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Punitha A
Assistant Professor, Department of Horticulture, Rice Research Station, Tirur, Tiruvallur, Tamil Nadu, India

Uma Sankareswari R
Assistant Professor, Department of Agricultural Microbiology, National Pulses Research Centre, TNAU, Vamban, Pudukkottai, Tamil Nadu, India

Palanikumar M
Associate Professor, Department of Horticulture, Regional Research Station, Virudhachalam, Tamil Nadu, India

Geethalakshmi I
Assistant Professor, Department of Horticulture, Horticultural College & Research Institute, Jeenur, Krishnagiri, Tamil Nadu, India

Sumathi T
Assistant Professor, Department of Horticulture, Horticultural College & Research Institute, TNAU, Coimbatore, Tamil Nadu, India

Adeline Vinila JE
Teaching Assistant, Department of Horticultural, College & Research Institute, TNAU, Coimbatore, Tamil Nadu, India

Subha L
Assistant Professor, Department of Plant Breeding & Genetics, ICAR, Krishi Vigyan Kendra, Salem TNAU, Vamban, Pudukkottai, Tamil Nadu, India

Corresponding Author:
Punitha A
Assistant Professor, Department of Horticulture, Rice Research Station, Tirur, Tiruvallur, Tamil Nadu, India

Regulation of growth and flowering in Golden rod (*Solidago canadensis* L.) by application of growth substances

Punitha A, Uma Sankareswari R, Palanikumar M, Geethalakshmi I, Sumathi T, Adeline Vinila JE and Subha L

Abstract
An investigation was undertaken to study the effect of exogenously applied growth substances on the growth and yield of Golden rod. The growth substances used were Gibberellic acid (GA_3 at 100, 150, 200 ppm), Chlormequat (CCC at 1000, 1500, 2000 ppm), Maleic hydrazide (MH at 500, 1000, 2000 ppm) and Salicylic acid (SA at 25, 50, 100 ppm). The growth substances were applied as foliar sprays at three stages *viz*., 15 days, 30 days and 45 days after transplanting with water spray as control. The growth parameters *viz*., plant height (66.93cm), flower stalk length (42.27cm), early flowering (71.07 days after transplanting) was significantly increased by the application of GA at 150 ppm also drastically reduced the number of days taken for 50 per cent flowering (74.30 days after transplanting). The yield parameters *viz*., number of flower stalks per meter square (36.50) and number of suckers per plant (8.60), maximum duration of flowering (33.13 days) and flower yield per meter square (1333.53 g) was significantly increased by the application of GA at 150 ppm whereas individual stalk weight (61.13g) was increased by the application of CCC at 1500 ppm. The application of GA at 200 ppm enhanced the vase life by 7.33 days.

Keywords: Golden rod, gibberellic acid, growth substances, growth, yield

Introduction
Golden rod (*Solidago canadensis* L.) belongs to the family Compositae. It is native to North America and an important floricultural crop, basically used as a filler material. This hardy perennial herb grows well in all types of soil and climate. It produces large panicles of attractive yellow flowers for several months in a year. It is cultivated for cut flowers all over the world, besides it is grown in beds, borders, rock garden etc. It is also used for indoor decoration in vases and used either singly or with other flowers in flower bouquets. Golden rod has got promising and untapped export potential, besides local demand. Growth regulators at an optimum concentration are known to modify the growth and development of plants without causing any malformation. Regulation of plant growth has been studied extensively in many flower crops to enhance the production of quality flowers.

Materials and Methods
The experiment was carried out to study the effect of certain growth substances on the growth and yield of golden rod (*Solidago canadensis* L.) in the Department of Floriculture, Horticulture College and Research Institute, TNAU, Coimbatore. The trial was laid out in randomized block design with three replications. The experiment comprised of 13 treatments *viz*., T_1 - GA_3(100 ppm), T_2 - GA_3(150 ppm), T_3 - GA_3(200 ppm), T_4 - CCC (1000 ppm), T_5 - CCC (1500 ppm), T_6 - CCC (2000 ppm), T_7 - MH (500 ppm), T_8 - MH (1000 ppm), T_9 - MH (2000 ppm), T_{10} - Salicylic Acid (25 ppm), T_{11} - Salicylic acid (50 ppm), T_{12} - Salicylic acid (100 ppm) and T_{13} - Control (water spray). The experiment was laid out in randomized block design with three replications and the growth substances were applied as foliar spray to the plant at three stages of crop growth *viz*., 15, 30 and 45 days after transplanting. The suckers were transplanted during October at a spacing of 30 x 30 cm. FYM is added at the rate of 5 kg per square meter. A fertilizer dose of 140:175:150 kg per hectare was applied as a basal and half of the N as top dressing after 30 days after transplanting. The panicles were harvested in the morning hours when about 25 per cent of the flowers have been opened in all the treatments.

Results and Discussion

Growth parameters

In the present study the growth parameter, plant height was greatly influenced by the chemical treatments. The growth promoter, GA provided the maximum increase in height of the plants over a period of time. The plants treated with GA at 150 ppm recorded the maximum plant height whereas the plants treated with MH at 500 ppm recorded the minimum plant height. The increase in plant height might be attributed by rapid elongation of internodes which is again due to increased cell division and enlargement, and this mostly confined to sub apical meristem. The plants treated with GA had higher mitotic index in the sub apical meristem and there might have enhanced cell division in this region. GA application reduced the duration of the cell cycle by 30 per cent and it caused a change in the plane of cell division i.e. the mitotic spindle of dividing cells becomes reoriented towards longitudinal direction, as a result of which the plane of the cell division becomes transverse. This results in vertical files of cells being added on. Hence, the new cells that are formed contribute to the length rather than to the girth of the stem. Therefore, the stem of GA treated plants increases in length. This has also been confirmed by the findings of Moore (1966) [9] in Chrysanthemum, Mittal (1967) [8] in Dahlia, Reddy (1977) [16] in China aster, Nagarjuna *et al*. (1988) [10] in Chrysanthemum. Reddy and Sulladmath (1983) [17] also noticed a direct correlation between the concentrations of GA sprayed and the increased China aster plant height. The present findings confirms the earlier reports that GA at 150 ppm increased the plant height of Shadeed *et al*. (1991) [18] in China aster, PadmaPriya *et al.* (2003) [12] in Chrysanthemum followed by the application of GA at 200 ppm increased the plant height in Golden rod which is in confirmation with the findings of Nagarjuna *et al*. (1988) [10] in Chrysanthemum, Prabhat *et al*.(2003) [14] in China aster, Anil *et al*.(2004) [1] in French Marigold and Patil *et al*.(2004) [13] in Golden rod. Maleic hydrazide sprays reduced the plant height and internodal length significantly and the reduction was more with higher doses. The reduction in the plant height could be because of its inhibitory effect on cell division both in the apical and the sub apical meristem. These results are in line with the findings of Reddy (1977) [16] and Reddy and Sulladmath (1983) [17] in China aster, Singh and Rathore (1992) [19] in Marigold, Aswath *et al*.(1995) [2] in China aster, Yadav (1997) [21] in African marigold, Khandelwal *et al*.(2003) [17] in African marigold.

The application of SA at 50 ppm followed by GA at 200 ppm concentration resulted in higher number of leaves. The increase in number of leaves might be due the effect on shoot elongation which produced more number of leaves. Similarly, increased stemlength with GA has been reported in China aster by Prabhat *et al*. (2003) [14] and Patil *et al*. (2004) [13] in Golden rod.

The application of GA at 150 ppm induced early flowering as compared to the control. The early flowering might be due to the fact that such plants have built up sufficient food reserves at the initial stages and also attributed to the raise in endogenous GA level. The delayed flowering was observed in the treatment CCC at 2000 ppm. Such delayed flowering is supposed to be due to its inhibitory effect on the plant growth. These findings were in line with Narayana Yadav (1997) [21]; Khandelwal *et al*. (2003) [7] in African marigold. The shortest duration to 50 per cent flowering was recorded in the treatment with GA at 150 ppm while the longest duration of flowering was registered by CCC at 2000 ppm. These findings were similar to the results of Nagarjuna *et al*. (1988) [10] in Chrysanthemum. Gibberellic acid application increased the length of the flower stalk which might be attributed to the increased internodal length and length of the branch. These findings were similar to the results of Dutta and Seemanthini Ramadas (1997) [4] and Rakesh *et al*. (2005) [15] in Chrysanthemum. The shortest flower stalk length was noticed in the treatment with CCC. These results are corroborated with the findings of Dutta and Seemanthini Ramadas (1993) [4] in Chrysanthemum.

Table 1: Mean performance of growth and yield parameters of Golden rod (*Solidago canadensis* L.)

Treatment	Plant height (cm)	No. of leaves/ plant	No. of days for Ist flowering (days)	No. of days for 50% flowering (days)	Length of flower stalk (cm)	No. of flower stalks/m^2	No. of suckers /plant	Weight. of Individual stalk (g)	Yield of flower stalks/m^2 (g)	Duration of flowering (days)	Vase life (days)
T1- GA_3(100 ppm)	60.60	54.93	73.60	78.13	40.27	25.07	6.27	22.80	571.95	32.40	4.80
T2 - GA_3(150 ppm)	66.93	52.13	71.07	74.30	42.27	36.50	8.60	38.67	1333.53	33.13	5.07
T3 - GA_3(200 ppm)	63.73	56.67	71.17	77.53	41.60	28.53	7.13	38.33	1094.67	28.60	7.33
T4 - CCC (1000 ppm)	53.53	42.33	74.43	77.40	37.13	34.40	8.27	28.87	999.43	21.47	4.73
T5- CCC (1500 ppm)	51.27	34.67	74.13	79.23	30.80	15.47	3.87	61.13	944.53	23.67	5.00
T6 - CCC (2000 ppm)	49.80	36.33	79.20	84.20	24.97	12.80	3.20	58.67	750.93	20.47	4.00
T7 - MH (500 ppm)	46.87	31.67	78.43	79.20	37.60	13.60	3.33	33.73	459.52	18.67	3.40
T8 - MH (1000 ppm)	47.13	28.33	78.10	79.23	36.03	12.27	3.07	39.53	485.07	17.67	5.00
T9 - MH (2000 ppm)	54.67	28.53	75.17	78.13	31.67	10.40	2.60	19.27	193.07	16.20	6.00
T10 - Salicylic acid (25 ppm)	51.20	46.50	78.00	81.33	34.60	11.00	2.07	45.33	498.67	29.00	6.00
T11 - Salicylic acid (50 ppm)	62.67	57.93	75.33	78.20	36.27	32.00	8.00	59.60	1267.63	24.20	6.67
T12 - Salicylic acid (100 ppm)	56.87	44.53	72.37	79.87	39.47	12.27	3.07	45.93	563.20	21.40	5.40
T13 – control (water spray)	54.07	21.50	77.40	82.33	21.93	10.00	2.00	19.60	196.00	18.60	3.00
SEd	1.31	1.40	1.03	0.84	0.78	0.62	0.15	1.04	30.72	0.37	0.15
CD at 5%	2.71	2.89	2.13	1.73	1.62	1.29	0.31	2.15	63.40	0.78	0.31
CD at 1%	3.70	3.95	2.90	2.36	2.21	1.76	0.42	2.94	86.40	1.06	0.42
CV%	2.91	4.18	1.68	1.30	2.75	3.92	3.91	3.26	5.23	1.98	3.61

Yield parameters

The treatment with GA recorded the highest number of flower stalks. This findings was in confirmation with Prabhat *et al*. (2003) [14] in China aster followed by the treatment with CCC.

The results are in consonance with the findings of Aswath (1991) [2], Singh and Rathore (1992) [19], Khandelwal *et al*. (2003) in African marigold, Patil *et al*. (2004) [7] in Golden rod. The treatment with GA recorded the maximum number of suckers followed by CCC and SA. This is in line with the findings of Patil *et al*. (2004) [13] in Golden rod, Padmapriya *et al*. (2003) [12] in Chrysanthemum. The maximum individual stalk weight was observed with CCC at 1500 ppm followed by SA at 50 ppm. The minimum stalk weight was recorded with MH application. The results are in consonance with the earlier findings of Khandelwal *et al*. (2003) [7] in African marigold.

The highest yield was recorded with the application of GA at 150 ppm. This is in confirmity with the results of Dutta *et al*. (1993) [4] in Chrysanthemum. The maximum flower yield and flower stalk yield were recorded when the plants were treated with GA at 200 ppm in China aster (Prabhat *et al*., 2003) [14]; (Rakesh *et al*., 2004) [15] in Chrysanthemum; (Varma *et al*., 2004) [20] in African marigold; and (Patil *et al*., 2004) [13] in Golden rod. The lowest yield was recorded with MH application by Khandelwal *et al*. (2003) [7] and Varma *et al*. (2004) [20] in African marigold also recorded the similar results for the yield. The maximum duration of flowering was noticed with the spray of GA at 150 ppm followed by GA at 100 ppm. The minimum duration of flowering was noticed with MH at 2000 ppm which had taken relatively lesser duration of flowering. The longest vase life was observed with GA application. Similar observations were made by Dutta *et al*. (1993) [4] in Chrysanthemum, Goyal *et al*. (1994) [6] in Rose. The shortest vase life was observed with the spray of MH at 500 ppm was also recorded.

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