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EFFECT OF DIFFERENT SIZE OF CUTTINGS ON VEGETATIVE GROWTH AND ROOTING OF CLONAL ROOTSTOCK CUTTINGS OF APPLE

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ABSTRACT
The present investigation on effect of different size of cuttings on vegetative growth and rooting of clonal rootstocks of apple was carried out under shade net house conditions in the experimental block of Department of Fruit Science, Dr Yashwant Singh Parmar University of Horticulture and Forestry Nauni, Solan Himachal Pradesh during the year 2018-19. The cuttings of four different rootstocks of apple (Merton 793, MM 106, MM 111, and M 9) and three different cutting lengths (8 cm, 10 cm and 12 cm) were used and cuttings in each treatment were treated with 2500 ppm IBA. The experiment was laid out in Randomized Block Design comprising of twelve treatment combinations which were replicated thrice. The maximum leaf area (29.35 cm^2), fresh and dry weight of shoots (37.47 g and 25.46 g, respectively), average length and diameter of shoots (106.36 cm and 14.47 mm, respectively), total biomass (42.60 g) and rooting percentage (73.53 %) were recorded in the treatment combination of 12 cm cutting length of Merton 793 rootstock. Hence it is concluded that the treatment combination of 12 cm long cuttings of Merton 793 rootstock was found best among all treatment combinations in respect of various vegetative growth and rooting percentage.

INTRODUCTION

Apple is one of the most important commercial fruit crop of temperate region. It belongs to family Rosaceae and sub-family Maloideae. The crop originated in Central Asia and was grown in Asia and Europe for thousands of years and was introduced to North America by European colonists. In India, apple is mainly grown in the North-Western Himalayan region comprising states of Jammu and Kashmir, Himachal Pradesh and Uttarkhand. Apple occupies a unique position among temperate fruits of India and ranks fifth worldwide with a production of 2,371 thousand MT per year from an area of 307 thousand hectares (Anonymous, 2018a). In Himachal Pradesh, the apple plantation occupy an area of 113 thousand hectares with a production of 368 thousand MT (Anonymous, 2018b). Clonal rootstocks of apple are in great demand as these are used worldwide commercially. Clonal rootstocks also play a prime role in establishing high density plantations of apple and enhancing orchard efficiency. Conventionally, the clonal rootstocks of apple are propagated through mound layering (stooling). One of the convenient method of clonal propagation is through hardwood cuttings (Hartmann *et al.*, 2002). Among the clonal rootstocks Merton 793, MM111, MM 106 and M 9 are most suitable and commercially accepted rootstocks of North - West Himalayas. While grafting of main commercial cultivars on these rootstocks, major upper part of rootstocks is generally wasted. If this wasted part is further utilized as hardwood cuttings the multiplication rate of clonal rootstocks can be increased manifold to fulfill the demand of orchardists. Generally, hardwood cuttings are used for vegetative propagation as it is the cheapest and simplest method of propagation, Cutting length also play a prime role in the rooting of cuttings which affects the rooting behavior, survival percentage, number of roots, total root length *etc.* Rooting in hardwood cuttings can be improved with the use of growth regulators and growing media (Ercisli *et al.*, 2003). Larger cutting lengths generally leads to better growth and higher rooting percentage due to more accumulated food material in comparison to shorter ones (Osterc and Stampar, 2008). In recent days, clonal rootstocks have been used commercially because of their reliable importance such as control of vigour, precocity, winter hardiness, adaptation to adverse soil conditions *etc.* (Doglov and Hanke, 2006). Keeping in view all above mentioned points, the present study was carried out with the objective to investigate the effect of different size of cutting length by addition of plant growth regulators (IBA) on vegetative growth and rooting percentage of clonal rootstock cuttings of apple.

MATERIALS AND METHODS

The present investigation was carried out at Apple Block of Department of Fruit Science, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, H.P. under the shade net house conditions during the year 2018-19. The experiment comprised of 12 treatments which were replicated three times and laid out in Randomized Block

Design in which 15 cuttings were planted in each replication. Cuttings of four different rootstocks of apple namely, Merton 793, MM 106, MM 111, M 9 and three different cutting lengths *i.e.* 8 cm, 10 cm and 12 cm were used in the present study. The cuttings were prepared by giving a straight cut slightly below a node on the basal end and a slanting cut above a node on apical end. The propagation beds of 2m X 1m size were prepared by mixing vermicompost, cocopeat, sand and forest soil in 1:1:1:1 ratio in the shade net house. Basal portion of the cuttings was dipped in 2500 ppm IBA solution prepared in 50 per cent ethanol (quick dip method). The cuttings were planted at an angle of 45° in the propagation beds at a distance of 15 cm between rows and 10 cm between adjacent cuttings. Various treatment combinations were T_1: R_1L_1 (8 cm length of Merton 793 rootstock),T_2 : R_1L_2 (10 cm length of Merton 793 rootstock),T_3 :R_1L_3 (12 cm length of Merton 793 rootstock), T_4 : R_2L_1 (8 cm length of MM 106 rootstock), T_5 : R_2L_2(10 cm length of MM 106 rootstock),T_6 : R_2L_3 (12 cm length of MM 106 rootstock),T7 : R_3L_1 (8 cm length of MM 111 rootstock),T_8 : R_3L_2 (10 cm length of MM 111 rootstock),T_9 : R_3L_3 (12 cm length of MM 111 rootstock),T_{10} : R_4L_1 (8 cm length of M 9 rootstock),T_{11} : R_4L_2 (10 cm length of M 9 rootstock), T_{12} : R_4L_3 (12 cm length of M 9 rootstock). The observations on vegetative growth and rooting parameters were recorded as average shoot length, diameter, fresh weight of shoots, and dry weight of shoots, leaf area, total biomass and rooting percentage. (Hartmann *et al*., 2002).The data collected were analyzed by using Randomized Block Design. The data on percentage were statistically analyzed using arc sin transformation to treat the data for removing skewness (Panse and Sukhamte, 1985). The level of significance for different variables was tested at 5 per cent level of significance.

RESULTS AND DISCUSSION

Average Length of Main Shoots

The length of cuttings exerted a significant effect on average length of main shoots (Table 1). Maximum average length of shoots (95.92 cm) was recorded in the cuttings of 12 cm length which was significantly higher than all other cutting lengths. However, the minimum average length of shoots (90.19 cm) was observed in the cuttings of 8 cm length.

The rootstocks also exhibited a significant effect on average length of main shoots (Table 1). The cuttings of Merton 793 rootstock recorded maximum average length of shoots *ie.* (102.39 cm) which was significantly higher than all other rootstocks under study. Contrastingly, the M 9 rootstock cuttings recorded minimum average length of shoots (84.43 cm).

The interaction between different cutting length and rootstock also exerted a significant effect on average length of main shoots (Table 1). Maximum average length of main shoots (106.36 cm) was observed in the combination of 12 cm cutting length and Merton 793 rootstock. On the other hand, the minimum average length of main shoots (81.43 cm) was recorded in the combination of 8 cm cutting length of M 9 rootstock. This may be due to more metabolic reserves and high Carbon:Nitrogen ratio in longer cuttings which resulted in early shoot initiation. It has also been observed that optimally longer cuttings initiated the shoots early and produced more shoot growth. The reduction of shoot growth in shorter cuttings may due to delayed root initiation and terminal bud break. Naidu and Jones (2009) also reported that 13 cm long cuttings recorded higher shoot length than 10 cm cuttings in Eucalyptus clone. So the longer cuttings encouraged the more shoot growth as well as shoot diameter. Similar results were also reported by Awan *et al*. (2012) who recorded maximum shoot length in 20 cm long cuttings of olive cv. Azarbaijan.

Average diameter of Main Shoots

The length of cuttings also exerted a significant effect on average diameter of main shoots (Table 1). The maximum

Table 1: Effect of size of cuttings on average length and diameter of main shoots of different clonal rootstocks of apple

Length/ Rootstock	Average length of main shoots (cm)				Average diameter of main shoots (mm)			
	8 cm	10 cm	12 cm	Mean	8 cm	10 cm	12 cm	Mean
Merton 793	97.56	103.27	106.36	102.39	11.6	12.46	14.47	12.85
MM 106	94.43	95.41	97.55	95.79	10.49	11.54	13.34	11.79
MM 111	87.36	88.42	92.36	89.38	8.88	10.63	12.15	10.55
M 9	81.43	84.48	87.39	84.43	8.04	9.85	11.32	9.74
Mean	90.19	92.89	95.92		9.75	11.12	12.82	

CD (0.05) Average shoot length
Rootstock = 0.16
Length = 0.14
Rootstock × Length = 0.28

CD (0.05) Average shoot diameter
Rootstock = 0.34
Length = 0.29
Rootstock × Length = NS

Table 2: Effect of size of cuttings on fresh and dry weight of shoots of different clonal rootstocks of apple

Length/ Rootstock	Fresh weight of shoots (g)				Dry weight of shoots (g)			
	8 cm	10 cm	12 cm	Mean	8 cm	10 cm	12 cm	Mean
Merton 793	31.8	34.53	37.47	34.6	20.45	22.48	25.46	22.8
MM 106	27.71	31.44	36.61	31.92	17.68	19.49	23.47	20.21
MM 111	25.56	28.53	33.47	29.19	14.59	17.57	21.46	17.87
M 9	23.33	26.49	31.46	27.09	12.56	14.57	19.59	15.57
Mean	27.1	30.25	34.75		16.32	18.53	22.5	

CD (0.05) Fresh weight of shoots
Rootstock = 0.25
Length = 0.22
Rootstock × Length = 0.44

CD (0.05) Dry weight of shoots
Rootstock = 0.18
Length = 0.16
Rootstock × Length = 0.32

Table 3: Effect of size of cuttings on leaf area, total biomass and rooting percentage of different clonal rootstocks of apple

	Leaf area (cm2)				Total biomass (g)				Rooting percentage (%)			
Length/ Rootstock	8 cm	10 cm	12 cm	Mean	8 cm	10 cm	12 cm	Mean	8 cm	10 cm	12 cm	Mean
Merton 793	25.20	28.24	29.35	27.59	38.76	40.67	42.6	40.68	60.43 (50.64)	65.17 (53.42)	73.53 (58.65)	66.37 (54.24)
MM 106	24.25	26.99	28.11	26.45	35.7	37.73	39.61	37.68	53.51 (46.68)	57.34 (48.82)	66.4 (54.2)	59.08 (49.9)
MM 111	22.31	24.12	26.12	24.18	31.61	33.7	35.3	33.54	44.5 (41.49)	52.73 (46.25)	62.33 (51.81)	53.18 (46.52)
M 9	20.37	22.15	24.08	22.2	28.74	30.74	32.78	30.75	37.23 (37.33)	48.17 (43.73)	59.06 (49.99)	48.15 (49.99)
Mean	23.03	25.37	26.91		33.71	35.71	37.57		48.92 (44.03)	55.85 (48.05)	65.32 (53.66)	

*Data in parenthesis are angular transformed values

CD (0.05) Leaf area		CD (0.05) Total biomass		CD (0.05) Rooting percentage	
Rootstock	= 0.23	Rootstock	= 0.22	Rootstock	= 0.39
Length	= 0.19	Length	= 0.19	Length	= 0.33
Rootstock × Length	= 0.39	Rootstock × Length	= NS	Rootstock × Length	= 0.67

diameter of main shoots (12.82 mm) was observed in the 12 cm cutting length which was significantly higher than all other cutting lengths. Whereas, the minimum average diameter of main shoots (9.75 mm) was found in 8 cm cutting length.

Among different rootstocks, the maximum diameter of main shoots (12.85 mm) was observed in the cuttings of Merton 793, which was significantly higher than all other rootstocks under study. While, the minimum diameter of main shoots (9.74 mm) was recorded in the cuttings of M 9 rootstock.

The interaction between cutting length and rootstock had a non-significant effect on average diameter of main shoots as presented in Table 1. The longer cuttings had enough metabolic reserves, high Carbon: Nitrogen ratio and endogenous shoot promoting co-factors which were responsible for early shoot initiation and more growth. Naidu and Jones (2009) also observed that 13 cm long cuttings recorded higher shoot diameter than 5 cm cuttings in Eucalyptus clone. Verma *et al*. (2015) also concluded that maximum diameter of shoots was recorded in 35 cm long cuttings of Merton 793 rootstock than 15 cm cutting length.

Fresh weight of shoots

The data presented in Table 2 indicates that fresh weight of shoots was significantly influenced by the length of cuttings. The maximum fresh weight of shoots (34.75 g) was recorded in the cuttings with a length of 12 cm, which was significantly higher than all other cutting lengths. While, minimum fresh weight of shoots (27.10 g) was observed in the cuttings with 8 cm length.

Among different rootstocks, the maximum fresh weight of shoots (34.60 g) was recorded from the cuttings of Merton 793 rootstock, which was significantly higher than all other rootstocks. On the other hand, the minimum fresh weight of shoots (27.09 g) was obtained from the M 9 rootstock cuttings.

The combined effect of cutting length and rootstock also showed a significant effect on fresh weight of shoots (Table 2). Maximum fresh weight of shoots was recorded in the cuttings of 12 cm length of Merton 793 rootstock (37.47 g). Contrastingly, the minimum fresh weight of shoots was observed in cuttings of 8 cm length of M 9 rootstock (23.33 g). The longer cuttings of rootstocks produced maximum fresh weight of shoots. These results are in agreement with the findings of Naidu and Jones (2009) who reported that 13 cm long cuttings recorded higher fresh weight of shoots than 5 cm long cuttings. The synergistic role between source and sink greatly influenced and regulated growth and development of plants like fresh weight of shoots (Davies and Zhang 1991). The maximum fresh weight of shoots recorded in 35-40 cm long cuttings might be due to higher food reserves and establishment of source and sink in the longer cuttings. In addition, it may also due to transportation of more food reserves to the sink simultaneously with the production of new photosynthates (Kakade *et al*. 2019). These results are also in accordance with the findings of Verma *et al*. (2015) who reported higher fresh weight of shoots in the cuttings of 45 cm length in Merton 793 rootstock than 15 cm long cuttings.

Dry weight of shoots

It is evident from the data (Table 2) that the length of cuttings exerted a significant effect on dry weight of shoots. The Cuttings with length of 12 cm recorded highest dry weight of shoots (22.50 g). Whereas, the cuttings of 8 cm length recorded the lowest fresh weight of shoots (16.32 g).

So far as different rootstocks are concerned, the maximum dry weight of shoots (22.80 g) was recorded in the cuttings of Merton 793 rootstock, which was significantly higher than all other rootstock cuttings. While the minimum dry weight of shoots (15.57 g) was observed in M 9 rootstock cuttings.

The interaction between cutting length and rootstock also exerted a significant effect on dry weight of shoots (Table2). The maximum dry weight of shoots (25.46 g) was recorded in treatment combination of cutting length 12 cm and Merton 793 rootstock. Whereas, the minimum dry weight of shoots (12.56 g) was recorded in treatment combination of 8 cm cutting length and M 9 rootstock. The cuttings of rootstocks with longer shoots produced maximum dry weight of shoots. These results are in agreement with the findings of Naidu and Jones (2009) who reported that 13 cm long cuttings recorded highest dry weight of shoots than 5 cm long cuttings. The synergistic role between source and sink greatly influence and regulate growth and development processes and thereby increasing the dry weight of shoots (Davies and Zhang 1991). The maximum dry weight of shoots was recorded in 35-40 cm long cuttings which resulted due to high food reserves in the longer cuttings (Kakade *et al.*, 2019). These results are also in line with the findings of Verma *et al.* (2015) who recorded higher dry weight of shoots in the cuttings with length of 45 cm in Merton 793 rootstock than 15 cm long cuttings.

Leaf area

It is clear from the data (Table 3) that length of cuttings exerted a significant effect on leaf area. The maximum leaf area (26.91 cm2) was recorded in the cuttings with 12 cm length. Whereas, the minimum leaf area (23.03 cm^2) was recorded in the cuttings with 8 cm length.

Regarding different rootstocks, the maximum leaf area (27.59 cm^2) was found in Merton 793 rootstock cuttings, which was significantly higher than all other rootstocks. However, the minimum leaf area (22.20 cm^2) was observed in M 9 rootstock cuttings.

The interaction between cutting length and rootstock also showed significant effect on leaf area as presented in Table 3. The maximum leaf area (29.35 cm2) was recorded in treatment combination of 12 cm cutting length in Merton 793 rootstock. Contrastingly, the minimum leaf area (20.37 cm^2) was recorded in treatment combination of cutting length 8 cm of M 9 rootstock. The results concluded that longer cuttings generally produced maximum length of shoots. The longer shoots had more number of nodes which led to maximum number of leaves that are responsible for highest leaf area that occurred in longer cuttings than shorter cuttings. Apart from this, some internal factors involved in production of maximum leaf area in longer cuttings was an equilibrium between photosynthesis and transpiration which is important for the production of maximum leaf area. Similarly, Verma *et al.* (2015) also reported that cuttings with 35 cm length showed higher leaf area (24.18 cm2) in Merton 793 rootstock, whereas cuttings with length 15 cm recorded the lowest leaf area (20.86 cm^2).

Total biomass

The perusal of data shown in Table 3 indicated that length of cuttings had significant effect on total biomass production. The maximum total biomass (37.57 g) was recorded in the cuttings with length of 12 cm. whereas, the minimum total biomass (33.71 g) was observed in the cuttings of 8 cm length.

So far as the effect of rootstocks (Merton 793, MM 106, MM 111 and M 9) is concerned, the maximum total biomass was obtained from the cuttings of Merton 793 rootstock (40.68 g), which was significantly higher than all other rootstocks. Contrastingly, the minimum total biomass obtained from the cuttings of M 9 rootstock (30.75 g).

The interaction between cutting length and rootstock was found to be non-significant for total biomass production (Table 3). The rootstocks with longer cuttings produced maximum total biomass compared to shorter cuttings. The longer cuttings have sufficient supply of photosynthates (Source), whereas the net importers (Sink) play a major role in growth and development of plant (Roots, shoots and leaves). The dependency of shoot upon root and vice versa occurs throughout the plant life (Kozlowski, 1971) and synergistic role between them greatly influenced and regulated overall plant growth and development (Davies and Zhang 1991). In the present study, dry weight of shoots was recorded maximum in the cuttings of 12cm length which may be due to higher food reserves. On the other hand longer cuttings with better source-sink equilibrium might have resulted in transportation of more food reserves to the sink simultaneously, with the production of new photosynthates which resulted in highest total biomass (Kakade et al. 2019).

Rooting percentage

The data on the rooting percentage as influenced by different size of cuttings of various clonal rootstocks of apple presented in Table 3 indicated that length of cuttings had a significant effect on percentage of rooted cuttings. Maximum rooting percentage (65.32%) was recorded in 12 cm long cuttings which was significantly higher than all other cutting lengths. The minimum rooting percentage (48.92%) was however obtained in 8 cm length of cuttings.

Different rootstocks also exerted a significant effect on percentage of rooted cuttings (Table 3). Maximum rooting (66.37%) was recorded in Merton 793 rootstock cuttings. However, the minimum rooting (48.15%) was observed in the cuttings of M 9 rootstock.

The interaction between cutting length and rootstock also exerted a significant effect on percentage of rooted cuttings (Table 3). The highest rooting percentage (73.53%) was recorded in the combination of cutting length 12 cm and Merton 793 rootstock whereas, the lowest rooting percentage (37.23%) was observed in the treatment combination of 8 cm length and M 9 rootstock cuttings.

The shorter length (8cm) of cuttings resulted in poor rooting percentage which increased as the size of cuttings increased to 12 cm. The increase in rooting percentage in longer cuttings may be due to the higher level of endogenous auxins, water and nutrient holding capacity and other root inducing factors which may be lower in smaller cuttings and may be the reason for reduction in rooting (Palanisamy and Kumar 1997). Significant effect of clonal rootstock and cutting length was observed with highest rooting in the larger cuttings. This could be attributed to the high storage reserves and photosynthetic area which produced more roots. In most of studies, cutting length has influenced rooting (Wang *et al.*, 1997, Kowalczyk, Kobryn 1999 and Parasana *et al.*, 2013). Similarly, Al-Abbasi (2012) also reported that 12 cm long cuttings recorded maximum rooting percentage than 8 cm and 10 cm cuttings. The highest rooting percentage of cuttings was also reported by Verma and Chauhan, 2015 in Merton 793 apple rootstock cuttings and Diengngan and Murthy, 2014 in strawberry cv. Festival.

The results obtained from the experiments indicated that different lengths of apple clonal rootstock cuttings, the treatment combination of 12 cm long cuttings of Merton 793 rootstock was best among all the treatment combinations in respect of various vegetative growth and rooting parameters.

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