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Effect of growth regulators on spike yield and quality parameters of goldenrod (*Solidago canadensis* L.) Cv. golden gate

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Abstract
This work explains the growth regulators that are responsible for spike yield and quality production of goldenrod (*Solidago canadensis* L.) cv. Golden gate. The experiment shown in this work was conducted at Department of Horticulture, SHUATS, Prayagraj, U.P. during rabi season of 2020-2021 to find out the most suitable treatment of growth regulators for growth and quality of goldenrod (*Solidago canadensis* L.) with different concentrations of GA_3 (150,200 and 250 ppm), CCC (500, 750 and 10-00 ppm), NAA (100,150 and 200 ppm) and MH (750 and 1000 ppm) along with control (water spray). A comparative study was performed and it was observed that among all the treatments GA_3 250 ppm showed an increase in spike length (72 cm), number of spikes per plant (5.8), estimated yield per hectare (5,59, 744.7 spikes/ ha^{-1}) and spike weight (63.4 g), while CCC 1000 ppm increased flower quality *viz*; longevity of spike in situ (14 days) and vase of spike (9.12 days). Among all the growth regulators, plants treated with GA_3 at all levels (150, 200, and 250 ppm) proved to be the best in terms of growth and yield of goldenrod.

Keywords: Goldenrod, GA_3, CCC, NAA, MH, growth regulators and spike quality

1. Introduction
Goldenrod belongs to the family Asteraceae, botanically known as *Solidago canadensis* L. It is also known as 'Sun medicine' because of its deep yellow color and its medicinal value. Goldenrod is a hardy perennial grown in almost all types of climates and soils but prefers a sunny location. They are generally used as cut flowers for indoor decoration as well as in bouquets along with other flowers. Goldenrod is used as filler material in bouquets and in flower arrangements. Literature shows that several glycosides and essential oil have been extracted from the goldenrod. It enriches the beauty of other flowers in vases and bouquets, since it opens its flowers in basipetal manner i.e., from top to bottom, while all others like tuberose, gladiolus open their florets from the base. Response of flowering plants to growth substances treatments is being increasingly studied with a view of having compact plants with a greater number of flowers and also to hasten or delaying flowering according to the needs of growers (Yawale *et al.*, 1998) [24].

Plant growth regulators are being effectively used for various purposes in agriculture including horticulture *viz*., rooting of cuttings, influencing vegetative and reproductive growth, increased duration of flowering, better quality of products, breaking seed dormancy, better fruit and flower setting and fruit maturity. Growth regulating chemicals improve the physiological efficiency of the plants by regulating the rate of photosynthesis, transpiration, photorespiration, water and nutrient uptake and leaf senescence by imparting resistance of environmental stresses and ultimately increasing the harvest index. It is generally accepted that exogenously applied growth substances produce their effects through the alteration in the levels of naturally occurring hormones, thus modifying the growth and development of plants.

A characteristic effect of gibberellic acid on plants is that it makes them taller by causing stem elongation. Rapid stem elongation takes place when rosette plants are sprayed with gibberellic acid. Gibberellins may regulate plant growth via nucleic acid and enzyme synthesis. Retardation of growth by chemical means has been made possible for many years.

Cocycle is known to retard the vegetative growth and so it is known as growth retardant. Weaver (1972) [23] reported that CCC retarded cell elongation by preventing cell division in sub-apical meristematic region. The suppression of vegetative growth in proportionate to chemical applied.

In most of the cases, CCC delay flowering because it restricts the biosynthetic pathway of gibberellin and therefore, it works as ant gibberellin (Shrivastava, 1994) [17].

In the global market, Netherlands, Germany, Japan, Europe, U.A.E and Hong Kong are the main markets for Indian flowers. The international trade of flowers has greatly expanded. Solidago, commonly known as golden rod, belongs to the family Asteraceae botanically known as *Solidago canadensis* L. The genus comprises about 130 species, mostly native to North America.

Few species like *Solidago canadensis, S. virgaurea, S. memoralis* are grown in beds borders or rock garden. Besides, they are also used as cut flowers for indoor decoration and bouquets. It produces large panicles of yellow flowers for several months a year, which are very attractive cut flowers. These hardy perennial herbs grown in almost all types of climates and soils but prefer a sunny location. Therefore, the present investigation was conducted to find out the effect of foliar spray of plant growth regulators on vegetative growth, flowering and spike quality respectively.

2. Materials and Methods

The present investigation was carried out at SHUATS, Prayagraj, (U.P), during Rabi season of 20-2021. The experimental site was situated at the latitude of 20^0 and 15^0 North and longitude of 60^0 East and at altitude of 98 meters above mean sea level (MSL). The experiment was laid out in randomized block design with 12 treatments and replicated thrice. Well rotten farm yard manure @ 20 tonnes per hectare was incorporated in the soil before the last ploughing. The seedlings of goldenrod crop were planted at 30 x 60 cm from row to row and plant to plant in a well prepared and levelled field. The treatments comprising of three doses of GA_3 (150, 200 and 250 ppm), CCC (500, 750 and 1000 ppm), NAA (100, 150 and 200 ppm) and two doses of MH (750 and 1000 ppm) along with control (water spray). Growth substances were sprayed after 30 and 45 days after transplanting. Spraying of growth substances solution was done uniformly with the help of a garden baby sprayer. All the leaves were thoroughly sprayed from all sides. The flowering parameters (weight of the spike, spike length, number of spikes per plant, estimated yield/ha^{-1}, longevity of spike in situ, keeping quality of spike kept in normal water, and in sugar solution) of four randomly selected plants in each treatment were recorded at 30, 60, 90 and 120 days after planting.

The observations on plant height (cm), plant spread (E-W), plant spread (N-S), number of stalks per plant, stock length (cm), weight of stock (gm), days for 50% flowering, days for 100% flowering, vase life when kept in water (days) and number stock ha^{-1}. Observations on vegetative, flowering and yield were recorded and the data was analyzed as suggested by Panse and Sukhatme (1985) [11].

3. Results and Discussion

The present study on the effect of growth regulators on spike yield and quality parameters of goldenrod (*Solidago canadensis* L.) Cv. Golden gate" was carried out with the objective of standardizing the most effective combination of organic, inorganic and biofertilizer for optimum growth and yield of Golden Rod at Sam Higginbottom University of Agricultural Technology and Sciences, NAINI. The results obtained from the present research work are briefly described hereunder along with relevant discussion.

3.1 Flowering and yield parameters

3.1.1 Length of the spike

The data pertaining to the spike length indicates that the differences were significant when the CD value was greater than the treatment difference. Among the various treatments significantly the highest length of spike was observed at GA_3 250 ppm (72 cm) as compared to control (44.6 cm). This was followed with GA_3 200 ppm (63.4 cm) and GA_3 150 ppm (56.4 cm). Whereas, the lowest length of spike was observed at MH 1000 ppm (37.6 cm), followed by CCC 1000 ppm (38.2 cm) as compared to the control (44.5 cm). This significant increase in the length is due to the cell elongation and cell division or both. These results are in accordance with the findings of Patil *et al*. (1996) [12] in golden rod; Dutta *et al*. (1993 and 1995) [3], Poshiya *et al*. (1995) [13], Kumar and Ugherja (1998) [5], Meher *et al*. (1999) [9] in chrysanthemum, Reddy and Sulladmath (1983) [15] in China aster; Poshiya *et al*. (1995b) [14] in gaillardia.

3.1.2 Weight of the spike (g)

The data pertaining to the spike weight indicates that the differences were significant when the CD value was greater than the treatment difference. It was observed from the data that significantly maximum weight of spike was recorded at GA_3 250 ppm (63.4 g) followed by GA_3 200 ppm (58.8 g) and GA_3 150 ppm (55.8 g) as compared to control (51.2 g). Whereas, minimum weight of spike was observed at CCC 500 ppm (50.4 g) which is at par with control (51.2 g). The increase in weight of spikes is attributable to the increased spike size and accumulation of more food material. Similar observation was also reported by Nagarjuna *et al*. (1988) [10], Choudhury Talukdar and Paswan (1994 and 1996) [22], and Poshiya *et al*. (1995) [13] in chrysanthemum; Reddy (1978) [16] in china aster; Singh *et al*. (1991) [19] in marigold and Dalal *et al*. (1999) [2] in tuberose.

3.1.3 Number of spikes per plant

The data pertaining to the number of spikes per plant indicates that the differences were significant when the CD value was greater than the treatment difference. It is clear from the table that different treatments significantly influence the yield of spikes per plant. Among the various treatments significantly the highest yield of spikes per plant was observed at GA_3 250 ppm (5.8) followed by GA_3 200 ppm (4.8) as compared to control (2.1). This was followed by GA3 150 ppm (3.8) which was at par with NAA 200 ppm (3.3). Whereas, the lowest yield of spikes per plant was observed with MH 1000 ppm (1.7) followed by CCC 1000 ppm (1.9) compared to the control (2.1). MH 1000 ppm and CCC 1000 ppm were statistically at par with each other. This increase in yield (number of spikes) is due to the availability of desirable food materials and more carbohydrate supply which ultimately effects on flower production.

3.1.4 Number of spikes per hectare

The data pertaining to the number of spikes per hectare indicates that the differences were significant when the CD value was greater than the treatment difference. It is clear from the table that treatments significantly influence the yield (number of spikes) per hectare. Among the various treatments, the significantly highest yield of spikes per hectare was observed at GA_3 250 ppm (5,59,744.7) followed by GA_3 200 ppm (4,98,629.3) as compared to control

(2,66,157). This was followed by GA_3 150 ppm (423,906) which was at par with NAA 150 ppm (392,660.5). Whereas, lowest yield of golden rod spikes per hectare was observed with MH 1000 ppm (192,262). This increase in yield (number of spikes) is due to the availability of desirable food materials and more carbohydrate supply which ultimately effects on flower production. Similar results have also been reported by Lal and Mishra (1986) [6], Syamal *et al*. (1990) [21], Pandya (2000) [14] in marigold; Reddy and Sulladmath (1983) [15], Lal and Mishra (1986) [6], Syamal *et al*. (1990) [21] in China aster; Poshiya *et al*. (1995b) [14], Makwana (1999) [7] in gaillardia; Maurya and Nagda (2002) [3] in gladiolus and Biswas *et al*. (1983) [1], Singh (2003) [7] in tuberose.

3.1.5 Longevity of spike in situ (days)

The data pertaining to the longevity of spike in situ indicates that the differences were significant when the CD value was greater than the treatment difference. Among the various treatments significantly the highest longevity of spike in situ was observed at CCC 1000 ppm (14 days) followed by CCC 750 ppm (13.3 days), as compared to control (7.5 days). The minimum longevity of spike is observed in control (7.5 days). NAA treatments 150 and 200 ppm are slightly increased longevity of spike over control but they all were at par with each other. The result presented in Table clearly showed that longevity of spike in situ was significantly increased by all the levels of CCC as compared to control. This is might be due to cycocel which is a growth retardant and it might have checked the metabolic processes which have reduced the action of senescence resulting in increasing longevity of spike in situ. These findings were in close conformity with Maurya and Nagda (2002) [8] in gladiolus.

3.1.6 Vase life of spike in water (days)

The data pertaining to the longevity of spike in water indicates that the differences were significant when the CD value was greater than the treatment difference. It is clear from the table that all treatments significantly influence the keeping quality of spikes. Among the various treatments, significantly highest days of keeping quality of spike was observed at CCC 1000 ppm (9.1 days) followed by CCC 750 ppm (8.8 days) and GA3 250 ppm (8.5 days) as compared to control (5.5 days). Whereas significantly minimum days of keeping quality of spikes was observed with control (5.5 days) followed by NAA 100 ppm (7 days).

Data presented in Table revealed that keeping quality of flower was considerably influenced by all the growth substances treatments. The results clearly revealed that maximum keeping quality of golden rod flowers was observed with CCC and MH treatments. Restricted respiration due to inhibitory action of retardant might have increased keeping quality of golden rod. Similar findings were also obtained by Dutta *et al*. (1993) [3], Talukdar and Paswan (1997) [22] in chrysanthemum; Pandya (2000) [14] in marigold; Makwana (1999) [7] in gaillardia.

3.1.7 Vase life of spike in 2% sugar solution (days)

The data pertaining to the vase life of spike in 2% sugar solution indicates that the differences were significant when the CD value was greater than the treatment difference. It is clear from the table that all treatments significantly influence the keeping quality of spikes. Among the various treatments significantly the highest days of keeping quality of panicle was observed at CCC 1000 ppm (10.4 days) followed by CCC 750 ppm (9.6 days) and GA_3 250 ppm (9.3 days) as compared to control (7 days). Whereas significantly minimum days of keeping quality of spikes was observed with control (7 days) followed by NAA 100 ppm (7.2 days) and NAA 150 ppm (7.6 days). Here, all the treatments of GA_3 and NAA (100 and 150 ppm) took significantly more days of keeping quality of spikes as compared to control.

Table 1: Floral parameters

Treatments (ppm)	Floral Parameters					
	Spike length (cm)	Spike weight (g)	Number of spikes per plant	Yield per hectare (spikes)	Longevity of spike in situ (Days)	Vase life of spike (Days)
T_1 GA_3 150	56.4	55.8	3.8	423,906	9.2	7.7
T_2 GA3 200	63.4	58.8	4.8	498,629.3	10.4	8
T_3 GA3 250	72.0	63.4	5.8	559,744.7	11.2	8.5
T_4 CCC 500	42.7	50.4	2.5	284,957.2	11.3	8.1
T_5 CCC 750	40.4	53.2	2.0	247,980.9	13.3	8.8
T_6 CCC 1000	38.1	54.3	1.9	205,572.4	14	9.1
T_7 NAA 100	47.3	52.2	2.5	311,229.3	8.4	7
T_8 NAA 150	51.2	53.9	3.1	392,660.5	8.7	7.5
T_9 NAA 200	54.4	55.09	3.3	356,836.7	9.8	7.2
T_{10} MH 750	40.2	53	1.9	207,821.5	11.7	7.9
T_{11} MH 1000	37.6	52.4	1.7	192,262	12.3	8.4
T_{12} Control (Water spray)	44.6	51.2	2.1	266,157	7.5	5.5
S.E. ±	0.70	0.38	0.14	7294.0	0.5	0.3
C.D. (P=0.05)	2.09	1.13	0.41	21530.6	1.5	0.8
C.V.%	2.5	1.22	8.16	3.8	8.3	6.2

Keeping quality of plants played very important role in influencing the vase life of plants. Different treatments reflected significant role in influencing the keeping quality of plants. Among all the treatments, notable significant improvement in the keeping quality of spike in 2% sugar solution over control was registered in plants treated with CCC 1000 and 750 ppm followed by GA_3 250 ppm. The longest keeping quality of spike was observed with CCC at 1000 ppm. This increase in shelf life reported by Gupta and Dutta (2000) [3] in chrysanthemum.

Fig 1: Golden rod flower plant.

4. Conclusion

The results obtained in this work lead to a conclusion that the foliar spray of GA_3 250 ppm at 30 and 45 days after transplanting influenced the vegetative growth, flower yield and flower quality of goldenrod. Application of NAA at varied levels caused marked effect on different plant parameters i.e., growth, flowering and quality parameters. On the other hand, the application of CCC and MH showed better results in terms of keeping the quality intact but failed to produce maximum yield and net realization and absolutely found inappropriate for an experiment on goldenrod due to its their inhibitory effects.

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