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Effect of bending and plant growth regulator on growth and cut flower yield of rose cv. top secret under protected condition

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Abstract
The present investigation was carried out at green house unit-3, Hi-tech Horticulture Park, College of Horticulture, Junagadh Agricultural University, Junagadh during the year 2022. The treatments comprised with five bending treatments *i.e.*, no bending (B_0), bending at shoot junction (B_1), bending above 1st leaf bud (B_2), bending above 2nd leaf bud (B_3) and bending above 3rd leaf bud (B_4) and four level of growth regulator *i.e.*, 150 ppm benzyl adenine (G_1), 200 ppm benzyl adenine (G_2), 250 ppm benzyl adenine (G_3) and water spray (G_4) which was replicated four times. The result revealed that the variation due to different bending treatments was found significant and maximum number of leaves (65.47), maximum shoot length (64.24 cm), maximum flower bud diameter (1.84 cm), maximum flower head diameter (7.57 cm), maximum stalk length (46.06 cm), highest stalk diameter (4.93 mm), maximum number of cut flower per plant (1.98) and per 1000 sq.m. (13856.31) were reported in treatment of bending at shoot junction (B_1). For plant growth regulator, the result was also observed significant and maximum stem diameter (6.75 mm), maximum flower head diameter (7.18 cm), maximum number of cut flower per plant (1.98) and per 1000 sq.m. (13830.07) were noted in treatment of 200 ppm benzyl adenine (G_2). Whereas, maximum shoot length (64.42 cm), maximum flower bud length (2.71 cm), highest stalk length (44.33 cm), highest stalk diameter (4.78 mm) and maximum number of petals (57.06) were observed in treatment of 150 ppm benzyl adenine (G_1). The interaction effect of bending and plant growth regulator was found non-significant.

Keywords: Rose, bending, benzyl adenine, growth, cut flower yield

Introduction
Rose is a woody perennial flowering plant of the genus *Rosa*, in the family Rosaceae and known as queen of flowers. There are over three hundred species and thirty thousand of cultivars. Rose plants range in size from compact, miniature roses to climbers that can reach seven meter in height. Their flowers vary in size and shape and are usually large and showy, in colours ranging from white through yellow and reds. The major producing regions of roses are Maharashtra, Karnataka, Punjab, Uttar Pradesh, Delhi and Chandigarh; while in Madhya Pradesh, Gujarat, Rajasthan, West Bengal, Haryana, Himachal Pradesh and Tamilnadu, they are cultivated to a limited extent. The total area under commercial production of rose is 4,337 ha with 40,836 MT production and 9.42 MT/ha productivity in Gujarat (Anon., 2022) [3].
In greenhouse mostly Dutch rose variety is cultivated. Dutch rose has high demand in national and international markets. Therefore, Dutch rose cultivation is increasing day by day. There are many popular varieties of Dutch rose in India, among which Top Secret is a superior quality to most red roses and have little or no fragrance.
Conventional upright growing technique is replacing gradually by shoot bending technique under protected condition. Normally 60-90 days after plantation mother shoot is bended and is generally done repetitively over the entire growing season. Instead of removing the whole stem of plant by pruning or other techniques, shoot-bending retained the stem in plants for maintaining foliage area and producing assimilates. Bent shoot act as a food factory for the upright growing shoots and provide extra assimilates for increasing growth of flowering shoots.
Plant growth regulators are an essential tool in the floriculture industry used to manage plant growth, improve plant quality and increase flower production. The most commonly used PGRs in floriculture are auxins, gibberellins and cytokinins. Among which cytokinins are used to stimulate cell division and promote lateral bud growth by breaking apical dominance. Benzyl adenine has been used as one of the sources that can maintain or increase the quality of various

ornamental plants (Han, 2001) [7]. Shoot-bending and BA both interactively promote lateral branch growth by breaking apical dominance, bud dormancy and transfer of assimilates to upright shoots.

Materials and Methods

An investigation was conducted at green house unit-3, Hi-tech Horticulture Park, College of Horticulture, Junagadh Agricultural University, Junagadh during the year 2022. The plants were planted in pots with a spacing of 60 x 45 cm. The experiment was laid out in Factorial Completely Randomized Design with twenty treatment combinations, consisting five level of bending *i.e.*, no bending (B_0), bending at shoot junction (B_1), bending above 1st leaf bud (B_2), bending above 2nd leaf bud (B_3) and bending above 3rd leaf bud (B_4) and four level of growth regulator *i.e.*, 150 ppm benzyl adenine (G_1), 200 ppm benzyl adenine (G_2), 250 ppm benzyl adenine (G_3) and water spray (G_4). The treatments were replicated four times.

Bending was done after 90 days of planting. It was done in afternoon because of less moisture content in plant which prevents the stem from breaking during bending. The well grown pencil thickness size shoots were selected for bending. Flower buds and flowers were removed from these shoots. The shoots were gently twisted and bent toward path as per different levels of treatments. Benzyl adenine solution of 150, 200 and 250 ppm concentration were prepared by dissolving calculated quantity of chemical in 75% ethanol and then volume was made up to one litre with distilled water. The prepared solution of BA was first sprayed uniformly with the help of hand atomizer to the treatments immediately after bending. Remaining three sprays were sprayed after 15 days interval. Necessary observations were recorded using standard procedure and statistically analysed.

Results and Discussion

Growth parameters

Effect of bending

Among the different treatments, maximum plant height at first flower opening (84.94 cm), plant height at full bloom stage (85.73 cm), number of branches per plant (2.93) and leaf area (37.88 cm^2) were obtained in treatment of no bending (B_0). Maximum number of leaves (65.47) and shoot length (64.24 cm) were observed in bending at shoot junction (B_1). Whereas, treatment of bending above 1st leaf bud (B_2) recorded maximum stem diameter (6.95 mm). Plant spread (E-W) and (N-S) was found non-significant for all the treatments of bending. It might be due to bending resulted in higher shoot quality but less harvestable shoots per plant in commercial greenhouses. The results are in agreement with those found by Ohkawa and Suematsu (1999) [15] in rose, Gawade *et al.* (2018) [6] in chrysanthemum, Sarkar and Ghosh (2006) [18], Samant *et al.* (2016) [17], Nandi *et al.* (2017) [13], and Mishra *et al.* (2020) [12] in guava and Vasava *et al.* (2023) [20] in brinjal.

Effect of plant growth regulator

The effect of various concentration of benzyl adenine on plant height at first flower opening, plant height at full bloom stage and plant spread (E-W) and (N-S) was found non-significant. While, significantly maximum shoot length (64.42 cm) was obtained in 150 ppm benzyl adenine (G_1); significantly maximum stem diameter (6.75 mm) was obtained in 200 ppm benzyl adenine (G_2) and highest number of leaves per branch (62.50) and maximum leaf area (33.31 cm^2) was obtained in 250 ppm benzyl adenine (G_3). This might be due to benzyl adenine increased chlorophyll content in leaves which increase photosynthesis and vegetative growth by cell division. Such type of variability was recorded by Nanjan and Muthuswamy (1975) [14] and Abadi (2010) [1] in rose and Chavan *et al.* (2012) [4] in gerbera, Gawade *et al.* (2019) [5] in chrysanthemum.

Interaction effect

The variation due to interaction of bending and plant growth regulator for growth parameters like plant height at first flower opening, plant height at full bloom stage, number of branches per plant, number of leaves per branch, leaf area, shoot length at full bloom stage, stem diameter at peak flowering stage and plant spread (E-W) and (N-S) were found non-significant.

Table 1 Effect of bending and plant growth regulator on growth parameters of rose cv. Top Secret under protected condition.

Treatment		Plant height at first flower opening (cm)	Plant height at full bloom stage (cm)	Number of branches per plant	Number of leaves per branch	Leaf area (cm^2)
Factor A - Bending (B)						
B_0	No bending	84.94	85.73	2.93	54.59	37.88
B_1	Bending at shoot junction	72.64	77.95	1.62	65.47	27.22
B_2	Bending above 1st leaf bud	74.08	77.27	1.60	63.34	30.06
B_3	Bending above 2nd leaf bud	69.27	72.39	1.43	60.23	27.62
B_4	Bending above 3rd leaf bud	73.65	76.74	1.38	59.52	34.43
S.Em.±		1.287	1.377	0.035	0.769	0.382
C.D. at 5%		3.66	3.92	0.10	2.19	1.08
Factor B – Plant growth regulator (G)						
G_1	150 ppm benzyl adenine	76.35	80.33	1.73	59.46	31.98
G_2	200 ppm benzyl adenine	75.16	78.07	1.81	61.43	30.93
G_3	250 ppm benzyl adenine	74.23	78.01	1.85	62.50	33.31
G_4	Water spray (control)	72.93	75.68	1.80	59.15	29.56
S.Em.±		1.151	1.231	0.031	0.688	0.342
C.D. at 5%		NS	NS	NS	1.95	0.97
Interaction (B x G)						
S.Em.±		2.575	2.754	0.071	1.539	0.764
C.D. at 5%		NS	NS	NS	NS	NS
C.V. %		6.87	7.06	7.91	5.07	4.86

Table 2 Effect of bending and plant growth regulator on growth parameters of rose cv. Top Secret under protected condition.

Treatment		Shoot length at full bloom stage (cm)	Stem diameter at peak flowering stage (mm)	Plant spread (E-W) (cm)	Plant spread (N-S) (cm)
Factor A - Bending (B)					
B_0	No bending	60.83	6.10	28.15	28.59
B_1	Bending at shoot junction	64.24	6.87	26.76	27.76
B_2	Bending above 1st leaf bud	64.07	6.95	27.13	27.90
B_3	Bending above 2nd leaf bud	62.93	6.49	26.66	27.95
B_4	Bending above 3rd leaf bud	63.42	6.48	27.07	28.06
S.Em.±		0.652	0.107	0.446	0.485
C.D. at 5%		1.85	0.30	NS	NS
Factor B – Plant growth regulator (G)					
G_1	150 ppm benzyl adenine	64.42	6.41	26.71	28.14
G_2	200 ppm benzyl adenine	62.91	6.75	27.28	28.22
G_3	250 ppm benzyl adenine	63.00	6.68	28.02	28.78
G_4	Water spray (control)	62.08	6.50	26.62	27.09
S.Em.±		0.583	0.096	0.399	0.434
C.D. at 5%		1.66	0.27	NS	NS
Interaction (B x G)					
S.Em.±		1.304	0.215	0.893	0.971
C.D. at 5%		NS	NS	NS	NS
C.V. %		4.13	6.52	6.57	6.92

Flowering and cut flower yield parameters

Effect of bending

In majority of flowering and cut flower yield parameters, treatment of bending at shoot junction (B_1) was found to be superior over other treatments. Bending at shoot junction (B_1) significantly recorded maximum flower bud diameter (1.84 cm), flower head diameter (7.57 cm), stalk length (46.06 cm), highest stalk diameter (4.93 mm), number of cut flowers per plant (1.98) and number of cut flowers per 1000 sq.m. (13856.31). It might be due to strong positive effects of assimilate supply from bent shoots on upright shoot organ size exist during the whole shoot growth period. The results were supported by Kool *et al.* (1996) [10] and Matloobi *et al.* (2009) [11] in rose and Parsana *et al.* (2023) [16] in pomegranate. Whereas, minimum days taken to first flower bud appearance (29.33) was recorded in no bending (B_0). It might be due to release of apical dominance. Without bending, the apical meristem is not inhibited, which allows the plant to grow and mature quickly. Maximum flower bud length (2.68 cm) was exhibited in bending above 3rd leaf bud (B_4) and maximum number of petals per flower (60.08) was noted in bending above 2nd leaf bud (B_3). There was no significant difference observed in different treatments of bending for days to first flower opening, flowering span and pedicel length of flower.

Table 3 Effect of bending and plant growth regulator on flowering and cut flower yield parameters of rose cv. Top Secret under protected condition

Treatment		Days to first flower bud appearance	Days to first flower opening	Flower bud length (cm)	Flower bud diameter (cm)	Flower head diameter (cm)	Flowering span (days)
Factor A - Bending (B)							
B_0	No bending	29.33	14.20	2.39	1.72	6.52	24.11
B_1	Bending at shoot junction	37.02	14.57	2.44	1.84	7.57	24.41
B_2	Bending above 1st leaf bud	37.41	14.30	2.56	1.60	6.88	24.13
B_3	Bending above 2nd leaf bud	38.53	14.18	2.46	1.63	7.13	23.97
B_4	Bending above 3rd leaf bud	37.58	14.51	2.68	1.64	7.00	24.01
S.Em.±		0.493	0.113	0.025	0.024	0.069	0.340
C.D. at 5%		1.40	NS	0.07	0.06	0.19	NS
Factor B – Plant growth regulator (G)							
G_1	150 ppm benzyl adenine	36.41	14.35	2.71	1.73	6.92	24.26
G_2	200 ppm benzyl adenine	34.98	14.50	2.48	1.64	7.18	24.21
G_3	250 ppm benzyl adenine	35.90	14.23	2.43	1.70	7.02	24.20
G_4	Water spray (control)	36.62	14.36	2.42	1.69	7.00	23.85
S.Em.±		0.441	0.101	0.023	0.021	0.062	0.304
C.D. at 5%		NS	NS	0.06	NS	0.17	NS
Interaction (B x G)							
S.Em.±		0.986	0.227	0.051	0.048	0.139	0.680
C.D. at 5%		NS	NS	NS	NS	0.39	NS
C.V. %		5.48	3.17	4.10	5.79	3.98	5.63

Table 4 Effect of bending and plant growth regulator on flowering and cut flower yield parameters of rose cv. Top Secret under protected condition

Treatment		Stalk length (cm)	Pedicel length of flower (cm)	Stalk diameter at the base of cut flower (mm)	Number of petals per flower	Number of cut flowers per plants	Number of cut flowers per 1000 sq.m.
Factor A - Bending (B)							
B_0	No bending	32.44	5.84	4.18	46.77	1.83	12847.55
B_1	Bending at shoot junction	46.06	6.07	4.93	54.19	1.98	13864.34
B_2	Bending above 1st leaf bud	43.04	5.92	4.61	53.09	1.97	13856.31
B_3	Bending above 2nd leaf bud	41.30	6.06	4.55	60.08	1.78	12498.52
B_4	Bending above 3rd leaf bud	44.50	6.02	4.50	48.58	1.80	12669.02
S.Em.±		0.515	0.077	0.052	0.925	0.035	246.292
C.D. at 5%		1.46	NS	0.14	2.63	0.10	701.00
Factor B – Plant growth regulator (G)							
G_1	150 ppm benzyl adenine	44.33	5.98	4.78	57.06	1.88	13192.97
G_2	200 ppm benzyl adenine	40.74	5.84	4.65	52.17	1.98	13830.07
G_3	250 ppm benzyl adenine	41.31	6.05	4.49	54.56	1.83	12830.86
G_4	Water spray (control)	39.51	6.08	4.31	46.39	1.82	12734.69
S.Em.±		0.460	0.069	0.046	0.827	0.031	220.290
C.D. at 5%		1.31	NS	0.13	2.35	0.08	627.00
Interaction (B x G)							
S.Em.±		1.030	0.154	0.104	1.850	0.070	492.584
C.D. at 5%		NS	NS	NS	5.26	NS	NS
C.V. %		4.96	5.16	4.56	7.04	7.49	7.49

Effect of plant growth regulator

The majority of flowering and cut flower yield parameters were superior due to treatments of 150 ppm benzyl adenine. Among which maximum flower bud length (2.71 cm), stalk length (44.33 cm), stalk diameter (4.78 mm) and number of petals per flower (57.06) were found with 150 ppm benzyl adenine. Whereas, maximum flower head diameter (7.18 cm), number of cut flowers per plant (1.98) and number of cut flowers per 1000 sq.m. (13830.07) were observed with 200 ppm benzyl adenine. This might be due to benzyl adenine stimulate cell division and growth in reproductive organ, leading to increase flower size. The results were in agreement with those found by Serek and Andersen (1993) [19] and Vasudevan and Kannan (2014) [21] in rose.

Interaction effect

The interaction effect of bending and plant growth regulator was found significant for flower head diameter and treatment combination of bending at shoot junction with 200 ppm benzyl adenine (B_1G_2) was found better with respect to flower head diameter (8.65 cm). This might be due to sufficient allocation of assimilates by bent shoot to upright growing shoot with appropriate cell division through benzyl adenine. The results were in agreement with those found by Kim and Lieth (2004) [8] and Vasudevan and Kannan (2014) [21] in rose. For number of petals per flower, treatment combination of bending above 2nd leaf bud with 150 ppm benzyl adenine (B_3G_1) was found better (72.49). It might be due to this treatment combination have provided a favourable environment for floral bud differentiation and development, resulting in an increased number of petals per flower. The results were in conformity with those obtained by Kool and Lenssen (1997) [9] and Amanullah *et al*. (2010) [2] in rose.

All the other parameters like days to first flower bud appearance, days to first flower opening, flower bud length, flower bud diameter, flowering span, stalk length, pedicel length of flower, stalk diameter at the base of cut flower, number of cut flowers per plant and number of cut flowers per 1000 sq.m. was showed non-significant variation.

Conclusion

Based on the experiment and foregoing discussion, there were many notable variations among the different treatments for growth, flowering and cut flower yield parameters. The treatment of bending at shoot junction performed better with majority of flowering and cut flower yield parameters as compared to other treatments. In case of plant growth regulators, the present study has showed that growth, flowering and cut flower yield parameters of cut roses could be increased with 150 ppm benzyl adenine as compared to other treatments. While, the interaction effect of bending and plant growth regulator was found non-significant for majority of growth and cut flower yield parameters. From the above, it can be concluded that bending at shoot junction and 150 ppm benzyl adenine is an effective approach which helps in increasing growth, flowering and cut flower yield of rose.

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