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Seed germination and seedling growth of peach under the influence of plant bioregulators in the mid hill condition of Uttarakhand

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Abstract
Peach, classified under Rosaceae family, is a temperate, fleshy stone fruit, which produces seeds that undergoes dormancy and take time to germinate after harvest. An interval of after ripening is required for specific biochemical and physiological changes to take place within the seed, which helps the dormant embryo to resume growth. The field research was conducted during 2022-23 under natural conditions with the pre-soaking of peach seeds in distilled water (control); GA_3 (250, 500, 750, 1000 ppm); kinetin (100, 150, 200, 250 ppm); thiourea (1500, 3000, 4500, 6000 ppm) for 24 hours and then sown in polybags. The results revealed that GA_3 500 ppm resulted in early germination (83), maximum germination rate (0.20 per day), germination percent (78.33%) and higher survival of peach seedlings (93.61%). However, final measurements for seedling attributes were reported at 180 days after sowing. Maximum shoot length (35.14 cm), shoot diameter (3.51 mm) and leaf count per seedling (42.44), highest leaf area (18.95 cm^2), fresh and dry weight of shoot (9.34 g and 3.14 g), root length (15.41 cm), root diameter (3.24 mm), fresh and dry weight of root (2.52 g and 1 g), total fresh weight of seedling (11.86 g) and total dry weight of seedling (4.15 g) were also noted best in GA_3 500 ppm. Thus, it can be concluded that application of GA_3 500 ppm will help in increasing the seed germination and better growth of peach seedlings.

Keywords: *Prunus persica*, seed germination, GA_3, kinetin, thiourea, seedling growth

1. Introduction
Peach, scientifically labelled as *Prunus persica* (L.) Batsch is the most deciduous stone fruit species, placed in family Rosaceae and subfamily Prunoideae. It's basic and somatic chromosome number is 8 and 16, respectively. The fruit is consumed all over the world and is commonly known as 'Aaru' in local language and 'Peach' in English language. The domestication of crop is thought to have arisen in Western China from its wild progenitors (Hedrick, 1917; Scorza and Okie, 1991) [11, 25]. In India, peach stands third in the list of temperate fruit crops, which occupies 0.16 Mha of area, with a production of 1.08 MT, and an average productivity of 6.75 t/ha (Anonymous, 2023) [7]. It is primarily grown in middle hills of Himalayas, expanding from Jammu & Kashmir to the Khasi Hills, at altitudes ranging between 1500-2000 meters above sea level.
The fleshy fruit, peach contains a single seed enclosed by pericarp, which is composed of three layers: endocarp, which is next to the seed, the mesocarp representing the tender consumable portion, and the exocarp or skin which indicates the protective covering of the fruit (Dardick and Callahan, 2014) [6]. The fruit type is botanically known as drupe. The species is a valuable source of vitamins such as carotene, thiamine, riboflavin and niacin, and minerals including potassium, sodium, calcium, magnesium, iron and zinc (Wills *et al.*, 1983) [35]. It has an important place in human nutrition and can be used as fresh, dried and processed fruit. The crop has various medicinal characteristics. The bark is used in treating cough and chronic bronchitis, soothes the nervous system, enhance digestive health, prevents scurvy and possess diuretic properties. The leaves of peach provide sedative, demulcent, astringent, and fever-lowering benefits. In addition, the leaves when fresh, exhibit anthelmintic activity, while powdered form can be applied externally as a styptic to stop bleeding (Raturi *et al.*, 2011; Kant *et al.*, 2018) [23, 14].

For peach propagation, wild peach seedlings are used in hills, while seeds of Sharbati, Sufeda and wild apricot are preferred in plains to grow the rootstock. A high germination percentage combined with a desirable seedling growth is the essential requirement of a good seedling rootstock.

The sprouting in seeds of stone fruits take time after being removed from the fruit, instead they need a period of maturation phase, during which internal physiological and biochemical changes occur within the seed, which enables the dormant embryo to develop (Shah *et al.*, 2013) [28]. Dormancy is a condition in which viable seeds fails to sprout even when the environmental factors such as water, temperature, oxygen and light are favourable for germination (Nikolaeva, 1977; Hartmann *et al.*, 1997) [18, 10]. The quiescence stage in peach seeds results from exogenous and endogenous dormancy which involves the seed coat and the embryo (Diaz and Martin, 1972) [7]. Seed germination is the resumption of active growth of embryo that results in the emergence of young plant (Copeland and McDonald, 1999) [4].

Plant Bioregulators (PBRs) are substances, either endogenous or artificially synthesized, regulate the activation of biochemical or physiological processes in plant tissues, and can modulate seed growth and development at very minimum concentrations (El-al and Faten, 2009) [8]. These include plant growth regulators (auxin, gibberellin and kinetin, etc.) and several chemicals such as thiourea, KNO_3, H_2SO_4 etc. These substances not only increase germination percentage but also inhibit the activity of abscisic acid, which causes cell wall to loosen, promote cell wall synthesis, increase cell wall extensibility and lowers the rigidity of cell wall. This leads to cell division and cell enlargement at the growing tissues of stem, which improves seedling growth of crop. Gibberellic acid (GA_3) has been shown to regulate the synthesis of hydrolytic enzymes, that help in breakdown of seed food reserves, and thus initiate germination (Paleg, 1965) [19]. It also accelerates the seedling height by increasing osmotic uptake of nutrients, causing cell multiplication and cell elongation in the cambium tissue of the internodal region (Shanmugavelu, 1966) [29]. The external application of kinetin has been reported to enhance germination rates and promote vegetative growth when applied at appropriate quantities (Bulard, 1985; Khan, 1971; Selim *et al.*, 1981) [2, 15, 27]. Numerous studies have also documented that exposure of seeds to thiourea chemical can enhance both germination and seedling growth in horticultural crops. In addition, thiourea can break some types of dormancy, such as the seed coat-imposed dormancy seen in deeply dormant *Prunus* species (Hartmann *et al.*, 1997) [10]. Collectively, multiple researches have shown that the application of plant bioregulators aids in the elimination or weakening of seed coat, which shortens the duration required for stratification to break dormancy and enhance the germination of unstratified peach seeds (Tukey and Barrett, 1936; Mehanna *et al.*, 1985) [33, 17].

2. Materials and Methods

2.1 Experimental site and treatment details

The field experiment was performed in Fruit Nursery, Department of Fruit Science, College of Horticulture, VCSG Uttarakhand University of Horticulture and Forestry, Bharsar, Pauri Garhwal, Uttarakhand during 2022-2023. The experiment was laid out in Randomized Complete Block Design and replicated thrice, consisting of 13 treatments including control (T_1), GA_3 250 ppm (T_2), GA_3 500 ppm (T_3), GA_3 750 ppm (T_4), GA_3 1000 ppm (T_5), kinetin 100 ppm (T_6), kinetin 150 ppm (T_7), kinetin 200 ppm (T_8), kinetin 250 ppm (T_9), thiourea 1500 ppm (T_{10}), thiourea 3000 ppm (T_{11}), thiourea 4500 ppm (T_{12}), thiourea 6000 ppm (T_{13}). Seeds were soaked for 24 hours with these concentrations of chemicals. Treated seeds were sown in black polythene bags filled with media (Sand+ Soil+ FYM @ 1:1:2). One seed per polybag was sown at a depth of 2-2.5 cm. On alternate days, manual irrigation was carried out and weeding was done by hand at an interval of 15 days.

Fig 1: View of the experimental site

Fig 2: Seeds soaked in distilled water (control), GA_3, kinetin and thiourea at different concentrations for 24 hours

2.2 Evaluation of germination parameters

2.2.1 Days taken for initial germination (days)-After seed sowing, the days needed for initial germination was noted every day until no further seedlings emerged. The period from the sowing date to the appearance of first seedling was considered as the time taken for commencement of seed germination.

2.2.2 Germination rate (per day): The observation on germination rate was calculated at the time of the experiment by using the formula:

$$GR = \frac{\text{Number of germinated seeds}}{\text{Day of First count}} + \cdots + \cdots + \cdots + \frac{\text{Number of germinated seeds}}{\text{Day of Final count}}$$

2.2.3 Germination percent (%): This data was noted after no additional seedlings emerged. Seeds were called sprouted when the plumule appeared above the soil surface and radical attained a length of 2 mm. Seed germination was calculated based on the number of seeds germinated out of the sown, and expressed as percentage.

$GP = \Sigma G/N*100$

where, GP is the germination percentage, G is the number of seeds germinated and N is the number of all seeds (Copeland and McDonald, 2001).

2.2.4 Survival percent (%): The observation on survival percentage was recorded at the end of the research by applying the following formula:

$$\text{Survival \%} = \frac{\text{Total no. of germinated seedlings} - \text{Total no. of dead seedlings}}{\text{Total no. of germinated seedling}}$$

2.3 Evaluation of Vegetative parameters

2.3.1 Shoot length (cm): The average length per shoot was recorded at 120, 150 and 180 days after sowing (DAS) by measuring the distance from the soil surface to the apical bud of the main axis.

2.3.2 Shoot diameter (mm): The diameter was calculated at a height of 3 cm from the ground level using the instrument Vernier caliper at 120, 150 and 180 DAS, and was expressed as average diameter per seedling in mm.

2.3.3 Number of leaves/seedling-The data of all the unfolded leaves, regardless of their size were recorded at 120, 150 and 180 DAS, and the average number of leaves per plant was assessed.

2.3.4 Leaf area (cm^2): The evaluation on leaf area was reported at the end of the experiment by randomly selecting fully expanded leaves from the seedlings. Each leaf was scanned with the help of Leaf Area Meter (LI-COR Model-3100) and the area was recorded and expressed in sqcm.

2.3.5 Shoot fresh weight and dry weight (g): The observation was noted at the end of study. Seedlings were cut from the point of transition of shoot and root and washed with water. The weight of shoot was weighed using an electronic balance. For shoot dry weight, shoots were chopped separately and oven dried at 60±20 ℃ temperature until a constant weight was obtained. The weight was taken using an electronic balance and average value was computed.

2.3.6 Root length (cm): The data was recorded at the end of the growing season. Plants were carefully uprooted, without disturbing the primary root and were washed in water. With the help of meter scale, the primary root length was evaluated from the junction of root and stem to the primary root tip.

2.3.7 Root diameter (mm): Vernier caliper was used to record diameter at the end of the research.

2.3.8 Root fresh weight and dry weight (g): The observation was recorded at the end of the experiment. For fresh weight, roots were cut from the junction point of shoot and root and washed with water. Then, weight of roots was assessed with the help of weighing balance. Whereas, for dry weight, roots were chopped and oven dried at 60±2 ℃ temperature till a constant weight was achieved, after which weight was taken and average value was calculated.

2.3.9 Total fresh weight and dry weight of seedling (g): The observation on total fresh weight of seedling was determined by combining total shoot and root fresh weight.

$$\text{Total fresh weight of seedling (g)} = \text{Fresh weight of shoot (g)} + \text{Fresh weight of root (g)}$$

Whereas, total dry weight of seedling was determined by adding total shoot and root dry weight.

$$\text{Total dry weight of seedling (g)} = \text{Dry weight of shoot (g)} + \text{Dry weight of root (g)}$$

2.4 Statistical Analysis

The statistical analysis was carried out for each observed parameter using MS-Excel and OPSTAT. The mean values of data were subjected to analysis of variance (ANOVA) according to the procedures outlined in "Statistical Procedures for Agricultural Research" by Gomez and Gomez (1984) [9] for Randomized Complete Block Design. The variation among treatments were assessed using the 'F' test, and the critical difference (C.D.) at the 5% significance level was evaluated to compare the mean values of all parameters across treatments.

3. Results and Discussion

3.1 Influence of plant bioregulators on Germination attributes

3.1.1 Days taken for initial germination: The data depicted in Table 1 showed that seeds treated with GA_3 500 ppm (T_3) reported less time (83 days) for the emergence of germination, which was statistically at par with GA_3 250 ppm (T_2) (83.66 days) and GA_3 750 ppm (T_4) (85.33 days). However, seeds dipped in only distilled water reported maximum time (99.66 days). The decline in days with GA_3, could be due to its capability to elevate the seed coat porosity and promotes endogenous gibberellin-like substances (Mathur *et al.*, 1971) [16]. Furthermore, GA_3 also activates cytological enzymes that generate energy and substrates, which in turn supply structural elements needed for commencement and rapid growth of embryo, along with enhanced cell wall plasticity and increased water absorption (Burns and Coggins, 1969) [3].

3.1.2 Germination rate: Maximum germination rate (0.20 per day) was observed in GA_3 500 ppm (T_3) which was statistically similar with GA_3 250 ppm (T_2) (0.18 per day) whereas, minimum was reported in T_1 (control) (0.08 per day) and T_{13} (thiourea 6000 ppm) (Table 1). The cause of enhanced rate in seed germination might be the GA_3 stimulatory effect, which antagonizes the impact of inhibitors and increases internal gibberellin-like substances and speeds up germination (Mathur *et al.*, 1971) [16].

3.1.3 Germination percent: The outcomes in Table 1 indicated that GA_3 500 ppm showed highest germination percent (78.33%), whereas lowest (41.66%) was observed in seeds treated with distilled water (control). The rise in germination percentage is because of the activity of gibberellic acids, which stimulate the production of hydrolytic enzymes (á-amylase and proteases) during germination phase. These enzymes degrade the stored food resources available in seeds by weakening barrier tissues (endosperm and seed coat). This breakdown of complex carbohydrates and storage proteins into simple sugar releases energy reserves from the endosperm to growth sites, supplying the embryo with the necessary nutrition and energy and thus promote germination (Hota *et al.*, 2018) [12].

3.1.4 Survival percentage: At the end of experiment, best peach seedlings survival response was noticed in GA_3 500 ppm (93.61%), while control recorded the lowest (75.47%) (Table 1). Maximum viability in GA_3 could be due to faster root and shoot development, which makes the seedling more resilient to transplant shock and root disease (Pavithra *et al.*, 2018) [22]. It might also be the result of overall performance of the growth attributes which performed well in the same treatment, and ultimately raised the seedling survival percentage.

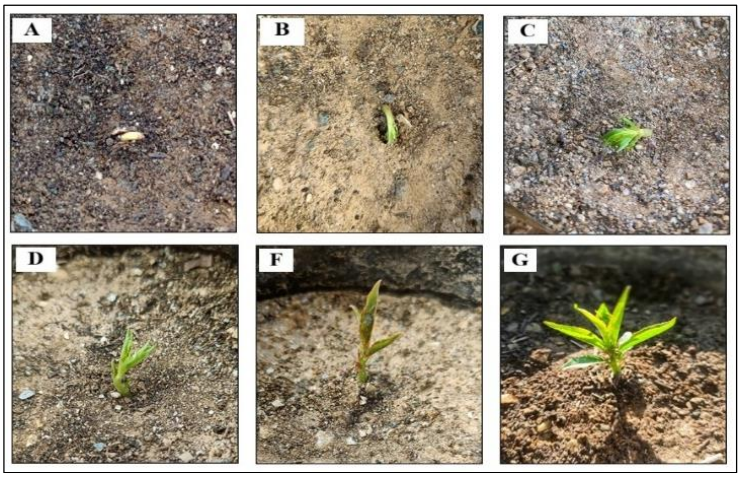

Fig 3: Emergence of seed in GA_3 500 ppm (T_3): A. 82 DAS; B. 84 DAS; C. 86 DAS; D. 88 DAS; E. 90 DAS; F. 94 DAS (DAS: Days after sowing)

Table 1: Influence of plant bioregulators on days taken for initial germination, germination rate, germination percent and survival percent

Treatments	Days taken for initial germination (days)	Germination rate (per day)	Germination percent (%)	Survival percent (%)
T_1 (Control)	99.66	0.08	41.66	75.47
T_2 (GA_3 @ 250 ppm)	83.66	0.18	75.00	86.92
T_3 GA_3 @ 500 ppm	83.00	0.20	78.33	93.61
T_4 GA_3 @ 750 ppm	85.33	0.16	71.66	88.25
T_5 GA_3 @ 1000 ppm	87.33	0.13	63.33	86.97
T_6 Kinetin @ 100 ppm	86.66	0.15	70.00	88.39
T_7 Kinetin @ 150 ppm	87.66	0.12	60.00	85.64
T_8 Kinetin @ 200 ppm	90.00	0.12	58.33	80.08
T_9 Kinetin @ 250 ppm	95.33	0.10	50.00	77.65
T_{10} Thiourea @ 1500 ppm	86.33	0.13	65.00	87.40
T_{11} Thiourea @ 3000 ppm	89.66	0.12	58.33	85.58
T_{12} Thiourea @ 4500 ppm	98.00	0.09	48.33	78.25
T_{13} Thiourea @ 6000 ppm	99.33	0.08	45.00	77.01
S.E (d)	1.52	0.01	6.74	4.31
$C.D_{(0.05)}$	3.15	0.02	13.99	8.96

3.2 Influence of plant bioregulators on Seedling attributes

3.2.1 Shoot parameters: The treatments showed significant differences on shoot length, shoot diameter and leaf count as compared to control (Table 2). At 180 DAS, tallest shoot length (35.14 cm) was recorded in GA_3 500 ppm solution (T_3), which was not significantly different from GA_3 250 ppm (T_2) (32.91 cm), whereas shortest was noticed in control (22.09 cm). The enhancement in shoot height of peach could be because of the capacity of hormone to increase osmotic uptake of nutrients, which might result in expansion and proliferation of cells in the cambium tissue of internodal section, and therefore, lengthen the shoot of the sapling (Shanmugavelu, 1970) [30].

In case of shoot diameter, same GA_3 500 ppm stated maximum diameter (3.51 mm), whereas control reported minimum (2.38 mm) at 180 DAS. The diameter increase may be the consequence of rise in photosynthetic activity, accelerated translocation, and efficient use of photosynthetic products, which lead to increased cell size, division, and expansion at the collar portion of the shoot (Sargent, 1965) [24]. Additionally, it is the consequence of elevated activity of NADPH2 (nicotinamide adenine dinucleotide phosphate-reduced), which is generated by potassium ions, as well as hydrolytic enzymes secretion during germination by gibberellic acid (Singh, 2020) [31].

The highest leaf count per seedling (42.44) (Table 2) and maximum leaf area (18.95 cm^2) (Table 3) at 180 DAS were also observed in GA_3 500 ppm, while the control recorded minimum values for leaf number (28.22) as well as leaf area (10.20 cm^2). The increase in leaf count and area with treatment GA_3 might be because of the migration of hormone at the apical meristem. This movement stimulates cell mitotic activity and growth, and increases production of nucleoprotein, which in turn increases the number and expansion of young leaves (Sen and Ghunti, 1976) [26]. It could also be due to quick development of seedlings which produces more branches and facilitate better sunlight absorption by the plants resulting in a greater number of leaves (Patil *et al.*, 2018) [21, 22].

Regarding fresh and dry weight of shoot (Table 3), significant variations was observed in treatments as compared to control at 180 DAS. Treatment T_3 (seeds exposed to GA_3 500 ppm) recorded maximum weight of fresh shoot *i.e.*, 9.34 g which was not significantly different from GA_3 250 ppm (T_2) (8.77 g), GA_3 750 ppm (T_4) (8.49 g), kinetin 100 ppm (T_6) (8.41 g) and thiourea 1500 ppm (T_{10}) (8.42 g), whereas minimum weight (4.98 g) was perceived in T_1 (control). This could be because of the seedlings overall growth and development, and higher photosynthetic rate, which causes photosynthates to be assimilated and redistributed to various plant parts. This is caused by an increased rate of water and nutrient mobilization (Yadav *et al.*, 2022) [36], which raises the fresh weight of the shoot. Also, T_3 showed highest shoot dry weight (3.14 g) which was statistically at par with T_2 (3.02 g), whereas lowest *i.e.*, 1.26 g was seen in control. This seems to be caused by the quick mobilization of nutrients and water within plant tissues, which increases the synthesis of photosynthetic products that are then transferred to several parts of the plant, thereby improving shoot growth and ultimately increased the dry weight of shoot (Singh and Kaur, 2020) [32].

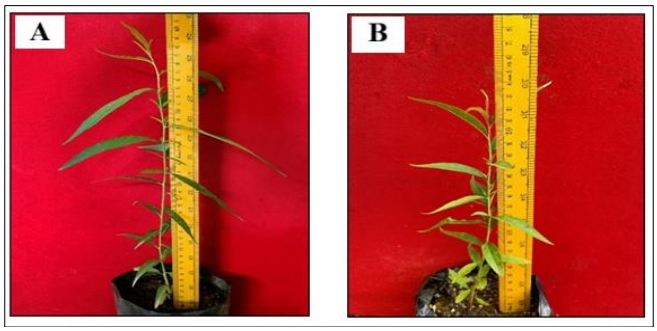

Fig 4: Shoot length at 180 days after sowing (DAS)
A. GA_3 500 ppm (T_3); B. Control (T_1)

Fig 5: Shoot diameter at 180 days after sowing (DAS) in T_3

Table 2: Influence of plant bioregulators on shoot length, shoot diameter, number of leaves per seedling at 120, 150 and 180 days after sowing (DAS)

Treatments	Shoot length (cm)			Shoot diameter (mm)			Leaf count per seedling		
	120 DAS	150 DAS	180 DAS	120 DAS	150 DAS	180 DAS	120 DAS	150 DAS	180 DAS
T_1 (Control)	7.03	14.14	22.09	1.72	2.09	2.38	9.73	18.80	28.22
T_2 (GA_3 250 ppm)	11.28	20.14	32.91	2.11	2.74	3.20	14.60	27.33	38.55
T_3 (GA_3 500 ppm)	13.52	22.30	35.14	2.27	3.04	3.51	15.60	28.33	42.44
T_4 (GA_3 750 ppm)	10.91	19.68	29.09	2.03	2.72	3.16	14.00	26.20	36.22
T_5 (GA_3 1000 ppm)	9.72	17.85	26.75	1.93	2.55	2.89	13.60	23.20	34.55
T_6 (Kinetin 100 ppm)	9.96	18.59	27.78	1.95	2.57	2.96	13.73	24.20	35.00
T_7 (Kinetin 150 ppm)	9.56	17.64	26.19	1.93	2.50	2.87	12.80	22.53	32.66
T_8 (Kinetin 200 ppm)	9.22	16.92	25.67	1.92	2.40	2.69	12.46	23.00	31.00
T_9 (Kinetin 250 ppm)	8.40	16.05	24.12	1.80	2.37	2.50	11.46	21.86	29.44
T_{10} (Thiourea 1500 ppm)	10.76	19.34	29.02	2.00	2.63	2.98	13.80	25.86	36.11
T_{11} (Thiourea 3000 ppm)	9.30	16.96	25.95	1.93	2.46	2.74	12.73	22.46	31.11
T_{12} (Thiourea 4500 ppm)	8.20	15.16	24.20	1.79	2.25	2.51	11.40	20.13	29.11
T_{13} (Thiourea 6000 ppm)	7.62	14.71	23.73	1.74	2.16	2.45	10.46	19.26	28.66
S.E (d)	1.02	1.29	1.09	0.09	0.09	0.06	1.26	1.49	1.30
$C.D_{(0.05)}$	2.12	2.68	2.27	0.18	0.19	0.14	2.62	3.11	2.71

Table 3: Influence of plant bioregulators on leaf area, shoot fresh weight and shoot dry weight at 180 DAS

Treatments	Leaf area (cm^2)	Shoot fresh weight (g)	Shoot dry weight (g)
T_1 (Control)	10.20	4.98	1.26
T_2 (GA_3 250 ppm)	17.88	8.77	3.02
T_3 (GA_3 500 ppm)	18.95	9.34	3.14
T_4 (GA_3 750 ppm)	17.32	8.49	2.92
T_5 (GA_3 1000 ppm)	16.15	8.00	2.67
T_6 (Kinetin 100 ppm)	17.04	8.41	2.70
T_7 (Kinetin 150 ppm)	15.81	7.93	2.50
T_8 (Kinetin @ 200 ppm)	13.54	7.74	1.81
T_9 (Kinetin @ 250 ppm)	11.97	5.55	1.38
T_{10} (Thiourea 1500 ppm)	16.85	8.42	2.86
T_{11} (Thiourea @ 3000 ppm)	15.14	7.80	2.16
T_{12} (Thiourea @ 4500 ppm)	10.91	5.33	1.29
T_{13} (Thiourea @ 6000 ppm)	10.35	5.65	1.31
S.E (d)	0.10	0.49	0.05
$C.D_{(0.05)}$	0.21	1.03	0.12

3.2.2 Root parameters-According to the data depicted in Table 4 (180 DAS), different plant bioregulators at different concentrations showed significant impact on root length, root diameter, root fresh weight and dry weight. Greater root length (15.51 cm) was retained in GA_3 500 ppm (T_3), which was statistically comparable with GA_3 250 ppm (T_2) (15 cm) and GA_3 750 ppm (T_4) (14.32 cm), while shorter length (10.74 cm) was noted under control (T_1). The function of gibberellic acid enlarges the vacuoles of already existing cells causing them to divide and elongate, which might be the reason for increase in root length or it may be due to the enhanced photosynthetic activity and their transportation to the root zone via phloem (Panda *et al.*, 2018) [20].

Root diameter was noticed highest (3.24 mm) in same treatment T_3, which was not significantly different from treatments T_2 (3.19 mm) and T_4 (3.15 mm), while minimum value for the same was observed (1.87 mm) in control. The increase in root diameter might be due to the activity of GA_3 which promoted faster translocation and efficient use of photosynthetic products and accelerate synthesis of amino acids, resulting in elongation and quicker multiplication of cells in the root tissues after the seed sprouting.

In case of fresh and dry weight of root, seeds exposed to solution GA_3 500 ppm showed maximum root fresh weight (2.52 g), whereas the minimum value (1.32 g) for same was noted in control. This appears to be the impact of GA_3 on various plant parts, stimulating cell division and elongation, auxin metabolism, cell wall plasticity, and cell membrane permeability, all of which increase root growth and, ultimately the fresh weight of root (Vasantha *et al.*, 2014) [34]. In addition, higher root dry weight was also seen in same treatment T_3 *i.e.* 1 g, while lower (0.39 g) was reported in control (T_3). This may be caused by overall development of the seedling and accelerated rate of photosynthesis that leads to the assimilation and redistribution of photosynthates within the roots, which leads to increased root dry weight (Joshi *et al.*, 2017) [13].

Table 4: Influence of plant bioregulators on root length, root diameter, root fresh weight and root dry weight at 180 days after sowing (DAS)

Treatments	Root length (cm)	Root diameter (mm)	Root fresh weight (g)	Root dry weight (g)
T_1 (Control)	10.74	1.87	1.32	0.39
T_2 (GA_3 @ 250 ppm)	15.00	3.19	2.11	0.85
T_3 (GA_3 @ 500 ppm)	15.51	3.24	2.52	1.00
T_4 (GA_3 @ 750 ppm)	14.32	3.15	1.96	0.82
T_5 (GA_3 @ 1000 ppm)	13.22	2.79	1.78	0.74
T_6 (Kinetin @ 100 ppm)	13.77	2.92	1.81	0.75
T_7 (Kinetin @ 150 ppm)	12.90	2.68	1.72	0.70
T_8 (Kinetin @ 200 ppm)	12.10	2.49	1.58	0.64
T_9 (Kinetin @ 250 ppm)	11.89	2.01	1.50	0.58
T_{10} (Thiourea @ 1500 ppm)	13.97	2.95	1.89	0.79
T_{11} (Thiourea @ 3000 ppm)	12.69	2.50	1.68	0.68
T_{12} (Thiourea @ 4500 ppm)	11.12	1.95	1.46	0.46
T_{13} (Thiourea @ 6000 ppm)	10.97	1.90	1.38	0.40
S.E (d)	0.63	0.07	0.087	0.01
$C.D_{(0.05)}$	1.31	0.16	0.18	0.02

3.2.3 Total fresh weight and dry weight of seedling-The data depicted in Table 5 indicated that treatments showed significant variations on fresh weight and dry weight of seedling as compared to control. Highest fresh weight of seedling (11.86 g) was perceived in treatment T_3 (GA_3 500 ppm) while minimum (6.30 g) was recorded under treatment T_1 (control). This is because maximum shoot fresh weight (9.34 g) and root fresh weight (2.52 g) were recorded under the same treatment T_3. It could also be due to the influence of GA_3 hormone that causes rise in the number of leaves, shoots and roots resulting in efficient absorption, assimilation and redistribution of photosynthetic products and nutrients within plant parts, consequently giving higher fresh weight of seedling. Moreover, maximum dry weight of seedling (4.15 g) was also retained in T_3, whereas minimum (1.65 g) was reported under treatment T_1. This is because maximum shoot dry weight (3.14 g) and root dry weight (1 g) were observed under the same treatment T_3. Also, it

might be due to more accumulation of the photosynthetic products within the plant resulting in higher dry weight of seedling.

Table 5: Influence of plant bioregulators on total fresh weight and total dry weight of seedling at 180 DAS

Treatments	Total fresh weight of seedling (g)	Total dry weight of seedling (g)
T_1 (Control)	6.30	1.65
T_2 (GA_3 @ 250 ppm)	10.88	3.87
T_3 (GA_3 @ 500 ppm)	11.86	4.15
T_4 (GA_3 @ 750 ppm)	10.45	3.74
T_5 (GA_3 @ 1000 ppm)	9.78	3.42
T_6 (Kinetin @ 100 ppm)	10.22	3.46
T_7 (Kinetin @ 150 ppm)	9.65	3.20
T_8 (Kinetin @ 200 ppm)	9.32	2.45
T_9 (Kinetin @ 250 ppm)	7.06	1.96
T_{10} (Thiourea @ 1500 ppm)	10.31	3.66
T_{11} (Thiourea @ 3000 ppm)	9.48	2.84
T_{12} (Thiourea @ 4500 ppm)	6.79	1.75
T_{13} (Thiourea @ 6000 ppm)	7.04	1.71
S.E (d)	0.51	0.05
$C.D_{(0.05)}$	1.06	0.12

Conclusion

The results of the study concluded that seeds dipped in different plant bioregulators at various concentrations for 24 hours duration had significantly improved the seed germination, seedling growth and survivability of peach seedlings in comparison to control (seeds dipped in only distilled water). The observations revealed that seeds primed with GA_3 500 ppm for 24 hours showed the best response among the different seed treatments with respect to germination as well as seedling attributes. Hence, standardization of GA_3 500 ppm treatment can be effectively used for improving seed germination of peach. Furthermore, in commercial peach propagation programs, this standardized protocol can serve as a practical and economical way to improve uniform seedling establishment and ensure higher orchard productivity.

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