The Future of Horticulture

FSA

Article

Effect of Foliar Spraying with Sodium Nitroprusside and Gibberellic Acid on the Growth and Chemical Composition of Solidago Plant

Naglaa F. S. I. Elbohy[1], K. E. Attia[2] and Randa I. Diab[1,*]

[1]Ornamental Plants and Landscape Gardening Research Department, Horticulture Research Institute, Agricultural Research Center, Giza, **Egypt.**
[2]Medicinal and Aromatic Plants Research Department, Horticulture Research Institute, ARC., **Egypt.**

[*]**Corresponding author:** randa_ebrahem@yahoo.com

Future Science Association

Available online free at
www.futurejournals.org

Print ISSN: 2692-5826

Online ISSN: 2692-5834

DOI:
10.37229/fsa.fjh.2023.08.04

Accepted: 15 July 2023
Published: 4 August 2023

Publisher's Note: FA stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Abstract: In order to obtain the best growth, flowering traits and chemical constituents of solidago (*Solidago canadensis*) plant, two field experiments were established during two summer consecutive seasons of 2022 and 2023 in the Experimental Farm of EL-Quassassin Horticultural Research Station, Ismailia Governorate, Egypt. Eight treatments of this experiment were applied which consisted of control (sprayed with a distilled water), sodium nitroprusside (25, 50 and 100 mg/l) and gibberellin (50, 100, 200 and 300 mg/l). The obtained results showed that exogenous sodium nitroprusside (SNP) or gibberellic acid (GA) five times per season significantly improved solidago plant growth and productivity compared to control. In addition, utilizing of gibberellic acid at 200 mg/l effectively enhanced the plant growth (plant height, stem diameter, number of branches per plant and fresh and dry weights of herb per plant), flowering traits (fresh and dry weights of flowering stem per plant and flowering stem length) and some chemical constituents (chlorophyll a and b, nitrogen, phosphorus and potassium percentages) compared to the other treatments under study. Whenever, the highest volatile oil percentage was noticed when sodium nitroprusside at 100 mg/l was used in comparison with the other ones under study. In general, GA especially at 200 mg/l as well as SNP especially at 100 mg/l can be used as a regulator to enhance the growth and productivity of solidago plants grown under Ismailia Governorate (sandy soil) conditions.

Key words: *Solidago canadensis*, sodium nitroprusside, gibberellic acid, growth, flowering, volatile oil, chlorophyll.

INTRODUCTION

The solidago plant known as goldenrod (*Solidago canadensis*, Tara) is classified under the Asteraceae or Compositae Family, commonly referred to as the daisy family. According to **Jeffrey *et al.* (2001)**, the growth of this particular flower occurs naturally in Europe, Asia and North America. The term "scientific name" originates from the Latin term "solida," which conveys the meaning of "to make whole" or "to strengthen." This terminology is derived from the medicinal attributes

of scientific names, which have been historically employed for the treatment of ailments such as arthritis, allergies, and sore throats. These botanical specimens exhibit a growth pattern characterized by the formation of compact clusters of erect, occasionally ramifying stems. The upper portion of these stems gives rise to inflorescences composed of little flowers with a vibrant golden yellow hue. The plant in question is recognized for its therapeutic properties, which include spasmolytic, diuretic, antihypertensive, anti-inflammatory, immunostimulating, antioxidant action, antiphlogistic and antimycotic (**Yarnell, 2002** and **Apati *et al*., 2003**).

Sodium nitroprusside (SNP) is commonly recognized as a nitric oxide donor. Nitric oxide (NO), functions as a signaling molecule involved in both intracellular and intercellular communication in the regulation of plant growth (**Beligni and Lamattina, 2000**). Its lipophilic properties enable it to effectively counteract oxidative stress, hence exerting its main physiological effects (**Neile *et al*., 2002**). Nitric oxide has been observed to play a role in the control of various biochemical and physiological processes in plants, as reported by **Kopyra and Gwozdz (2003)** and **Neile *et al*. (2003)**. Spraying of SNP improved plant growth, flowering and chemical constituents in other flowering plants as found by **El-Zohiri and Abd El-Aal (2015)** on globe artichoke, **Arun *et al*. (2017)** on chrysanthemum, **Sadeghi and Jabbarzadeh (2022)** on *Alstroemeria aurea* and **Piri and Jabbarzadeh (2023)** on *Eustoma grandiflorum.*

Gibberellins serve as plant growth regulators that exert influence over several developmental processes in the life cycle of plants, including but not limited to stem elongation, germination, flowering, dormancy release, enzyme activation, sex determination and senescence of leaf and fruit (**Brian, 1959**). Gibberellic acid is a prominent plant growth regulator that is currently employed by numerous cultivators of ornamental plants (**Thakur *et al*., 2023**). Spraying of GA_3 recorded maximum plant growth, flowering and chemical constituents in solidago and other flowering plants as reported by **Kumar *et al*. (2003)** on China aster, **Rana *et al*. (2005)** on gladiolus, **Soner and Karagüzel (2010)** on solidago, **Sajid *et al*. (2016)** on *Chrysanthemum morifolium*, **Elsadek (2018)** on dahlia and **Khangjarakpam *et al*. (2019)** on *Tagetes erecta*.

The objective of this study was to investigate the effects of SNP and GA regulators on the growth, flowering characteristics and chemical composition of *Solidago hybrida*. The findings of this study will contribute to the enhancement of solidago growth and production in places with the same conditions.

MATERIALS AND METHODS

During two summer consecutive seasons of 2022 and 2023, field experiments were done to examine the effect of sodium nitroprusside and gibberellic acid as a foliar spray on growth, flowering traits volatile oil and some chemical constituents of solidago plant. This experiment was established in the Experimental Farm of EL-Quassasin Horticultural Research Station, Ismailia Governorate, Egypt. The physical and chemical characteristics of the utilized experimental soil are tabulated in Table (1), according to **Chapman and Pratt (1978**).

Table (1). Physical and chemical characteristics of the utilized experimental farm soil (average of 2022 and 2023 seasons)

Physical analysis			Soil texture
Clay (%)	Silt (%)	Sand (%)	Sandy
20.81	9.39	69.68	

Chemical analysis												
pH	E.C. (dsm^{-1})	Soluble cations (m.mol/l)					Soluble anions (m.mol/l)			Available (ppm)		
		Ca^{++}	Mg^{++}	Na^{+}	Zn^{++}	Mo^{++}	Cl^{-}	HCO_3^{-}	SO_4^{--}	N	P	K
7.81	1.25	1.82	0.93	0.33	1.07	1.30	3.02	1.40	1.03	122	39	62

Experimental design and treatments

The eight treatments were arranged as simple experiment in a randomized complete block design with three replicates.

Treatments

1. Control (sprayed with a distilled water).
2. SNP 25 (sprayed with sodium nitroprusside at 25 mg/ l).
3. SNP 50 (sprayed with nitroprusside at 50 mg/ l).
4. SNP 100 (sprayed with nitroprusside at 100 mg/ l).
5. GA 50 (sprayed with gibberellic acid at 50 mg/ l).
6. GA 100 (sprayed with gibberellic acid at 100 mg/ l).
7. GA 200 (sprayed with gibberellic acid at 200 mg/ l).
8. GA 300 (sprayed with gibberellic acid at 300 mg/ l).

Five spraying times per the season were applied till run off the plant. The initial application was conducted one month following the transplantation date, followed by subsequent applications every 15 days until the completion of the designated number of applications during two-months period.

Plant material

The solidago seedlings were acquired from a privately-owned nursery located in El Qanater El Khayreya, Qalyubia Governorate, Egypt. All transplants exhibited comparable growth patterns, measured 10 cm in height and possessing 10 leaves per seedling. The seedlings were planted within the designated experimental plots on March 10st in both seasons of 2022 and 2023.

Cultivation and irrigation

The plot area was a total of 10.80 m^2, with dimensions of 1.80 m × 6.00 m and featured three ridges. Each ridge had a width of 60 cm and a length of six meters. In the ridge, solidago plants were planted at 40 cm between them, solidago plants were spaced at 40 cm, while being cultivated under a drip irrigation system. The seedlings were subjected to immediate irrigation following transplantation, with daily irrigation for one week, followed by twice-weekly irrigation until the end of the experiment.

Pinching and fertilization

The plants were cultivated for duration of one month before being subjected to a pinching technique at a height of 12 cm in order to promote growth. The fertilization rates that were recommended were utilized. Phosphorus fertilization was administered at the soil preparation stage in the form of calcium superphosphate (15.5% P_2O_5) at a rate of 200 kg per feddan. The application of nitrogen fertilization in the form of ammonium nitrate (33.5% N) at a rate of 75 kg per feddan, together with potassium sulfate (50% K_2O) at a rate of 50 kg per feddan, were separated into two (equal) separate doses. The initial dose was administered one month after the date of pinching, and thereafter, the second one was administered one month (later) after the date of fertilization following the first dose.

Recorded data

1- Plant growth: Plant height (cm), stem diameter (cm), number of branches/ plant, total herb fresh and dry weights / plant (g) was estimated at 110 days after transplanting by taking 3 random guarded solidago plants from each experimental unit.

2- Flowering characteristics: fresh and dry weights of flowering stem/ plant (g) and flowering stem length (cm) were determined at the full flowering stage (110 days after transplanting).

3- Chemical analysis

-The volatile oil from air-dried flowers of Solidago was extracted by hydro distillation for duration of three hours, as described by Guenther (1961). Next, the calculation of the volatile oil yield per plant (in milliliters) was performed.

- The determination of chlorophyll a and b (mg/g as fresh weight) was conducted of Solidago plant using the methodology described by (Cherry, 1973).

* For chemical analysis, a random selection of dry solidago herb was obtained from each treatment.

- The percentage of total nitrogen was measured in desiccated leaves using the procedures outlined by **Chapman and Pratt, (1978)**.

- The phosphorus in dried herb of Solidago was quantified using the methodologies modified from **Hucker and Catroux, (1980)**.

- The determination of potassium % in herb was conducted using a flame photometer, following the methodology outlined by **Brown and Lilleland, (1946)**.

Statistical Analysis

Data were first generated, tabulated and then analyzed using the analysis of variance (ANOVA) method. The statistical software used for this analysis was Statistix Version 9 (**Analytical Software, 2008**). The means were compared using Duncan's multiple range tests at a significance level of $P < 0.05$.

RESULTS AND DISCUSSION

Plant growth

The application of both SNP and GA rates resulted in significant increases in plant height, stem diameter, number of branches per plant, as well as fresh and dry weights of the herb/plant as compared to the control plants. These findings were consistent over the two seasons in which the experiment was conducted. The aforementioned parameters exhibited a progressive increase as the rate of SNP or GA was incrementally raised, as indicated in Tables (2 and 3). In the majority of means, the application of gibberellic acid at the concentration of 200 mg/l resulted in significant superior solidago development parameters as compared to the other treatments being investigated, in both season.

Plant growth regulators, namely gibberellic acid, are organic chemical substances that have the ability to modify or regulate plant physiological processes. These plant regulators exert their effects even when applied in extremely small quantities (**Iqbal *et al.*, 2011**). Moreover, the application of sodium nitroprusside (SNP) through foliar spraying resulted in the most significant growth traits in solidago when compared to the control plants. This could potentially be attributed to the presence of nitric oxide (NO), which is released by SNP. Nitric oxide is a bioactive free radical that plays a crucial role in various physiological processes in plants, including growth and development (**El-Zohiri and Abd El-Aal, 2015**). Likewise, **Tabrizi *et al*. (2023)** indicated that SNP foliar spray resulted in enhancement of morphological traits of *Narcissus tazetta*.

Furthermore, the study conducted by **Shinde *et al*. (2010)** revealed a notable augmentation in the expansion of plant height, number of branches, and the presence of numerous suckers per plant of *Chrysanthemum morifolium* cv. IIHR-6 when treated with GA_3 at a concentration of 200 ppm. **Abd Al Lateef and Hade (2018)** pointed out that the application of GA_3 to pansy plants resulted in significant enhancements in vegetative growth characteristics. The most notable improvements were observed in plant height, number of leaves, and leaf area, with the dosage of 100 mg/l yielding the highest increases. Also, **Jayshree *et al*. (2020)** conducted an experiment to examine the impact of different concentrations of gibberellic acid (50, 100 and 150 ppm) on the morphological characteristics of Asiatic lilies. The application of gibberellic acid (GA_3) at a concentration of 200 ppm led to the attainment of optimal plant height, maximum leaf number and early sprouting.

Table (2). Effect of spraying with sodium nitroprusside (SNP) and gibberellic acid (GA) rates on plant height, Number of branches and stem diameter of solidago plants during the two seasons of 2022 and 2023

Treatments (mg/l)	Plant height (cm)		Stem diameter(cm)		Number of branches/plant	
	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
Control	37.7 h	41.3 h	2.197 h	2.337 h	15.7 h	17.3 f
SNP25	45.7 g	49.7 g	2.967 g	3.050 g	22.0 g	24.3 e
SNP50	52.0 f	57.7 f	3.187 e	3.330 e	25.7 e	28.3 d
SNP100	55.7 d	58.7 e	4.163 c	4.310 c	34.0 d	37.0 b
GA50	52.7 e	60.3 d	3.140 f	3.297 f	24.7 f	28.3 d
GA100	60.3 c	65.3 b	3.693 d	3.853 d	35.7 c	35.0 c
GA200	65.3 a	67.3 a	4.250 a	4.543 b	42.3 a	43.7 a
GA300	63.3 b	63.3 c	4.190 b	4.597 a	39.3 b	43.0 a

Table (3). Effect of spraying with sodium nitroprusside (SNP) and gibberellic acid (GA) rates on fresh and dry weights of herb(g) of solidago plant during the two seasons of 2022 and 2023

Treatments (mg/l)	Fresh weight of herb/plant(g)		Dry weight of herb/plant (g)	
	1st Season	2nd Season	1st Season	2nd Season
Control	32.7 g	35.1 h	7.81 f	8.70 h
SNP25	40.8 f	47.5 g	9.61 g	11.67 g
SNP50	55.3 e	62.1 e	13.36 e	15.07 e
SNP100	63.6 d	68.1 d	16.22 d	17.98 d
GA50	54.5 e	58.1 f	13.24 f	13.95 f
GA100	68.7 c	73.7 c	17.02 c	18.30 c
GA200	92.6 a	96.9 a	22.87 a	24.07 a
GA300	90.5 b	91.8 b	22.36 b	22.82 b

Flowering characteristics

Table (4) demonstrates that the application of either sodium nitroprusside or gibberellic acid, regardless of its rates, results in a noteworthy augmentation in the fresh and dry weights of solidago flowering stems, as well as an increase in the length of the flowering stem, as compared to the control in both seasons. Moreover, the steady augmentation of gibberellic acid concentrations resulted in an observable enhancement of the flowering characteristics of Solidago. The treatment of GA at the rate of 200 mg/l resulted in the greatest values for fresh and dry weights of solidago flower stems, as well as flowering stem length. These values were significantly different from those obtained with other rates examined in the study, during the two seasons.

In addition, **Abou-El-Ghait *et al.* (2018)** found that all of the GA_3 treatments (100, 200 and 300 mg/l) tested resulted in a significant increase in number of *Dendranthema grandiflorium* flowers per plant, as well as the fresh and dry weights of the flowering head. **Singh *et al*. (2018)** documented that the treatment of GA_3 at a rate of 150 ppm resulted in the highest recorded values for maximum blossom size and length of bloom stalk in the chrysanthemum cultivar Birbal Sahni. Likewise, **Shrestha *et al.* (2020)** observed statisticall significant variations ($p<0.05$) in the weight of flowers across several treatments. The highest weight of *Calendula officinalis* flowers was observed in plants treated with GA_3 at a concentration of 250 ppm, whilst the lowest weight of flowers was recorded in the control plants. Moreover, **Abdi and Jabbarzadeh (2022)** showed that 50 µM sodium nitroprusside ramped up flowering stem length of *Rosa hybrida*. Also, sodium nitroprusside (SNP) had beneficial effects on flower (fresh and dry weight), diameter and length of *Eustoma grandiflorum* flower (**Piri and Jabbarzadeh, 2023**).

Table (4). Effect of spraying with sodium nitroprusside (SNP) and gibberellic acid (GA) rates on fresh and dry weights of flowering stem and flowering stem length of solidago plant during the two seasons of 2022 and 2023

Treatments (mg/l)	Fresh weight of flowering stem (g)		Dry weight of flowering stem (g)		Flowering stem length (g)	
	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
Control	13.3 h	14.4 g	3.070 h	3.007 h	22.67 h	22.67 h
SNP25	24.9 g	26.5 f	5.190 g	5.633 f	26.67 g	27.00 g
SNP50	31.0 e	33.2 e	6.507 e	6.950 e	33.33 e	35.33 e
SNP100	35.1 c	38.7 c	7.330 c	8.097 c	36.33 c	39.00 c
GA50	25.2 f	26.3 f	5.297 f	5.477 g	28.00 f	30.67 f
GA100	32.3 d	35.0 d	6.753 d	7.327 d	34.33 d	37.00 d
GA200	42.2 a	46.9 a	8.803 a	9.807 a	40.00 a	40.67 a
GA300	39.0 b	44.7 b	8.113 b	9.360 b	38.33 b	39.67 b

Chemical constituents

Data documented in Table (5) indicated that, the highest volatile oil percentage resulted from the treatments of sodium nitroprusside (100 mg/l) and gibberellic acid (200 mg/l) with no significant difference between them, in the first season, while in the second one, sodium nitroprusside (100 mg/l) gave the highest percentage over gibberellic acid (200 mg/l) with significant difference between them. On the other side, the volatile oil yield/plant exhibited a progressive and significant increase when the GA rates increased from 50 to 300 mg/l. The treatment of GA 300 or 200 mg/l resulted in the greatest values for volatile oil production per plant in the 1st and 2nd seasons, respectively.

Data tabulated in Tables (6 and 7) showed that, chlorophyll a and b, total nitrogen, total phosphorus and total potassium percentages were affected with sodium nitroprusside (SNP) and gibberellic acid (GA) rates. The highest results of chlorophyll a and b were achieved from the treatment of GA at 200 followed by 300 mg/l. (Table, 6). Additionally, it was showen that the application of GA 200 mg/l. through foliar spray resulted in a notable increase in the overall nitrogen, phosphorus and potassium percentage. This increase was found to be statistically significant when compared to the other treatments examined during the 2022 and 2023 seasons, as indicated in Table (7).

Overall, the presence of each sodium nitroprusside (SNP) and gibberellic acid (GA) had a significant impact on the production of volatile oil as well as the chemical composition of solidago herb. This was observed through the high increases in the percentage of volatile oil and yield per plant, as well as the contents of chlorophyll a and b, and the percentages of nitrogen (N), phosphorus (P) and potassium (K) in comparison to the control, which was sprayed with distilled water. These effects were

consistent over both seasons. Furthermore, **Goharia *et al*. (2020)** revealed that using 200 µM SNP appeared to be the most effective treatment by causing significant increases in chlorophyll a and b and guaiacol peroxidase and ascorbate peroxidase enzymes activities of sweet basil.

Moreover, **Sardoei and Shahdadneghad (2014)** suggested that chlorophyll a and b in *Calendula Officinalis* were enhanced by the increase in GA_3 concentration up to 250 mg L^{-1} treatment. Also, **Gad *et al*. (2016)** revealed that, plant pigments (chlorophyll a, b, a+ b and carotenoids) were increased at 300 ppm GA_3 concentration. According to the research conducted by **Othman *et al*. (2021)**, the administration of 50 mg L^{-1} of GA_3 to gerbera and lily cultivars at the seedling stage has the ability to enhance the chlorophyll content index.

Table (5). Effect of spraying with sodium nitroprusside (SNP) and gibberellic acid (GA) rates on volatile oil percentage and yield/plant (ml) of solidago plant during the two seasons of 2022 and 2023

Treatments (mg/l)	Volatile oil percentage		Volatile oil yield/plant (ml)	
	1st Season	2nd Season	1st Season	2nd Season
Control	0.0417 f	0.0733 g	0.119 h	0.150 h
SNP25	0.0900 e	0.1033 e	0.269 g	0.486 f
SNP50	0.1133 c	0.1200 d	0.606 d	0.717 e
SNP100	0.1300 a	0.1400 a	0.827 b	0.998 c
GA50	0.0900 e	0.1000 f	0.390 f	0.451 g
GA100	0.1067 d	0.1233 d	0.582 e	0.752 d
GA200	0.1300 a	0.1367 b	0.686 c	1.205 a
GA300	0.1233 b	0.1300 c	0.880 a	1.091 b

Table (6). Effect of spraying with sodium nitroprusside (SNP) and gibberellic acid (GA) rates on chlorophyll a and chlorophyll b (mg/gm as fresh weight) of solidago plant during the two seasons of 2022 and 2023

Treatments (mg/l)	Chlorophyll a (mg/g as fresh weight)		Chlorophyll b (mg/g as fresh weight)	
	1st Season	2nd Season	1st Season	2nd Season
Control	1.313 e	1.317 h	0.4173 g	0.4247 h
SNP25	1.431 d	1.439 f	0.4430 f	0.4540 g
SNP50	1.449 c	1.450 e	0.5140 c	0.5280 d
SNP100	1.498 b	1.518 c	0.5547 b	0.5620 c
GA50	1.087 f	1.432 g	0.4507 e	0.4657 f
GA100	1.446 c	1.458 d	0.4700 d	0.5210 e
GA200	1.566 a	1.585 a	0.5622 a	0.6120 b
GA300	1.563 a	1.578 b	0.5547 b	0.6370 a

Table (7). Effect of spraying with sodium nitroprusside (SNP) and gibberellic acid (GA) rates on total nitrogen, total phosphorus and potassium percentages of solidago plant during the two seasons of 2022 and 2023

Treatments (mg/l)	Total nitrogen percentage		Total phosphorus percentage		Potassium percentage	
	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
Control	1.667 h	1.697 h	0.4433 h	0.4767 h	1.447 h	1.477 h
SNP25	1.733 g	1.760 g	0.5100 g	0.5500 g	1.530 g	1.580 f
SNP50	1.817 e	1.847 f	0.5933 e	0.6267 e	1.637 d	1.677 d
SNP100	2.063 c	2.127 c	0.6967 c	0.7467 c	1.723 c	1.760 c
GA50	1.757 f	1.860 e	0.5467 f	0.5933 f	1.550 f	1.567 g
GA100	1.893 d	1.973 d	0.6400 d	0.6967 d	1.627 e	1.660 e
GA200	2.107 a	2.227 a	0.7533 b	0.7767 a	1.737 a	1.793 a
GA300	2.067 b	2.177 b	0.7300 a	0.7633 b	1.733 b	1.773 b

Conclusion

From above mentioned results, it could be concluded that, sprayed solidago plants with 200 mg/l rate five times of gibberellic acid per season is suitable for improve the growth, flowering characters, volatile oil production as well as chemical constituents of solidago (*Solidago hybrida*, Tara) plant under Ismailia Governorate conditions.

REFERENCES

Abd Al Lateef, S. and Hade, S. (2018). The effect of foliar applications with gibberellic acid and benzyladenin on vegetative and floral growth of pansy plant (*Viola tricolor*). IOSR Journal of Agriculture and Veterinary Science, 11 (3): 12-17.

Abdi, R. and Jabbarzadeh, Z. (2022). Investigation of some growth and biochemical and post-harvest characteristics of *Rosa hybrida* cv. Avalanche cut flower using combined application of sodium nitroprusside and putrescine. Plant Process and Function, 50 (11): 37-56.

Abou-El-Ghait, E.M.; Gomaa, A.O.; Youssef, A.S.M. and EL-Nemr, A.M. (2018). Effect of kinetin and GA_3 treatments on growth and flowering of *Dendranthema grandiflorium* cv. Art Queen plants. Middle East Journal of Agriculture Research, 7 (3): 801-815.

Analytical Software (2008). Statistix Version 9, Analytical Software, Tallahassee, Florida, USA.

Apati, P.; Szentmihalyi, K.; Kristo, S. T.; Papp, I.; Vinkler, P.; Szoke, E. and Kery, A. (2003). Herbal remedies of *Solidago*-correlation of phytochemical characteristics and antioxidative properties. J. Pharm. Biomed. Anal., 32 (4/5): 1045–1053.

Arun, M.; Naing, A. H.; Jeon, S. M.; Ai, T. N.; Aye, T. and Kim, C. K. (2017). Sodium nitroprusside stimulates growth and shoot regeneration in chrysanthemum. Hort. Environ. Biotechnol., 58 (1): 78-84.

Beligni, M. V. and Lamattina, L. (2000). Nitric oxide stimulates seed germination and de-etiolation and inhibits hypocotyls elongation, three light inducible responses in plants. Planta, 210**:** 215-221.

Brian, P.V. (1959). Effects of gibberellins on plant growth and development. Biological Reviews, 34 (1): 37-77.

Brown, J. D. and Lilleland, O. (1946). Rapid determination of potassium and sodium in plant material and soil extracts by flame photometry. Proc. Amer. Soc. Hort. Sci., 48: 341-46.

Chapman, D. H. and Pratt, R. F. (1978). Methods Analysis for Soil, Plant and Water. Univ. of California Div. Agric. Sci., 16: 38-56.

Cherry, J. H. (1973). Molecular Biology of Plants (A text manual). Columbia Univ. Press, New York.

Elsadek, M. A. (2018). Improvement yield and quality of dahlia flowers by exogenous application of gibberellic acid and salicylic acid under sandy soil conditions. J. Plant Production, Mansoura Univ., 9 (3): 289-297.

El-Zohiri, S.S.M. and Abd El-Aal, A. M. H. (2015). The role of sodium nitroprusside in improving nitrogen use efficiency and reduce nitrate accumulation of globe artichoke. Current Science International, 4 (3): 245-258.

Gad, M.M.; Abdul-Hafeez, E.Y. and Ibrahim, O.H.M. (2016). Foliar application of salicylic acid and gibberellic acid enhances growth and flowering of *Ixora coccinea* L. plants. J. Plant Production, Mansoura Univ., 7 (1): 85-91.

Goharia, G.; Alavib, Z.; Esfandiarib, E.; Panahiradc, S.; Hajihoseinlouc, S. and Fotopoulos, V. (2020). Interaction between hydrogen peroxide and sodium nitroprusside following chemical priming of *Ocimum basilicum* L. against salt stress. Physiologia Plantarum, 168: 361–373.

Guenther, E. (1961). The Essential Oil D. Von Nostrand Comp., New York, 1: 236.

Hucker, T.W.G. and Catroux, G. (1980). Phosphorus in sewage ridge and animal waster slurries. Proceeding of the EEC Seminar, Haren (Gr); Groningen Netherlands 12, 13 June.

Iqbal, N.; Nazar, R.; Khan, M.; Masood, A. and Khan, N. A. (2011). Role of gibberellins in regulation of source-sink relations under optimal and limiting environmental conditions. Current Science (Bangalore), 100 (7): 998-1007.

Jayshree, N.; Chandrashekar, S.Y.; Hemla Naik, B.; Hanumantharaya, L. and Ganapathi, M. (2020). Influence of benzyl adenine and gibberellic acid on morphological behavior of Asiatic lily. International Journal of Chemical Studies, 8 (5): 2028-2031.

Jeffrey, L.; Walck, J.M.B. and Carol, C.B. (2001). Why is *Solidago shortii* narrowly endemic and *S. altissima* geographically widespread? A comprehensive comparative study of biological traits. J. Biogeography, 28 (10): 1221-1237.

Khangjarakpam, G.; Singh, L.J.; Maitra, S. and Mandal, S. (2019). Influence of foliar application of gibberellic acid on growth, development, yield and biochemical constituents of African marigold cv. 'Pusa Narangi Gainda'. Journal of Pharmacognosy and Phytochemistry, 8 (4): 1581-1585.

Kopyra, M. and Gwozdz, E.A. (2003). Nitric oxide stimulates seed germination and counteracts the inhibitory effect of heavy metals and salinity on root growth of *Lupinus luteus*. Plant Physiology & Biochemistry, 41**:** 1011-1017.

Kumar, P.; Raghava, S.P.S.; Mishra, R.L. and Singh, K.P. (2003). Effect of GA_3 on growth and yield of China aster. J. Orn. Hort., 6(2): 110-112.

Neile, S.J.; Desikan, R.; Clarke, A. and Hancock, J.T. (2002). Nitric oxide is a novel component of abscisic acid signaling in stomata guard cells. Plant Physiology, 128: 13-16.

Neile, S. J.; Desikan, R. and Hancock, J.T. (2003). Nitric oxide signaling in plants. New Phytologist, 159: 11-35.

Othman, Y.A.; Al-Ajlouni, M.G., A'saf, T.A.; Sawalha, H.A. and Bany Hani, M. (2021). Influence of gibberellic acid on the physiology and flower quality of gerbera and lily cut flowers. Int. J. Agric. Nat. Resour., 48 (1): 21-33.

Piri, M.; and Jabbarzadeh, Z. (2023). The effect of foliar application of salicylic acid, spermidine and sodium nitroprusside on some growth and flowering characteristics, photosynthetic pigments and vase life of lisianthus 'Mariachi Blue'. J. of Hort., Sci., 36 (4): 917-936.

Rana, P.; Kumar, J. and Kumar, M. (2005). Response of GA_3, plant spacing and planting depth on growth, flowering and corm production in gladiolus. J. Orn. Hort., 8 (1): 41-44.

Sajid, M.; Amin, N.; Ahmad, H. and Khan, K. (2016). Effect of gibberellic acid on enhancing flowering time in *Chrysanthemum morifolium*. Pak. J. Bot., 48 (2): 477-483.

Sadeghi, S. and Jabbarzadeh, Z. (2022). Characterization of the role of sodium nitroprusside, a nitric oxide donor, on vase life and postharvest attributes of *Alstroemeria aurea* 'Orange Queen', 20 April 2022, PREPRINT (Version 1) available at Research Square [https://doi.org/10.21203/rs.3.rs-1563424/v1].

Sardoei, A. S. and Shahdadneghad, M. (2014). Effects of foliar application of gibberellic acid on chlorophyll and carotenoids of marigold (*Calendula officinalis* L.). International Journal of Advanced Biological and Biomedical Research, 2 (6): 1887-1893.

Shinde, K.H.; Parekh, N.S.; Upadhyay, N.V. and Patel, H.C. (2010). Investigation of different levels of gibberellic acid (GA_3) and pinching treatments on growth, flowering and yield of chrysanthemum (*Chrysanthemum morifolium* R.) cv. 'IIHR-6' under middle Gujrat conditions. Asian Journal of Horticulture, 5 (2): 416-419.

Shrestha, B.; Karki, A. and Shrestha, J. (2020). Effect of foliar application of gibberellic acid (GA_3) on quality attributes of calendula flowers (*Calendula officinalis*) cv. Gitana Fiesta in Chitwan, Nepal. Journal of Agricultural Science and Practice, 5 (4): 168-173.

Singh, J.; Nigam, R.; Singh, R.; Kumar, A. and Kumar, A. (2018). Effect of gibberellic acid and cycocel on growth, flowering and yield of chrysanthemum (*Dendranthema grandiflora* Ramat) cv. Birbal Sahni. Journal of Pharmacognosy and Phytochemistry, SP1: 2753-2758.

Soner, K. and O. Karagüzel (2010). Influence of growth regulators on the growth and flowering characteristics of goldenrod (*Solidago* × *hybrida*). European Journal of Scientific Research, 45: 498-507.

Tabrizi, D.R.; Kalateh, J.S.; Naderi, D.; Ghanbari, J.M.; Asadi, G.H.A. (2023). Role of foliar application of sodium nitroprusside on induction of antioxidant enzyme activities of narcissus (*Narcissus tazetta* L.) in response to saline water irrigation. Plant Process and Function, 54 (12): 73-90.

Thakur, R.; Thakur, R.; Chandermohan, N.C. and Kanwar, B. (2023). Effect of gibberellic acid and benzyl adenine on ornamental plants: A review**.** The Pharma Innovation Journal, 12 (2): 101-105.

Yarnell, E. (2002). Botanical medicines for the urinary tract. World J. Urol., 20 (10): 285–293.