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Effect of Foliar Application of GA_3 on Morphological Features of Popular Cultivars of Apple (*Malus×Domestica* Borkh.) under Nursery Conditions in Mid-hill Asia

Palak Sharma[1*], C. L. Sharma[2], Neeraj Sankhyan[3] and Vibhas[1]

[1]Dept. of Seed Science and Technology, [2]Dept. of Fruit Science, [3]Dept. of Basic Sciences, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh (173 230), India

Corresponding Author

Palak Sharma
e-mail: plkshrma007@gmail.com

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Abstract

The experiment was conducted during April, 2018 to February, 2019 at Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India to study the effect of foliar applications of GA_3 on nursery plants of three different cultivars of apple, viz. Gale Gala, Super Chief, and Jeromine. The experiment was laid out in Randomised Block Design (Factorial) and was replicated thrice. The growth regulators were applied at three different concentrations namely, 6.25 ppm, 12.5 ppm and 25 ppm. The growth regulators were applied to the leaves of different replications twice; once in the first week of July and the second time, a month later. The analysis of data of different treatments revealed that GA_3 @ 12.5 ppm significantly increased plant growth with respect to all the growth parameters of different apple cultivars viz. plant height, stock girth, scion girth, number of leaves plant^{-1}, leaf area, internodal length, primary root length, secondary root number, secondary root length, fresh weight of shoots, dry weight of shoots, fresh weight of roots, dry weight of roots, biomass of nursery plants, and percentage of saleable plants over control. Further, it was also observed that amongst the cultivars, Gale Gala performed noticeably better in terms of all the growth parameters namely, plant height, stock girth, scion girth, number of leaves plant^{-1}, leaf area, internodal length, primary and secondary root length, secondary root number, fresh and dry weight of shoots and roots, biomass of nursery plants as well as percentage of saleable plants.

Keywords: Apple, cultivars, growth parameters, GA_3

1. Introduction

Apples (*Malus×Domestica* Borkh.) are one of the main horticultural crops in the world (Kaplan et al., 2024). It is the most important temperate fruit of the north-western Himalayan region (Verma et al., 2022) and belongs to family Rosaceae. Apple is a deciduous crop (Bharti et al., 2016) and is rich in phytonutrients, antioxidants, Vitamin-C, β-carotene and is consumed fresh or occasionally as a cooked product (Verma et al., 2022). The cultivated apple originated in the region which includes Asia Minor, Caucasus and Central Asia. In India, its cultivation dates back to second half of the 18th century (Chauhan, 2021). It is predominantly grown in Jammu and Kashmir, Himachal Pradesh and parts of Uttarakhand however, it is also cultivated in Arunachal Pradesh, Nagaland and Meghalaya (Kumari and Thakur, 2019). It is the most remunerative crop for the inhabitants of these states. India is ranked as the fifth largest world's Apple producing country (Singh et al., 2023). Hence, there is a huge demand of good quality apple plants every year. A prerequisite for the dynamic cultivation of orchard plants is high-quality nursery material (Kaplan et al., 2023). The quality of nursery trees can have influence on growth and precocity (Kumawat et al., 2024). The demand for some popular new coloured strains of apple suitable for mid-hill regions of the state has increased manifold in the recent years. Among these cultivars, Jeromine, Super Chief and Gale gala have become more popular in the mid-hill zone of the state. Therefore, the fundamental requirement for satisfying the enormous demand for nursery plants is the development of high-quality nursery plants. It is crucial for a successful orchard that nursery plants are not only true to type but also healthy and of high quality. However, at the end of the growing season, all the grafted plants do not attain a standard size and hence are found to be unsaleable. Presently growth regulators are given considerable importance for their value in regulating the various growth

and development processes in plants (Thorat et al., 2018). Plant growth regulators are the naturally occurring hormones in the higher plants for controlling growth and physiological factors. They are synthesized in one site of the plant and utilized by the other part of the plant (Kumar et al., 2022). Their synthetic counterparts initiate a variety of biochemical and physiological processes related to plant growth and development (Sabagh et al., 2021). Nine major classes of plant hormones have been discovered and categorized in the last century (Taiz et al., 2015). These nine classes include auxins, gibberellins, cytokinins, abscisic acid, ethylene, salicylic acid, brassinosteroids, jasmonates and strigolactones. Gibberellins (GA) are diterpene plant hormones that influence various aspects of growth and development through complex biosynthetic processes (Kumar et al., 2022). Gibberellic acid (GA_3) has been reported to increase cell division (Sachs et al., 1959) and cell enlargement (Haber and Leopold, 1960; Haber et al., 1969) but has low phytotoxic effect (Kumar et al., 2022). By changing the rheological characteristics of the cell wall, gibberellins promote cell elongation. As a result, the cell's water potential is lowered, enabling water absorption and consequently, an increase in the cell volume (Jones and Kaufman, 1983). Gibberellins stimulate vegetative growth and their growth stimulating responses in fruit trees are well documented. Furthermore, they also result in stem elongation of the plants (Manzoor, 2021). The purpose of the current investigation is to determine how GA_3 foliar sprays affect the growth and quality indicators in apple nursery plants.

2. Materials and Methods

2.1. Experimental location

The present investigation was undertaken in April, 2018–February, 2019 at the Khaltoo farm of Department of Seed Science and Technology, Dr. Y.S. Parmar University of Horticulture and Forestry Nauni, Solan, Himachal Pradesh, India. The experimental location was situated at 30° 50' 45" latitude and 77° 88' 33" longitude at an elevation of 1320 m above mean sea level, representing the mid hill zone of the state. Experimental field was prepared by repeated ploughing with the help of a power tiller and well rotten FYM @ 60 kg m^{-2} area was mixed in the soil at the time of preparation of beds. The nursery beds were prepared in East-West direction and one year old seedlings were planted in these beds at a distance of 20 cm and 30 cm apart in rows in North-West direction in the first week of February. After planting, the nursery beds were irrigated lightly. Nursery operations like irrigation and weeding were done at regular intervals. Scion wood of apple cultivars suitable for mid-hills viz., Jeromine (C_1), Super Chief (C_2) and Gale Gala (C_3) were tongue grafted on these seedlings in the second week of March. The experiment was laid out in a Randomised Block Design (Factorial) having three replications. Twenty grafted seedlings with uniform diameter and growth were selected under each replication for the various treatment applications and observations to be recorded.

The grafted seedlings were sprayed with three different levels of GA_3 @ 6.25 ppm (T_1), 12.5 ppm (T_2) and 25 ppm (T_3), along with control-water spray (T_4) in respective treatments with a hand spray pump in the first week of July followed by another spray one month later. Before spraying, 0.5 ml of wetting agent (Indtron-AE) $litre^{-1}$ of solution was added as a surfactant to reduce surface tension and to facilitate the absorption of solution sprayed. The spraying operation was performed on a clear and calm day during the morning hours to obtain better absorption. Spraying was done till the leaves were wet. The spray was started with lower concentration of each chemical in order to avoid the dilution of any particular strength of spray solution used.

2.2. Observations recorded

2.2.1. Above ground parameters

Five plants $replication^{-1}$ were randomly selected for recording the observations.

2.2.1.1. Plant height (cm)

Plant height was measured with a measuring scale from the surface of soil to the terminal bud of the main axis and the data was expressed in centimetres (cm).

2.2.1.2. Stock and scion girth (cm)

The stock and scion diameters of plants were recorded 5 cm below and 5 cm above the graft union, respectively with the help of Vernier Calipers and expressed in millimetres (mm). The stock and scion girths were calculated by using the following formula: Stock/Scion girth=$2\pi r$.

2.2.1.3. Number of leaves $plant^{-1}$

All the leaves, irrespective of their size were counted before the onset of leaf fall in November and the average number of leaves $plant^{-1}$ was calculated.

2.2.1.4. Leaf area (cm^2)

The leaf area was measured before the onset of leaf fall, with the help of LI-COR Model-3100 leaf area meter and average leaf area was expressed in square centimetres (cm^2).

2.2.1.5. Internodal length (cm)

The internodal length was calculated by dividing the plant height with the total number of nodes and expressed as average internodal length $plant^{-1}$ in centimetres (cm).

2.2.2. Below ground parameters

Five plants $replication^{-1}$ were randomly selected from the uprooted plants.

2.2.2.1. Primary and secondary root length (cm)

The length of primary and secondary roots (arising from primary root and upto 2 millimeters in diameter) of these plants was then measured with the help of a measuring tape

and expressed in centimetres (cm).

2.2.2.2. Secondary root number

The number of such secondary roots was counted and expressed as the number of secondary roots seedling^{-1}.

2.2.2.3. Fresh weight of shoots and roots (g)

The shoot and root portions of five plants replication^{-1} used for recording data on biomass were cut into small pieces and the fresh weight of shoots and roots was recorded on a top pan electronic balance and expressed in grams (g).

2.2.2.4. Dry weight of shoots and roots (g)

The shoots and roots cut for recording the fresh weight were dried in an oven at a temperature of 65°C for about 72 hours. The dry weight of shoots and roots was recorded on a top pan electronic balance and expressed in grams (g).

2.2.3. Biomass of nursery plants (g)

The total dry weight of shoot and root of each plant was added to work out the total biomass of plants and expressed in grams (g) on dry weight basis. It is important to note that the vegetative characteristics viz., plant height, stock and scion girth and internodal length were recorded at the cessation of growth in December. The other parameters viz., primary and secondary root length, secondary root number, fresh and dry weight of shoots and roots, biomass of nursery plants and proportion of saleable plants were estimated after the plants were uprooted.

2.2.4. Proportion of saleable plants (%)

After the end of season, *i.e.,* in the last week of December, when all the plants were uprooted, the proportion of saleable plants was estimated. The plants with a height of 90 cm or more with well-developed root system and free from insect-pest and disease infestations were considered fit for sale and the number of such saleable plants was counted in each treatment and the results were expressed in per cent.

2.3. Statistical analysis

All the parameters were statistically analyzed with the standard procedure as suggested by Gomez and Gomez (1983). The level of significance for different variables was tested at 5% (p<=0.05) value of significance. The calculated f value was compared to the table f value to determine the significance of a treatment in case of all the parameters.

3. Results and Discussion

3.1. Above ground parameters

The effect of foliar sprays of GA_3 on the above ground parameters of nursery plants of different apple cultivars is depicted in Table 1. It is evident from the data (Table 1) that all the above ground plant parameters were significantly

Table 1: Effect of foliar sprays of GA_3 on above ground parameters on different cultivars of apple

Treatment details	Plant height (cm)				Stock girth (mm)				Scion girth (mm)			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
T_1	118.90	122.47	129.47	123.61	28.51	31.50	31.57	30.53	23.27	24.18	28.35	25.27
T_2	127.93	131.80	138.53*	132.76**	34.50	36.64	38.72*	36.62**	28.43	31.09*	31.92*	30.15**
T_3	120.00	123.80	133.53	125.78	31.14	31.66	32.05	31.62	23.81	25.54	26.82	25.39
T_4	99.27	109.67	119.40	109.44	21.87	22.50	25.57	23.31	15.90	16.22	18.92	17.01
Mean	116.53	121.93	130.23**		29.00	30.58	31.98**		22.60	24.26	26.51**	
	C	T			C	T			C	T		
CD (p=0.05)	1.88	2.17			1.21	1.40			1.12	1.30		

Tabe 1: Continue...

Treatment details	Number of leaves plant^{-1}				Leaf area (cm^2)				Internodal length (cm)			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
T_1	46.27	47.20	50.40	47.96	28.72	29.39	33.49	30.53	2.26	2.37	2.67	2.43
T_2	51.77	52.87	54.73*	53.12**	32.04	34.42	42.23*	36.23**	2.44	2.57	2.91*	2.64**
T_3	47.53	48.13	50.33	48.67	29.07	30.14	39.95	33.05	2.32	2.39	2.70	2.47
T_4	42.20	44.67	46.73	44.87	27.55	27.32	32.33	29.07	2.05	2.15	2.32	2.18
Mean	47.19	48.22	50.55**		29.34	30.32	37.00**		2.27	2.37	2.65**	
	C	T			C	T			C	T		
CD (p=0.05)	0.66	0.77			0.81	0.93			0.06	0.08		

influenced by the application of different concentrations of GA_3. The maximum plant height (132.76 cm) was observed in treatment T_2 (GA_3 @ 12.5 ppm) which was significantly higher than all the other treatments. The minimum plant height (109.44 cm) was recorded in T_4 (Control-Water Spray). Among the cultivars, the maximum plant height (130.23 cm) was observed in Gale Gala whereas the minimum (116.53 cm) was recorded in Jeromine. This may be attributed to the fact that GA fine-tunes multiple aspects of biological events and plays a pivotal role in plant height determinant (Wang and Wang, 2022). The increase in plant height with the application of GA_3 might be due to the increased cell enlargement effect in plants (Haber and Leopold, 1960; Haber et al., 1969). These findings are in line with those of Katel et al. (2022) who revealed in their review paper that gibberellins enhance plant height in strawberry. Similar to this, Kumar et al. (2018) also found that field bean plants sprayed with GA_3 recorded higher plant height. Zhang et al. (2016a) also found that GA_3 stimulated vegetative growth in Fuji cultivar of apple. Kumar et al. (2013) also found that GA_3 at 12.5 ppm resulted in maximum plant height in the apple nursery plants.

The stock girth (36.62 mm) was significantly higher in treatment T_2 (GA_3 @ 12.5 ppm), while it was minimum (23.31 mm) in T_4 (Control-Water Spray). Among the cultivars, Gale Gala produced plants with significantly higher stock girth (31.98 mm) whereas the minimum (29.00 mm) stock girth was recorded in Jeromine. Fatima et al. (2024b) found that plant girth was greatly influenced by the application of combination with GA_3 with macro-nutrients in chilli seedlings. Similarly, Das et al. (2021) found that GA_3 led to an enhanced stem girth over control in case of lemon.

The scion girth was maximum (30.15 mm) in T_2 (GA_3 @ 12.5 ppm) which was significantly higher than all the other treatments while the minimum scion girth (17.01 mm) was found in T_4 (Control-Water Spray). Among the cultivars, scion girth was maximum (26.51 mm) in Gale Gala and minimum (22.60 mm) in Jeromine. Mosa et al. (2022) also found that application of GA improved shoot thickness of pear over control. Canli and Orhan (2013), while studying the effect of GA_3 on pear and cherry seedlings also observed that the maximum stem thickness (6.6 mm) in pear seedlings was obtained with single application of 400 ppm GA_3 in combination with plastic tunneling, while the minimum value was observed in control.

The number of leaves plant^{-1} was found to be maximum (53.12) in T_2 (GA_3 @ 12.5 ppm) and was significantly higher than all the other treatments, whereas it was minimum (44.87) in T_4 (Control-Water Spray). Among the cultivars, the number of leaves plant^{-1} (50.55) in Gale Gala was significantly higher than the other cultivars. The number of leaves plant^{-1} was minimum (47.19) in Jeromine. Bala et al. (2024) observed that application of GA_3 led to an enhanced number of leaves over control in Radish. Joolka et al. (2010) also studied the influence of bio-fertilizers, GA_3 and their combinations on the growth of pecan seedlings and reported that GA_3 application exerted significant influence on leaf number.

The highest leaf area (36.23 cm^2) was recorded in T_2 (GA_3 @ 12.5 ppm) whereas the minimum (29.07 cm^2) was observed in T_4 (Control-Water Spray). Within the cultivars, the leaf area was maximum in Gale Gala (37.00 cm^2) while Jeromine was found to have the lowest leaf area (29.35 cm^2). The findings are in line with those of Zhang et al. (2016b) who found that foliar application of GA_3 increased leaf area of rabbit eye blueberry. Dev (2002) also reported that the application of different concentrations of GA_3 significantly increased the average leaf area as compared to control in pear cv. Flemish Beauty.

The internodal length was found to be maximum (2.64 cm) in T_2 (GA_3 @ 12.5 ppm) while it was minimum (2.18 cm) in T_4 (Control-Water Spray). Among the cultivars, the highest internodal length was found in Gale Gala (2.65 cm) whereas the lowest internodal length (2.27 cm) was recorded in Jeromine. The increase in the internodal length of nursery plants might be due to the fact that gibberellins stimulate cell elongation by altering the rheological properties of cell wall. As a consequence, the water potential of the cell is lowered allowing for more water uptake and therefore an increase in cell volume (Jones and Kaufman, 1983). These findings are in line with those of Shan et al. (2021) who found that application of GA_3 to soybean increased its internode length.

Table 2: Effect of foliar sprays of GA_3 on below ground parameters on different cultivars of apple

Treatment details	Primary root length (cm)				Secondary root number				Secondary root length (cm)			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
T1	20.10	23.47	25.13	22.90	7.33	8.67	9.33	8.44	8.73	12.93	13.07	11.58
T2	24.97	28.53	31.17*	28.22**	11.00	12.67	14.67*	12.78**	14.70	16.30	18.30*	16.43**
T3	20.43	24.63	26.17	23.74	8.67	10.33	11.67	10.22	9.90	13.03	13.93	12.29
T4	23.03	26.17	27.23	25.48	6.33	8.33	8.67	7.78	10.17	12.43	12.83	11.81
Mean	22.13	25.70	27.43**		8.33	10.00	11.08**		10.88	13.68	14.53**	
	C	T			C	T			C	T		
CD (p=0.05)	0.43	0.49			0.47	0.55			0.42	0.49		

3.2. Below ground parameters

Table 2 depicted the effect of foliar sprays of GA_3 on the below ground parameters of the nursery plants of different apple cultivars. These parameters were also significantly influenced by the application of different GA_3 concentrations. The primary root length was maximum (28.22 cm) in T_2 (GA_3 @ 12.5 ppm) which was significantly higher than all the other treatments while the minimum primary root length (25.48 cm) was observed in T_4 (Control-Water Spray). Among the cultivars, the maximum primary root length (27.43 cm) was found in Gale Gala whereas the minimum (22.13 cm) was observed in Jeromine. These findings are in line with those of Leilah and Khan (2019) who found that application of GA_3 enhanced root length in sugar beet. Kumar et al. (2013) also studied the effect of growth regulators on apple nursery plants and reported that GA_3 @ 12.5 ppm increased the root length of plants.

The highest number of secondary roots (12.78) was observed in T_2 (GA_3 @ 12.5 ppm) while the lowest was reported (7.78) in T_4 (Control-Water Spray). Within the cultivars, the maximum number of secondary roots (11.08) was found in Gale Gala whereas the minimum number of secondary roots (8.33) was observed in Jeromine. While studying the effect of different concentrations of GA on seedling growth of Rangpur Lime, Dilip et al. (2017) also found that application of GA @ 80 ppm significantly increased the number of roots in the seedlings. The maximum secondary root length (16.43 cm) was observed in T_2 (GA_3 @ 12.5 ppm) whereas the minimum (11.81 cm) was recorded in T_4 (Control-Water Spray). Among the cultivars, Gale Gala produced plants with the highest secondary root length (14.53 cm) while the secondary root length was minimum (10.88 cm) in Jeromine.

3.3. Biomass of nursery plants

The effect of foliar sprays of GA_3 on biomass of nursery plants of different cultivars of apple is shown in Table 3. It is evident from the data that different concentrations of GA_3 significantly influenced the fresh and dry weights of both the shoots and roots as well as the overall biomass of nursery plants of apple. The fresh weight of shoots was maximum (83.28 g) in T_2 (GA_3 @ 12.5 ppm) minimum (40.94 g) in T_4 (Control-Water Spray). Among the cultivars, the maximum fresh weight of shoots (76.92 g) was recorded for Gale Gala whereas the minimum was recorded for Jeromine the minimum (46.96 g). Similar to this, Fatima et al. (2024a) found that compared with the control, gibberellic acid recorded the highest increase in dry weight of shoots in case of turnip. Jamwal et al. (2021) found that the fresh weight in *Fagopyrum esculentum* shoots was maximum in plants treated with Benzylaminopurine+GA. Dilip et al. (2017) also found that application of GA @ 80 ppm resulted in the maximum fresh weight of shoots in Rangpur Lime.

Table 3: Effect of foliar sprays of GA_3 on biomass of different cultivars of apple

Treatment details	Fresh weight of shoots (g)				Dry weight of shoots (g)				Fresh weight of roots (g)			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
T_1	42.17	44.50	75.00	53.89	28.33	28.50	41.50	32.78	31.83	30.17	45.00	35.67
T_2	62.17	89.33	98.33*	83.28**	41.33	49.00	50.67*	47.00**	46.85	49.33	63.17*	53.12**
T_3	49.83	63.33	84.50	65.89	33.50	36.83	46.83	39.06	34.33	34.83	45.67	38.28
T_4	33.67	39.33	49.83	40.94	23.00	24.50	34.83	27.44	24.67	31.50	39.83**	32.00
Mean	46.96	59.13	76.92**		31.54	34.71	43.46**		34.42	36.46	48.42	
	C	T			C	T			C	T		
CD (p=0.05)	0.93	1.07			0.90	1.04			1.22	1.41		

Tabe 3: Continue...

Treatment details	Dry weight of roots (g)				Biomass of nursery plants (g)			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
T_1	23.50	25.00	32.50	27.00	51.83	53.50	74.00	59.78
T_2	37.00	41.33	44.83*	41.06**	78.33	90.33	95.50*	88.06**
T_3	25.33	29.67	34.00	29.67	58.83	66.50	80.83	68.72
T_4	18.67	19.50	25.33**	21.17	41.67	44.00	60.17**	48.61
Mean	26.13	28.88	34.17		57.67	63.58	77.63	
	C	T			C	T		
CD (p=0.05)	0.61	0.71			1.00	1.15		

The maximum dry weight of shoots (47.00 g) was found in T_2 (GA_3 @ 12.5 ppm) which was significantly higher than that derived from all the other treatments while the minimum dry weight of shoots (27.44 g) was reported in T_4 (Control-Water Spray). Within the cultivars, the dry weight of shoots was the highest (43.46 g) in Gale Gala and the lowest (31.54 g) in Jeromine. Chauhan et al. (2019) found that GA_3 significantly promoted the dry weight of oat seedling. Similarly, GA_3 treatment promoted dry weight in *Leymus chinensis* (Ma et al., 2018). The effect of GA_3 on plant dry weight in peach seedlings was studied by Casper and Taylor (1989) who found that the application of GA_3 @ 50 mg l^{-1} resulted in the increased plant dry weight by 38%.

The fresh weight of roots was maximum (53.12 g) in T_2 (GA_3 @ 12.5 ppm) whereas the minimum fresh weight of roots (32.00 g) was found in T_4 (Control-Water Spray). Among the cultivars, the highest fresh weight of roots (48.42 g) was observed in Gale Gala whereas the lowest (34.42 g) was recorded in Jeromine. The above findings are in accordance Leilah and Khan (2019) who found that GA_3 significantly increased root fresh weight in sugar beet. Dilip et al. (2017) also reported that the application of GA_3 @ 80 ppm on Rangpur Lime significantly increased the fresh weight of roots.

The maximum dry weight of roots (41.06 g) was found in T_2 (GA_3 @ 12.5 ppm) whereas the minimum (21.17 g) was observed in T_4 (Control-Water Spray). Within the cultivars, the dry weight of roots was the highest (34.17 g) in Gale Gala and the lowest (26.13 g) in Jeromine. Our findings are in line with those of Dilip et al. (2017), who found that GA_3 application on Rangpur Lime plants significantly increased the dry weight of roots.

The biomass of nursery plants was maximum (88.06 g) in T_2 (GA_3 @ 12.5 ppm) which was significantly higher than all the other treatments. The biomass of nursery plants was minimum (48.61 g) in T_4 (Control-Water Spray). Among the cultivars, Gale Gala plants had the highest biomass (77.63 g) while Jeromine plants had the lowest biomass (57.67 g). These observations are in consonance with those of Joolka et al. (2004), who while studying the influence of bio-fertilizers, GA_3 and their combinations on the growth of pecan seedlings reported that the application of bio-fertilizers and GA_3 alone and in combinations exerted significant influence on the biomass of seedlings.

Table 4: Effect of foliar sprays of GA_3 on proportion of saleable plants (%) on different cultivars of apple

Treatment details	Proportion of saleable plants (%)			
	C_1	C_2	C_3	Mean
T_1	81.67 (9.09)	75.00 (8.72)	91.67 (9.63)	82.78 (9.15)
T_2	95.00 (9.80)	96.67* (9.88)	98.33* (9.97)	96.67** (9.88)
T_3	86.67 (9.39)	88.33 (9.45)	93.33 (9.71)	89.44 (9.51)
T_4	61.67 (7.92)	75.00 (8.72)	76.67 (8.81)	71.11 (8.48)
Mean	81.25 (9.04)	83.75 (9.19)	90.00** (9.53)	
	C	T		
CD (p=0.05)	0.11	0.13		

Figures in parenthesis are square root transformed values

3.4. Proportion of saleable plants

Table 4 depicted the effect of foliar sprays of GA_3 on the proportion of saleable plants (%) in different cultivars of apple. The proportion of saleable plants was significantly higher (96.67%) in T_2 (GA_3 @ 12.5 ppm) and the minimum (71.11%) in T_4 (Control-Water Spray). Gale Gala produced the maximum proportion of saleable plants (90.00%) among the cultivars while Jeromine produced the minimum proportion (81.25%). The increased proportion of saleable plants by the middle dose of GA_3 might be attributed to the fact that the plant growth regulators at appropriate concentrations improve the vegetative characteristics of plants. The gibberellins usually promote cell elongation. However, the synthesis other phytohormones is also responsible for the overall growth and developmental process within plants, which are synergised by the exogenous applications of growth regulators at appropriate concentrations.

4. Conclusion

The foliar applications of GA_3 @ 12.5 ppm significantly improved the nursery plants of apple in terms of all above-ground and below-ground parameters as well as biomass. The proportion of saleable plants was also higher in this treatment. Among the cultivars, Gale Gala performed significantly better than the other two cultivars in terms of all the plant parameters.

5. Acknowledgement

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6. References

Bala, R., Rattan, P., Reddy, A.H., 2024. Influence of growth regulators on growth, seed yield and quality of radish (*Raphanus sativus* L.). International Journal of Economic Plants 11(3), 240–246.

Bharti, Mahajan, P.K., Chandel, A., 2016. Multivariate analysis of yield data of apple crop for optimizing productivity in Himachal Pradesh. International Journal of Bio-resource and Stress Management 7(2), 191–194.

Canli, F.A., Orhan, H., 2013. Effects of foliar gibberellic acid applications on vegetative growth of pear, apple and

cherry seedlings. International Journal of Natural and Engineering Sciences 3, 95–98. https://www.ijnes.org/index.php/ijnes/article/view/443.

Casper, J.A., Taylor, B.H., 1989. Growth and development of young 'Loring' peach tree after foliar spray of paclobutrazol and GA_3. HortScience 24(2), 240–242. https://doi.org/10.21273/HORTSCI.24.2.240.

Chauhan, A., AbuAmarah, B.A., Kumar, A., Verma, J.S., Ghramh, H.A., Khan, K.A., Ansari, M.J., 2019. Influence of gibberellic acid and different salt concentrations on germination percentage and physiological parameters of oat cultivars. Saudi Journal of Biological Sciences 26(6), 1298–1304. https://doi.org/10.1016/j.sjbs.2019.04.014.

Chauhan, N., 2021. Effect of PGR's and nursery techniques on production of feathered nursery plants of apple (*Malus*×*Domestica* Borkh.). MSc Thesis, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India.

Das, P., Prasad, V.M., Bahadur, V., Topno, S.E., Paruchuru, V.S.K.K., 2021. Effect of foliar application of bio-regulators (GA_3 and NAA) on vegetative growth characters and establishment of lemon *Citrus limon* (L.) cv. Eureka under subtropical Prayagraj agro climatic condition. Biological Forum 13(3), 159–162.

Dev, N., 2002. Effect of plant growth regulators, branch bending and trunk girdling on growth, flowering and fruiting of pear (*Pyrus communis* L.) cv. flemish beauty. MSc thesis, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan.

Dilip, W.S., Singh, D., Moharana, D., Rout, S., Patra, S.S., 2017. Effect of gibberellic acid (GA) different concentrations at different time intervals on seed germination and seedling growth of Rangpur Lime. Journal of Agroecology and Natural Resource Management 4, 157–165.

Fatima, A., Umbreen, S., Sadia, S., Waheed, M., Arshad, F., Malik, M.R., Hashem, A., Kumar, A., AbdAllah, E.F., 2024a. Mitigation of salinity-induced adverse effects through exogenous application of gibberellic acid in turnip (*Brassica rapa* L.). Cogent Food & Agriculture 10(1), 2392042. https://doi.org/10.1080/23311932.2024.2392042.

Fatima, I., Fatima, A., Shah, M.A., Farooq, M.A., Ahmad, I.A., Ejaz, I., Adjibolosoo, D., Laila, U., Rasheed, M.A., Shahid, A.I., Tariq, A., Hani, U., 2024b. Individual and synergistic effects of different fertilizers and gibberellin on growth and morphology of chili seedlings. Ecological Frontiers 44(2), 275–281. https://doi.org/10.1016/j.chnaes.2023.06.003.

Gomez, K.A., Gomez, A.A., 1983. Statistical procedures for agricultural research. John Wiley and Sons Inc., New York.

Haber, A.H., Leopold, H.J., 1960. Effect of gibberellins on gamma irradiated wheat. American Journal of Botany. doi:10.1002/j.1537-2197.1960.tb07106.x.

Haber, A.H., Ford, D.E., Perdue, U., 1969. Action of GA and abscisic acid on lettuce seed germination without acting as nucleus DNA Synthesis. Plant Physiology. http://www.jstor.org/stable/4261674.

Jamwal, K., Bhattacharya, S., Puri, S., 2021. Effects of plant growth regulators on biomass, number of nodes, internodal length and leaf water relative content of *Fagopyrum esculentum* Moench of Himalayan region. International Journal of Economic Plants 8(2), 094–102.

Jones, R.L., Kaufman, P.B., 1983. Role of gibberellins in plant cell elongation. Critical Reviews in Plant Sciences. doi: 10.1080/07352688309382170.

Joolka, N.K., Singh, R.R., Sharma, M.K., 2004. Influence of biofertilizers, GA_3 and their combinations on the growth of pecan seedlings. Indian Journal of Horticulture Indian Journal of Horticulture 61(3), 226–228. https://eurekamag.com/research/004/202/004202555.php.

Kaplan, M., Klimek, K., Borkowska, A., Buczynski, K., 2023. Effect of growth regulators on the quality of apple tree whorls. Applied Sciences 13(20), 11472. https://doi.org/10.3390/app132011472.

Kaplan, M., Klimek, K., Buczynski, K., 2024. Analysis of the impact of treatments stimulating branching on the quality of maiden apple trees. Agriculture 14(10), 1757. https://doi.org/10.3390/agriculture14101757.

Katel, S., Mandal, H.R., Kattel, S., Yadav, S.P.S., Lamshal, B.S., 2022. Impacts of plant growth regulators in strawberry plant: A review. Heliyon 8, e11959.

Kumar, E.S., Channaveerswami, A.S., Merwade, M.N., Naik, V.R., Krishna, A., 2018. Influence of nipping and hormonal sprays on growth and seed yield in field bean [*Lablab purpureus* (L.) Sweet] genotypes. International Journal of Economic Plants 5(1), 008–014.

Kumar, J., Sharma, V.P., Thakur, D., 2013. Studies on the effect of growth regulators on production of apple nursery plants. The Asian Journal of Horticulture 8(1), 93–96.

Kumar, P., Singh, V., Johar, V., Kumar, A., Kadlag, S.S., 2022. Uses of plant growth regulators and biofertilizers in fruit crops: A review. International Journal of Environment and Climate Change 12(11), 314–326.

Kumari, S., Thakur, A., 2019. Morphological and physio-biochemical changes in response to foliar application of brassinosteroid and water stress in apple plants under pot culture study. International Journal of Bio-resource and Stress Management 10(1), 039–045.

Kumawat, K.L., Raja, W.H., Nabi, S.U., 2024. Quality of nursery trees is critical for optimal growth and inducing precocity in apple. Applied Fruit Science 66, 2135–2143. https://doi.org/10.1007/s10341-024-01202-9.

Leilah, A.A.A., Khan, N., 2019. Interactive effects of gibberellic acid and nitrogen fertilization on the growth, yield, and quality of sugar beet. Agronomy 11, 137. https://doi.org/10.3390/agronomy 11010137.

Ma, H.Y., Zhao, D.D., Ning, Q.R., Wei, J.P., Li, Y., Wang, M.M.,

Liu, X.L., Jiang, C.J., Liang, Z.W., 2018. A multi-year beneficial effect of seed priming with gibberellic acid-3 (GA_3) on plant growth and production in a perennial grass, *Leymus chinensis*. Scientific Reports 8, 13214. https://doi.org/10.1038/s41598-018-31471-w.

Manzoor, S., 2021. Effect of plant bio-regulators and urea on seedling growth of walnut (*Juglans regia* L.). MSc Thesis, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, India.

Mosa, W.F.A., EL-Megeed, N.A.A., Ali, M.M., Abada, H.S., Ali, H.M., Siddiqui, M.H., Sas-Paszt, L., 2022. Preharvest foliar applications of citric acid, gibberellic acid and humic acid improve growth and fruit quality of 'Le Conte' pear (*Pyrus communis* L.). Horticulturae 8, 507. https://doi.org/10.3390/horticulturae8060507.

Sabagh, A.E., Mbarki, S., Hossain, A., Iqbal, M.A., Islam, M.S., Raza, A., Llanes, A., Reginato, M., Rahman, M.A., Mahboob, W., Singhal, R.K., Kumari, A., Rajendran, K., Wasaya, A., Javed, T., Shabbir, R., Rahim, J., Barutcular, C., Habib ur Rahman, M., Raza, M.A., Ratnasekera, D., Konuskan, l.O., Hossain, M.A., Meena, V.S., Ahmed, S., Ahmad, Z., Mubeen, M., Singh, K., Skalicky, M., Brestic, M., Sytar, O., Karademir, E., Karademir, C., Erman, M., Farooq, M., 2021. Potential role of plant growth regulators in administering crucial processes against abiotic stresses. Frontiers in Agronomy 3, 648694.

Sachs, K.M., Bretz, C., Lang, A., 1959. Cell division and gibberellic acid. Experimental Cell Research. doi: 10.1016/0014-4827(59)90003-5.

Shan, F., Zhang, R., Zhang, J., Wang, C., Lyu, X., Xin, T., Yan, C., Dong, S., Ma, C., Gong, Z., 2021. Study on the regulatory effects of GA_3 on soybean internode elongation. Plants 10, 1737. https://doi.org/ 10.3390/plants10081737.

Singh, S., Sharma, P., Saini, M., Mehta, P., 2023. Perceived constraints in high-density apple cultivation by the farmers of the mid-hills area of Himachal Pradesh. International Journal of Economic Plants 10(3), 246–251.

Taiz, L., Zeiger, E., Moller, I.M., Murphy, A., 2015. Signals and signal transduction. In: Plant physiology and development, Sixth Edition. Sunderland, MA: Sinauer Associates, 408–446.

Thorat, U.K., Dheware, R.M., Jadhav, A.R., 2018. Influence of growth regulators on quality and fruit attributes of custard apple (*Annona squamosa* L.) cv. Balanaga. International Journal of Economic Plants 5(3), 151–153.

Verma, S., Gautam, H.R., Khosla, K., 2022. Apple scab (*Venturia inaequalis* Wint) management using a novel fungicide combination in the north-western Himalayas of India. International Journal of Economic Plants 9(1), 011–017.

Wang, S., Wang, Y., 2022. Harnessing hormone gibberellin knowledge for plant height regulation. Plant Cell Reports 41, 1945–1935.

Zhang, S., Zhang, D., Fan, S., Du, L., Shen, Y., Xing, L., Li, Y., Ma, J., Han, M., 2016a. Effect of exogenous GA_3 and its inhibitor paclobutrazol on floral formation, endogenous hormones, and flowering-associated genes in 'Fuji' apple (*Malus domestica* Borkh.). Plant Physiology and Biochemistry 107, 178–186.

Zhang, Y.X., Chun, I.J., Zhang, L.L., Hong, S.B., Zheng, W.W., Xu, K., 2016b. Effect of gibberellic acid application on plant growth attributes, return bloom, and fruit quality of rabbiteye blueberry. Scientia Horticulturae 200, 13–18.