Int.J.Curr.Microbiol.App.Sci (2018) *7*(4): 2341-2348

International Journal of Current Microbiology and Applied Sciences
***ISSN: 2319-7706* Volume 7 Number 04 (2018)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2018.704.268

Effects of Rootstocks on Horticultural Characteristics of Various Exotic Apple Cultivars in Kashmir Climatic Conditions

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Keywords

Apple, Dwarf and semi vigrous rootstocks, Vegetative and horticultural traits

Article Info

Accepted:
20 March 2018
Available Online:
10 April 2018

A B S T R A C T

This study was aimed to determine the rootstock effect on various horticultural traits like annual extension growth, tree volume, TCSA, fruit weight, fruit volume and yield were significantly affected by rootstocks and recorded maximum vegetative growth in trees on MM_{106} compared to M_9 rootstock during the studies. The vegetative growth also varied significantly among cultivars which are genetically controlled feature in different apple cultivars. Fruits harvested from trees on MM_{106} were significantly higher in quality parameters like fruit weight, fruit volume and yield compared to those on M_9 rootstocks. Different varieties on MM_{106} rootstock recorded significantly higher yield of 16.55 and 20.19 kg/tree compared to 13.7 and 18.65 kg/tree on M_9 rootstock during the studies. Results showed that the Vista Bella on the MM_{106} rootstock had the most mean shoot length of the current year (39.97 cm), Vista Bella and Mollies Delicious observes highest tree volume (19.22, 19.76 m^3) and the lowest tree volume (15.01, 17.45 m^3) was recorded in Cooper IV. Cultivars also had a significant effect on the TCSA and record maximum (78.97 and 86.68cm^2) in Starkrimson and minimum (59.92 and 60.18cm^2) in Vista Bella and Cooper IV respectively during both years of studies. Fruit weight and fruit volume was maximum recorded in Starkrimson (218.04, 228.56 g and 171.36, 175.91 cm^3) as compared to other cultivars. Among cultivars Vista Bella had maximum yield kg/tree (19.60 and 23.58 kg/tree) and Cooper-IV recorded lowest (7.20 and 12.81 kg/tree) during the study period.

Introduction

Trees must be trained and pruned to achieve a manageable uniform size, a balance between growth and regular yield, and to allow good penetration of light and spray to the tree center (Malavolta and Cross, 2009). Most apple scion cultivars grown on their own roots or on seedling rootstocks produce large standard trees of 7-10 m in height and spread. While as such trees are acceptable in countries where land and labor are very inexpensive, in most apple producing areas of the world some reduction in this natural vigor is desired (Ferree and Warrington, 2003; Ahmad Dadashpour *et al.*, 2012). Dwarf and semi vigrous rootstocks such as M_9 reduce 20-30% tree size compared with seedling rootstock (Fazio and Baldo, 2005). However, the final size of trees grown on M_9 will depends greatly

on the inherent vigor of the scion cultivar, the soil fertility and the management system adopted by the grower (Ferree and Warrington, 2003). Dwarfing rootstocks have become widely acceptable by the industry as a tool for increasing orchard efficiency because they influence the size of tree, yield and planting density per unit area (Barritt *et al.*, 1995). Modern orchards planting systems are based on higher tree densities with a range from 1000 to 6000 trees per hectare and some up to 10000 trees per hectare (Robinson, 2003). However, increasing planting density alone does not increase yield, as planting density and yield are not linearly related and a threshold can be found beyond which a further increase in density may not result in greater yield (Webster, 2001; Hampson *et al.*, 2002).

Clonal dwarfing apple rootstocks control scion growth by the reduction of canopy spread, branches compression and tree height. M_9 introduced as a dwarf that induces excellent yield, precocity, efficiency and large fruit size. Although semi-dwarfing MM_{106} causes high yield efficiency and fruit size can be smaller than M_9 (Ferree and Warrington, 2003). More reduction in shoot growth, nods number, trunk diameter, and trunk cross sectional area are inductive effects vegetative dwarfing rootstock in comparison with semi-dwarf or seedling rootstock (Blanco *et al.*, 2008; McAfee and Rom, 2003; Neem *et al.*, 2006). Thus, our objective was to study the influence of vegetative M_9 and MM_{106} rootstocks on reaction of four apple cultivars to achieve large quantities of fruit relative to the amount of wood produce in Kashmir region in India.

Materials and Methods

Plant material, experimental design, sample collection field experiments were carried out in 2013-14 at an orchard of Central Institute of Temperate Horticulture Srinagar. The experiment was done on twelve year old apple cultivars consist of 'Starkrimson, Cooper IV, Mollies Delicious and Vista Bella' grafted on M_9 dwarf and MM_{106} semi-vigrous rootstock. The trees were planted in 2000 in four replications at a distance 3×1.5 for M_9 and 3×2.5 m for MM_{106} rootstock. Twenty four representative trees within each replication and then four uniform branches in the cardinal points of each tree were selected for sampling and data collection. The split plot design based on a randomized complete block (RCBD) with four replications was used for statistical analysis. Analysis of variance (ANOVA) was carried out using the procedure of the OPSTAT software.

Agromorphological characteristics

In order to measure the shoot growth, average current season growth of four branches in each tree at the end of the seasonal growth was recorded in cm. Also average length of the current seasonal internode was measured in middle of each branch in cm. The average tree volume of each treatment was calculated from height and spread measurements according to the formula given by Westwood (1988). For calculating the trunk cross sectional area (TCSA), trunk circumference about 20 cm above the graft union was measured with a hand caliper at the end of the growing season and converted to trunk cross sectional area (TCSA) in cm^2. Fruit volume was measured by water displacement method and expressed as cubic centimetres (Mazumdar and Majumder, 2003).

Results and Discussion

Annual extension growth

Semi vigrous rootstock MM_{106} recorded maximum (69.25 and 72.08 cm) annual extension growth as compared to (63.75 and 68.16 cm) observed in M_9 dwarf rootstock during both the years of investigation.

Similarly, the maximum (88.83 and 82.83cm) AEG was recorded in Vista Bella and minimum (51.33 and 55.16 cm) AEG in Cooper IV during both the years of studies. Hirst and Ferree, (1995) also reported that tree growth and development can be markedly influenced by both cultivar and rootstock. Feree and Warrington (2003) reported that the rate of basipetal auxin translocations were less in dwarfing than in invigorating rootstock, also indicated that the ratio of abscisic acid to auxin content were higher in the bark of dwarfing rootstock. Thus, reduction of auxin translocation in M_9 bark causes reduction of root growth, subsequently less translocation of gibberellin and cytokinin to scion and finally reduces the vegetative growth (Avery, 1970).

Tree volume

The highest tree volume (21.05 and 21.57 m^3) was observed on MM_{106} semi vigrous rootstock as compared with the lowest value (13.48 and 15.54 m^3) observed in M_9 dwarf rootstock. Among the cultivars Vista Bella observes highest tree volume and the lowest tree volume was recorded in Cooper IV and Starkrimson respectively (Table 1).

Trunck cross sectional area

The highest trunck cross sectional area was recorded in MM $_{106}$ rootstock (75.35 and 75.07cm^2) as compared to minimum M_9 rootstock (57.48 and 72.10cm^2). Cultivars also had a significant effect on the TCSA and record maximum (78.97 and 86.68cm^2) in Starkrimson and minimum (59.92 and 60.18cm^2) in Vista Bella and Cooper IV respectively during both years of studies. This increase in TCSA among rootstock significantly influences growth and development of the trees. Further the results are in agreement with those of Dolp and Probsting (1989) who reported that the tree size is controlled by rootstock.

Fruit length diameter ratio

Fruit L/D ratio was highly influenced by various cultivars, whereas, the rootstocks did not show any significant difference.

MM_{106} recorded maximum fruit L/D ratio (0.86) as compared with lowest value (0.84) recorded in M_9 rootstock. However, during next year M_9 and MM_{106} rootstocks did not show any significant difference.

As for the cultivars where concerned, maximum fruit L/D ratio (0.95 and 0.93) was recorded in Mollies Delicious and Starkrimson as compared with minimum value recorded in Vista Bella (0.75 and 0.89) during both the years of studies. Barritt *et al.,* (1995) observed that the physiological mechanisms by which dwarfing rootstocks affect fruit characteristics like length, diameter and length diameter ratio can be due to the reduction in transport of nutrients and hormones, especially gibberellins across the scion/rootstock union.

Ahmad *et al.,* (2012) also reported that bigger fruit size cultivar has more marketable value than other cultivars although this characteristic is affected by both genetic and environmental factors. L/D (≥1) is a criteria for insufficient cell elongation in apple but fruits L/D <1, probably was due to fruit size is smaller on the most dwarfing rootstock and large with the semi vigorous rootstocks.

Fruit weight

Among the rootstocks MM_{106} recorded maximum fruit weight (213.23 and 207.86 g) as compared to M_9 rootstock (184.00 and 203.44 g) during both the years of studies. Similarly, cultivars significantly affected the fruit weight and recorded maximum (218.04 and 228.56g) in Starkrimson and minimum (171.36 and 175.91g) in Vista Bella during the study.

Table.1 Rootstock effect on agro morphological characteristics in various exotic cultivars of apple

Treatment	Annual extension growth (cm)						Tree volume (m^3)						Tree trunk cross-sectional area (cm^2)					
	2013			2014			2013			2014			2013			2014		
	Rootstock		Mean	Rootstock		Mean	Rootstock		Mean	Rootstock		Mean	Rootstock		Mean	Rootstock		Mean
	M_9	MM_{106}		M_9	MM_{106}		M_9	MM_{106}		M_9	MM_{106}		M_9	MM_{106}		M_9	MM_{106}	
SK	55.00	60.66	57.83	58.33	64.00	61.16	10.40	21.81	16.10	11.46	23.97	17.71	78.15	79.80	78.97	84.92	88.44	86.68
C.IV	50.00	52.66	51.33	55.33	55.00	55.16	10.30	19.72	15.01	13.99	20.90	17.45	44.56	78.15	61.35	47.12	73.24	60.18
MD	63.33	72.66	67.99	70.00	92.66	81.33	15.99	21.46	18.72	18.86	20.67	19.76	63.90	66.95	65.42	74.84	73.24	74.04
VB	86.66	91.00	88.83	89.00	76.66	82.83	17.26	21.19	19.22	17.86	20.73	19.30	43.33	76.51	59.92	81.52	65.39	73.45
Mean	63.75	69.25		68.16	72.08		13.48	21.05		15.54	21.57		57.48	75.35	66.41	72.10	75.07	73.58
CD (p≤0.05) 2013= R 3.89 V 5.50 RXV NS, 2014= R 2.47 V 3.49 RXV NS Legend= SK= Starkrimson C.IV= Cooper IV MD= Mollies Delicious VB= Vista Bella R= Rootstock, V= variety,							CD (p≤0.05) 2013= R 0.08V 0.12 RXV 0.17 2014= R 1.25 V 1.77 RXV 2.50						CD (p≤0.05) 2013= R 0.30 V 0.43 RXV 0.61 2014= R 0.61 V 0.87 RXV 1.23					

Table.2 Rootstock effect on fruit quality parameters in various exotic cultivars of apple

Treatment	Fruit length diameter ratio						Weight (g)						Fruit volume (cm^3)					
	2013			2014			2013			2014			2013			2014		
	Rootstock		Mean	Rootstock		Mean	Rootstock		Mean	Rootstock		Mean	Rootstock		Mean	Rootstock		Mean
	M_9	MM_{106}		M_9	MM_{106}		M_9	MM_{106}		M_9	MM_{106}		M_9	MM_{106}		M_9	MM_{106}	
SK	0.91	0.95	0.93	0.94	0.91	0.92	211.25	224.83	218.04	215.03	242.10	228.56	187.00	198.33	192.66	206.66	221.00	213.83
C.IV	0.87	0.93	0.90	0.90	0.90	0.90	188.63	216.16	202.40	211.18	201.93	206.55	150.66	189.00	169.83	178.00	201.00	189.50
MD	0.84	0.81	0.82	0.95	0.96	0.95	170.13	235.22	202.67	211.86	211.30	211.58	145.33	207.66	176.50	201.00	205.33	203.16
VB	0.74	0.77	0.75	0.90	0.88	0.89	166.00	176.73	171.36	175.70	176.13	175.91	121.00	140.33	130.66	139.33	136.66	138.00
Mean	0.84	0.86	0.85	0.91	0.91	0.91	184.00	213.23		203.44	207.86		150.99	183.83		180.49	190.99	
CD (p≤0.05) 2013= R NS V 0.04 RXV NS 2014= R NS V 0.03 RXV NS Legend= SK= Starkrimson C.IV= Cooper IV MD= Mollies Delicious VB= Vista Bella R= Rootstock, V= variety,							CD (p≤0.05) 2013= R 5.58 V 7.89 RXV 11.12 2014= R NS V 11.97 RXV 16.92						CD (p≤0.05) 2013= R 13.57 V 19.19 RXV 27.14 2014= R NS V 11.57 RXV 16.36					

Table.3 Rootstock effect on chemical parameters and yield in various exotic cultivars of apple

Treatment	TSS (B%)						Total sugar (%)						Yield (Kg/tree)					
	2013			2014			2013			2014			2013			2014		
	Rootstock		Mean	Rootstock		Mean	Rootstock		Mean	Rootstock		Mean	Rootstock		Mean	Rootstock		Mean
	M_9	MM_{106}		M_9	MM_{106}		M_9	MM_{106}		M_9	MM_{106}		M_9	MM_{106}		M_9	MM_{106}	
SK	14.50	15.63	15.06	14.16	15.00	14.58	13.20	14.03	13.61	14.20	14.50	14.35	13.83	19.43	16.63	20.93	23.90	22.41
C.IV	13.46	13.93	13.69	12.90	13.23	13.06	10.96	11.50	11.23	11.20	12.0	11.6	8.30	6.26	7.28	15.00	10.63	12.81
MD	14.16	15.03	14.59	14.36	15.00	14.68	11.16	12.03	11.59	12.40	12.50	12.45	18.71	15.56	17.14	15.96	21.76	18.86
VB	11.96	13.56	12.76	11.36	12.63	11.99	9.70	8.23	8.96	9.36	8.96	9.16	14.33	24.93	19.63	22.70	24.46	23.58
Mean	13.52	14.53	14.02	13.19	13.96	13.57	11.25	11.44		11.79	11.99		13.79	16.55		18.65	20.19	
CD (p≤0.05) **2013= R 0.75 V 1.06 RXV 1.50** **2014= R NS V 1.33 RXV 1.88** **Legend= SK= Starkrimson C.IV= Cooper IV MD= Mollies Delicious VB= Vista Bella** **R= Rootstock, V= variety,**							CD (p≤0.05) 2013= R NS V 1.32 RXV NS 2014= R NS V 1.24 RXV 1.75						CD (p≤0.05) 2013= R 1.47 V 2.08 RXV 2.94 2014= R NS V 2.55 RXV 3.60					

EL-Sabagh (2012) also reported that as for the effect of rootstocks, it was found that MM_{106} rootstock increased significantly the means of Anna apple fruit weight, fruit size, fruit diameter and fruit volume as compare to *Malus* rootstock in both seasons. Groot (1997) observed that the relationship between scion fruit quality and rootstock may be due to function of nutrients.

Fruit volume

Fruit volume was maximum recorded in MM_{106} rootstock (183.83 and 190.99 m^3) and minimum (150.99 and 180.49 m^3) was produced in M_9 rootstock. Similarly the cultivars significantly affected the fruit volume with maximum (192.66 and 213.83m^3) was recorded in Starkrimson and minimum (130.66 and 138.00m^3) recorded in Vista Bella.

Our results are closely related to Georgiou (2000), and Jaskani, *et al.*, (2006) who observed that rootstocks widely affect the fruit volume and size in citrus. EL. Sabagh (2012) also reported that as for the effect of rootstocks, it was found that MM_{106} rootstock increased significantly the means of Anna apple fruit volume, fruit size, fruit diameter and fruit weight as compare to *Malus* rootstock in both seasons (Table 2).

Total soluble solids

The total soluble solid content of various cultivars of apple showed a significant difference among rootstocks. Whereas Starkrimson produced the maximum TSS (15.06 and 14.58 ^oB) and Vista Bella produced the lowest TSS (12.76 and 12.63 ^oB) during both the years of studies. MM_{106} rootstock recorded maximum TSS (14.53, 13.96 ^oB) as compared with the lowest value observed in M_9 rootstock (13.52 and 13.19 ^oB) (Table 3).

Total sugar

It is clear that on both rootstocks total sugar did not reveal any significant difference, maximum total sugar (11.44 and 11.99%) was recorded on MM_{106} rootstock as compared with minimum M_9 rootstock (11.25 and 11.79%). Among the cultivars Starkrimson observed maximum total sugar (13.61 and 14.35%) whereas minimum was recorded in Vista Bella (8.96 and 9.16%) on both rootstocks during both the years of study. Dolp and Probsting (1989) observed a significant variation on both rootstocks and reported that MM_{106} rootstock recorded highest total sugar as compared with the lowest value observed in M_9 rootstock. The results are in agreement with Orazem *et al.*, (2011) in respect of sugars and acids a balanced sugar to acid ratio in apple fruit could provide sweet but refreshing taste.

Fruit yield

Fruit yield is of prime concern to orchardists as they grow trees for better yield and good quality fruit. Fruit yield was found to be significantly influenced by rootstocks and cultivars. MM_{106} rootstock recorded significantly higher yield (16.55 and 20.19 kg/tree) compared to that on M_9 rootstock (13.79 and 18.65 kg/tree) during the studies respectively, MM_{106} rootstock produced more number of fruits/ tree, because the vegetative growth being higher. Therefore rate of photosynthesis is higher resulting in higher yield in MM_{106} rootstock compared to M_9.

These results are in agreement with the findings of Path *et al.*, (1989) and Wustcher and Shull (1976) who reported that rootstocks widely affect the yield. Among the cultivars, Vista Bella produced highest fruit yield (19.63 and 23.58 kg/tree) and Cooper IV produced the lowest yield (7.28 and 12.81 kg/tree) during the two years respectively,

which might be due to higher fruit size in the former compare to late.

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How to cite this article:

Rather, J.A., F.A. Misgar, G.A. Dar and Qurashi, S.N. 2018. Effects of Rootstocks on Horticultural Characteristics of Various Exotic Apple Cultivars in Kashmir Climatic Conditions. *Int.J.Curr.Microbiol.App.Sci.* 7(04): 2341-2348.
doi: https://doi.org/10.20546/ijcmas.2018.704.268