

RESPONSE OF APPLE (*Malus domestica* Borkh.) CULTIVARS GRAFTED ON TWO ROOTSTOCKS UNDER SUB-HUMID TEMPERATE CLIMATE OF AZAD JAMMU AND KASHMIR

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Nine apple (*Malus domestica* Borkh.) cultivars grafted on two rootstocks were assessed on morphological and biochemical basis under sub-humid temperate region of Azad Jammu and Kashmir. Starking Delicious, Kala Kulu, Fuji, Red Chief, Royal Gala, Red Labnani, Red Delicious, Star Crimson and Sky Spur grafted on local Crab apple and MM.111 were studied for various growth characteristics. Red Chief exhibited maximum (415.8 cm) plant height on crab apple whereas, more flower (1866) tree⁻¹, higher number (967.0) of fruit set tree⁻¹, fruits matured (490.0) tree⁻¹ and maximum (46.33 kg) weight of fruits tree⁻¹ were recorded on MM.111. Minimum duration (5 days) of flowering was presented by Sky Spur on local crab apple while minimum (92.0) days for fruit maturation were required by Royal Gala on MM.111. Maximum (112.5 g) fruit weight, total soluble solids (13.95%), total sugars (10.9 %) and reducing sugars (7.94%) were recorded for Starking Delicious on MM.111. On the other hand more pH (3.51) and ascorbic acid (9.2 %) content were recorded for Kala Kulu on crab apple. Red Chief found to be high yielding cultivar on MM.111 than crab apple while total sugars, TSS and average fruit weight were better for Starking Delicious. It was concluded that performance of apple cultivars were variable on both rootstocks. However, MM.111 proved better than local crab apple under prevailing conditions.

Keyword: Apple, Rosaceae, scion stock interaction, vegetative characteristics, biochemical analysis

INTRODUCTION

Apple (*Malus domestica* Borkh.) is an important temperate fruit of the family *Rosaceae* (Kheiralipour *et al.*, 2008). Apple has been cultivated in various parts of the world since 4000 BC. Asia Minor, Central Asia, Himalayan regions of India, Pakistan including Western China is believed as center of origin of apple (Muzher *et al.*, 2007). It contains different proportion of carbohydrates, vitamins, minerals, sugars, fat, protein, and dietary fiber. It also contains the calcium, magnesium, phosphorus, potassium, iron and zinc in different proportions (Fereneand and Estrada, 2008).

In Pakistan apple is successfully cultivated in temperate hilly tracts of Quetta, Zairat, Pishin, Mustang, Kalat, Murree hills of Punjab, Chitral, Swat, Manshera, Kalam, Gilgit, Sakardu, Chilas, Hunza and Kashmir. In Azad Jammu and Kashmir apple is a major fruit crop and grown in Districts Poonch, Bagh, Sudhnoti Muzaffarabad, and Neelum. Commercial varieties of apple grown in Pakistan and Azad Jammu and Kashmir are Kashmiri Amri, Kulu, Sky Spur, Red Chief, Golden Delicious, Red Delicious, Starking Delicious, Fuji, Star Crimson, Red Labnani and Royal Gala (Ahmed and Raza, 2005).

Rootstock plays major role in growth pattern, tree size, drought tolerance, adoptability in climate and soil conditions, winter hardiness, bearing age, total yield plus

quality of fruits (Herrera, 2002; Jaskani *et al.*, 2006; El-Mouei *et al.*, 2011). Scion stock interaction is a well documented fact. Rootstock plus scion cultivars interact with each other as well as with soil and climatic conditions of the prevailing area (Kosina, 2009).

Altitude, latitude, soil and climatic conditions of Azad Jammu and Kashmir are in general agreement with better production of apple; however, cultivars growing in the area are facing yield and quality problems (Ahmed and Raza, 2005). Rawalakot (study area) lies at an altitude of 1800-2000 m and latitude of 33-36° in North Eastern Pakistan, under the foothills of Himalaya. The climate of the area is temperate sub-humid with annual rainfall (irregular) ranging from 500-2000 mm with annual temperature ranges from 0°C - 30°C, with severe cold and snow fall in winter (Abbasi and Khan, 2004).

At Present, locally produced crab apple is being used frequently as preferred rootstock followed by dwarf rootstocks (MM 111, MM 106), without knowing their adoptability to the climate and resultant effect on growth, yield and quality characteristics. Suitability of crab apple and dwarf rootstock for the area and climate was not clear. There was need for evaluation and selection of rootstocks for its suitability to the growth pattern, yield, and quality of the commercial apple cultivars and to the environment. Keeping in view the issue present studies were started to find out

more suitable root stock for better growth, yield and quality of commercial apple cultivars.

MATERIAL AND METHODS

The present research work was conducted in apple orchard that was established in 1998 at Fruit and Vegetable Research Unit, Rawalakot, Department of Agriculture, Azad Jammu and Kashmir and Post Graduate Laboratory, Department of Horticulture, Faculty of Agriculture, University of Poonch Rawalakot. Two plants (10 years old) each of nine cultivars (Starking Delicious, Kala Kulu, Fuji, Red Chief, Royal Gala, Red Labnani, Red Delicious, Star Crimson, Sky Spur) for each rootstock [Crab Apple (local), MM.111 (colonel)] was selected tagged and replicated thrice. One hundred and eight plants of nine cultivars on two rootstocks were selected for the experiment. Data were collected from March to October 2011-12 on morphological [plant height (cm), trunk cross sectional area (cm^2) [TCSA], duration of flowering (days), flowers tree⁻¹, fruit set tree⁻¹, fruits matured tree⁻¹, duration of fruit maturity (days), fruit weight (g), fruit weight plant⁻¹ (kg), and biochemical (total soluble solids, pH, total sugars, reducing sugars, ascorbic acid. Total soluble solids were measured by hand digital refractometer (RX 5000, ATAGO, Japan) and pH with the help of pH meter. Ascorbic acid were measured by standard methods of AOAC (1984) whereas, reducing and total sugars by standard methods of AOAC (1994). Experiment was laid out using randomized complete block design RCBD. Data collected were analyzed for analysis of variance and means were compared using least significant difference test (Steel *et al.* 1997).

RESULTS AND DISCUSSION

Plant height (cm): The results given in Table 1 shows maximum (445.3 cm) plant height for Red Chief on crab apple (local) that significantly different from Starking Delicious (386.7 cm) on Crab apple, Red Chief (386.3 cm) on MM 111, Red Labnani (383.3 cm) on Crab apple and

Sky Spur (375.0 cm) on Crab apple. Intermediate plant height of (338.3 cm) for Red Delicious on Crab apple, (323.3 cm) for Star Crimson on Crab apple and (318.3 cm) for Starking Delicious on MM.111 were observed. Similarly, Star Crimson on MM.111 and Kala Kulu on Crab apple gained a plant height of 308.3 cm and 305.0 cm respectively while Royal Gala on Crab apple, Royal Gala on MM111, Red Delicious on MM.111, Star Crimson on MM111 and Kala Kulu on MM.111 obtained 287.5 cm, 281.7 cm, 255 cm, 251.7 cm and 248.3 cm plant height respectively. Minimum (210 cm) plant height was obtained by Fuji on Crab apple that increased to 216.7 cm for Fuji on MM.111.

It is evident from above results that the cultivar and rootstock combination affected the plant height. Results on interactive studies showed maximum (415.8 cm) plant height for Red Chief on Crab apple whereas, minimum for (210 cm) Fuji on Crab apple. It was also confirmed by the findings of Nielson and Kappel (1996) who reported that selection of appropriate graft combination is critical as scion rootstock interaction influenced water relations, leaf gas exchange, minerals uptake and plant size.

Trunk cross sectional area (cm^2)[TCSA]: The results collected (March to October 2011-12) showed that there was maximum (106.00 cm^2) trunk cross sectional area for Red Chief that decreased to 95.57 cm^2 and 87.43 cm^2 for Red Labnani and Starking Delicious, respectively (Table 2). Minimum (37.36 cm^2) TCSA was recorded for Fuji that increased to 40.92 cm^2 and 43.42 cm^2 for Sky Spur and Star Crimson respectively. Interactive effect of scion stock showed non-significant differences for TCSA. However, in general cultivars showed better TCSA (66.56 cm^2) for crab apple than 64.77 cm^2 for MM. 111. Results on TCSA showed that cultivars significantly affected this parameter. Maximum (106.00 cm^2) TCSA was recorded for Red Chief while minimum (37.36 cm^2) for Fuji. Variation among the cultivars was found on TCSA. These results were also in line with the findings of Ferree *et al.* (1998) who reported that trunk cross sectional area significantly affected by the rootstocks. Trunk diameter is also influenced by the

Table 1. Effect of scion stock interaction on plant height (cm) duration of flowering (days) of apple

Cultivars	Plant Height (cm)		Duration for flowering (days)	
	Crab apple	MM.111	Crab apple	MM.111
Starking Delicious	386.7 b	318.3 defg	14.33 a	13.50 ab
Kala Kulu	305.0 efg	248.3 ij	13.50 ab	13.00 abc
Fuji	210.0 k	216.7 jk	11.50 cde	12.17 bcd
Red Chief	445.3 a	386.3 b	13.67 ab	11.33 cdef
Royal Gala	287.5 fgh	281.7 ghi	11.00 def	11.17 cdef
Red Labnani	383.3 b	350.0 bcd	10.83 def	10.50 def
Red Delicious	338.3 cde	255.0 hi	9.66 ef	9.50 f
Star Crimson	323.3 def	251.7 hij	7.50 g	7.33 g
Sky Spur	375.0 bc	308.3 efg	5.00 h	6.00 gh

Any means not sharing same letter in the column differ significantly at $p < 0.05$

rootstock

Table 2. Effect of apple cultivars on trunk cross sectional area (TCSA cm²)

Cultivars	TCSA (cm ²)
Starking Delicious	87.43 b
Kala Kulu	57.35 d
Fuji	37.36 e
Red Chief	106.0 a
Royal Gala	57.57 d
Red Labnani	95.57 b
Red Delicious	69.57 c
Star Crimson	43.42 e
Sky Spur	40.92 e

Any means not sharing same letter in the column differ significantly at $p < 0.05$

(Pal *et al.*, 1999; Kviklys *et al.*, 2006).

Duration of flowering (days): Mean values for interactive effect of cultivars and rootstocks presented in Table 1 shows significant differences for duration of flowering. Maximum duration (14.33 days) for flowering was required by Starking Delicious on Crab apple followed by 13.67 days, 13.50 days, 13.50 days and 13.0 days for Red Chief on Crab apple, Starking Delicious on MM.111, Kala Kulu on Crab apple and Kala Kulu on MM.111, respectively. Fuji on MM.111, Fuji on Crab apple, Red Chief on MM.111, Royal Gala on MM.111 and Royal Gala on Crab apple presented flowering duration of 12.17, 11.50, 11.33, 11.17 and 11.00 days, respectively. Similarly, Red Labnani on Crab apple, Red Labnani on MM.111, Red Delicious on Crab apple and Red Delicious on MM.111 exhibited flowering duration of 10.83, 10.50, 9.067 and 9.50 days respectively. Star Crimson on Crab apple and on MM.111 showed flowering period of 7.50 and 7.33 days, respectively. Minimum duration (5.0 days) for flowering was presented by Sky Spur on MM.111 and 6.0 days on Crab apple.

Results on duration of flowering depicted significant

differences for cultivars and rootstocks. Interactive studies showed maximum (14.33 days) duration for flowering by Starking Delicious on Crab apple while minimum (5.0 days) by Sky Spur on MM.111. All other cultivar showed intermediate results with significant differences for each other. It was evident the effect of cultivars, rootstocks and their interaction on duration for flowering was significant. The combination (Starking Delicious on crab apple) presented maximum duration of flowering due to synergistic effect of both scion and stock. These results were similar to the findings of Ferree *et al.* (1998 and Bielicki (2006) who observed significant effect of apple cultivars and tall and dwarf rootstocks on blooming of apple.

Number of Flowers tree⁻¹: The results presented in Table 3 reveals that Red Chief on MM.111 produced maximum (1866.0) number of flowers tree⁻¹ that significantly differed from other scion stock combinations. Similarly, 1438.0 flowers tree⁻¹ were produced by Red Chief on Crab apple while Star Crimson on MM.111, Red Delicious on Crab apple and Sky Spur on MM.111 produced 804.8, 792.7 and 783 flowers tree⁻¹, respectively. Star Crimson on Crab apple, Red Delicious on MM.111, Red Labnani on MM.111, Fuji on MM.111, Sky Spur on Crab apple, Red Labnani on Crab apple, Starking Delicious on MM.111 and Royal Gala on Crab apple produced 761.2, 753.3, 747.3, 745.3, 741.8, 724.7, 716.2 and 710.7 flowers tree⁻¹, respectively. Royal Gala on MM.111, Starking Delicious on Crab apple and Kulu on MM.111, Fuji on Crab apple produced 680.2, 649.0 and 635.7, 573.3 flowers tree⁻¹ respectively. On the other end Kulu on Crab apple produced 492.0 flowers tree⁻¹ and remained at bottom.

These results showed that there was significant effect of cultivars, rootstocks combination for flowers production. Studies also showed that Red Chief on MM.111 produced maximum (1866.0) number of flowers tree⁻¹ while minimum (492.0) by Kala Kulu on Crab apple. Red Chief on MM.111 presented maximum flower production that was due to synergism whereas minimum number of flowers was

Table 3. Effect of scion stock interaction on flowers tree⁻¹, fruit set tree⁻¹ and fruits matured tree⁻¹ of apple

Cultivars	Flowers tree ⁻¹		Fruit set tree ⁻¹		Fruits matured tree ⁻¹	
	Crab apple	MM.111	Crab apple	MM.111	Crab apple	MM.111
Starking Delicious	649.0 cde	716.2 cd	309.3 cdef	347.5 cde	151.2 cd	152.3 cd
Kala Kulu	492.0 e	635.7 cde	253.5 ef	285.0 cdef	136.7 de	152.8 cd
Fuji	573.3 de	745.3 cd	263.5 def	359.7 cd	152.3 cd	155.0 cd
Red Chief	1438.0 b	1866.0 a	726.7 b	967.8 a	341.3 b	490.7 a
Royal Gala	710.7 cd	680.2 cde	321.3 cdef	319.7 cdef	58.5 f	112.8 def
Red Labnani	724.7 cd	747.3 cd	301.7 cdef	342.2 cde	132.2 de	128.8 de
Red Delicious	792.7 Cc	761.2 cd	353.7 cde	351.0 cde	144.3 cd	161.0 cd
Star Crimson	761.2 cd	804.8 c	234.2 f	110.0 g	120.0 def	79.2 ef
Sky Spur	741.8 cd	783.0 c	324.7 cdef	380.2 c	65.2 cd	200.7 c

Any means not sharing same letter in the column differ significantly at $p < 0.05$

produced because of antagonistic effect of Kala Kulu and crab apple on one another. Results of Denardi and Spengler (2001) also confirmed these findings that cultivars and rootstocks affect flowers production.

Number of Fruits set tree⁻¹: Red Chief on MM.111 set maximum (967.8) number of fruits tree⁻¹ followed by 726.7 fruits set tree⁻¹ for Red Chief on Crab apple (Table 3). Fruits set tree⁻¹ of 380.2 were noted for Sky Spur on MM.111, 359.7 for Fuji on MM.111, 353.7 for Red Delicious on Crab apple, 351.0 for Red Delicious on MM.111, 347.5 for Starking Delicious on MM.111, 342.2 for Red Labnani on MM.111, 324.7 for Sky Spur on Crab apple, 321.3 for Royal Gala on Crab apple, 319.7 for Royal Gala on MM.111, 309.3 for Starking Delicious on Crab apple and 301.7 for Red Labnani on Crab apple with descending order. Kulu on MM.111, Fuji on Crab apple and Kulu on Crab apple and Star Crimson on Crab apple set 285.0, 263.5, 253.5 and 234.2 fruits tree⁻¹, respectively. Minimum (110.0) fruits set tree⁻¹ were recorded for Star Crimson on MM.111.

It is clear from the results that maximum (967.8) number of fruit set tree⁻¹ was recorded for Red Chief on MM.111 and minimum (110.0) for Star Crimson on MM.111. Variability in fruit set was related with the genetic makeup of the cultivars that interact differently with the rootstock. Results recorded here showed that fruit set tree⁻¹ significantly affected by rootstocks and cultivars which was also confirmed by the findings of Chauhan and Sharma (2008) that varieties and rootstocks have variable effect on fruit set.

Number of Fruits matured tree⁻¹: The results presented in Table 3 clearly showed that Red Chief on MM.111 retained maximum (490.7) matured fruits tree⁻¹ than other cultivars and rootstock combinations. Matured fruit (341.3 and 200.7 tree⁻¹) were recorded for Red Chief on crab apple and Sky Spur on MM.111, respectively. Similarly, matured fruits of 65.2, tree⁻¹ were presented by Sky Spur on Crab apple, 161.0 by Red Delicious on MM.111, 155.0 by Fuji on MM.111, 152.8 by Kala Kulu on MM.111, 152.3 by Starking

Delicious on MM.111, 152.3 by Fuji on Crab apple, 151.2 by Starking Delicious on crab apple and 144.3 by Red Delicious on Crab apple. Kala Kulu on crab apple, Red Labnani on crab apple and Red Labnani on MM.111, Star Crimson on crab apple, Royal Gala on MM.111, and Star Crimson on MM.111 exhibited matured fruit of 136.7, 132.2 and 128.8, 120.2, 112.8 and 79.17, tree⁻¹, respectively. Royal Gala on crab apple produced minimum (58.5) matured fruits tree⁻¹. It is clear from the data that fruits matured tree⁻¹ significantly affected by cultivars, rootstocks and with their interaction. Red Chief on MM.111 presented maximum figure (490.7) while minimum (58.50) matured fruits tree⁻¹ were recorded for Royal Gala on Crab apple. These results has close link with the findings of Tareen *et al.* (2003) who reported that performance of apple cultivars on different rootstocks affected pre-harvest fruit drop. Fruit retained and other characters are significantly affected by the rootstock (Schupp and Koller, 1997).

Duration of fruit maturity (days): Mean values for interaction presented in Table 4 showed that maximum days (125.0) were required by Starking Delicious on Crab apple for fruit maturity. Similarly, Starking Delicious on MM.111, Star Crimson on Crab apple and Red Chief on Crab apple required reasonable days of 119.5, 109.8 and 109.0 respectively for fruit maturity. Red Delicious on Crab apple, Red Chief on MM.111, Star Crimson on MM.111, Red Labnani on MM.111, Kala Kulu on Crab apple and Red Delicious on MM.111 utilized days of 108.1, 107.7, 105.8, 104.3, 103.7 and 103.3 respectively for fruit maturation. Kulu on MM.111 and Sky Spur on MM.111 as well as Crab apple used 100.8, 100.7 and 100.7 days respectively and significantly remain at par. Comparatively lower number of days 98.50 d, 98.00 and 97.33 for maturity were exhibited by Red Labnani on Crab apple, Fuji on MM.111 and on Crab apple respectively. On the other end, Royal Gala on MM.111 presented minimum (92.0) days for fruit maturation. Starking Delicious on Crab apple took the

Table 4. Effect of scion stock interaction on duration of fruit maturation, average fruit weight and total weight of fruits tree⁻¹ of apple

Cultivars	Maturity Duration		Average fruit weight (g)		Total wt. of fruits plant ⁻¹ (kg)	
	Crab apple	MM.111	Crab apple	MM.111	Crab apple	MM.111
Starking Delicious	125.0 a	119.5 b	112.50 a	106.50 b	17.00 cd	16.33 cd
Kala Kulu	103.7 def	100.8 fg	97.83 c	94.47 cd	13.43 def	15.40 cde
Fuji	97.3 gh	98.0 gh	86.50 f	91.50 de	13.57 def	14.00 de
Red Chief	109.0 c	107.7 cde	95.17 cd	95.83 c	32.40 b	46.33 a
Royal Gala	96.0 hi	92.0 i	63.33 i	68.67 h	3.90 j	7.83 hi
Red Labnani	98.5 gh	104.3 def	68.33 h	78.50 g	9.50 ghi	9.90 fgh
Red Delicious	108.1 cd	103.3 ef	69.50 h	76.00 g	10.17 fgh	12.27 efg
Star Crimson	109.8 c	105.8 cde	71.50 h	71.00 h	8.43 hi	6.00 ij
Sky Spur	100.7 fg	100.7 fg	87.83 ef	91.00 de	14.20 de	18.67 c

Any means not sharing same letter in the column differ significantly at $p < 0.05$

maximum time (125.0 days) for fruit maturity while the minimum (92.0 days) by Royal Gala on MM.111. Studies of other scientists also confirmed the present findings as Tareen *et al.* (2003) reported that stage of maturity was related with the type of cultivars, rootstocks and with their interaction.

Average fruit weight (g): The results presented in Table 4 shows that Starking Delicious on Crab apple showed maximum (112.5 g) average fruit weight that decreased to 106.5 g for Starking Delicious on MM.111, 97.8 g for Kulu on Crab apple, 95.8 g for Red Chief on MM.111, 95.17 g for Red Chief on Crab apple, 94.47 g for Kala Kulu on MM.111, 91.50 g for Fuji on MM.111 and 91.00 g for Sky Spur on MM.111. Average fruit weight of 87.83 g was noted for Sky Spur on Crab apple and 86.50 g for Fuji on Crab apple while 78.50 g for Red Labnani on MM.111 and 76.0 g for Red Delicious on MM.111. Minimum average fruit weight (63.33 g) was recorded for Royal Gala on Crab apple that increased up to 68.33g, 68.67g, 69.50g, 71.00g and 71.50g for Red Labnani on Crab apple, Royal Gala on MM.111, Red Delicious on crab apple, Star Crimson on MM.111 and on Crab apple, respectively. Maximum (112.5 g) average fruit weight for Starking Delicious on Crab apple and minimum (63.33 g) for Royal Gala on Crab apple was recorded (Table 4). It is evident from results that average fruit weight was significantly affected by cultivars and rootstocks individually and also in combination. Jakubowski (2000) also stated that fruits of different weights and sizes were produced by apple cultivars on different rootstocks because of their individual or combined effect.

Total fruit weight tree⁻¹ (kg): Mean values for total fruits weight tree⁻¹ (kg) given in Table 4 showed that Red Chief on MM.111 obtained maximum (46.33 kg) total fruits weight tree⁻¹ that decreased up to 32.40 kg for Red Chief on Crab apple. Total fruits weight of 18.67 kg tree⁻¹ was recorded for Sky Spur on MM.111, 17.0 kg for Starking Delicious on Crab apple, 16.33 kg for Starking Delicious on MM.111 and 15.40 for Kala Kulu on MM.111 whereas, Sky Spur on Crab apple, Fuji on MM111 as well as Crab apple

and Kulu on Crab apple produced 14.20, 14.00, 13.57 and 13.43 kg of total fruits weight tree⁻¹ respectively. Similarly, Red Delicious on MM.111 as well as Crab apple, Red Labnani on MM.111 and on Crab apple produced 12.27, 10.17, 9.90 and 9.50 kg total fruit weight tree⁻¹ respectively. Minimum (3.90 kg) total fruits weight tree⁻¹ was produced by Royal Gala on Crab apple that increased up to 6.0, 7.83 and 8.43 kg tree⁻¹ for Star Crimson on MM.111, Royal Gala on MM.111 and Star Crimson on Crab apple, respectively. Maximum (46.33 kg) fruit tree⁻¹ produced by Red Chief on MM.111 and minimum (3.90 kg) by Royal Gala on Crab apple was noted. It was also confirmed by the findings of Ruess (2002) that different apple cultivars and rootstocks vary with respect to their yield efficiency. Barritt *et al.* (1996) also supported our findings. Findings of the Uselis and Kviklys (2007) on apple also supported our findings.

Total soluble solids (TSS): The results on interactive effect of cultivars and rootstock on TSS presented in Table 5 shows that Starking Delicious on MM.111 presented maximum (13.95) TSS that decreased up to 12.80, 12.32 and 12.32 for Red Delicious on MM.111, Starking Delicious on crab apple and Red Delicious on crab apple respectively. Total soluble solid contents were recorded 11.87 for Fuji on MM.111 and 11.63 for Royal Gala on MM.111. On the other hand Star Crimson on crab apple presented lower (11.03) TSS content. Minimum (10.20) TSS content was recorded for Sky Spur on Crab apple that increased up to 10.30 and 10.72 for Sky Spur on MM.111 and Kala Kulu on MM.111, respectively. It was also observed that there was more TSS for Starking Delicious on MM.111 and low for Sky Spur on crab apple. Findings of Javant and Verma (2001) also showed that total soluble solid contents vary with apple cultivars, rootstocks and with interaction of both.

pH of Juice: Mean values for interactive effects on pH presented in Table 5 shows that Kala Kulu on crab apple showed maximum (3.52) pH value that decreased up to 3.48, 3.37, 3.35, 3.35, 3.35, 3.35, 3.32, 3.30 and 3.30 for Starking Delicious on crab apple, Royal Gala on MM.111, Red

Table 5. Effect of scion stock interaction on total soluble solids and pH of apple

Cultivars	Total soluble solids (°Brix)		pH	
	Crab apple	MM.111	Crab apple	MM.111
Starking Delicious	12.32 bc	13.95 a	3.483 ab	3.250 abc
Kala Kulu	11.60 cd	10.72 efg	3.517 a	3.300 abc
Fuji	11.35 de	11.87 cd	3.283 abc	3.267 abc
Red Chief	11.55 cde	11.57 cde	3.350 ab	3.350 ab
Royal Gala	11.32 de	11.63 cd	3.317 abc	3.367 ab
Red Labnani	11.10 def	11.48 cde	3.350 ab	3.350 ab
Red Delicious	12.32 bc	12.80 b	3.283 abc	3.283 abc
Star Crimson	11.03 defg	11.27 de	3.200 bc	3.017 c
Sky Spur	10.20 g	10.30 fg	3.300 abc	3.283 abc

Any means not sharing same letter in the column differ significantly at $p < 0.05$

Labnani on crab apple, Red Chief on crab apple, Red Chief on MM.111, Red Labnani on MM.111, Royal Gala on crab apple, Sky Spur on crab apple and Kala Kulu on MM.111 respectively. Similarly, pH values of 3.28 were observed for Fuji on Crab apple, for Red Delicious on MM.111 as well as crab apple and for Sky Spur on MM.111, 3.26 for Fuji on MM.111 and 3.25 for Starking Delicious on MM.111 that showed non-significant differences. Star Crimson on MM.111 presented lowest (3.02) pH value that increased up to 3.2 for Star Crimson on crab apple. Cultivars, rootstocks and their interaction significantly affected juice pH and maximum pH value (3.52) was recorded in Kala Kulu on crab apple and minimum (3.02) in Star Crimson on MM.111. The results of Sasnauskas *et al.* (2007) also showed that fruit quality and biochemical composition of apple were significantly influenced by scion, stock and their interaction.

Total sugars (%): The results given in Table 6 shows that Starking Delicious on MM.111 showed the highest (10.92) total sugar contents that decreased to 10.60, 10.55 and 10.42 for Red Delicious on MM.111 as well as on crab apple and Starking Delicious on crab apple respectively. Similarly, total sugars of 10.10 were observed for Kala Kulu on MM.111, 10.03 as well as on crab apple, 9.83 for Red Chief on MM.111 and 9.7 for Fuji on MM.111 whereas, 9.48 for Red Chief on crab apple, 9.35 for Star Crimson on MM.111, 9.33 for Fuji on Crab apple and 9.23 for Star Crimson. On the other end Red Labnani on MM.111 as well as on crab apple and Royal Gala on crab apple presented total sugar contents of 8.85, 8.48 and 8.08, respectively. The lowest value (7.32) total sugars were yielded by Royal Gala on MM.111 that increased to 7.70 and 7.8 for Sky Spur on crab apple and Sky Spur on MM.111. Similarly maximum (10.92) total sugars contents were noted for Starking Delicious on MM.111 and minimum (7.32) for Royal Gala on MM.111. Javant and Verma (2001) also reported that total sugars and reducing sugars were affected by apple cultivars on different rootstocks and by their

interaction. Total and reducing sugars are significantly influenced by the rootstock as well as scion cultivars (Sumrah, 2000; Sotiropoulos, 2008).

Ascorbic acid (%): Maximum (9.20) ascorbic acid content was examined in Kala Kulu on crab apple which decreased up to 8.65, 8.43, 8.40, 8.40, 8.35, 8.23 and 8.08 for Sky Spur on crab apple, Royal Gala on MM.111, Sky Spur on MM.111, Royal Gala on crab apple, Red Labnani on MM.111, Kala Kulu on MM.111 and Red Labnani on crab apple, respectively (Table 6). Star Crimson on crab apple, Starking Delicious on MM.111, Red Delicious on MM.111 and Red Delicious on crab apple presented ascorbic contents of 7.90, 7.83, 7.73 and 7.67, respectively. As far as other combinations were concerned, ascorbic acid content of 7.55 for Starking Delicious on Crab apple, 7.53 for Fuji on Crab apple and 7.50 on MM.111 plus 7.47 for Star Crimson on MM.111 were recorded. On the other side, minimum (6.98) ascorbic acid content was recorded for Red Chief on MM.111 that increased to the level of 7.05 for Red Chief on crab apple. Overall maximum (9.20) value of ascorbic acid content was for Kala Kulu on crab apple and minimum (6.98) for Red Chief on MM.111. Sasnauskas *et al.* (2007) also observed that fruit quality and biochemical composition of apple was affected by cultivars and rootstocks. Ikase (2000) observed that there was a strong relation of rootstocks with the composition of the fruits.

Reducing sugar (%): Maximum (7.94) reducing sugars were recorded for Starking Delicious while minimum (5.28) for Royal Gala (Table 7). Other cultivars obtained intermediate values for reducing sugars contents of apple cultivars. Non-significant differences on reducing sugars were showed by rootstocks and cultivars-rootstocks interaction. Javant and Verma (2001) also reported that TSS, total sugars and reducing sugars were affected by apple cultivars on different rootstocks. Czynczyk, (1999) found a close interaction of apple cultivars quality with rootstocks.

Table 6. Effect of scion stock interaction on total sugars and ascorbic acid contents of apple

Cultivars	Total sugars (%)		Ascorbic acid (% ¹)	
	Crab apple	MM.111	Crab apple	MM.111
Starking Delicious	10.42 bc	10.92 a	7.55 f	7.83 def
Kala Kulu	10.03 cd	10.10 cd	9.20 a	8.23 bcd
Fuji	9.33 ef	9.70 de	7.53 f	7.50 f
Red Chief	9.48 ef	9.98 d	7.05 gh	6.98 h
Royal Gala	8.08 hi	7.31 j	8.40 bc	8.43 bc
Red Labnani	8.48 gh	8.58 g	8.08 cde	8.35 bc
Red Delicious	10.50 ab	10.60 ab	7.66 ef	7.73 ef
Star Crimson	9.23 f	9.35 ef	7.90 de	7.46 fg
Sky Spur	7.70 ij	7.80 i	8.65 b	8.40 bc

Any means not sharing same letter in the column differ significantly at $p < 0.05$

Table 7. Effects of apple cultivars on reducing sugars.

Cultivars	Reducing sugars %
Starking Delicious	7.943 a
Kala Kulu	7.208 bc
Fuji	6.783 cd
Red Chief	6.875 cd
Royal Gala	5.283 f
Red Labnani	6.358 de
Red Delicious	7.60 ab
Star Crimson	6.48 de
Sky Spur	6.18 e

Any means not sharing same letter in the column differ significantly at $p < 0.05$

Conclusion: The performance of nine apple (*Malus domestica* Borkh.) cultivars grafted on crab apple and MM.111 for morphological and biochemical characteristics under sub-humid temperate region of Azad Jammu and Kashmir was evaluated. Among various cultivars Red Chief exhibited maximum plant height on crab apple whereas, more flower tree⁻¹, higher number of fruit set tree⁻¹, fruits tree⁻¹ and maximum weight of fruits tree⁻¹ were recorded on MM.111. Similarly, Starking Delicious on MM.111 presented more fruit weight, total soluble solids, total sugars and reducing sugars. Although growth of cultivars was more on crab apple but MM 111 showed good performance for almost all other morphological and biochemical characteristics (even better than local conventional crab apple rootstock) and can be recommended as a useful rootstock under conditions like Rawalakot.

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