European Journal of Biotechnology and Bioscience
ISSN: 2321-9122; Impact Factor: RJIF 5.44
Received: 27-01-2019; Accepted: 28-02-2019
www.biosciencejournals.com
Volume 7; Issue 2; March 2019; Page No. 82-88

A Review: Effect of auxins, rooting media and vegetative propagation methods of apple (*Malus spp.*)

Krishan Kumar Singh[1], JS Chauhan[2], Prabhat Kumar[3], JMS Rawat[4], RL Suwalka[5]
[1, 5] School of Agriculture Science, Department of Horticulture, Career Point University Kota, Rajasthan, India
[2] Department of Seed Science and Technology, Chauras Campus, HNB Garhwal University, Srinagar Garhwal, Uttarakhand, India
[3] Principal Scientist, Indian Agricultural Research Institute, Delhi, India
[4] Government Degree College, Rudraprayag, Uttarakhand, India

Abstract
Apple *Malus domestica* is a woody plant belonging to the family Rosaceae. Vegetative or clonal propagation is the most important propagation method used for the commercial production of many horticultural crops. The rooting may be increased by the use of growth regulators such as IBA, NAA and different rooting media. Intermittent mist is often used on cuttings because it reduces the temperature of the leaves, lowers respiration, and increases relative humidity around the leaf surface. Factors such as cultivar and age of the source tree; the collection date, length, diameter and degree of hardening of the cuttings; injury and heat treatments of the cuttings and the treatment concentrations of auxin-like compounds. The maximum graft height, scion diameter, rootstock diameter, number of leaves per graft, root length and root diameter were observed in the rootstock and scion combination of Vance Delicious and M-793. Rooting hormones, planting time, maturity of the stock plants and propagation environment might be among the important factors affecting the rooting of stem cuttings.

Keywords: apple, auxins, propagation, rooting media and rooting percentage

1. Introduction
Apple *Malus domestica* is a woody plant belonging to the family, Rosaceae. In India, apple is produced predominantly in North-Western Himalayan region comprising of Jammu and Kashmir, Himachal Pradesh and Uttarakhand. However, its cultivation has been extended to Arunachal Pradesh, Sikkim, Nagaland, and Meghalaya and Nilgiri hills of Tamil Nadu, where mild temperate climatic conditions prevail.The Department of Horticulture has introduced different apple rootstocks, out of them Merton 793 has been reported to be suitable for replanting appleorchard at old sites (Jindal & Gautam, 2001) [42].

In apple, both the seedling and clonal rootstocks are employed all over the world. Seedling still continues to be the most widely and commonly used rootstock. But seedlings are vigorous highly variable and their use as a rootstock results in delayed cropping and great variability in the productivity of the cultivars grafted on them. The vegetative raised clonal rootstocks, on the other hand, are not only uniform but they are also precocious, productive and resistant to biotic and abiotic factors. Thus, in apple the use of clonal rootstocks has become an acceptable practice of eliminating variability arising from the use of variable seedling rootstocks and of reducing tree size and increasing precocity and productivity. Nursery plants of fruits on seedling rootstocks are usually sold as one to three years old and cause the loss of time and cost.

Stool layering, sometimes referred as mound layering or stooling, is old nursery propagation method standardized and improved to propagate specific apple clonal rootstocks Malling and Malling Merton series at England. This is most convenient and cheap method of obtaining a fully developed stronger stock in considerably less time. Some clonal rootstocks are difficult to root such as MM 109, M 4, M 9, crab apple (Tripathi *et al.* 2006) [93], M 26, M 27, M 11, MM 111 and Merton 793 (Gul-ko, 1986) [28]. The rooting can be improved in these rootstocks through the use of plant growth regulators particularly auxins. The rooting may be increased by the use of growth regulators such as IBA, NAA and different rooting media. Among the growth regulators, synthetic auxins are extensively used for inducing rooting. Synthetic auxin that is IBA (Indolebutyric acid) is widely used due to its ability to increase rooting and to induce a fibrous root system.

Langhans, (1955) [52] reported that the Intermittent mist is often used on cuttings because it reduces the temperature of the leaves, lowers respiration, and increases relative humidity around the leaf surface. The cutting ofshoothas been generally operated for propagation of fruits species and clonal root-stocks (Hartmann *et al.*, 2002) [34]. Factors such as cultivar and age of the source tree; the collection date, length, diameter and degree of hardening of the cuttings; injury and heat treatments of the cuttings and the treatment concentrations of auxin-like compounds (Tsipouridis *et al.*, 2003) [94]. Tajbakhsh *et al.* (2009) [92] also examined the rooting% in cuttings of apple (31.4%) was in 3000 mg/L concentration. The rooting percentage in M.26 and MM106 rootstock cuttings was 7.2 and 25%, respectively with 2000 mg/L (Fukuda *et al.* 1988) [21].

2. Effect of Different Concentrations of bioregulators
The increase in percentage of rooting in cuttings with application of auxin treatment might be due to the beneficial effect of auxin in stimulation of natural reserves and their

mobilization to the region of root formation (Doak, 1941) [14]. Stautmeyer (1954) [88] and Pearse (1948) observed that IBA, generally has distinct advantage over NAA, as it is a strong auxin and its activity is slowly destroyed by the auxin destroying enzyme system.

Mixtures of root promoting substances are more effective than either component alone. Equal parts of IBA and NAA combination when used on a number of widely diverse species, were found to induce higher percentage of rooted cuttings and more roots per cutting (Davis and Haissing, 1990) [11]. Longest stool shoots in MM106 with 4 per cent Dormex and 1000 ppm Antonik treatments given during early March (Gomma and Stino 1990) [23]. Suriyapananot (1990) [91] observed that among three apple rootstock cuttings (MM-106, Indonesian and Marubakaido N^{-1}), Marubakaido N^{-1} cuttings gave highest rooting percentage (98.2%), when treated with 8000 ppm IBA. The rooting in apple rootstocks may be increased by wounding and use of growth regulators such as IBA (Gomma *et al*. 1989) [24]. Badiyala and Badyal (1986) [3] observed 100 per cent rooting and 68 per cent field survival in pecan nut with IBA 5000 ppm on stooling five shoots per stool.

NAA has synergistic effect on the rooting, when mixed with IBA formulations. Sun and Bassuk (1991) [89, 90] observed that bending and IBA treatment increased both the rooting percentage and number of roots in MM 106 cuttings. Ramesh chand (1999) reported that the best rooting with the application of IBA 2500 ppm in M 7, M 9 and MM 111 rootstocks. El-Sabrout and El-Shazly (1994) while studying propagation of MM 106 apple rootstock through cuttings, recorded the highest rooting (52.25%) with basal cuttings taken from girdled shoots and dipped in 2500 ppm IBA. Noor Badshah *et al.* (1995) reported that 3000 ppm IBA is the optimum concentration for rooting of M 26 and M 27 apple rootstock cuttings as it resulted in the highest sprouting and survival percentage.

Sharma *et al.* (2005) [78-80] observed that IBA 3000 ppm induced a greater number of roots, and increased the emergence of new leaves in semi-hardwood cuttings of MM 106 which produced the highest number of new leaves, followed by M 9 and M 2. Highest number of rooted shoots, length of longest root and rooted sprouts with ringing of shoot bases + IBA 2500 ppm in apple rootstock MM 106 through trench layering (Srivastava *et al.* 2006) [87]. Gupta and Brahmachari (2004) [29] observed that growth regulators, whether singly or in combination, significantly enhanced the rooting and survival of stools in custard apple. The highest rooting percentage (37.03%) was obtained in the concentration of 2500 mg/LIBA and cocopeat + perlite medium (Dvin *et al*. 2011) [69].

Experiments have been conducted by various workers on the effect of different concentrations of IBA, NAA treated with different combinations in cuttings on the rooting percentage, number of roots, promoting better shoot characters using different media and observed better performance on the root as well as shoot characteristics (Gryzeb, 1980; Pathak, *et al.* 1976; Nyomora and Mnzava, 1982; Joshi *et al*. 1987; Tripathi *et al.* 2006) [26, 65, 60, 43, 93].

3. Effect of Different Rooting Media

Rooting medium also play avery important role in the root proliferation and further growth in plants raised by stem cutting, although information on this aspect in very limited in citrus spp. The uses of different organic and inorganic substrates allow the plants for best nutrient uptake and sufficient growth and development to optimize water and oxygen holding (Verdonck *et al.*, 1982) [98]. Sangcheol *et al*. (1998) [74] reported that the gravelly rock fragments alone or in combination with compost were the most effective mounding material for M 9 rootstock. Ramesh chand (1999) observed that the higher number of rooted suckers and total root length with saw dust as mounding-up medium. While, M 7 rootstock gave higher number of rooted suckers, number of main roots and higher total root length per sucker with soil + FYM as mounding-up medium.

Use of organic substrates such as soil, peat, sawdust and bark improved the root quality of all the rootstocks of apple, while the use of peat, resulted in the longest and thickest rootstocks. The use of sawdust resulted in highest total number of rooted shoots per stool (Koptowski, 2001) [45]. El-Aziz *et al.* (1992) [1, 17] observed that the best rooting of softwood cuttings of apple rootstock MM 106 was found in the treatment of IBA 2000 ppm and planting in sand + peat moss or perlite + vermiculite (1:1). Turovskaya (1986) [95] observed that the soft wood cuttings of clonal apple rootstock (54-118, PB 9, MM 106 and 58-69) rooted equally well (up to 97.8%) under mist in peat blocks or peat pots filled with peat + sand mixture (1:1). Soft wood cuttings of red currant and apple rootstock J-TE-B rooted best when taken on 23 June and rooted in peat: perlite: sand (1:1:1) medium (Habajova and Jurcak 1984) [30]. Cocopeat is a waste product of coir industry and it is prepared by composting the coir dust for several months. Cocopeat (Synonyms cocofibre, coir dust, coco shell dust, and coconut dust and coir pith) is becoming very important substrate for growing plants. Yau and Murphy (2000) [101] reported that raw form of cocopeat was unsuitable for use as it contained phytotoxic elements which inhibit plant growth.

4. Methods of Propagation

Cutting

Vegetative propagation of plants by stem cuttings is the most commonly used method for producing herbaceous and woody landscape plant in many part of the world. Hardwood cuttings are those made of matured, dormant firm wood after leaves abscised. The use of hardwood cuttings is one of the least expensive and easiest method of vegetative propagation. (Fourrier 1984) [21]. Auxin application has been found to enhance the histological features like formation of callus and tissue and differentiation of vascular tissue (Mitra and Bose 1954, Satpal *et al*., 2014) [56, 75]. Intermittent mist is often used on cuttings because it reduces the temperature of the leaves, lowers respiration, and increases relative humidity around the leaf surface (Langhans, 1955 and Singh, 2018) [52, 82]. There are various factors that can changes the rooting potential of stem cuttings counting species and specific cultivar needs; juvenility and condition of stock plant; the source, position, and type of cutting taken, leaf removal; stock plant etiolation and girdling; cutting date; or is influenced by growing conditions such as media, mist, bottom heat, hormones, fertilizer, and supplemental lighting (Hartmann *et al*., 2002) [34].

The longest root was reported from control group (2.04 cm) in 96-100% humidity level and 500 ppm IBA hormone dose (1.81 cm) in 86-90% humidity. The short root was reported from 2500 ppm IBA hormone dose application (0.08 cm) in 86-90% humidity level. The highest root branching value was obtained from 1500 ppm hormone dose application

(0.88 number/cutting) in 95 - 100% humidity level (Ersoy *et al*. 2009) [18]. The results indicate that multiplying the combination of IBA by double and triple, bacteria and carbohydrates are more effective in increasing rooting capacity and more quality rooting when juxtapose to control, or carbohydrate, IBA and, bacteria alone (Karakurt *et al*. 2009) [44]. The cuttings stored for 7 days along with IBA 2500 ppm treatment recorded highest rooting percentage, number of primary roots, length and diameter of primary roots, fresh and dry weight of roots recording 46.67%, 4.60, 28.60 cm, 2.63 mm, 2.89g and 1.83 g, respectively (Verma, 2015) [99]. Similar experiments have been carried out by different workers in apple species on various parameters of cuttings and root formations with minimum time with respect to the various concentrations of growth substances (Child and Hughes, 1978; Pandit *et al*., 2011; Webster *et al*., 1990; Delargy *et al*. 1979; Bassuk *et al*. 1981; Lone *et al*. 2007; Robinson *et al*.1977; Sivaci *et al*., 2008; Abd.,1992; Christensen *et al*., 1980; Fachinello *et al*., 1988; Gardner,1937; Grzyb *et al*.,1989; Hansen, 1990; Harrison, 1981; Howard *et al*. 1985; Howard *et al*. 1985; Imtiyaz *et al*., 2007; Karakurt *et al*. 2009; Noor *et al*. 1995; Nyomora *et al*. 1982; Pandey *et al*., 1979; Pandey *et al*., 1981; Rahimi *et al*. 2011; Sabrout *et al*., 1994; Sharma *et al*., 2005; Shawky *et al*. 1993; Sun *et al*., 1991; Sun *et al*., 1991; Suriyapananont *et al*., 1990; Tustin, 1976) [9, 64, 100, 12, 5, 53, 73, 84, 1, 10, 20, 27, 31, 32, 37, 41, 44, 60, 62, 67, 69, 70, 80, 81, 89, 91, 96].

Budding

Pathak and Srivastava (1973) [66] reported that the 80-90% bud take and 60.00 to 70.00% budding success in the month of July in apple. Dimri *et al*. (2005) [13] reported that the chip budding performed on Ist March proved to be superior in terms of the highest grafting success (94.42%), linear growth (97.07 cm), number of branches (3.60), number of nodes (38.62), number of leaves (62.30), canopy spread (176.04 cm^2) and proportion of saleable plants (91.90%). Sharma *et al*. (2005) [78-80] observed that the length of total roots and fibrous roots were found to be significantly higher in the trees grown on M7 rootstock. In 75-100 cm soil profile, trees on MM106 had increased root length and root weight juxtapose to M7 rootstock which manifest that roots of MM106 reached deeper in soil than M7 rootstock. Dwivedi *et al*. (2000) [16] observed that the 14 and 21 August have given the best results in terms of sprouting (88.30%), bud-take success (81.60%) and linear growth (24.70 cm) in apricot under cold arid condition of Ladakh. The mean radial growth (0.64 cm) was recorded maximum with 7 August.

Bogdanov (1976) [7] recorded that the optimum results for the apple cvs. Ural'skoe and Borovinka were obtained when budding was carried out on 25 July and 15 August. Kuden and Kaska (1991) [50] reported that the highest percentage of bud-take and the maximum length of shoot were reported in chip budding. Ponchia *et al*. (1995) [67] also found chip budding to be more successful for apple cvs. Golden Delecious, Fuzi and Florina grafted on M-9 or M-26 rootstocks over other methods used, i.e., triangular grafting, simple cleft grafting and T-budding. Negi and Ananda (1997) [58] revealed that graft union to be smooth with chip budding having rapid and more complete union formation ultimately giving higher percentage of strong saleable plants, while in tongue grafted plants even after infilling of callus between stock and scion, the parenchymatous cells still needed lignification for proper strengthening of the grafts. Skene *et al*. (1983) [103] studied the effect of chip budding in various fruit and ornamental trees and found that the chip budding gave a greatly improved bud- take as compared to T- budding further, a superior number and length of laterals in apple cv. Cox and pear cv. Conference, while in Tilia, high bud-take and proportion of tall maiden trees at the end of the following growing season were reported after chip budding compared to 'T' budding. Anatomically, the bud take percentage was high in chip budded plants due to the formation of excessive new xylem and better cambial activity as compared to other methods.

Negi (1995) [57] obtained the maximum proportion of saleable plants in apple, almond and plum with chip budding, which may be attributed to greater linear and radial growth of grafted plants due to quick union formation, early bud sprouting and longer period of growth as compared to shield and angular budding at Solan condition. They also reported that longer chip gave a higher percentage of bud-take than small chips or shields. Kuden*et al*. (1997) [50] obtained more than 70% bud sprouting for both chip budding andwhip grafting in temperate fruit crops with the plant height after one year ranging from 91.30 to 118.20 cm for chip budding and 74.50 to 115.20 cm for whip grafting. Howard and Skene (1974) [39] recorded the use of chip budding to grafts four apple cvs. onto a range of commercially important rootstocks in various combinations produced large and more uniform one-year-old plants. The effect of propagation methods in respect of production of feather, tongue grafting resulted in to the maximum number and length of feather and height of feather emergence in both the cvs., viz.; Redspur and Wellspur (Kumar *et al*. 2004) [51].

Layering

Vegetative or clonal propagation is the most important propagation method used for the commercial production of many horticultural crops.Mound (stooling) and other layering methods have been most commonly and commercially used for the propagation of clonal rootstocks of various fruit plants.The mound layering as the method, where the shoots are cut back to the ground and soil or rooting medium is mounded around them to stimulate roots at their bases (Hartmann *et al*., 2007) [33].

Shaltout (1994) [77] studied three different seasons of stool layering in MM 106 rootstock and found 3.65 average number of plants produced per stool in the first season, increasing to 6.75 during the second season and only slight increase in the third season. Plant height did not differ considerably between seasons but the number of plants increased in successive seasons.The rootstocks which produced the maximum number of first class layers per hectare were A 2 (70,000), Margolina (55,900), M 5 (51,000), MM 102 (45,400) and M 4 (42,600) (Gryazev 1994) [25]. Tamai *et al*. (2002) observed that the 'M 9 Nagano' rooted well in the stool bed by etiolating young shoots and an average of about 10 rooted shoots were harvested in 3 to 5-year old stool beds. Tabakov and Yordanov (2006) concluded that the largest number of overgrown (thicker than 12 mm) stool shoots is a characteristic of M 9. The highest yield of stool shoots was obtained from J-TE-F, M 26 and smallest from M 9.

Grafting

Malasi *et al*. (2017) [54] observed that the maximum graft height (92.40 cm), scion diameter (1.12cm), rootstock diameter (1.26), number of leaves per graft (105.07), root length (25.34 cm) and root diameter (1.21 cm) were perceive in the rootstock and scion combination of Vance Delicious and M-793. The minimum days taken to bud sprout (10.58) and maximum% survival was observed in Oregon Spur and MM111. Rabi *et al*. (2014) [68] reported that the Increase in graft take success (91.10%), plant height (107.97 cm), scion diameter (9.38 mm), number of leaves plant-1 (116.57) were noted in cultivar Gala must with rootstock Crab apple. Dolgun, *et al*. (2009) [15] reported that the scions of apple cultivars were whip-grafted onto rootstocks in May, 2007 in order to observe graft union development. 100 plants were grafted for each combination. Samples of grafts were taking on 14th and 30 th day and every month thereafter for a year. Samples of graft unions from each rootstock specimens were fixed in 70% alcohol. Transverse sections (20 - 30 µm) were cut with a rotary microtome. The rootstock are grafted with desired scion variety during February-March.

In apple bud unions, the xylem cells between the scion and the dwarfing M.9 rootstock were small and the adjacent cells in the rootstock were larger, while the vigorous 'MM.106' rootstock had normal xylem development in the rootstock (Soumelidou *et al*., 1994) [85]. Similar experiments have been carried out by different workers in apple species on various parameters of grafting and root formations with minimum time (Norelli *et al*. 2003; Robinson *et al*. 2007; Russo *et al*. 2007; Howard *et al*. 1974; Atkinson *et al*. 2003;Soumelidou *et al*. 1994; Hirsch *et al*. 1995; Howard *et al*. 1974; Koutinas *et al*. 2009; Michael *et al*. 2006; Omer *et al*. 2011; Yefalvi *et al*. 2013; Evans *et al*. 1997; Singh *et al*. 2005; Tworkoski *et al*. 2007; Rana *et al*. 2004; Bhatia *et al*. 2009; Kosina, 2009; Kosina, 2010) [59, 73, 73, 39, 2, 85, 36, 85, 48, 55, 61, 102, 19, 80, 97, 71, 6, 46, 47].

Conclusion

All the above investigation shows that IBA treatment is better than the other form of treatments for apple cutting development. The rootstock are grafted with desired scion variety during February-March. Increase in graft take success, plant height, scion diameter, number of leaves plant-1 were noted in cultivar Gala must with rootstock Crab apple.

References

1. Abd El, Aziz E, Hamouda A, Abd El Hamid Z. Effect of planting date and IBA on rooting of MM 106 apple cuttings. Egyptian Journal of Agricultural Research. 1992; 70(3):941-949.
2. Atkinson CJ, Else MA, Taylor L, Dover CJ. Root and stem hydraulic conductivity as determinants of growth potential in grafted trees of apple (*Malus pumila* Mill.). J. Expt. Bot. 2003; 54:1221-1229.
3. Badiyala SD, Badyal JM. Studies on stooling of pecan nut. Punjab Horticultural journal. 1986; 26:102-104.
4. Badshah N, Rahman N, Zubair M. Effect of indole butyric acid (IBA) on the cuttings of M 26 and M 27 apple rootstocks. Sarhad Journal of Agriculture. 1995; 11(4):449-453.
5. Bassuk NL, Howard BH. A positive correlation between endogenous root-inducing cofactor activity in vacuum-extracted sap and seasonal changes in rooting of M26 winter apple cuttings. Journal of Horticultural Science. 1981; 56(4):301-312.
6. Bhatia HS, Kumar J. Performance of new apple cultivars on ^ different rootstocks under high density plantation. Agricultural Science Digest. 2009; 29(4):303-305.
7. Bogdanov SM. The effect of budding time and soil moisture on bud take and production of standard apple maidens. Sbornik- Nauch. Rabot. Saratov. S. Kh. Institute. 1976; 62:135-139.
8. Chand R. Clonal propagation of some Malling and Malling Merton apple rootstocks through stool layering. M.Sc. Thesis. Department of Fruit science. Dr. Y S Parmar University of Horticulture and Forestry, Nauni, Solan-173230 (HP), 1999.
9. Child RD, Hughes RF. Factors influencing rooting in hardwood cuttings of apple cultivars. Acta Horticulturae. 1978; 79:43-48.
10. Christensen MV, Eriksen EN, Andersen AS. Interaction of stock plant irradiance and auxin in the propagation of apple rootstocks by cuttings. Scientia Hort. 1980; 12:11-17.
11. Davis TD, Hassig BE. Chemical control of adventitious root formation in cuttings. Plant Growth Regulators Soc. Amer. Quart. 1990; 18(1):1-17.
12. Delargy JA, Wright CE. Root formation in cuttings of apple in relation to auxin application and to etiolation. New Phytol. 1979; 82:341-347.
13. Dimri DC, Petwal A, Kamboj P. Determination of Optimum Time for Chip Budding in Apple cv. Red Fuji. Acta Hortic. 2005; 696:173-176.
14. Doak BW. Changes in the carbohydrate and nitrogenous constituents of cuttings as affected by hormone treatment. New Zealand Journal of Science and technology. 1941; 22:192-195.
15. Dolgun O, Yıldırım A, Polat M, Yıldırım F, Akın A. Apple graft formation in relation to growth rate features of rootstocks. African Journal of Agricultural Research. 2009; 4(5):530-534.
16. Dwivedi SK, Attrey DP, Elipaljor. Standardization of budding in apricot (Prunus armeniaca L.) in cold arid conditions of Ladakh. Prog. Hort. 2000; 32(2):117-120.
17. El Aziz EA, Makarem MM, El Hamid ZA. The effect of rooting media and IBA concentration on stem cuttings of MM 106. Egyptian Journal of Agricultural Research. 1992; 70(2):599-612.
18. Ersoy N, Kalyoncu IH, Aydin M, Yilmaz M. Effects of some humidity and IBA hormone dose applicatıons on rooting of M9 apple clonal rootstock Softwood top cuttings. African Journal of Biotechnology. 2009; 9(17):2510-2514.
19. Evans RR, Evans JR, Rademacher W. Prohexadione calcium for suppression of vegetative growth in Eastern apples. Acta Hort. 1997; 451:663-666.
20. Fachinello JC, Lucchesi AA, Gutierrez LE. The effect of girdling on nutrition and rooting of hardwood cuttings of apple rootstock Malling Merton. Pesquisa Agropecuaria Brasileira. 1988; 23(9):1025-103l.
21. Fourrier B. Hardwood cutting propagation at McKay nursery. Comb. Proc. Intl. Plant. Prop. Soic. 1984; 34:540-43.
22. Fukuda H, Ohnuma K, Nishiyama U. Rooting behavior of hardwood cuttings of several rootstocks in relation to

root primordia. Bull. Fruit Tree Res. Sta. 1988; 15:29-40.
23. Gomma AH, Stino GR. Effects of various promoters on bud burst and side branching of MM 106 apple stools. Egyptian Journal of Horticulture. 1990; 16(1):17-23.
24. Gomma AH, Khattab MM, El Rahman EA. Effect of rooting media and auxin treatments in apple rootstock stooling. Egyptian Journal of Horticulture. 1989; 16(1): 1-8.
25. Gryazeve VA. Quick raising of transplants on clonal rootstocks. Sadovodstvo-i-vinogradarstvo. 1994; 3:10.
26. Gryzeb ZS. Growth and rooting of Brompton plum, F 12/1 cherry and M 26 apple clonal rootstocks. Effect of selected treatments on number of shoots, their length and the rooting ability. Fruit science Reports. 1980; 7(4):161-178.
27. Grzyb ZS, Czyhczyk A, Radwan PP. Influence of covering mother plants on the dwarfing apple rootstocks with polyethylene foil on rooting ability of softwood cuttings obtained from them. Fruit Sci. Reports. 1989; 16:51-58.
28. Gul Ko IP. Root forming capacity of clonal apple rootstocks. Sadovodstvo I Vinogradarstuo Maldavii. 1986; 11:28-30.
29. Gupta RK, Brahmachari VS. Effect of IBA and NAA on stooling of custard apple (Annona squamosa). Orissa Journal of Horticulture. 2004; 32(1):38-40.
30. Habajova S, Jurcak S. Research on the best substrate, growth promoter and plant material for rooting cuttings under mist. Vedecke-Prace-Vyskumneho-Ustavu-Ovocnych-a-Okrasnych-Drevn-v-Bojniciach. 1984; 5: 51-63.
31. Hansen OB. Rapid production of apple rootstock by softwood cuttings. Scientia Hort. 1990; 42:277-287.
32. Harrison MRS. Etiolation of stock plants for improved rooting of cuttings: Opportunities suggested by work with apple. Proc. Internat. Plant Propagator's Soc. 1981; 31:386-392.
33. Hartmann HT, Kester DE, Davies FT, Geneve RL. Plant propagation: principals and practices. Prentice Hall of India. New Delhi, 2007, 277-403.
34. Hartmann HT, Kester DE, Davies FT. Geneve RL. Plant Propagation: Principles and Practices. 7th Edn., Prentice Hall, USA, 2002, 199-236.
35. Hiroshi T, Ono T, Koike H, Shigehara I, Iijima A. Morphological Characteristics of 4 Clones of M.9 Apple Rootstock and Propagation of M.9 Nagano in the Stool Bed. Horticultural Research: Japan. 2002; 1(4):241-244.
36. Hirsch PM, Ferre DC. Effect of rootstock and cultivar on the growth and precocity of young apple trees. Fruit varieties J. 1995; 49(1):34-41.
37. Howard BH. Factors affecting the response of leafless winter cuttings of apple and plum to IBA applied in the powder formulation. J. Hort. Sci. 1985; 60(2):161-168.
38. Howard BH, Harrison RSM, Arjyal SB. Responses of apple summer cuttings to severity of stock plant pruning and stem blanching. J. Hort. Sci. 1985; 60(2):145-152.
39. Howard BH, Skene DS, Coles JS. The effects of different grafting methods upon the development of one year old nursery apple trees. Journal of Horticultural Science. 1974; 49(3):287-295.
40. Howard BH, Skene DS, Coles JS. The effects of different grafting methods upon the development of one-year-old nursery apple trees. J. Hort. Sci. and Biotech. 1974; 49(3):287-296.
41. Imtiyaz AL, Sofi KA. Studies on the effect of indolebutyric acid and time of planting on performance of M9 and M26 apple rootstock cutting under high altitude. Asian J. Hort. 2007; 2(1):34-36.
42. Jindal KK, Gautam DR. Compendium of winter school on Enhancement of productivity of temperature fruits held at Dr. Y.S. Parmar University of Horticulture and Forestry On September 16 – 8 October, 2000. Department of Fruit Science, 2001, 43-54.
43. Joshi KR, Mishra RS, Seth JN. A note on clonal multiplication of apple rootstocks through stool layering. Progressive Horticulture. 1987; 19(1-2):143-144.
44. Karakurt H, Aslantas R, Ozkan G, Guleryuz M. Effects of Indol-3-Butyric Acid (IBA), plant growth promoting rhizobacteria (PGPR) and carbohydrates on rooting of hardwood cutting of MM106 Apple rootstock. Afr. J. Agric. Res. 2009; 4:60-64.
45. Koptowski J. Effect of different substrates on rootage of shoots in mother plantation of selected apple clones. Sodininkyste-ir-Darzininkyste. 2001; 20(3(2)):155-159.
46. Kosina J. Performance of Gloster and Melrose apple trees on Czech Rootstocks and M.9 clones. Acta Horticulture. 2009; 814:425-428.
47. Kosina J. Effect of dwarfing and semi dwarfing flowering and fruit setting of some peach and apple rootstocks on growth and productivity of selected apple cultivars. Horticulture Science. 2010; 37(4):121-126.
48. Koutinas N, Pepelyankov G, Koutina G. Rootstock influence on the time of cessation of the shoot growth and the time of differentiation of flower buds in two apple cultivars., Acta Horticulturae. 2009; 825:231-236.
49. Kuden A, Kaska N. Research of different budding methods in propagation of temperate zone fruit nursery plants grown in subtropical areas. Doga Turk Tarim Ve Ormancilik Desgisi. 1991; 15(3):759-763.
50. Kuden A, Gulen H, Duden AB, Dennis FG. Propagation of apples, pear and plums by grafted cutting. Acta Hort. 1997; 441:231-235.
51. Kumar R, Anada SA. Effect of methods and heights of grafting on the growth and proportion of saleable plants in spur type apples. Prog. Hort. 2004; 36(1):12-15.
52. Langhans RW. Mist for growing plants. Farm Res. (Cornell Univ.). 1955; 21(3):3.
53. Lone IA, Sofi KA. Studies on the effect of Indole Butyric Acid and time of planting on performance of M9 and M26 apple rootstock cutting under high altitude conditions. The Asian Journal of Horticultural. 2007; 2(1):34-36.
54. Malasi P, Thakur N, Chetanchidambar N Mangalore. (2017). Response of Different Rootstock and Scion Combinations on the Success of Grafting in Apple (Malus xdomestica). Int. J. Curr. Microbiol. App. Sci. 2017; 6(9):1193-1200.
55. Michael JC, Seleznyova A, Thorp TG, Blattmann P, Barnett AM, Lowe RG, *et al.* Vigor-controlling rootstock affects early shoot growth and leaf area development of kiwi fruit., Tree Physiology. 2006; 26(4):505-515.
56. Mitra GC, Bose N. Rooting and histological responses of detached leaves to B-Indolebutyric acid with special

reference to Boerhaviadiffusa Linn. Phytomorphology. 1954; 7:370.
57. Negi KS. Evaluation of Chip Budding in Temperate Fruit Plant Propagation. M. Sc. Thesis, Submitted to Dr. Y.S. Parmar University of Horticulture and Forestry, Sloan, H.P, 1995.
58. Negi KS, Ananda SA. Performance of different grafting methods in plum. Indian J. Agri. Res. 1997; 31(4):213-216.
59. Norelli JL, Holleran HT, Johnson WC, Robinson TL, Aldwinkle HS. Resistance of Geneva and other apple rootstocks to Erwinia amylovora. Plant Dis. 2003; 87:26-32.
60. Nyomora AMS, Mnzava NA. Rooting response of juvenile and adult cuttings of apple (Malus sylvestris L.) and peach (Prunus persica L.) to indole-3-butyric acid (IBA) and season in Tanzania. Beitrage-zur-tropischen-Landwirtschaft-und-Veterinarmedizin. 1982; 20(2):135-140.
61. Omer FK, Kalyoncu IH. Nursery growing of some apple varieties using different grafting methods in greenhouse and orchard. Afric. J. biotech. 2011; 10(83):19375-19384
62. Pandey D, Pathak KK. Anatomical basis of rooting potentiality in apple hardwood cuttings. Indian J.Hort. 1979; 36(1):1-5.
63. Pandey D, Pathak RK. Biochemical basis of rooting potentiality in apple hardwood cuttings and rooting cofactor and inhibitors. Indian J. Hort. 1981; 38(3-4): 171-177.
64. Pandit *et al*. Also reported that highest rooting percent, maximum number and length of primary roots were obtained with 3000 ppm IBA with rootstock MM.106 and MM, 2011,111.
65. Pathak RK, Pandey VS, Pandey D. ICAR Fruit Research Workshop, Ranikhet, 1976, 17-20.
66. Pathak RK, Srivastava RP. Studies on the vegetative propagation of apple by grafting. Prog. Hort. 1973; 4:57-70.
67. Ponchia G, Fila G, Gardiman M, Scarabello A. Effect of grafting method on the production of maiden trees of apple, pear and peach. IngormatoreAgrarop. 1995; 51(38):43-46.
68. Rabi F, Rab A, Rahman KU, Munir M, Bostan N. Response of Apple Cultivars to Graft Take Success on Apple Rootstock. Journal of Biology, Agriculture and Healthcare. 2014; 4(3):78-84.
69. Rahimi Dvin S, Ganji Moghadam E, Kiani M. Rooting Response of Hardwood Cuttings of MM111 Apple Clonal Rootstock to Indole butyric Acid and Rooting Media. Asian Journal of Applied Sciences. 2011; 4: 453-458.
70. Rahimi DS, Ganji ME, Eiani M. Rooting response of hardwood cuttings of MM111 apple clonal rootstock to indole-3-butyric acid (IBA) and rooting media. Asian J. Appl. Sci. 2011; 4(4):453-458.
71. Rana SS, Bhatia HS. Performance of Vance Delicious apple on different semi dwarfing rootstocks in Kullu valley. Acta Horticulturae. 2004; 662:265-268.
72. Robinson T, Anderson L, Autio W, Barritt B, Cline J, Cowgill W, *et al*. A multi-location comparison of 'Geneva® 16', 'Geneva® 41' and 'M.9' apple rootstocks in North America. Acta Hort. 2007; 732:59-65.
73. Russo NR, Robinson TL, Fazio G, Aldwinckle HS. Field evaluation of 64 apple rootstocks for orchard performance and fire blight resistance. HortScience. 2007; 42:1517-1525.
74. Sangcheol Lim, Cheolku Youn, Young Ho Kim, HagHyun, CheolHee Lee, Kwansoon Choi, *et al*. Effect of several mounding materials on rooting of M 9 part in M 9/seedling double grafted nurseries. Journal of Korean Society of Horticultural Science. 1998; 39(6): 713-715.
75. Satpal Manju, Rawat SS, Singh KK. Effect of various concentrations of iba, type of cuttings and planting time on the rooting of cuttings of lemon (Citrus limonburm.) Cv. Pant lemon 1- under valley conditions of garhwal himalaya. International Journal of Current Research. 2014; 6(12):10974-10976.
76. Sava T, Anton Y. Performance of some vegetatively propagated apple rootstocks in the nursery. Sodininkysteir Darzininkyste. 2006; 25(3):85-89.
77. Shaltout AD. Propagation of MM 106 apple rootstock by stool layering. Annals of Agricultural Sciences, Mostohor. 1994; 32(3):1665-1676.
78. Sharma MK, Bhat KM, Srivastava KK, Singh SR. Effect of IBA on production of apple clonal rootstocks by semi-hardwood cuttings. Environment and Ecology. 2005; 23S (Special 4): 794-796.
79. Sharma DD, Chauhan JS. Effect of Different Rootstocks on Root Distribution of Apple. Acta Hortic. 2005; 696:167-171.
80. Sharma MK, Bhat KM, Srivastava KK, Singh SR. Effect of IBA on production of apple clonal rootstock by semi-hardwood cuttings. Environ. & Ecol. 2005; 23(4):794 -796.
81. Shawky I, Hennawy HM, Wakeel HF. Effect of IBA and cold storage on rooting of hardwood cuttings of MM106 apple rootstock. Ann. Agric. Sci. 1993; 38(2):683-690.
82. Singh KK. A review: Macro-propagation of guava (*Psidium guajava*). Journal of Pharmacognosy and Phytochemistry. 2018; 7(2):2629-2634.
83. Singh RKD, Ananda SA. Rootstocks and scion interactions on certain growth characteristics in apple. Indian Journal of Horticulture. 2005; 62(1):76-78.
84. Sivaci A, Yalcin I. The Seasonal Changes in Endogenous Levels of Indole-3-Acetic Acid, Gibberellic acid, Zeatin and Abscisic Acid Stems of Some Apple Varieties (Malus sylvestris Miller). Asian Journal of Plant Sciences. 2008; 7:319-322.
85. Soumelidou K, Battey, John NH, P, Barnett JR. The anatomy of the developing bud union and its relationship to dwarfing in apple. Ann. Bot. 1994; 74:605- 611.
86. Soumelidou K, Morris DA, Battey NH, Barnett JR, John P. Auxintransport capacity in relation to the dwarfing effect of apple rootstocks. J. Hortic. Sci. 1994; 69:719-725.
87. Srivastava KK, Bhat KM, Sharma MK, Nazki TT. Studies on multiplication of MM 106 rootstock of apple through trench layering in Kashmir Valley. Research on Crops. 2006; 7(1):311-312.
88. Stautmeyer VT. Encouragement of roots by plant regulators. (cf. Book, Plant Regulators in Agriculture, Turkey H B), 1954, 45.
89. Sun WQ, Bassuk NL. Effects of banding and IBA on rooting and bud break in cuttings of apple rootstock

MM106 and Franklinia. J. Environ. Hort. 1991; 9(1):40-43.
90. Sun WQ, Bassuk NL. Stem banding enhances rooting and subsequent growth of M9 and MM106 apple root stock cuttings. Hort. Sci. 1991; 26(11):1368-1370.
91. Suriyapananot Vithaya. Propagation of apple rootstocks in Thailand: propagation by cuttings as related to seasonal changes, growth regulators and rooting media. Acta Horticulturae. 1990; 279:469-474.
92. Tajbakhsh M, Korkan M, Ghiyasi M. Effect of timing on callus formation and rooting ability in IBA-treated hardwood stem cutting of Persian walnut, hazelnut and apple. Not. Bot. Hort. Agrobot. Cluj-Napoca. 2009; 37:103-107.
93. Tripathi PC, Verma MK, Verma RK, Pandey G, Sofi AA. Response of NAA on root initiation and growth in apple rootstocks. Indian Journal of Horticulture. 2006; 63(1):81-82.
94. Tsipouridis CT, Thomidis, Isaakidis A. Rooting of peach hardwood and semi-hardwood cuttings. Aust. J. Exp. Agric. 2003; 43:1363-1368.
95. Turovskaya NI. Raising planting material with a whole root system. Sbornik-Nauchnykh-Trudov-Vsesoyuznyi-Nauchno-Issledovatel-Skiiinstitut-Sadovodstva-Imemi-iv-Michurina. 1986; 48:65-68.
96. Tustin DS. Some endogenous factors affecting root formation on hardwood cuttings of two clones of apple (Malus sylvestris Mill.) rootstocks. Ph.D. Thesis, Massey University, 1976, 185.
97. Tworkoski T, Miller S. Studies on the rootstock effect on growth of apple scion with different growth habits. Scienta Horticulturae. 2007; 111(4):335-343.
98. Verdonck O, Vleeschauwer De D, Boodt De M. The influence of the substrate to plant growth. *Acta Horticulturae*. 1982; 126:251-258.
99. Verma P, Chauhan PS. Effect of Storage Conditions (Growth Chamber) and Iba Treatments on Rooting of Cuttings of Apple Clonal Rootstock Merton 793 in Net House Conditions. The Bioscan. 2015; 10(3):1049-1052.
100. Webster AD, Christine A, Howard BH, Harrison RS. Factors involved in the rooting response of apple winter cuttings to high basal temperatures. J Horticultural Science. 1990; 65:7-14.
101. Yau PY, Murphy RJ. Biodegraded cocopeat as a horticultural substrate. Acta Horticulturae. 2000; 517:275-278.
102. Yefalvi JI, Festila A, Platon L. Comparative study of two bench grafting methods of apple (Malus domestica, Borkh) and pear (*Pyrus communis* L.). Bul. UAVSM Hort. 2013; 70:147-156.
103. Skene DS, Shepherd HR, Howard BH. Characteristic anatomy of union formation in T and chip-budded fruit and ornamental trees. J Hort. Sci. 1983; 58(3):295-299.