol, and eugenol play a great role as antibacterial. [9]. Thyme oil, cumin oil, clove oil, and cinnamon oil prolongs ed the vase life, enhanced the water relations, maintained the fresh and dry weights, increased the stalk and flower diameters, decreased the degradation of photosynthetic pigments and anthocyanin pigment, raised the total sugar content and suppressed the growth of the microorganisms in the vase solution of chrysanthemum, lily and rose cut flowers [10].

Gibberellins and cytokinins effectively delay leaf senescence in many plant species. However, growth regulators, such as benzyl adinine (BA) and gibberellic acid (GA_3), delay the flowers' senescence and inhibit the action of ethylene which leads to the rapid downfall of the petals [11]. Moreover, growth regulators limit the activity of the analyst enzymes in flower cells by delaying the appearance of the signs of the deterioration of vase life such as wrap, shrinkage of the petals, and reducing the transpiration rates of petals. Benzyl adenine (BA), a synthetic cytokinin, postponements senescence by its possessions on ethylene synthesis in tissue, leading the activity of protein hydrolytic enzymes (epoxygenase) to be decreased, delaying the change in fresh weight, respiration rate and water uptake, moreover, prolongs ing the number of days taken to the full opening of primary florets [12]. Some chemical materials such as sodium hypochlorite, which is a component of commercial bleach, play a main role as a germicide to control the harmful bacteria and to prevent the plugging of the conducting tissues. Huntsman [13] demonstrated that, bleach characteristics could overpower the pH effects as an antimicrobial substance in the vase solution of carnation cut flowers. They added that, bleach diminished the amount of bacteria in the xylem, so carnation cut flowers absorbed more water, which led to preventing wilting. Nevertheless, the positive effects on the vase life, absorbed water, fresh and dry weight, flower quality and the stem blockage by microorganisms, bleach washed and yellowished the flowers pigments.

Cut flowers are generally treated with anionic complex silver thiosulphate (STS), as an inhibitor of ethylene, to increase the longevity of cut flowers. STS could reduce the flower abscission of flowers when they were subjected to ethylene. Moreover, STS provides some antimicrobial activity inside the plant tissues and changes chrysanthemum flower weight by up to 50% versus the control as demonstrated by Sedaghathoor [14]. Moreover, STS prolongs ed the vase life of gypsophila cut flowers and maintained all their quality features as well as their water relations. However, the previous advantages, the silver compounds remain hazardous residuals and non-eco-friendly substances [7]. Therefore, the aim of this investigation was to determine the most suitable postharvest treatments, plus find out some other quality considerations, for keeping quality, and extending the vase life of *Solidago* cut inflorescences.

2. Material and Methods

2.1. Location and Duration

This experiment was conducted at the laboratory of Ornamental Plants and Woody Trees Department at the National Research Centre, Dokki, Giza, Egypt during 13th to 28th of December, in two consecutive years in 2021 and 2022.

2.2. Plant Material

Solidago (*Solidago canadensis*, L c.v. "Tara") cut inflorescences were brought from a commercial farm (Floramix) in Kafr Hakim, Mansouryah, Giza. Inflorescences were harvested at the normal commercial harvest stage at 85 cm in length and were re-cut under tap water to a standard length of 80 cm, leaving only four upper leaves while the basal leaves were removed to reduce contamination and water loss. The laboratory temperature was adjusted to 24°C+/-2, the light intensity was 44 Lux, and the percentage of the humidity was between 30-35%.

2.3. Experiment Materials

The used essential oils were secured from "Squeezing and Extracting Natural Oils Unit", National Research Centre, Dokki, Giza. GA_3 and BA were obtained from Science Lab Company, USA. STS was composed from two substances: sodium thiosulphate and silver nitrate as described by the produced company, Phytotechnology Laboratories. Tween-20 was produced by Rohm and Haas Company, USA.

2.4. Procedures and Treatments

Each inflorescence was put in a separate graduated cylinder, covered by Para film sheet to prevent evaporation, having 500 ml of holding solution which contained one of the following: Distilled Water (D.W.) as control, STS (150 mgL^{-1}); BA (25 mgl^{-1}); GA_3 (25 mgl^{-1}); STS (150 mgL^{-1}) + GA_3 (25 mgL^{-1}); STS (150 mgL^{-1}) + BA (25 mgL^{-1}); BA (25 mgL^{-1}) + GA_3 (25 mgl^{-1}); bleach 1 tps /L; distilled water + tween-20 (0.5 μlL^{-1}), thyme oil (250 μlL^{-1}); cumin oil (250 μlL^{-1}); cinnamon (250 μlL^{-1}); clove oil (250 μlL^{-1}); a mixture of the four used EOs. The essential oils were dissolved in 0.5 μlL^{-1} of tween-20 then added to the distilled water before using them as a preservative solution.

2.5. Experiment Layout

The layout of the experiment was complete randomized block design. The experiment contains 14 treatments, each treatment contains 3 replicates and each replicate has one inflorescence. The control inflorescences were placed in distilled water.

2.6. Assessment of vase life

2.6.1. Vase life of the cut inflorescences (days)

This was recorded from the day of harvesting to the day of senescence.

2.6.2. Relative fresh weight (R.F.W. %)

The fresh weight of inflorescence (F.W.) was registered day after day during the vase period and its relative changes (in relation to the fresh weight on the day of harvesting) was calculated from the formula: R.F.W. (%) = $(W_t/W_{t=0})\times100$; where, W_t (in grams) is the weight of the inflorescence at particular day (t= 3, 5, 7, etc.) and $W_{t=0}$ is the fresh weight of the inflorescence (on the day of harvesting) in grams [15].

2.6.3. Dry matter percentage (D.M. %)

Fresh weight of inflorescence of each treatment was measured using the digital balance at the end of inflorescence vase life, then inflorescences were dried in 70°C oven, for 24 h. Dry matter percentage was measured by this formula: D.M. (%) = dry weight/fresh weight×100 [16].

2.7. Water relations

2.7.1. Water uptake, total water uptake and daily water uptake (ml inflorescence^{-1} day^{-1})

The readings of the graduated cylinders were recorded day after day through the vase period. Water uptake was calculated by the formula: Water uptake = R_t-R_{t+2}; where, R_t is the cylinder reading at day 0, 3, 5, etc., and R_{t+2} is the cylinder reading after two days. The total water uptake was the sum of the water uptake of the inflorescence during the vase life, while the daily water uptake was calculated by dividing the total water uptake on the longevity of the inflorescence's vase life.

2.7.2. Water loss, total water loss and daily water loss (g inflorescence^{-1} day^{-1})

Every two days, the weight of cylinders (WC) and the weight of inflorescences (WF) were registered. Water loss was calculated by the formula: Water loss = (WC_t-WC_{t+2})-(WF_t-WF_{t-2}); whereas, WC_t is the cylinder weight at day 0, 3, 5, etc., WC_{t+2} is the cylinder weight after two days, WF_t is the inflorescence weight at day 3, 5, 7, etc., and WF_{t-2} is the weight of inflorescence after two days. The total and the daily water loss were calculated like it was done in the total and the daily water uptake.

2.7.3. Water balance, total water balance and daily water balance (g inflorescence^{-1} day^{-1})

Water balance was calculated by the formula: Water balance = water uptake-water loss, every two days during the vase life of the inflorescence. By the same way of which it had been calculated the total and the daily water uptake and loss, the total and the daily water balance were figured.

2.8. Assessment of inflorescences quality

2.8.1. Stalk diameter (cm)

Stalk diameter of solidago cut inflorescences was measured every other day with a Vernier caliper.

2.8.2. Days to the first opening (days)

2.8.3. Days to the first wilting (days)

2.9. Chemical composition

2.9.1. Total carotenoid content (µgg^{-1} of fresh inflorescences)

To determine the total amount of carotenoids, the method used by Carvalho [17] was applied.

2.9.2. Photosynthetic pigments (mgg^{-1} of fresh leaves)

Chlorophyll a, b and total Carotenoids were determined in leaf samples (mgg^{-1} F.W.) two times; in zero time (the day of harvesting) and in the 8th day of the vase life of the spikes, according to Nornai [18].

2.9.3. Total flavonoid content (mgg^{-1} of the fresh inflorescences)

Total flavonoid content in fresh inflorescences was determined in absolute ethanol extract using the aluminium chloride at the 8th day colorimetric method described by Chang [19].

2.9.4. Total sugar content (percentage of the fresh inflorescences)

The total sugar content in fresh inflorescences was determined at the 8th day using the phenol -sulphuric acid method, according to Dubois [20].

2.10. Biological Studies

Total plate count of microorganisms in preservation solution (CFU/ml)

In the 8th day of the vase life of the inflorescences, samples of 3 ml of the vase solutions were taken to detect microbial analysis. The microbiology analysis was accomplished at the microbiology department, National Research Centre. The used method was according to Page [21].

2.11. Statistical analysis

The data in the two seasons were statistically analysed as described by Snedecor and Cochran [22].Means of all characters were compared by LSD test at 0.05 level of significance.

3. Results

3.1. Assessment of vase life

3.1.1. Vase life of the cut inflorescences (days)

As presented in Fig. 1, all the applied preservatives significantly prolongs ed the vase life of solidago cut inflorescences compared to the control and tween-20. The greatest vase life was 15 days which achieved by using GA_3 or bleach in both years.

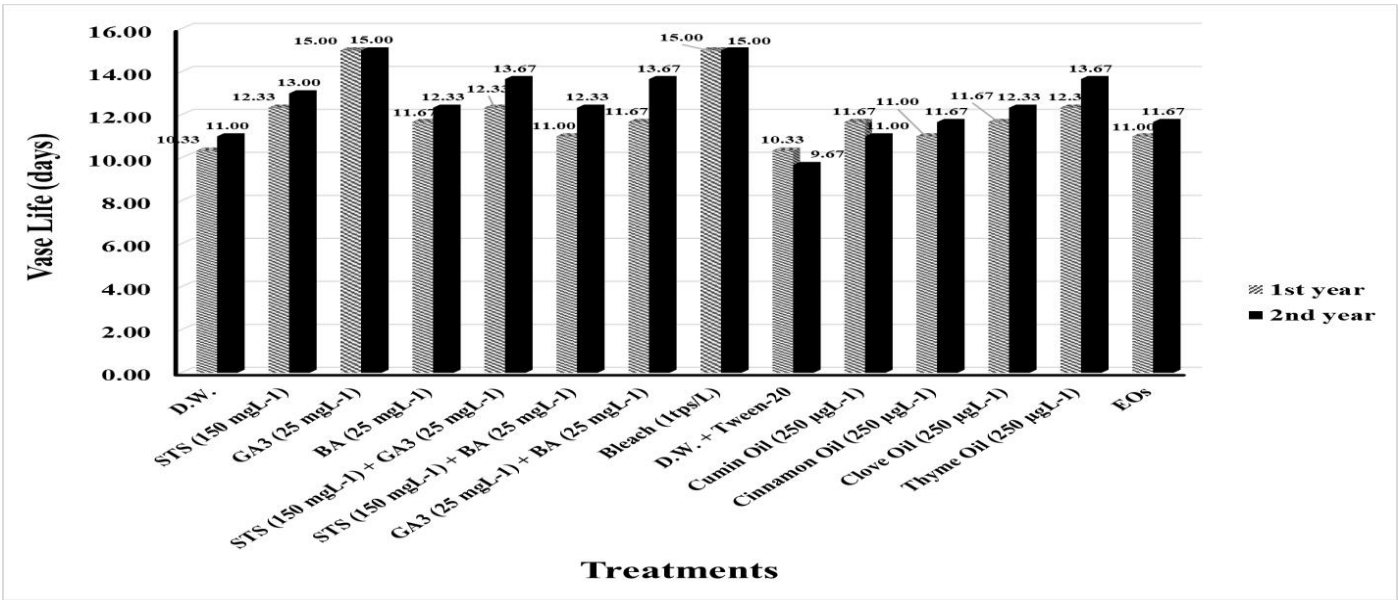

Fig. 1. Effect of different preservative solutions on the vase life of *Solidago canadensis* L.cut inflorescences (days) during 2021 and 2022 years

3.1.2. Relative fresh weight (R.F.W. %)

The fresh weight of solidago cut inflorescences raised in most treatments till the 5th day, except bleach which could raise the weight until the 7th day, while tween-20 and mixtures of EOs cut inflorescences gained weight till only the 3rd day. All applied preservatives could maintain and decrease the rate of reduction in weight compared to the control and tween-20 which suffered their inflorescences from fast rate of reduction. The most effective preservatives were bleach and GA_3 in the two years (Fig. 2).

3.1.3. Dry matter percentage (D.M. %)

As shown in Table (1), all the preservatives significanly raised the dry matter of the inflorescences than the control and tween-20. The most efficient treatments were BA alone then GA_3 + BA in the two years.

3.2. Water relations

3.2.1. Water uptake (ml inflorescence^{-1} day^{-1}) and daily water uptake (ml inflorescence^{-1} day^{-1})

Adding tween-20 to the preservative solution caused in decreasing the water uptake significantly to the lowest amount among all treatments in both years. At the 3rd day tween-20 the cut inflorescences absorbed 21.67 ml inflorescence^{-1} day^{-1} in both years, as well as their daily water uptake were 9.06, 9.19 ml inflorescence^{-1} day^{-1} in the 1st and the 2nd year, respectively. On the other hand, bleach was statistically the superior presrvative, which recorded 113.33, 115.00 ml inflorescence^{-1} day^{-1} at the third day in the 1st day and the 2nd day, respectively (Fig.3). The combination between GA_3 and BA registered the greatest values in the daily water uptake 32.04 in the 1st season and bleach 31.00 ml inflorescence^{-1} day^{-1}) in the 2nd season, respectively. (Table 1, and Table 2).

3.2.2. Water loss (g inflorescence^{-1} day^{-1})

The same last trend was achieved by the utilized preservatives, either it measured two days intervals, for total or daily water uptake in the two years (Fig. 3, Table 1, and Table 2).

3.2.3. Water balance (g inflorescence^{-1} day^{-1})

Although the results were close to each other, it was obvious that GA_3 was the best in maintaining water balance when measured in two days intervals, (Fig. 3). While thyme oil was the best when measuring the total and the daily water balance in the 1st year, and cumin oil in the 2nd year (Table 1, and Table 2).

3.3. Assessment of scapes quality

3.3.1. Stalk diameter (cm)

As shown in Fig. 4, all applied treatments maintained the stalk diameter, moreover, they protect the stalks from the rapid decrease in their diameter compared to the control cut inflorescences , in the two years. STS and bleach were the best preservatives which not only increase the stalk diameter till the 5th day, they also maintain the diameter at almost the same diameter during the vase life in both years.

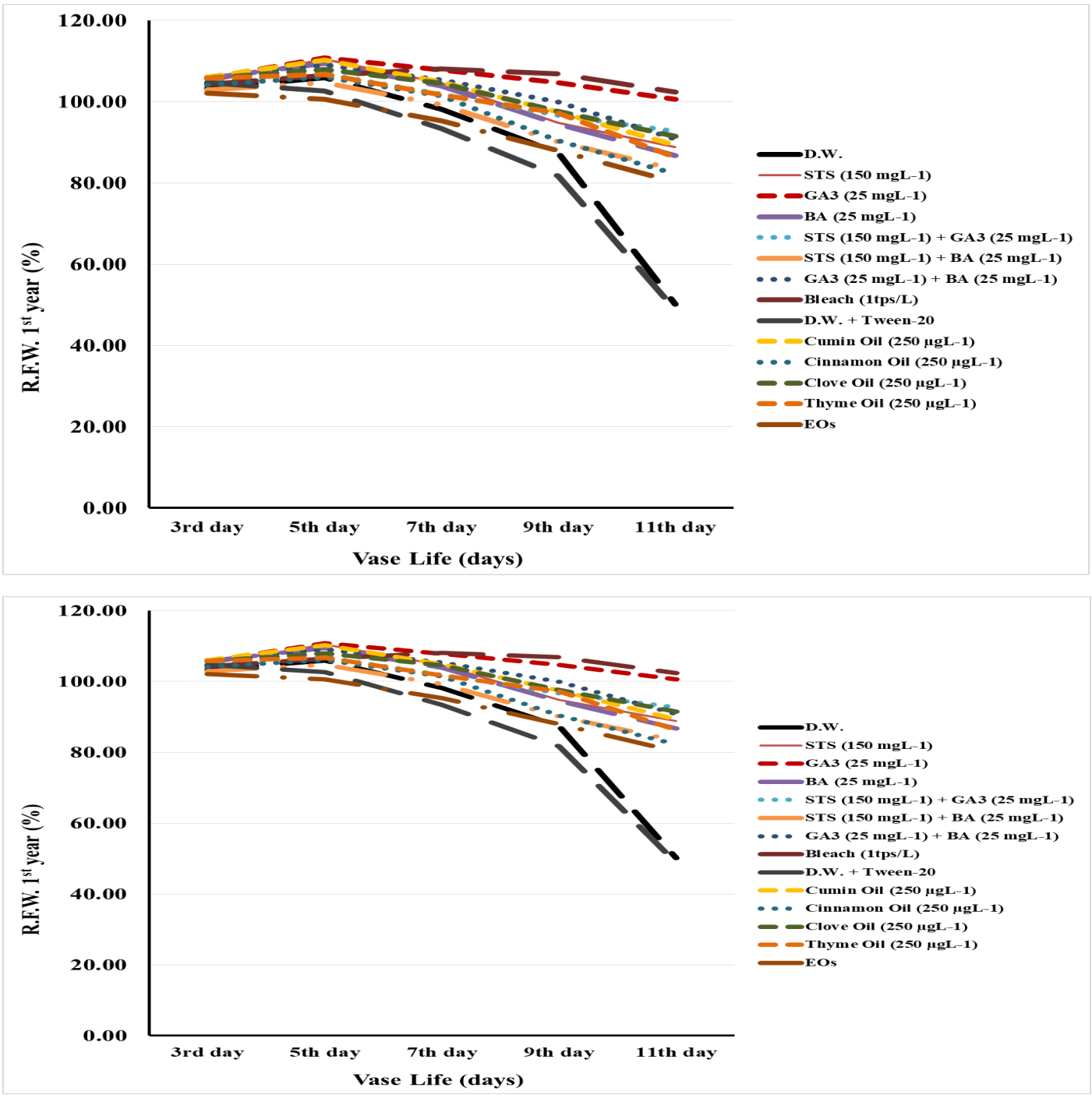

Fig. 2. The effect of different preservatives on the R.F.W. (%) of *Solidago canadensis* L. during 2021 and 2022 years

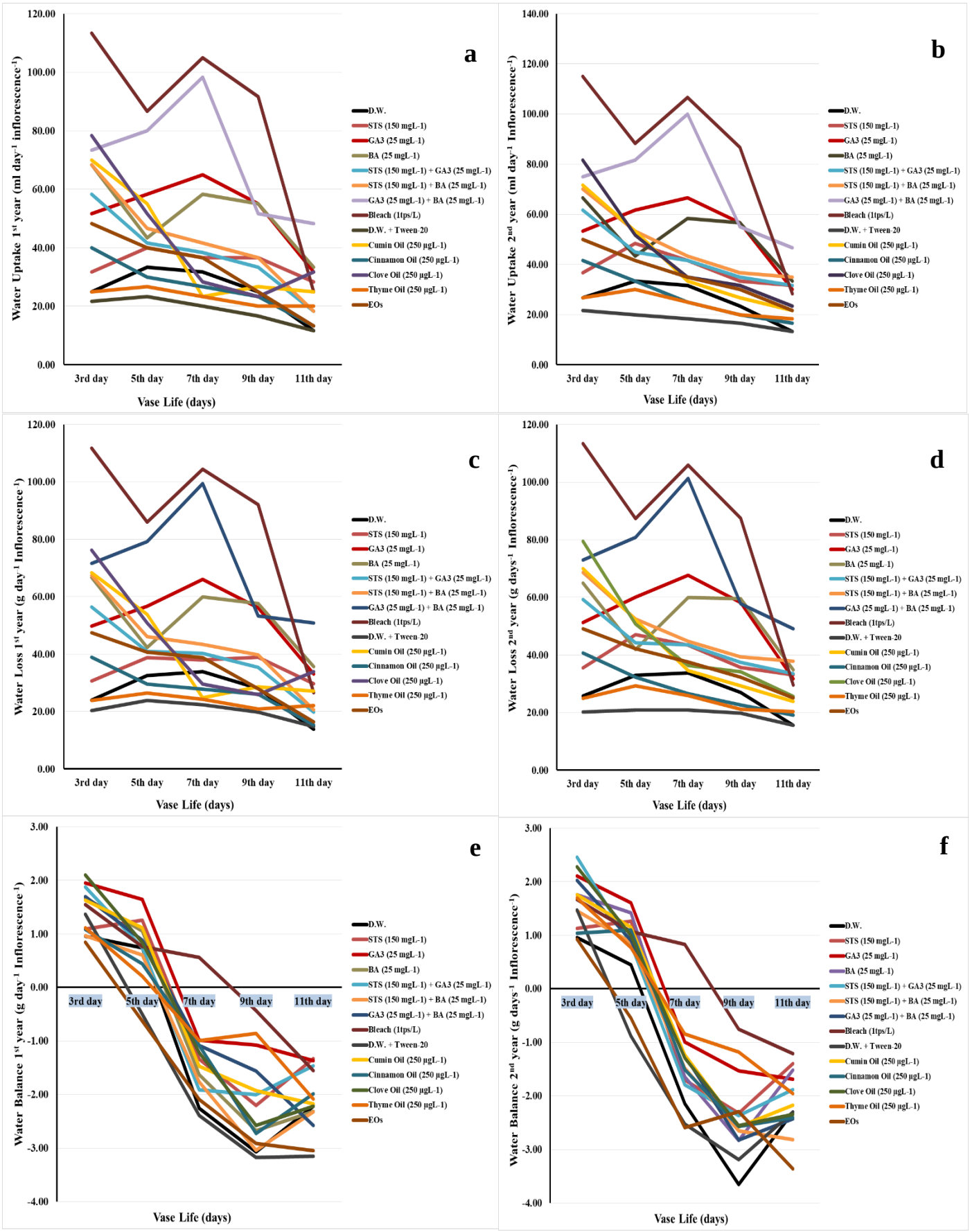

Fig. 3. The effect of different preservatives on: (a and b) water uptake; (c and d) water loss; and (e and f) water balance, of *Solidago canadensis* L. cut inflorescences during 2021 and 2022 years

Table 1. Effect of different preservatives solution on dry matter, total and daily water uptake of *Solidago canadensis* L. cut inflorescences during 2021 and 2022 years

Treatment	Dry Matter (%)		Total Water Uptake (ml Inflorescence^{-1})		Daily Water Uptake (ml day^{-1} inflorescence^{-1})	
	1st year	2nd year	1st year	2nd year	1st year	2nd year
D.W.	14.05^{k}	14.97^{k}	126.67^{h}	128.33^{g}	12.29^{h}	11.67^{hi}
STS (150 mgL^{-1})	21.48^{i}	22.63^{i}	191.67^{f}	215.00^{ef}	15.58f^{g}	16.54^{g}
GA_3 (25 mgL^{-1})	22.72^{h}	23.92^{h}	311.67^{c}	318.33^{c}	20.78^{c}	21.22^{d}
BA (25 mgL^{-1})	34.31^{a}	35.17^{a}	273.33^{d}	278.33^{d}	23.40^{b}	22.58^{c}
STS (150 mgL^{-1}) + GA_3 (25 mgL^{-1})	23.34^{g}	24.06^{h}	206.67^{ef}	250.00^{de}	16.88^{ef}	18.27^{f}
STS (150 mgL^{-1}) + BA (25 mgL^{-1})	26.58^{d}	26.85^{e}	211.67^{ef}	258.33^{d}	19.24^{cd}	20.99^{d}
GA_3 (25 mgL^{-1}) + BA (25 mgL^{-1})	30.07^{b}	30.93^{b}	371.67^{b}	398.33^{b}	32.04^{a}	29.14^{b}
Bleach (1tps/L)	24.67^{f}	25.89^{f}	455.00^{a}	465.00^{a}	30.33^{a}	31.00^{a}
D.W. + Tween-20	11.45^{l}	12.58^{l}	93.33^{i}	90.00^{h}	9.06^{i}	9.19^{j}
Cumin Oil (250 µgL^{-1})	23.83^{g}	25.06^{g}	211.67^{ef}	206.67^{f}	18.17^{de}	18.79^{ef}
Cinnamon Oil (250 µgL^{-1})	25.81^{e}	27.68^{d}	133.33^{h}	148.33^{g}	12.12^{h}	12.76^{h}
Clove Oil (250 µgL^{-1})	27.64^{c}	28.86^{c}	225.00^{e}	245.00^{de}	19.36^{cd}	19.87^{de}
Thyme Oil (250 µgL^{-1})	20.35^{j}	21.04^{j}	125.00^{h}	145.00^{g}	10.13^{i}	10.57^{i}
EOs	25.50^{e}	26.81^{e}	163.33^{g}	193.33^{f}	14.85^{g}	16.55^{g}

Means within a column having the same letters are not significantly different according to Duncan's Multiple Range Test (DMRT) at 5% level

Table 2. Effect of different preservatives on total and daily water loss and total and daily water balance of *Solidago canadensis* L. cut inflorescences during 2021 and 2022 years.

Treatment	Total Water Loss (g inflorescence^{-1})		Daily Water Loss (g day^{-1} Inflorescence^{-1})		Total Water Balance (g inflorescence^{-1})		Daily Water Balance (g day^{-1} inflorescence^{-1})	
	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year
D.W.	132.51^{h}	135.03^{gh}	12.85^{g}	12.28^{hi}	-5.85^{ab}	-6.69^{ab}	-0.56^{abc}	-0.61^{abcd}
STS (150 mgL^{-1})	196.53^{f}	220.29^{ef}	15.97^{f}	16.95^{g}	-4.87^{ab}	-5.29^{ab}	-0.39^{a}	-0.41^{bcd}
GA_3 (25 mgL^{-1})	319.79^{c}	326.59^{c}	21.32^{c}	21.77^{cd}	-8.12^{b}	-8.26^{ab}	-0.54^{abc}	-0.55^{abcd}
BA (25 mgL^{-1})	280.21^{d}	284.61^{d}	23.97^{d}	23.07^{c}	-6.88^{ab}	-6.27^{ab}	-0.57^{abc}	-0.49^{abc}
STS (150 mgL^{-1}) + GA_3 (25 mgL^{-1})	212.19^{ef}	258.29d^{e}	17.33^{ef}	18.87^{ef}	-5.53^{ab}	-8.29^{ab}	-0.45^{ab}	-0.59^{abcd}
STS (150 mgL^{-1}) + BA (25 mgL^{-1})	217.22^{ef}	266.58^{d}	19.75^{cd}	21.65^{cd}	-5.55^{ab}	-8.25^{ab}	-0.50^{abc}	-0.66bcd
GA_3 (25 mgL^{-1}) + BA (25 mgL^{-1})	376.21^{b}	406.73^{b}	32.43^{a}	29.74^{b}	-4.54^{ab}	-8.40^{ab}	-0.39^{a}	-0.60^{abcd}
Bleach (1tps/L)	462.84^{a}	470.55^{a}	30.86^{a}	31.37^{a}	-7.84^{ab}	-5.55^{ab}	-0.52^{abc}	-0.37^{ab}
D.W. + Tween-20	101.19^{i}	97.43^{h}	9.81^{h}	9.94^{j}	-7.86^{ab}	-7.43^{a}	-0.75^{c}	-0.75^{cd}
Cumin Oil (250 µgL^{-1})	215.90^{ef}	209.74^{f}	18.52^{de}	19.07^{e}	-4.23^{a}	-3.08^{ab}	-0.35^{a}	-0.28^{a}
Cinnamon Oil (250 µgL^{-1})	137.61^{h}	154.81^{g}	12.51^{g}	13.32^{h}	-4.27^{ab}	-6.48^{ab}	-0.39^{a}	-0.55^{abcd}
Clove Oil (250 µgL^{-1})	229.25^{e}	250.79^{de}	19.72^{cd}	20.33^{de}	-4.25^{ab}	-5.79^{ab}	-0.36^{a}	-0.46^{abc}
Thyme Oil (250 µgL^{-1})	129.19^{h}	151.65^{g}	10.46^{h}	11.05^{ij}	-4.19^{a}	-6.65^{ab}	-0.34^{a}	-0.47^{abc}
EOs	171.17^{g}	203.96^{f}	15.56^{f}	17.44^{fg}	-7.84^{ab}	-10.63^{b}	-0.71^{bc}	-0.89^{d}

Means within a column having the same letters are not significantly different according to Duncan's Multiple Range Test (DMRT) at 5% level

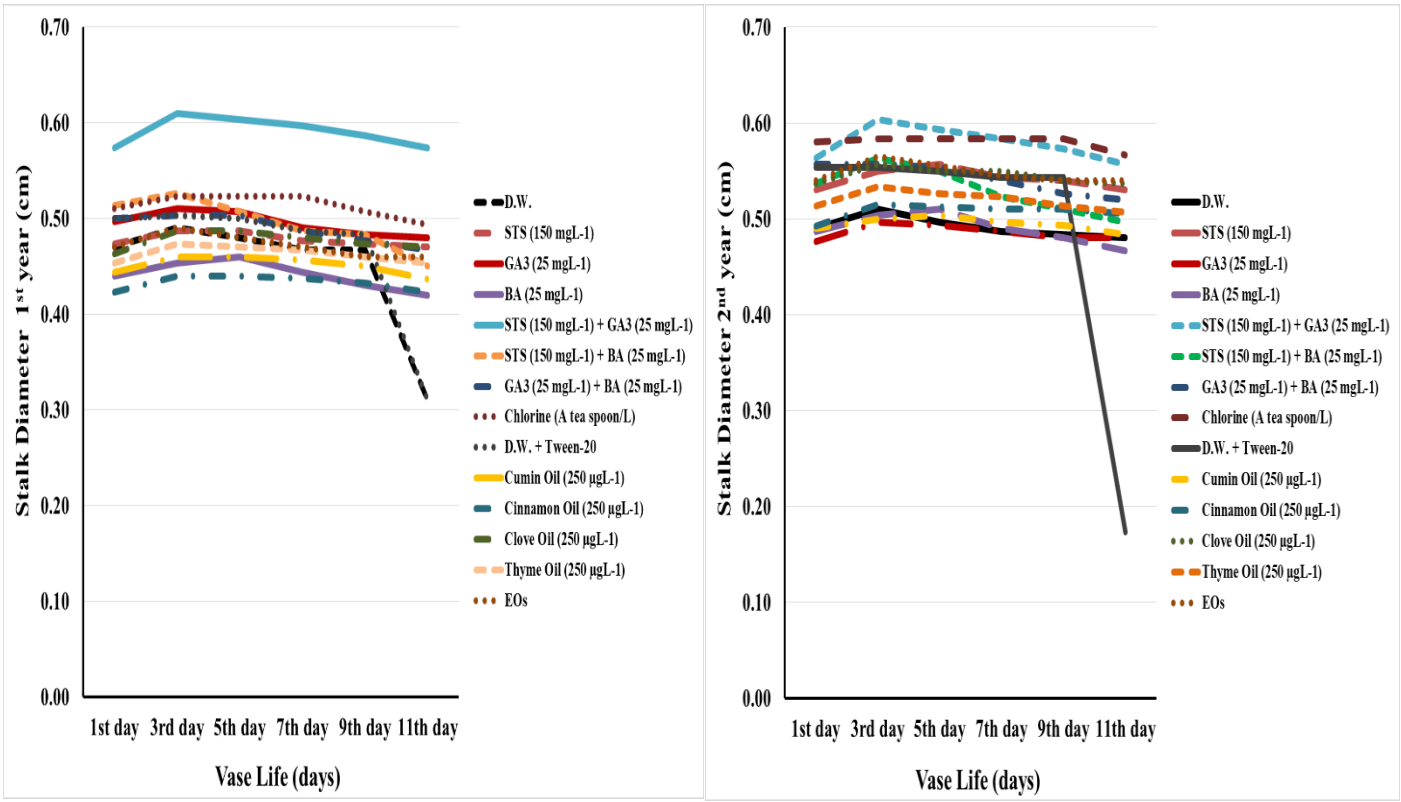

Fig. 4. Effect of different preservatives on *Solidago canadensis* L. stalk diameter of *Solidago canadensis* L. cut inflorescences during 2021 and 2022 years

Table 3. Effect of different preservatives on days to the first opening and days to the first wilting of *Solidago canadensis* L. cut inflorescences during 2021 and 2022 years

Treatment	Days to the first opening (days)		Days to the first wilting (days)	
	1st year	2nd year	1st year	2nd year
D.W.	1.33^{e}	1.67^{g}	3.33^{h}	3.67^{h}
STS (150 mgL^{-1})	4.67^{ab}	5.67^{ab}	8.33^{bc}	8.67^{c}
GA_3 (25 mgL^{-1})	5.33^{ab}	6.00^{a}	10.33^{a}	11.00^{a}
BA (25 mgL^{-1})	4.33^{b}	5.33^{abc}	7.67^{bcd}	8.33^{cd}
STS (150 mgL^{-1}) + GA_3 (25 mgL^{-1})	5.33^{ab}	5.67^{ab}	5.33^{f}	5.67^{g}
STS (150 mgL^{-1}) + BA (25 mgL^{-1})	4.67^{ab}	5.00^{bc}	6.33^{ef}	6.67^{f}
GA_3 (25 mgL^{-1}) + BA (25 mgL^{-1})	5.00^{ab}	5.67^{ab}	8.33^{bc}	8.67^{c}
Bleach (1tps/L)	2.67^{cd}	2.67^{ef}	9.67^{a}	9.67^{b}
D.W. + Tween-20	2.33^{d}	2.00^{fg}	4.33^{g}	4.00^{h}
Cumin Oil (250 μgL^{-1})	3.33^{c}	3.67^{d}	6.33^{ef}	7.33^{ef}
Cinnamon Oil (250 μgL^{-1})	5.33^{ab}	5.33^{abc}	7.33^{cde}	7.67^{de}
Clove Oil (250 μgL^{-1})	5.67^{a}	6.00^{a}	8.67^{b}	8.67^{c}
Thyme Oil (250 μgL^{-1})	3.00^{cd}	3.33^{de}	7.00^{de}	7.33^{ef}
EOs	4.33^{b}	4.67^{c}	6.33^{ef}	7.00^{ef}

Means within a column having the same letters are not significantly different according to Duncan's Multiple Range Test (DMRT) at 5% level

3.3.2. Days to first opening (days)

Data located in Table (3) claimed that, all the applied materials significantly prolongs ed the time needed to the first opening compared to the control cut inflorescences in both years. Clove oil was the most delayed in the first opening, in both years.

3.3.3. Days to first wilting (days)

The control and tween-20 treatments revealed that the cut inflorescences suffered from rapid symptoms of wilting after short period. Other treatments significantly delayed the first wilting than former treatments. The highest values were obtained by the GA_3 (10.33 and 11.00 days in the 1st and the 2nd year, respectively), followed by bleach in the two years.

3.4. Chemical composition

3.4.1. Total carotenoid content (µgg^{-1} of fresh inflorescences)

Data demonstrated that, GA_3 + BA cut inflorescences contained the most amounts of carotenoids in both years (0.10 and 0.11 µgg^{-1} of fresh inflorescences in the 1st and the 2nd year, respectively). EOs results was so near to GA_3 + BA in the two years (Table 4).

3.4.2. Total flavonoid content (mgg^{-1} of the fresh inflorescences)

Referring to the data located in the Table (4), the highest values were recorded with tween-20 in the 1st year and STS in the 2nd year. Followed by EOs registered high amounts of total flavonoid content as well in both years.

3.4.3. Total sugar content (% of the fresh inflorescences)

All the applied preservatives significantly raised the total sugar content compared to the control in both years. The highest amount of total sugar content was recorded with clove oil in both years.

3.5. Photosynthetic pigments (mgg^{-1} of fresh leaves)

3.5.1. Chlorophyll (a) (mgg^{-1} of fresh leaves)

Data presented in Fig. 5 clarified that, all the used EOs, except thyme oil, were the most efficient compounds in protecting chlorophyll (a) from rapid degradation during the vase life. Cinnamon oil registered the lowest reduction in chlorophyll (a) content 0.076 and 0.045 mgg^{-1} of fresh leaves in the 1st and the 2nd year, respectively. On the contrary, GA_3 and the control cut inflorescences recorded the most reduction of chlorophyll (a) content in the two years.

3.5.2. Chlorophyll (b) (mgg-1 of fresh leaves)

Bleach and cinnamon oil significantly diminished the reduction of chloropyll (b) content from zero time to the 8th day as compared to the control and other treatments in the both years (Fig.5).

3.5.3. Total carotenoid content (mgg^{-1} of fresh leaves)

According to data presented in Fig. (5), except the control, GA_3, bleach, and all the other preservatives were efficiently decreased the degradation of total carotenoid content in leaves. Clove oil and the mixture of the used EOs were the best preservatives in the 1st and the 2nd year, (the amounts of reduction were 0.001 and 0.002 for clove oil and EOs in the 1st and the 2nd year, respectively).

Table 4. Effect of different preservatives solution on total carotenoid content, total flavonoid content, and total sugars of *Solidago canadensis* L. cut inflorescences during 2021 and 2022 years

Treatment	Total carotenoid content (µgg^{-1} of fresh inflorescences)		Total flavonoid content (mgg^{-1} of the fresh inflorescences)		Total sugar content (% of the fresh inflorescences)	
	1st year	2nd year	1st year	2nd year	1st year	2nd year
D.W.	0.05^{e}	0.06^{g}	1.26^{cd}	1.47^{g}	22.36^{h}	23.93^{j}
STS (150 mgL^{-1})	0.05^{e}	0.06f^{g}	1.63^{a}	2.11^{a}	27.18^{g}	28.22^{h}
GA_3 (25 mgL^{-1})	0.05^{e}	0.06^{f}	1.29^{cd}	1.29^{i}	35.89^{e}	37.38^{f}
BA (25 mgL^{-1})	0.06^{d}	0.07^{e}	1.46^{b}	1.76^{d}	34.22^{e}	36.54^{f}
STS (150 mgL^{-1}) + GA_3 (25 mgL^{-1})	0.08^{b}	0.09^{c}	1.21^{d}	1.67^{e}	31.42^{f}	33.07^{g}
STS (150 mgL^{-1}) + BA (25 mgL^{-1})	0.06^{d}	0.08^{d}	1.32^{cd}	1.40^{gh}	46.28^{b}	47.47^{b}
GA_3 (25 mgL^{-1}) + BA (25 mgL^{-1})	0.10^{a}	0.11^{a}	1.68^{a}	1.78^{d}	41.93^{c}	43.28^{d}
Bleach (1tps/L)	0.05^{e}	0.05^{h}	1.28^{cd}	1.36^{hi}	41.65^{c}	42.87^{d}
D.W. + Tween-20	0.07^{c}	0.08^{d}	1.75^{a}	1.85^{c}	25.89^{g}	26.88^{i}
Cumin Oil (250 µgL^{-1})	0.08^{b}	0.09^{c}	1.38^{bc}	1.67^{e}	43.89^{bc}	44.95^{c}
Cinnamon Oil (250 µgL^{-1})	0.06^{d}	0.08^{d}	1.31^{cd}	1.42^{gh}	39.30^{d}	42.29^{de}
Clove Oil (250 µgL^{-1})	0.08^{b}	0.10^{b}	1.06^{e}	1.41^{gh}	48.68^{a}	49.72^{a}
Thyme Oil (250 µgL^{-1})	0.07^{c}	0.08d^{e}	1.34^{c}	1.56^{f}	39.12^{d}	41.36^{e}
EOs	0.08^{b}	0.09^{c}	1.71^{a}	1.98^{b}	44.05^{bc}	45.53^{c}

Means within a column having the same letters are not significantly different according to Duncan's Multiple Range Test (DMRT) at 5% level

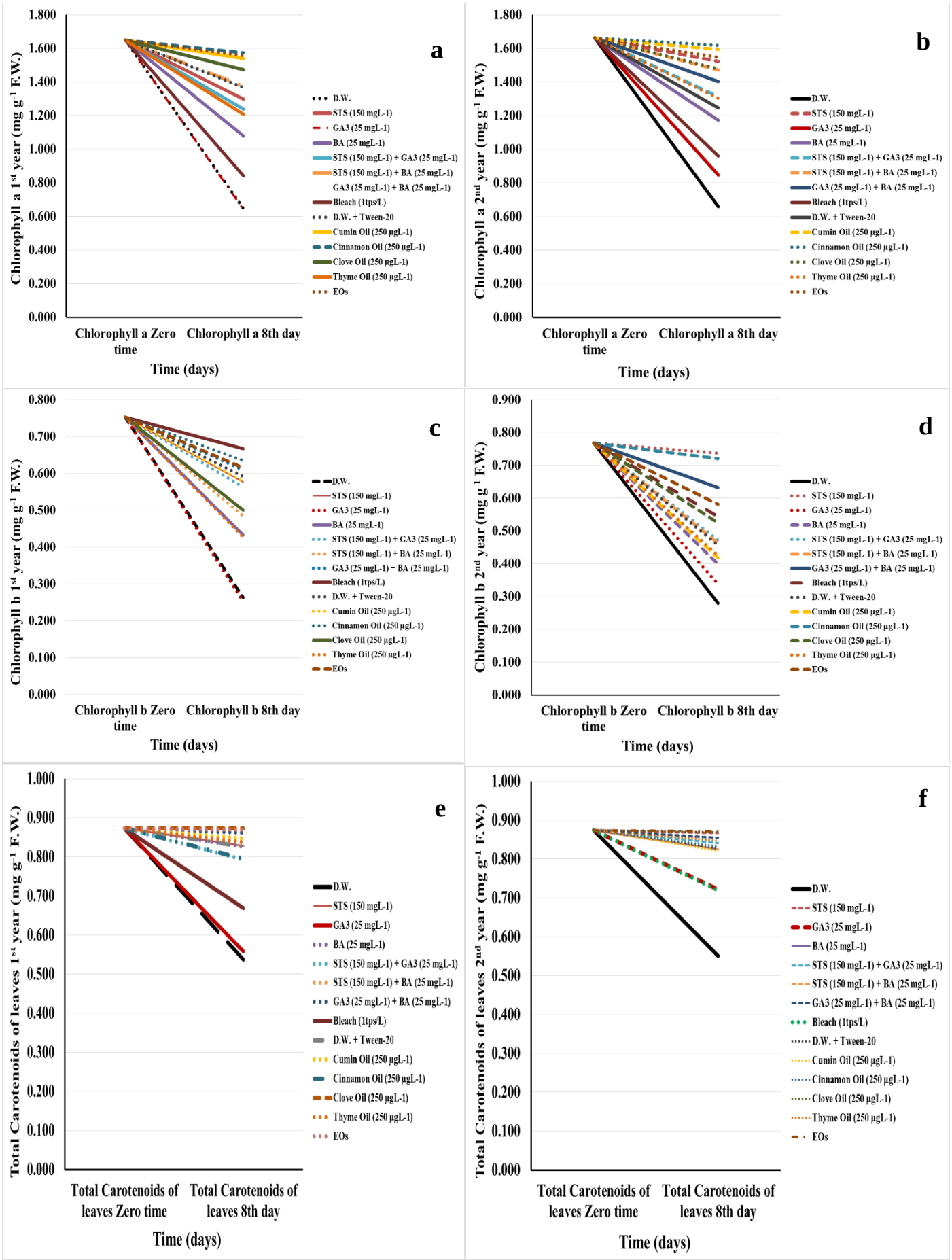

Fig. 5. The effect of different preservatives on: (a and b) chlorophyll a; (c and d) chlorophyll b; and (e and f) total carotenid content in leaves of *Solidago canadensis* L. cut inflorescences during 2021 and 2022 years

3.6. Biological studies

3.6.1. Total plate count of microorganisms in preservative solution (CFU/ml)

Referring to Table (5), all used preservatives could significantly decrease the count of microorganisms in the vase solution of solidago cut inflorescences compared to the control in both years. All used EOs and their mixture, bleach, tween-20, and STS were the most effective treatments in suppressing the growth of microorganism in the vase solution with superiority to the mixture of EOs. Moreover, it was noticeable that, adding STS to GA_3 or BA could significantly diminish the count of microorganisms than they were alone without STS in both years.

Table 5. Effect of different preservatives solution on total plate count of microorganisms in the vase solution of *Solidago canadensis* L. cut inflorescences during 2021 and 2022 years

Treatment	Total plate count of microorganisms in the vase solution (CFU/ml) (The count × 10^4)	
	1st year	2nd year
D.W.	22.667[a]	27.333[a]
STS (150 mgL^{-1})	2.500[f]	1.500[e]
GA_3 (25 mgL^{-1})	12.333[c]	13.333[b]
BA (25 mgL^{-1})	11.500[c]	9.167[c]
STS (150 mgL^{-1}) + GA_3 (25 mgL^{-1})	8.667[d]	7.833[cd]
STS (150 mgL^{-1}) + BA (25 mgL^{-1})	6.500[e]	5.500[d]
GA_3 (25 mgL^{-1}) + BA (25 mgL^{-1})	14.833[b]	14.000[b]
Bleach (1tps/L)	0.040[g]	0.028[e]
D.W. + Tween-20	0.075[g]	0.059[e]
Cumin Oil (250 μgL^{-1})	0.035[g]	0.027[e]
Cinnamon Oil (250 μgL^{-1})	0.048[g]	0.046[e]
Clove Oil (250 μgL^{-1})	0.025[g]	0.018[e]
Thyme Oil (250 μgL^{-1})	0.015[g]	0.012[e]
EOs	0.005[g]	0.004[e]

Means within a column having the same letters are not significantly different according to Duncan's Multiple Range Test (DMRT) at 5% level

4. Discussion

The use of preservative solutions is a widespread method for the storage of floral stems. In addition, the applying of these preservatives prolongs the shelf life of cut flowers. It also, control the ethylene synthesis , inhibit the pathogen development, preserve the flower water and respiration balance, and conserve the floral color, floral bud development and opening [23].

In our current study, many naturals (essential oils and growth regulators), chemicals (STS, bleach, and tween-20) and a mix between naturals and chemical compounds (STS + GA_3 and STS + BA) were examined to determine their efficacy in preserve *Solidago canadensis* L. cut inflorescences. The obtained data revealed that, all the previous compounds were signifcantly elongated the vase life of Solidago cut inflorescences as compared to the control and tween-20. GA_3 is competed bleach in the superiority; both achieved 15 day of vase life in the two years of the experiment. They also recorded the highest values in the water uptake and the water loss, however, GA_3 was more able to sustain the water balance in adition to clove oil. Bleach and GA_3 worthily raised and maintained the fresh weight of the cut inflorescences during the vase life, while BA had the superiority in increasing the dry matter of the cut inflorescences. These results are in agreement with those obtained by (Ichimura and Saeed [24,25]. The longest vase life of *Asparagus umbellatus* was obtained by using GA_3 as a vase solution [26]. The beneficial effect of gibberellins is in delay the onset of symptoms and achieving the longest vase life may be due to its ability in preventing the breakdown of proteins by reducing the activity of the proteases [[27]. They added that gibberellins could inhibit the chlorophyll deterioration, prevent plant leaves chlorosis and preserve the cell membrane fluidity and avoid electrolyte leakage leading to delay the aging and extend the postharvest life. Flower species and cultivars may adapt to various constituents and concentrations in the solution [28]. Gandaby [29] reported the increase in solution uptake of lily cut flowers treated with 0.88 mM benzyl adenine .The utilized preservatives adroitly enhanced the quality characteristics of solidago cut inflorescences. They maintained the stalk diameter, delayed the first opening and the first wilting and thus prolongs ed the vase life of the cut inflorescences. GA_3 had the superiority in this retardation. GA_3 also proved its ability in delaying the senescence of chrysanthemum cut flowers as well as

preserving their fresh and dry weight, increasing the absorbed water and enhancing the quality features of the cut flowers. These effects are refered to the ability of GA_3 of delaying the flowers' senescence and inhibiting the action of ethylene which leads to the rapid downfall of the petals [11].

Regarding to the chemical compositions, essential oils were the highest values in the most of measured features. Clove oil and EOs had the highest increase in the total carotenoid content of inflorescences and leaves. The former results are similar to those obtained by previous researchers; Amin and Diab [30] on gladiolus cut flowers. Cinnamon oil effectively reduced the degradation of chlorophyll (a) as well as chlorophyll (b). The highest values of total sugar content were obtained when solidago cut inflorescences treated with clove oil as a vase solution. These findings are contributed with Amin and Diab [30] that found gladiolus cut spikes had the maximum value of total sugars content compared to control when placed in preservative solution containing clove oil. However, the highest values of total flavonoid content was obtained by tween-20 and STS. These results are acceptable because of the roles of essential oil which, partially prevent the impact of ethylene; the essential oils reduced the ethylene production in cut flowers. Consequently, treated cut flowers with clove oils may inhibit ACC-oxidase activity that is the direct precursor of ethylene and decrease ROS (reactive oxygen species) leading to increase the enzyme antioxidant activity as confirmed by Prabha [31].

Silver thiosulfate (STS) completely blocked the ethylene production normally prior to the onset of senescence in carnation. This effect could be described as the silver inhibited the endogenous ACC (1-aminocyclopropene-1-carboxylate) content and rise in the respiration of flowers, by blocking the ethylene action. STS appears to have additional profits as a biocide [32].

Microorganisms growing in the vase solution obstruct the water uptake in flower stems and may be blame for the loss of solution uptake by flowers. As a result of this, the blooms wilt eventually. Controlling the microbial activity in cut flowers is capable to inhibit this harmful effect and improve the water relations [33]. The applied essential oils and their mixture as well bleach were the most effective preservatives in suppressing the growth of microorganisms with a superiority to EOs in both years. Sodium hypochlorite, as a component of commercial bleach, could effectively elongate the shelf life of carnation and hyacinth cut flowers by maintain their water relations, fresh and dry weight, and their quality, due to its function as a germicide which prevent the blockage of stems by microorganisms [13].

Essential oils as thyme oil, cumin oil, clove oil, and cinnamon oil prolongs ed the vase life, enhanced the water relations, maintained the fresh and dry weights, raised the stalk and flower diameters, decreased the degradation of photosynthetic pigments and anthocyanin pigment, upraised the total sugar content and suppressed the growth of the microorganisms in the vase solution of chrysanthemum, lily and rose cut flowers [10]. These essential oils contain phenolic compounds such as carvacrol, thymol, and eugenol play a great role as antibacterial, so they forbid the closure of the stalks end by microorganisms [7].

5. Conclusions

According to the data obtained from this study, it can be recommended to use biotic compounds as growth regulators and essential oils as alternatives to chemical and hazardous compounds like bleach and STS, or at necessity use a combination between them as efficient preservatives of cut flowers. GA_3 in this study could easily compete with bleach in prolonging the vase life of the Solidago cut inflorescences, in addition to increasing the water uptake of Solidago cut inflorescences. On the other hand, GA_3 was the more effective in maintining the balance between the water absorbed and the water lost, and delaying the days needed to the first opening as well the first wilting. While different usage of EOs, bleach and STS proved the efficiacy in preseving and raising different chemical compositions, however, EOs mixture had the superiority in suppressing the growth of microorganisms in the vase solution of *Solidago canadensis* L. cut inflorescences.

Conflict of interest

There is no conflict of interest**.**

Acknowledgments

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