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# Evaluation of Different Doses of Indole-3-Butyric Acid (IBA) and Rooting Media on the Vegetative Growth Parameters of Apple Clonal Rootstocks

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**ABSTRACT: Apple is one of the most important temperate fruit crop grown throughout the world. The high-density planting system (HDP) is now being conceived as an alternative production system having a potential for improving productivity, increasing yield efficiency, reducing input cost, minimizing risks and maximizing returns. Clonal rootstocks used in high density plantations (like M9 T337, M9 T339, MM 111, MM 106 and so on) have the benefit of producing uniform, precocious, dwarfing trees with simpler canopies which ultimately result in greater productive orchards. For propagating these rootstocks in large number and in lesser space hardwood cuttings are used. Rooting percentage of these is however poor, thus to obtain higher percentage of rooted cuttings the use of root promoting growth regulators and appropriate rooting media is essential. So in order to find best combination of rooting media and IBA concentration for propagation of apple rootstocks, an experiment was conducted in the nursery block of Division of Fruit Science, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar. The experiment was carried out with three rootstocks $S_1$: M7, $S_2$: M9 T337 and $S_3$: MM106. IBA concentration was tested at three- level viz, G1: 2500 ppm, G2: 3000 ppm and G3: 3500 ppm. Four combinations of rooting media was used, described as; M1: Sand + Vermicompost (1:1), M2: Sand + Vermicompost + Vermiculite (1:1:1), M3: Sand + Vermicompost + Perlite (1:1:1) and M4: Sand + Vermicompost + Cocopeat (1:1:1). Each treatment was replicated thrice in controlled randomized design (CRD). The results revealed that minimum number of days to first leaf initiation (12.33), maximum leaf area (28.98 $cm^2$), highest dry and fresh weigh of leaves (5.20g and 13.10g), highest leaf number (47.33) and highest survival percentage (86.66 %) was obtained in the interaction of $S_3G_2M_3$. Sprouting percentage of cuttings was recorded to be maximum (100%) in combination of $S_3G_2M_3$ and $S_1G_2M_3$. Using IBA @ 3000 ppm and combination of sand: vermicompost : perlite :: 1:1:1 as rooting media, resulted in reduced number of the days taken for first leaf initiation, enhanced the sprouting percentage of cuttings, maximum leaf area and number of leaves, maximum fresh and dry weight of the leaves and also maximum survival percentage of the cuttings. Thus from the present investigation, it can be concluded that rooting capacity changes with genotype, rooting media, growth hormone concentration, etc. Moreover the hardwood cuttings of MM106 clonal rootstock with treatment combination of $G_2$ (IBA: 3000ppm) and $M_3$ (sand + vermicompost + perlite) (1:1:1) were superior to obtain higher survival of superior rootstock cuttings.**

**Keywords:** vermiculite, perlite, sprouting, survival percentage.

## INTRODUCTION

Apple is one of the most important temperate fruit crop grown throughout the world. It belongs to genus Malus, family Rosaceae with basic chromosome number 17. Jammu and Kashmir with the area of 1,64,742 hectares and production of 18,82,319 MT (2018-19) is leading in both area and production in the country. In recent years, productivity of apple orchards has been decreasing thereby causing a serious concern for the apple growers. Main cause for decline in production and productivity are non-availability of quality planting material, proper selection of varieties of rootstocks and inadequate adoption of advanced production technologies. The high-density planting system (HDP) is now being conceived as an alternative production system having a potential for improving productivity, increasing yield efficiency, reducing input cost, minimizing risks and maximizing returns. In high density plantation rootstock is considered as an essential component which enhances fruit quality and productivity because of its wider adoptability to diverse environmental condition and cultural practices besides

having the traits that are absent in the scion, such as soil pest and disease resistance, better hostage, improved nutrient uptake, better tolerance to soils with high saline soils as well as other soil limiting factors. On the other hand, they can modify the performance of scion by reducing tree vigor and modifying canopy structure that would allow the establishment of high density orchards. Clonal rootstocks use in high density plantations have the benefit of producing uniform, precocious, dwarfing trees, that are less complicated to manipulate and result in greater productive orchards. Apple clonal rootstocks are conventionally propagated through mound layering (stooling). Numerous other vegetative techniques have additionally been employed to propagate apple clonal rootstocks. One of the convenient methods of clonal propagation is through hardwood cuttings. By this method, it is possible to propagate large number of rootstock in less space and also in less amount of time. The rooting may be improved via using plant growth regulators (like IBA) and different rooting media. Synthetic auxin like IBA (Indolebutyric acid) is broadly used due to its capability to increase rooting and to develop a good fibrous root system. The use of different organic and inorganic substrates allows the plant to initiate early nutrient uptake and results in early growth and improvement in water and oxygen utilization. A good rooting medium provides support for the plant, serves as a nutrient and water reservoir, allows oxygen diffusion to roots and permits gaseous exchange between roots and atmosphere (Agro, 1998). Cocopeat has been recognized to have high water holding capacity which causes poor air-water relationship, thereby leading to reduced aeration within the medium, thus affecting the oxygen diffusion to the roots (Abad *et al*., 2002). Incorporation of coarser materials into cocopeat has the ability to improve the aeration status of the media (Sambo *et al*., 2008). Perlite is recognized to have a unique capillary action which makes it a superior growing medium for hydroponic cultures. It is useful for increasing aeration and drainage within the container because of its uniformity and lightness (Paradiso and Pascale, 2008). So keeping in view the above facts the present investigation was carried with the aim to find best combination of rooting media and IBA concentration for propagation of apple rootstocks. In this investigation we also studied the influence of different IBA concentrations and rooting media on the survival and sprouting percentage of cutting and also on various vegetative parameters of the rooted cuttings.

## MATERIAL METHODS

The experiment was conducted in the nursery block of Division of Fruit Science, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar. The experiment was carried out with three rootstocks $S_1$: **M7**, $S_2$: **M9 T337** and $S_3$: **MM106**. IBA concentration was tested at three- level viz, G1: **2500 ppm**, G2: **3000 ppm** and G3: **3500 ppm**. Four combinations of rooting media was used, described as; M1: **Sand + Vermicompost (1:1)**, M2: **Sand + Vermicompost + Vermiculite (1:1:1)**, M3: **Sand + Vermicompost + Perlite (1:1:1)** and M4: **Sand + Vermicompost + Cocopeat (1:1:1)**. Hard wood cutting from previous years growth were collected in February (dormant season). The cuttings were thereafter stored in a cool place by covering the cuttings with sand and proper level of moisture was ensured in the sand by sprinkling water till they were planted in polybags. Cuttings were then taken out from the sand and washed with water to remove the sand particles that adored the cuttings. The cuttings having character, length of 15-20 cm, 4-5 nodes and thickness of 0.8-1.0 cm were taken from the hard wood portion of the branches. For making cuttings, the first basal cut was given just below the node and the top cut half to one inch above the node. The basal cut was straight while the top cut was slant. Thickness of each cutting varied from 3 mm to 15 mm. Cutting were treated with IBA at the time of planting by quick dipping the cutting for 10-15 seconds. Each treatment was replicated thrice in controlled randomized design (CRD).

Time taken to initiate leaf for each rootstock cutting was determined by counting days from first day of planting until leaf bud initiation. Sprouting percentage of cuttings for each treatment was determined by counting the number of sprouted rootstock cuttings. The observations on the leaf area were recorded during the first week of October, 2019, when leaves were fully developed. Twenty fully expanded leaves were collected at random from the cuttings and area of these leaves was measured with the help of Leaf Area Meter 211 and expressed in square centimeter ($cm^2$). For determining the fresh weight, fully grown leaves from the middle part of the shoot during first week of October, in each replication and under each treatment were collected. These were weighed using electronic weighing balance. Its average was expressed in grams (g). To record leaves dry weight, same leave samples were used. These were dried in a hot air oven at a temperature of 65° for about 48 hours until the constant weight of samples were obtained. Dry leaves weight was recorded with the help electronic weighing balance. Its average was expressed in grams (g). The data on leaf number was recorded during the month of October. All the leaves, irrespective of their size were counted. The survival of cuttings for each treatment were determined by counting the total number of survived rootstock cuttings under each replication and the values were expressed in percentage (%). For analysis and interpretation, statistical methods described by Gomez and Gomez (1984) were followed with 5 per cent level of significance.

## RESULTS AND DISCUSSION

The main effects of rooting media and growth hormone on the rooting behavior of apple clonal rootstocks was significant on days taken to first leaf initiation (Table 1). The minimum number of days to first leaf initiation (16.02) was observed in rootstock, $S_3$ (MM106) which was statistically at par with $S_1$ (M7) rootstock (16.11). However, the maximum number of days taken to first leaf initiation (21.27) was observed in $S_2$ (M9 T337) rootstock. This may attributed to avoidance of downward translocation of carbohydrate and collection of better degree of endogenous and exogenous auxin in MM106. All the concentrations of growth hormone showed significant influence and minimum number of days taken to first leaf initiation (15.22) was observed in rootstock cuttings treated with $G_2$ (IBA: 3000 ppm) growth hormone while as maximum number of days taken to first leaf initiation (19.61) was observed in $G_1$ (IBA: 2500 ppm) growth hormone. It may be due to the fact that auxin application enhances the histological features like arrangement of callus and tissue and differentiation of vascular tissue. IBA at a lower concentration induces early development of callus and vascular bundles thereby resulting in early leaf initiation (Satpal *et al*., 2014). Chandramouli (2001) observed that the increase levels of IBA substantially decreased the range of days taken to first leaf initiation of cuttings and earliness in sprouting. This might be because of higher utilization of stored carbohydrates, nitrogen and other factors with the assist of growth regulators. Rooting media $M_3$ (sand + vermicompost + perlite) (1:1:1) exhibited less number of days taken to first leaf initiation (14.63). More number of days taken to first leaf initiation (21.77) was exhibited by $M_1$ (sand + vermicompost) (1:1) rooting media. This is attributed to the perfect nutrient take-up, aeration and upgraded accessibility of vitamins. Combined effect of rootstock, growth hormone and rooting media showed significant influence on the days taken to first leaf initiation. The interaction $S_3G_2M_3$ observed lowest number of days taken to first leaf initiation (12.33), which was statistically at par with $S_3G_1M_3$ (13.00), $S_1G_2M_3$ (13.33), $S_3G_2M_4$ (13.66) and $S_2G_2M_3$ (14.00). Highest number of days taken to first leaf initiation registered in $S_2G_1M_1$ (34.33). Similar results for the interactions were observed by (Malakar *et al*., 2019 and Kareem *et al*., 2016).

**Table 1: Influence of rootstock, growth hormone and rooting media on days taken to first leaf initiation**

| M / S | $M_1$ | | | Sub mean | $M_2$ | | | Sub mean | $M_3$ | | | Sub mean | $M_4$ | | | Sub mean | Mean | Factor Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| G | $G_1$ | $G_2$ | $G_3$ | | $G_1$ | $G_2$ | $G_3$ | | $G_1$ | $G_2$ | $G_1$ | | $G_1$ | $G_2$ | $G_3$ | | | |
| $S_1$ | 17.33 | 16.00 | 23.00 | **18.77** | 16.00 | 15.33 | 16.00 | **15.77** | 14.33 | 13.33 | 15.00 | **14.22** | 15.00 | 14.66 | 17.33 | **15.66** | **16.11** | $G_1$=19.61 |
| $S_2$ | 34.33 | 20.66 | 30.00 | **28.33** | 33.00 | 15.66 | 22.33 | **23.66** | 20.00 | 14.00 | 14.66 | **16.22** | 20.66 | 14.66 | 15.33 | **16.88** | **21.27** | $G_2$=15.22 |
| $S_3$ | 18.00 | 17.33 | 19.33 | **18.22** | 17.66 | 15.00 | 18.00 | **16.88** | 13.00 | 12.33 | 15.00 | **13.44** | 16.00 | 13.66 | 17.00 | **15.55** | **16.02** | $G_3$=18.58 |
| **Mean** | **23.22** | **18.00** | **24.11** | **21.77** | **22.22** | **15.33** | **18.77** | **18.77** | **15.77** | **13.22** | **14.88** | **14.63** | **17.22** | **14.33** | **16.55** | **16.03** | | |

**C.D at 5%**
Rootstock = 0.736 ; Rootstock × Rooting media = 1.472
Growth hormone = 0.736 ; Growth hormone × Rooting media = 1.472
Rooting media = 0.850 ; Rootstock × Growth hormone × Rooting media = 2.550

The data present in Table 2 indicates that the percentage of sprouting in rootstock cuttings was influenced by rootstock, rooting media and growth hormone. It was noticed that rootstock, $S_3$ (MM106) recorded highest sprouting percentage of cuttings (89.44%) which may be attributed to maximum utilization of saved carbohydrate, nitrogen and other issue. $S_2$ (M9 T337) recorded lowest sprouting percentage of cuttings (81.38%). Application of growth hormone, $G_2$ (IBA: 3000 ppm) recorded significantly maximum sprouting percentage of cuttings (90.00%) which was followed by the treatment of growth hormone, $G_1$ (IBA: 2500 ppm) with 84.72% and the minimum sprouting percentage of cuttings (78.05%) resulted in growth hormone, $G_3$ (IBA: 3500 ppm). Similar results were obtained by Siddiqui and Hussain (2007) and Barahyi *et al*., 2015. They recorded most intense sprouting percentage of 48.25 per cent in the hardwood cuttings of *Ficus hawaii* treated with 4000 ppm of IBA. Rooting media, $M_3$ (sand + vermicompost + perlite :: 1:1:1) also significantly resulted with the maximum sprouting percentage of cuttings (88.51%) which was statistically at par with the $M_4$ (sand + vermicompost + cocopeat :: 1:1:1) (85.55%). Minimum sprouting percentage of cuttings observed in $M_2$ (sand + vermicompost + vermiculite :: 1:1:1) rooting media having 80.00%. The combination of rootstock, growth hormone and rooting media was noted significant influence on sprouting percentage of cuttings. Sprouting percentage of cuttings was recorded to be maximum (100%) in combination of $S_3G_2M_3$ and $S_1G_2M_3$ which was statistically at par with the treatment combination of $S_2G_2M_4$ with value of 96.66%. The lowest sprouting percentage of cuttings was recorded to be 60.00% in combination of $S_1G_3M_1$. These results are similar in *Citrus auriantifolia* Swingle (Kagzi-lime) as reported by Bhatt and Tomar (2011).

**Table 2: Influence of rootstock, growth hormone and rooting media on sprouting of cuttings (%)**

| M / S | $M_1$ | | | Sub mean | $M_2$ | | | Sub mean | $M_3$ | | | Sub mean | $M_4$ | | | Sub mean | Mean | Factor Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| G | $G_1$ | $G_2$ | $G_3$ | | $G_1$ | $G_2$ | $G_3$ | | $G_1$ | $G_2$ | $G_1$ | | $G_1$ | $G_2$ | $G_3$ | | | |
| $S_1$ | 73.33 | 76.66 | 60.00 | **70.00** | 66.66 | 90.00 | 63.33 | **73.33** | 93.33 | 100.00 | 90.00 | **94.44** | 93.33 | 93.33 | 83.33 | **90.00** | **81.94** | $G_1$=84.72 |
| $S_2$ | 96.66 | 90.00 | 83.33 | **90.00** | 86.66 | 73.33 | 70.00 | **76.66** | 76.66 | 83.33 | 66.66 | **75.55** | 80.00 | 96.66 | 73.33 | **83.33** | **81.38** | $G_2$=90.00 |
| $S_3$ | 83.33 | 93.33 | 90.00 | **88.88** | 86.66 | 96.66 | 86.66 | **90.00** | 96.66 | 100.00 | 90.00 | **95.55** | 83.33 | 86.66 | 80.00 | **83.33** | **89.44** | $G_3$=78.05 |
| **Mean** | **84.44** | **86.66** | **77.77** | **82.96** | **80.00** | **86.66** | **73.33** | **80.00** | **88.88** | **94.44** | **82.22** | **88.51** | **85.55** | **92.22** | **78.88** | **85.55** | | |

**C.D at 5%**
Rootstock = 3.532 ; Rootstock × Rooting media = 7.064
Growth hormone = 3.532 ; Growth hormone × Rooting media = N/S
Rooting media = 4.078 ; Rootstock × Growth hormone × Rooting media = 12.235

All the treatments showed significant influence on leaf area (Table 3). Significantly maximum leaf area (26.21 cm²) was recorded in rootstock, $S_3$ (MM106) which was followed by $S_1$ (M7) having the leaf area of 5.12 cm². Minimum leaf area (20.68 cm²) was recorded in rootstock, $S_2$ (M9 T337). Significantly highest leaf area (28.78 cm²) was observed with the growth hormone, $G_2$ (IBA: 3000 ppm) followed by $G_1$ (IBA: 2500 ppm): (22.82 cm²). Lowest leaf area (20.42 cm²) was observed with the influence of growth hormone, $G_3$ (IBA: 3500 ppm). Highest leaf area (28.98 cm²) was recorded in rooting media, $M_3$ (sand + vermicompost + perlite) :: (1:1:1) which was significantly followed by $M_4$ (sand + vermicompost + cocopeat) :: (1:1:1) having of 25.23 cm² leaf area. Minimum leaf area was observed in rooting media, $M_1$ (sand + vermicompost) :: (1:1) : (20.80 cm²). The combination of rootstock, growth hormone and rooting media showed a significant effect on leaf area. Highest leaf area was recorded in $S_3G_2M_3$ (35.23 cm²), it was statistically at par with treatment combination of $S_1G_2M_3$, $S_3G_1M_3$ and $S_3G_2M_4$ having leaf area of 35.20 35.16 and 33.00 cm² respectively. The lowest leaf area (14.83 cm²) was recorded in $S_2G_1M_1$ combination. Concurring to Nia *et al.,* (2015), culture media including manure, soil, peat, tea wastes and rice husks have noteworthy impacts on cation exchange capacity and soil pH, air circulation and water maintenance capacity of soils which enhances the retention of nutritional components. The leaf area of the rooted cuttings has the coordinate relation with the number of leaves as well as shoot growth. These results are in conformity with Bhat (2000) and Siddiqui and Hussain (2007).

**Table 3: Influence of rootstock, growth hormone and rooting media on leaf area ($cm^2$).**

| M / S | $M_1$ | | | Sub mean | $M_2$ | | | Sub mean | $M_3$ | | | Sub mean | $M_4$ | | | Sub mean | Mean | Factor Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| G | $G_1$ | $G_2$ | $G_3$ | | $G_1$ | $G_2$ | $G_3$ | | $G_1$ | $G_2$ | $G_1$ | | $G_1$ | $G_2$ | $G_3$ | | | |
| $S_1$ | 20.30 | 27.53 | 16.06 | **21.30** | 21.13 | 29.93 | 17.90 | **22.94** | 30.46 | 35.20 | 24.80 | **30.15** | 26.36 | 30.23 | 21.60 | **26.06** | **25.12** | $G_1$=22.82 |
| $S_2$ | 14.83 | 19.86 | 17.46 | **17.38** | 16.10 | 21.46 | 17.76 | **18.48** | 20.76 | 28.93 | 24.53 | **24.74** | 20.63 | 25.40 | 20.46 | **22.16** | **20.68** | $G_2$=28.78 |
| $S_3$ | 21.80 | 30.73 | 18.63 | **23.72** | 20.56 | 27.83 | 16.50 | **21.63** | 35.16 | 35.23 | 25.73 | **32.04** | 25.76 | 33.00 | 23.63 | **27.46** | **26.21** | $G_3$=20.42 |
| **Mean** | **18.97** | **26.04** | **17.38** | **20.80** | **19.26** | **26.41** | **17.38** | **21.02** | **28.80** | **33.12** | **25.02** | **28.98** | **24.25** | **29.54** | **21.90** | **25.23** | | |

**C.D at 5%**
Rootstock = 0.968 ; Rootstock × Rooting media = 1.937
Growth hormone = 0.968 ; Growth hormone × Rooting media = N/S
Rooting media = 1.118 ; Rootstock × Growth hormone × Rooting media = 3.354

Influence of rootstock, rooting media and growth hormone on fresh as well as dry weight of leaf reveals that rootstock had a significant influence on fresh weight of leaf (Table 4). Significantly maximum fresh weight of leaf (9.87 g) and dry weight of leaf (3.79 g) was recorded in $S_3$ (MM106). Minimum fresh as well as dry weight of leaf (6.53 g and 2.27 g respectively) was observed in rootstock $S_2$ (M9 T337). Growth hormone application also significantly influenced fresh as well as dry weight of leaf. Application of growth hormone $G_2$ (IBA: 3000 ppm) resulted in highest fresh and dry weight of leaf (10.11 g, 3.50 g respectively). Lowest fresh weight (7.15 g) and dry weight (2.69 g) was recorded in growth hormone $G_3$ (IBA: 3500 ppm). As far as the effect of rooting media is concerned significant influence on fresh as well as dry weight of leaf was observed. Significantly highest fresh and dry weight of leaf (9.50 g, 3.48 g respectively) was shown by rooting media $M_3$ (sand + vermicompost + perlite) (1:1:1). The lowest fresh as well as dry weight of leaf (7.35 g and 2.68 g respectively) was revealed by rooting media $M_1$ (sand + vermicompost) (1:1). The interaction of $S_3G_2M_3$ combination had registered highest result of fresh and dry weight of leaf (13.10 g and 5.20 g respectively) The interaction of $S_2G_1M_1$ combination has registered lowest fresh as well as dry weight of leaf (4.40 g and 1.60 g respectively). Kaur, (2017) recorded significantly higher leaf weight (2.0 g) at 3000 ppm IBA treatments and these parameter decreased with increase in IBA concentration above 3000 ppm. It may be due to, need to improve the photosynthetic rate and to produce more photosynthates by expanding their leaves and hence more leaf area was observed (Shahab *et al.,* 2013). These results are supported by the work of Mir *et al.,* (2016) wherein they obtained maximum fresh and dry weight in vermicompost + FYM + azotobacter than the treatments used individually.

**Table 4: Influence of rootstock, growth hormone and rooting media on fresh weight of leaf (g).**

| M / S | $M_1$ | | | Sub mean | $M_2$ | | | Sub mean | $M_3$ | | | Sub mean | $M_4$ | | | Sub mean | Mean | Factor Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| G | $G_1$ | $G_2$ | $G_3$ | | $G_1$ | $G_2$ | $G_3$ | | $G_1$ | $G_2$ | $G_1$ | | $G_1$ | $G_2$ | $G_3$ | | | |
| $S_1$ | 7.40 | 9.60 | 6.60 | **7.86** | 7.80 | 10.00 | 7.20 | **8.33** | 8.80 | 12.10 | 7.70 | **9.53** | 8.70 | 10.20 | 7.20 | **8.70** | **8.60** | $G_1$=7.74 |
| $S_2$ | 4.40 | 7.30 | 5.30 | **5.66** | 4.70 | 7.70 | 6.10 | **6.16** | 6.30 | 8.60 | 7.60 | **7.50** | 5.70 | 8.10 | 6.60 | **6.80** | **6.53** | $G_2$=10.11 |
| $S_3$ | 8.10 | 11.20 | 6.30 | **8.53** | 9.10 | 11.30 | 7.80 | **9.40** | 11.70 | 13.10 | 9.60 | **11.46** | 10.20 | 12.20 | 7.90 | **10.10** | **9.87** | $G_3$=7.15 |
| **Mean** | **6.63** | **9.36** | **6.06** | **7.35** | **7.20** | **9.66** | **7.03** | **7.96** | **8.93** | **11.26** | **8.30** | **9.50** | **8.20** | **10.16** | **7.23** | **8.53** | | |

**C.D at 5%**
Rootstock = 0.194 ; Rootstock × Rooting media = 0.389
Growth hormone = 0.194 ; Growth hormone × Rooting media = 0.389
Rooting media = 0.224 ; Rootstock × Growth hormone × Rooting media = 0.673

The perusal of data (Table 5) reveals that number of leaves was positively influenced by various rootstock. The highest number of leaves (32.88) were recorded in $S_3$ (MM106) rootstock which was statistically followed with $S_1$ (M7) rootstock having leaf number of 29.38. Minimum number of leaves (26.30) was observed in $S_2$ (M9 T337) rootstock. The different growth hormone concentrations had a significant effect on number of leaves per cuttings. The maximum number of leaves (33.94) was recorded in rootstock cuttings treated with growth hormone $G_2$ (IBA: 3000 ppm), which was followed by rootstock cuttings treated with growth hormone $G_1$ (IBA: 2500 ppm) recorded 28.25 leaf number. However, the minimum number of leaves (26.38) was recorded in rootstock cuttings treated with growth hormone $G_3$ (IBA: 3500 ppm). Similar results for IBA treatments were obtained by Sadiq (1991) and Mehta *et al.*, 2018. It is clearly evident from the perusal of data presented in Table 6 that influence of different rooting media exerted a significant effect on number of leaves. The maximum number of leaves (32.96) was recorded in rootstock cuttings planted in rooting media $M_3$ (sand + vermicompost + perlite (1:1:1)), which was significantly better than any other rooting media. This could be because of the vitamins present in rooting media at root stages, resulting greater number of leaves in cuttings. The multiplied roots in the cuttings due to auxin movement can also have improved the photosynthetic and other motion carried out in leaves (Taiz and Zeiger 2006). Contrastingly, the minimum number of leaves (26.63) was found in rootstock cuttings planted in rooting media $M_2$ (sand + vermicompost + vermiculite (1:1:1)). The interaction effect of rootstock, growth hormone and rooting media showed significant influence on number of leaves. Number of leaves was highest in the combination of $S_3G_2M_3$ (47.33) which was followed by $S_3G_1M_4$ (42.66). $S_2G_1M_1$ combination was recorded minimum number of leaves (20.33).

The data pertaining to survival percentage of cuttings (Table 6) was influenced by main effect of rootstock, rooting media and growth hormone treatments. The perusal of data indicates the highest survival percentage of cuttings (73.61%) was recorded in $S_3$ (MM106) rootstock which was followed by $S_1$ (M7): (70.27%). The minimum survival percentage of cuttings 70.00% was recorded in $S_2$ (M9 T337) rootstock. The growth hormone exerted a significant effect on survival percentage of cuttings. The maximum survival percentage of cuttings (74.44%) was recorded in rootstock cuttings treated with $G_2$ (IBA: 3000 ppm) growth hormone which was significantly at par with $G_1$ (IBA: 2500 ppm) growth hormone having (73.61%). However, the minimum survival percentage of cuttings 65.83% was recorded in rootstock cuttings treated with $G_3$ (IBA: 3500 ppm) growth hormone. Survival percentage of cuttings was observed significantly higher (75.92%) in $M_3$ (sand + vermicompost + perlite) (1:1:1) rooting media which was statistically at par with $M_4$ (sand + vermicompost + cocopeat) (1:1:1) (74.07%). It could be attributed to the ability of the rooting media and plant growth hormone to deliver vitamins and circulate air required for immediate acclimatization (Agro, 1998).While as minimum survival percentage of cuttings (66.66%) was recorded in rooting media $M_1$ (sand + vermicompost) (1:1). These results are in conformity with the findings of, Badshah *et al.* (1995), Rajeshwara *et al.*, 2008 and Gupta *et al.* (2004), It is clearly evident that interaction effect of growth hormone and rooting media on the survival percentage of cuttings was found to be non-significant.

**Table 5: Influence of rootstock, growth hormone and rooting media on dry weight of leaf (g).**

| M / S | $M_1$ | | | Sub mean | $M_2$ | | | Sub mean | $M_3$ | | | Sub mean | $M_4$ | | | Sub mean | Mean | Factor Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| G | $G_1$ | $G_2$ | $G_3$ | | $G_1$ | $G_2$ | $G_3$ | | $G_1$ | $G_2$ | $G_1$ | | $G_1$ | $G_2$ | $G_3$ | | | |
| $S_1$ | 2.60 | 3.00 | 2.30 | **2.63** | 2.90 | 3.40 | 2.40 | **2.90** | 3.60 | 4.20 | 2.90 | **3.56** | 3.40 | 3.70 | 2.70 | **3.26** | **3.09** | $G_1$=2.96 |
| $S_2$ | 1.60 | 2.50 | 1.90 | **2.00** | 1.80 | 2.60 | 2.10 | **2.16** | 2.50 | 2.10 | 2.80 | **2.46** | 2.20 | 2.70 | 2.50 | **2.46** | **2.27** | $G_2$=3.50 |
| $S_3$ | 3.30 | 4.00 | 2.93 | **3.41** | 3.43 | 4.30 | 3.10 | **3.61** | 4.70 | 5.20 | 3.40 | **4.43** | 3.50 | 4.40 | 3.30 | **3.73** | **3.79** | $G_3$=2.69 |
| **Mean** | **2.50** | **3.16** | **2.37** | **2.68** | **2.71** | **3.43** | **2.53** | **2.89** | **3.60** | **3.83** | **3.03** | **3.48** | **3.03** | **3.60** | **2.83** | **3.15** | | |

**C.D at 5%**
Rootstock = 0.105; Rootstock × Rooting media = 0.209
Growth hormone = 0.105; Growth hormone × Rooting media = 0.209
Rooting media = 0.121' Rootstock × Growth hormone × Rooting media = 0.363

**Table 6: Influence of rootstock, growth hormone and rooting media on number of leaves/cutting.**

| M / S | $M_1$ | | | Sub mean | $M_2$ | | | Sub mean | $M_3$ | | | Sub mean | $M_4$ | | | Sub mean | Mean | Factor Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| G | $G_1$ | $G_2$ | $G_3$ | | $G_1$ | $G_2$ | $G_3$ | | $G_1$ | $G_2$ | $G_1$ | | $G_1$ | $G_2$ | $G_3$ | | | |
| $S_1$ | 27.33 | 29.66 | 24.00 | **27.00** | 24.66 | 30.33 | 25.00 | **26.66** | 32.00 | 38.00 | 30.33 | **33.44** | 30.00 | 32.66 | 28.66 | **30.44** | **29.38** | $G_1$=28.25 |
| $S_2$ | 20.33 | 27.33 | 22.00 | **23.22** | 24.00 | 29.66 | 24.00 | **25.88** | 26.00 | 32.00 | 27.66 | **28.55** | 24.66 | 30.66 | 27.33 | **27.55** | **26.30** | $G_2$=33.94 |
| $S_3$ | 28.00 | 40.33 | 26.00 | **31.44** | 26.33 | 33.00 | 22.66 | **27.33** | 33.00 | 47.33 | 30.33 | **36.88** | 42.66 | 36.33 | 28.66 | **35.88** | **32.88** | $G_3$=26.38 |
| **Mean** | **25.22** | **32.44** | **24.00** | **27.22** | **25.00** | **31.00** | **23.88** | **26.63** | **30.33** | **39.11** | **29.44** | **32.96** | **32.44** | **33.22** | **28.22** | **31.29** | | |

**C.D at 5%**
Rootstock = 0.859 ; Rootstock × Rooting media = 1.718
Growth hormone = 0.859 ; Growth hormone × Rooting media = 1.718
Rooting media = 0.992; Rootstock × Growth hormone × Rooting media = 2.976


Rootstock: M 9
IBA concentration: 2500 ppm


Rootstock: M 9
IBA concentration: 3000 ppm


Rootstock: M 9
IBA concentration: 3500 ppm

**Fig. 1.** Shoot growth of M 9 rootstock treated with growth hormone IBA and planted in different rooting media.


Rootstock: MM 106
IBA concentration: 2500 ppm


Rootstock: MM 106
IBA concentration: 3000 ppm


Rootstock: MM 106
IBA concentration: 3500 ppm

**Fig. 2.** Shoot growth of MM106 rootstock treated with growth hormone IBA and planted in different rooting media.

## CONCLUSION

From the present investigation, it can be concluded that rooting capacity changes with genotype, rooting media, growth hormone concentration, etc. Moreover the hardwood cuttings of MM106 clonal rootstock with treatment combination of $G_2$ (IBA: 3000ppm) and $M_3$ (sand + vermicompost + perlite) (1:1:1) were superior to obtain higher survival of superior rootstock cuttings. These result can be utilized to create a convention for generation of quality planting material of apple clonal rootstocks through cuttings. Further research on the rooting of these cuttings need to be done using different media and different harmone concentrations. Also development of protocols for in vitro rooting of cuttings, scion propagation protocols and also in vitro-grafting (micro grafting) for the production of large scale disease free planting materials need to be done.

**Conflict of Interest.** Nil.

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