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Effect of growth regulators and disbudding on relative growth rate (RGR) and net assimilation rate (NAR) in dahlia (*Dahlia variabilis*) cv. Charmit

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Abstract
The experiment entitled “Effect of growth regulators and disbudding on Relative Growth Rate (RGR) and Net Assimilation Rate (NAR) in dahlia (*Dahlia variabilis*) cv. Charmit” was conducted at Urban Technology Park, Habak during 2021, to evaluate the response of dahlia to different growth regulators (Ethephon @ 500, 750 and 1000 ppm, Alar @ 1000, 2000 and 3000 ppm and Maleic hydrazide @ 500, 750, and 1000 ppm) and disbudding. Twenty different treatment combinations were replicated thrice in a Randomized Completely Block Design. Significant differences were observed in Relative Growth Rate (RGR) and Net Assimilation Rate (NAR) under the influence of growth regulators and disbudding. Removal of flower buds had a significant influence on all the vegetative and tuber parameters. Disbudded plants recorded lower values for RGR of stem but higher values for RGR of tuber and NAR compared to plants with no disbudding. Among all growth regulators Maleic hydrazide was found most effective followed by Ethephon and Alar in modifying the plant architecture.

Keywords: Disbudding, dahlia, plant growth regulator, biomass, sprays

Introduction
The native land of dahlia is known to be Mexico (Willis, 1966) [15]. Dahlia is half-hardy herbaceous perennial with tuberous roots belonging to family Asteraceae. It was named by the pioneering Swedish botanist and taxonomist Carl Linnaeus to honor his late student, Anders Dahl. Dahlia is amongst the popular bulbous flowers found in the most gardens of the world. A multitude of colors, great variation in size, attractive shapes, various forms, prolific flowering and easy cultivation have made it immensely popular. The Netherland is the largest producer of tuberous rooted dahlias. Other countries producing dahlias on a large scale are Japan, France, South Africa, UK, Italy, Germany and the USA (De Hertogh and Le Nard, 1998) [3]. The commercial cultivation of dahlias is limited to the hills and plains of Eastern India. Dahlias are grown for various purposes and used in several situations and locations. Dwarf types are excellent for borders, beds or even in mixed borders. The long stemmed dahlias are extensively used in different parts of India for exhibition, garden display and decoration. All flowers of various forms and colors are utilized in flower arrangements. Plant growth regulators (PGRs) are chemicals that are designed to affect plant growth and/or development and applied for specific purposes to elicit specific plant responses (Joyce, 2012) [7]. Growth regulators are generally used in floriculture industry for height control, lateral branching, rooting and flowering. Various plant growth regulators having growth inhibiting properties (Plant growth retardants) are incredibly useful tool for achieving crop-specific height control by selecting the proper growth retardants, application technique and optimum dosage (Douglas and Brian, 1998) [4].Gibberellins influence tuberization by influencing shoot growth (Kumar *et al.*, 1981) [8]. Applying gibberellic acid to the tops stimulates leaf and stem growth, while indirectly reducing tuber growth. Besides chemical treatments, plant size and tuber production can be regulated by various cultural practices. Complete disbudding has been found effective in increasing the bulb/tuber yield in bulbous crops as it diverts more plant nutrients resources towards storage organs. Muzain (2011) [10] obtained higher bulb yield in different cultivars of lilium through complete disbudding.

Material and Methods
The present investigation entitled Effect of growth regulators and disbudding on Relative Growth Rate (RGR) and Net Assimilation Rate (NAR) in dahlia (*Dahlia varibilis*) cv.

Charmit" was carried out under open field conditions at Urban Technology Park, Habak during the dahlia growing season of 2021. The Urban Technology Park, Habak is situated at 340.9´ N latitude and 740.50´ E longitude at an elevation of 1606 meters above sea level. Uniform sized tubers of dahlia cv. Charmit, with at least one growing bud were selected after division of previous year's tuber clumps that were kept under underground trenches during the winter (November 2020 to May 2021). The climate of the area in general is temperate-cum-mediterranean and of continental type characterized by hot summers and severe winters. Hottest months are July and August during which temperature shoots up to 34℃. Winter is severe, extending over 70 days from the middle of December to March, when the temperature often goes below the freezing point and the whole of Kashmir valley remains covered under snow. The plants were planted in plots of size 2 x 1m, with 8 plants in each plot. The experiment was laid out in Randomized Complete Block Design (RCBD). The total number of treatments were twenty with three replications. Three different growth regulators *viz*; Ethephon (500, 750 and 1000 ppm), Alar (1000, 2000 and 3000 ppm) and Maleic hydrazide (500, 750 and 1000 ppm) were used. The growth regulators were sprayed 20 days after first pinching. The stock solution of ethephon, alar and maleic hydrazide was prepared by dissolving the weighed quantity of these substances in ethanol and then diluted with distilled water to prepare the required concentrations. The experimental land was well prepared by cultivator and leveled. The land was divided into three blocks each with a width of 1 m leaving a path of 0.3 m between the blocks. Each block was divided into 20 plots of 2 x 1 m size. Uniform dose of fertilizers and FYM was added to each plot at the final preparation prior to planting of tuber. The tubers were planted at the spacing of 50 × 50cm as per the treatment combinations and layout specification. The tubers were sown on 16th of May, 2021 at a depth of 7cm in plots of size 2 x 1m. Eight tubers were sown in each plot. Vigorous and healthy uniform sized tubers were planted in the well prepared land. Light irrigation with rose cane was given immediately after planting and subsequent irrigations were given at the appropriate stages. Following sprouting of tubers, pinching off the tip of main shoot was done on 25th of July, when the shoots were about at least two pairs of leaves. Only one main shoot was maintained per tuber. Extra shoot developing from the tuber were removed. Staking was done when plants achieved an average height of 1 ft to avoid lodging. The harvesting of the tubers was done on 16th of November, 2021, when plant growth retarded and leaves begin to change colour towards yellow due to onset of low temperatures. All the adhering soil was removed from the tuber clumps. Above ground portion of the plants was removed from the tuber keeping about 10 cm stem portion attached to each tuber clump. Different parts of the plants were taken from randomly selected plants from each treatment in every replication at the appropriate time to record the observations.

Results and Discussion

Disbudding, pinching and growth retardants have been effectively used for modifying the architecture of ornamental crops. In recent year, a number of plant growth retardants have been used for producing more desirable traits and acceptable plant characteristics in modern floriculture industry like compact growth, dwarfness, increase number of healthy branches and more number of quality flowers. During the present study results obtained in dahlia under the influence of disbudding and growth regulators have been discussed with the available literature.

Effect of growth regulator and disbudding on Relative growth and Net assimilation rates

The relative growth rate (RGR) and net assimilation rate (NAR) are the important growth parameters influencing yield, which are dependent not only on the genotype but also on the environmental factors and managements practices.

1. **Relative growth rate (mg/g/day) of stem between 140-155, 155-170, 170-185 DAP**

RGR of stem was significantly influenced by growth regulator treatments at all the intervals with highest during the first interval between 140-155 DAP, which decreased in the second interval and became negative in the third interval between170-185 DAP. During the first and second interval highest RGR of stem (59.88 and 45.89 mg/g/day) was recorded with 1000 ppm MH as compare to lowest (39.14 and 29.62 mg/g/day) with alar 1000 ppm (Table 1and 2). During third interval of 170-185 DAP, RGR became negative with highest value of -9.15 mg/g/day recorded under control which was at par with -9.60 mg/g/day under alar 1000 ppm while lowest (-23.50 mg/g/day) was recorded under MH 1000 ppm (Table 3). Growth regulators had a positive response on the RGR of stem during first two intervals. This is because the growth regulators suppressed the shoot growth and increased production of photosynthates. During the third interval, there was more accumulation of dry matter in the underground parts, which resulted in negative RGR of stem. These results are in agreement with Upadhyaya *et al.* (1986) [13] and Tekalign and Hammes (2005) [12]. Disbudded plants recorded significantly a lower RGR of stem as compared to plants with no disbudding at all the three intervals (Table 1, 2 and 3). It might be due to diversion of the nutrients towards the underground parts. Inamoto *et al.* (2013) [6] observed that sink activity of flowers before anthesis was very high and bulb scales were markedly competitive with flowers as a sink. There was dominant dry matter (DM) accumulation in the flower buds and bulb between the visible bud stage and flowering stage. Removal of flower buds resulted in diversion of photosynthates towards bulb (Xia *et al.*, 2005) [16] and hence lower RGR of stem.

Table 1: Effect of growth regulators and disbudding on relative growth rate (mg/g/day) of stem between 140-155 DAP in dahlia (*Dahlia variabilis* cv. Charmit)

Growth regulators	Disbudding		Mean
	No disbudding	Complete disbudding	
Control (Distilled water)	50.39	45.06	47.72
Ethephon @500 ppm	46.93	41.72	44.32
Ethephon@ 750 ppm	53.13	48.53	50.83
Ethephon @ 1000 ppm	57.82	53.23	55.52
Alar @ 1000 ppm	41.62	36.65	39.14
Alar @ 2000 ppm	46.03	41.53	43.78
Alar @ 3000 ppm	52.38	47.35	49.86
MH @ 500 ppm	51.60	43.45	47.52
MH @ 750 ppm	59.28	50.66	54.97
MH @ 1000 ppm	63.37	56.40	59.88
Mean	52.26	46.46	

C.D ($p \leq 0.05$)
Growth regulators = 2.76
Disbudding = 2.44
Growth regulators x Disbudding = 2.93

The interaction effect between growth regulators and disbudding indicated that application of MH at 1000 ppm with no disbudding recorded highest RGR (63.37 and 49.43 mg/g/day) during the first two intervals while alar 1000 ppm with complete disbudding recorded lowest RGR (36.65 and 27.05 mg/g/day) (Table 1 and 2). During the third interval of 170-185 DAP, RGR became negative and highest RGR (-7.24 mg/g/day) was recorded by control without disbudding while lowest RGR (-31.37 mg/g/day) was recorded by MH at 1000 with complete disbudding (Table 3). Both growth regulators and disbudding helped in diversion of more photosynthates towards the underground parts, which resulted in lower dry weight of stem.

Table 2: Effect of growth regulators and disbudding on relative growth rate (mg/g/day) of stem between 155-170 DAP in dahlia (*Dahlia variabilis* cv. Charmit)

Growth regulators	Disbudding		Mean
	No disbudding	Complete disbudding	
Control (Distilled water)	41.49	34.06	37.78
Ethephon @500 ppm	33.63	29.72	31.68
Ethephon@ 750 ppm	41.16	35.52	38.34
Ethephon @ 1000 ppm	48.73	41.23	44.98
Alar @ 1000 ppm	32.19	27.05	29.62
Alar @ 2000 ppm	37.29	32.66	34.98
Alar @ 3000 ppm	44.36	36.40	40.38
MH @ 500 ppm	39.29	29.27	34.28
MH @ 750 ppm	43.67	38.65	41.16
MH @ 1000 ppm	49.43	42.35	45.89
Mean	41.12	34.69	

C.D ($p \leq 0.05$)
Growth regulators = 2.23
Disbudding = 1.76
Growth regulators x Disbudding = 2.64

Table 3: Effect of growth regulators and disbudding on relative growth rate (mg/g/day) of stem between 170-185 DAP in dahlia (*Dahlia variabilis* cv. Charmit)

Growth regulators	Disbudding		Mean
	No disbudding	Complete disbudding	
Control (Distilled water)	-7.24	-11.06	-9.15
Ethephon @500 ppm	-7.52	-13.54	-10.53
Ethephon@ 750 ppm	-10.51	-19.03	-14.77
Ethephon @ 1000 ppm	-14.57	-26.28	-20.42
Alar @ 1000 ppm	-7.03	-12.18	-9.60
Alar @ 2000 ppm	-10.30	-18.19	-14.24
Alar @ 3000 ppm	-15.76	-26.82	-21.29
MH @ 500 ppm	-10.93	-21.19	-16.06
MH @ 750 ppm	-13.12	-27.02	-20.07
MH @ 1000 ppm	-15.63	-31.37	-23.50
Mean	-11.26	-20.67	

C.D ($p \leq 0.05$)
Growth regulators = 0.79
Disbudding = 0.71
Growth regulators x Disbudding = 0.93

Relative growth rate (mg/g/day) of tuber between 140-155, 155-170, 170-185 DAP

Application of growth regulators had a significant effect on relative growth rate (RGR) of tubers at all the three intervals. There was a general increasing trend in the RGR of tuber

From 155 DAP up to harvesting. Highest concentration of each growth regulator recorded maximum RGR. Among all the three growth regulators tested, application of MH 1000 ppm recorded highest RGR (22.56, 33.62, 36.02 mg/g/day) during all the intervals followed by ethephon 1000 ppm (21.97, 26.60 and 30.38 mg/g/day) or alar 3000 ppm (21.40, 33.62 and 27.45 mg/g/day) (Table 4, 5 and 6). Minimum RGR (11.64, 19.00 and 21.98 mg/g/day) was observed in control or lowest concentration of growth regulator (Table 4, 5 and 6). This is because the growth regulators greatly increased the portioning of assimilates to the tubers while reducing the aboveground vegetative growth. Increase in RGR at higher concentrations of growth regulators could be attributed to an increase in the rate of dry matter production and accumulation as a result of application of growth retardants (Prakash *et al.*, 2001) [11]. This may probably be attributed to a decrease in gibberellic acid accumulation that is known to influence tuber sink, strength, and starch synthesis and deposition (Tekalign and Hammes, 2005) [12]. These results are also supported by Banerjee and Das (1984) [2] and Madalgeri (1996) [9].

Table 4: Effect of growth regulators and disbudding on relative growth rate (mg/g/day) of tuber between 140-155 DAP in dahlia (*Dahlia variabilis* cv. Charmit)

Growth regulators	Disbudding		Mean
	No disbudding	Complete disbudding	
Control (Distilled water)	10.12	13.16	11.64
Ethephon @500 ppm	16.39	17.29	16.84
Ethephon@ 750 ppm	17.17	21.28	19.22
Ethephon @ 1000 ppm	18.61	25.33	21.97
Alar @ 1000 ppm	14.66	18.89	16.78
Alar @ 2000 ppm	14.90	19.63	17.26
Alar @ 3000 ppm	19.09	23.70	21.40
MH @ 500 ppm	17.37	19.43	18.40
MH @ 750 ppm	19.49	22.56	21.02
MH @ 1000 ppm	20.87	24.25	22.56
Mean	16.87	20.55	

C.D (p≤ 0.05)
Growth regulators =1.21
Disbudding =0.80
Growth regulators x Disbudding =1.38

During all the three intervals, disbudded plants recorded significantly a higher RGR of tuber as compared to plants with no disbudding. Removal of flower buds means removal of one sink for the photosynthates, which get diverted towards other sink i.e. the tuber. Hence relatively higher RGR of tuber in disbudded plants might be due to better translocation of the nutrients towards the tubers. Similar results were found by Wang and Breen (1984) [14]. Highest concentration of growth regulators with complete disbudding recorded maximum RGR during all the three intervals (25.23, 27.15 and 31.24 mg/g/day with Ethephon 1000, 23.70, 39.81 and 28.16 mg/g/day with Alar 3000 ppm, and 24.25, 39.81 and 41.17 mg/g/day with MH 1000 ppm, respectively) while minimum value for this parameter was observed in control with no disbudding (10.12 and 18.10 mg/g/day, and ethephon 500 with no disbudding (21.23 mg/g/day). Both growth regulators and disbudding increased the dry weight of tubers by diverting more photosynthates towards the underground parts and hence higher RGR of tubers.

Table 5: Effect of growth regulators and disbudding on relative growth rate (mg/g/day) of tuber between 155 -170 DAP in dahlia (*Dahlia variabilis* cv. Charmit)

Growth regulators	Disbudding		Mean
	No disbudding	Complete disbudding	
Control (Distilled water)	18.10	24.91	21.50
Ethephon @500 ppm	18.13	19.87	19.00
Ethephon@ 750 ppm	22.17	24.21	23.19
Ethephon @ 1000 ppm	26.04	27.15	26.60
Alar @ 1000 ppm	19.31	20.80	20.06
Alar @ 2000 ppm	23.11	27.80	25.46
Alar @ 3000 ppm	27.42	39.81	33.62
MH @ 500 ppm	19.96	20.56	20.26
MH @ 750 ppm	23.11	27.80	25.46
MH @ 1000 ppm	27.42	39.81	33.62
Mean	22.20	25.39	

C.D (p≤ 0.05)
Growth regulators = 1.28
Disbudding = 0.92
Growth regulators x Disbudding = 1.51

Table 6: Effect of growth regulators and disbudding on relative growth rate (mg/g/day) of tuber between 170-185 DAP in dahlia (*Dahlia variabilis* cv. Charmit)

Growth regulators	Disbudding		Mean
	No disbudding	Complete disbudding	
Control (Distilled water)	22.11	28.13	25.12
Ethephon @500 ppm	21.23	22.74	21.98
Ethephon@ 750 ppm	25.15	29.41	27.28
Ethephon @ 1000 ppm	29.53	31.24	30.38
Alar @ 1000 ppm	23.87	25.86	24.86
Alar @ 2000 ppm	26.84	27.65	27.24
Alar @ 3000 ppm	27.65	28.16	27.45
MH @ 500 ppm	23.43	25.75	24.59
MH @ 750 ppm	25.41	29.67	27.54
MH @ 1000 ppm	30.87	41.17	36.02
Mean	25.52	28.98	

C.D ($p \leq 0.05$), Growth regulators = 1.69
Disbudding = 1.36, Growth regulators x Disbudding = 1.98

3. Net Assimilation Rate between 140-155, 155-170 and 170-185 days after planting (DAP)

Net assimilation rate in general increased during the first interval of 140-155 DAP, started declining in the second interval and reached minimum in the third interval between 170-185 DAP. Growth regulators had a significant effect on net assimilation rate, which increased with the increase in concentration of growth regulators. During all the three intervals, alar 3000 ppm recorded significantly highest (24.43, 17.35 and 15.43 mg/cm^2/day) NAR followed by ethephon 1000 ppm (20.89, 15.24 and 12.71 mg/cm^2/day) and MH 1000 ppm (20.53, 14.31 and 11.80 mg/cm^2/day) (Table 7, 8 and 9). Lowest NAR (8.95, 6.37 and 3.71 mg/cm^2/day) was recorded by control (Table 7, 8 and 9). This increasing trend with the increase in the concentration of the growth regulators might be attributed to increase in the chlorophyll content in the leaves, which helped in increasing photosynthetic activity and hence net assimilation rate. Harmath (2012) [5] observed higher photosynthetic rate in leaves of plants sprayed with growth retardants like alar, cultar and cococyl. Madalgeri (1996) [9] observed 8.3% improvement in NAR by spraying growth retardants in potato. Results of present studies are in agreement with Balamani and Poovaiah (1985) [1].

Table 7: Effect of growth regulators and disbudding on net assimilation rate (mg/cm^2/day) between 140-155 DAP in dahlia (*Dahlia variabilis* cv. Charmit)

Growth regulators	Disbudding		Mean
	No disbudding	Complete disbudding	
Control (Distilled water)	8.89	9.01	8.95
Ethephon @500 ppm	11.52	11.89	11.71
Ethephon@ 750 ppm	14.95	15.23	15.09
Ethephon @ 1000 ppm	20.78	20.99	20.89
Alar @ 1000 ppm	14.09	14.51	14.30
Alar @ 2000 ppm	19.07	19.47	19.27
Alar @ 3000 ppm	24.17	24.69	24.43
MH @ 500 ppm	9.03	9.17	9.10
MH @ 750 ppm	15.07	15.43	15.25
MH @ 1000 ppm	20.31	20.74	20.53
Mean	15.79	16.11	

C.D ($p \leq 0.05$), Growth regulators =1.37
Disbudding = NS, Growth regulators x Disbudding = NS

Table 8: Effect of growth regulators and disbudding on net assimilation rate (mg/cm^2/day) between 155 -170 DAP in dahlia (*Dahlia variabilis* cv. Charmit)

Growth regulators	Disbudding		Mean
	No disbudding	Complete disbudding	
Control (Distilled water)	6.26	6.49	6.37
Ethephon @500 ppm	9.54	9.86	9.70
Ethephon@ 750 ppm	10.53	10.83	10.68
Ethephon @ 1000 ppm	15.02	15.46	15.24
Alar @ 1000 ppm	10.73	10.97	10.85
Alar @ 2000 ppm	11.87	12.16	12.01
Alar @ 3000 ppm	17.21	17.49	17.35
MH @ 500 ppm	6.87	7.14	7.01
MH @ 750 ppm	10.77	11.03	10.90
MH @ 1000 ppm	14.10	14.51	14.31
Mean	10.16	11.59	

C.D ($p \leq 0.05$), Growth regulators = 1.01
Disbudding = NS, Growth regulators x Disbudding = NS

Table 9: Effect of growth regulators and disbudding on net assimilation rate ($mg/cm^2/day$) between 170-185 DAP in dahlia (*Dahlia variabilis* cv. Charmit)

Growth regulators	Disbudding		Mean
	No disbudding	Complete disbudding	
Control (Distilled water)	3.45	3.97	3.71
Ethephon @500 ppm	5.88	6.15	6.01
Ethephon@ 750 ppm	8.99	9.18	9.09
Ethephon @ 1000 ppm	12.43	12.98	12.71
Alar @ 1000 ppm	9.29	9.55	9.42
Alar @ 2000 ppm	9.86	10.05	9.95
Alar @ 3000 ppm	15.29	15.58	15.43
MH @ 500 ppm	7.35	7.99	7.67
MH @ 750 ppm	7.85	8.13	7.99
MH @ 1000 ppm	11.63	11.97	11.80
Mean	9.20	9.55	

C.D ($p \leq 0.05$)
Growth regulators = 0.99
Disbudding = NS
Growth regulators x Disbudding = NS

Conclusion

Growth regulators had a significant effect on the plant architecture and tuber production. They were effective in reducing plant height, primary branch length and increasing number of branches, leaves and stem diameter. This had a significant effect on all the tuber parameter, recording maximum tuber fresh weight, number and size compared to control. Among the three growth regulators, MH 1000 ppm proved very effective. Growth regulators were effective in increasing the relative growth rate of stem, tuber and net assimilation rate of plant. Disbudding significantly reduced plant height, increased leaf number, primary and secondary branches, which made the plant bushy. This had a significant positive effect on all the tuber parameters.

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