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Effect of clonal rootstocks on the stomatal conductance, transpiration rate, photosynthetic rate and leaf nutrient status of apple cultivars scarlet gala and red fuji

SARITA DEVI, P.S. CHAUHAN[1] AND **DISHA THAKUR[1]**

Members of the Research Forum

Associated Authors:
[1] Department of Fruit Science, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, SOLAN (H.P.) INDIA

[2] Regional Horticultural Research Station (Dr. Y.S. Parmar University of Horticulture and Forestry), Bajaura, KULLU (H.P.) INDIA

Author for correspondence :
SARITA DEVI
Fruit Development Project Bajaura, KULLU (H.P.) INDIA
Email : kapooruhf@gmail.com

ABSTRACT : A field experiment was conducted on five rootstocks *viz.*, EMLA 9, EMLA 26, EMLA 7, EMLA 106 and EMLA 111 on 12 year old plantations of two cultivars *viz.*, Scarlet Gala and Red Fuji. The experiment was laid out to study the effect of clonal rootstocks on the stomatal conductance, transpiration rate, photosynthetic rate and leaf nutrient status of the scion grafted on them. The experiment was laid out in a split plot design with 5 rootstocks and two cultivars with the treatment combinations of 10 and replicated 5 times. The maximum stomatal conductance (0.17 and 0.20 mol/ m^2/s),transpiration rate (3.88 and 3.93 m mol/m/s) and photosynthetic rate(11.08 and 11.16 µ mol/ m^2/s) during 2008 and 2009, respectively, were observed in EMLA 7 rootstock. Red Fuji on EMLA 7 rootstock recorded the maximum stomatal conductance (0.18 and 0.22 mol /m^2/s), transpiration rate (3.92 and 3.99 m mol/m^2/s) and photosynthetic rate (11.32 and 11.39 µ mol/m^2/s) as compared to Scarlet Gala on EMLA 26 rootstock which recorded the minimum values of all these parameters. The maximum content of leaf leaf nitrogen (2.23% and 2.26%), leaf phosphorus (0.154 % and 0.159%) and leaf potassium (1.64% and 1.65%) and leaf calcium content (1.66% and 1.69%) was recorded in EMLA 111 rootstock during 2008 and 2009, respectively, whereas the maximum leaf magnesium content (0.51% in 2008 and 0.56 % in 2009) was recorded in EMLA 7 rootstock. Red Fuji on EMLA 111 rootstock recorded maximum of N, P, K, however, Scarlet Gala on EMLA 111 rootstock recorded the maximum of leaf calcium. Scarlet Gala on EMLA 7 rootstock recorded maximum of leaf magnesium content. Based on these results, it may be inferred that Red Fuji on EMLA 111 and Scarlet Gala on EMLA 7 rootstock performed better in terms of photosynthetic efficiency and nutritional uptake.

KEY WORDS : Clonal rootstocks, Apple, Stomatal conductance, Photosynthetic efficiency

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The cultivated apple (*Malus x domestica* Borkh.) a member of family Rosaceae and sub family Pomoidae, is native to South West Asia. Most of existing apple orchards in the state are on seedling rootstocks, planted at low density. Such trees are variable in vigour and cropping potential. The trees on seedling rootstock also attain large size as of result of which cultural operations are difficult to perform. Low returns coupled with high production cost are forcing apples growers to improve efficiency and productivity. The difficulties faced in managing trees on seedling rootstocks and the variability in tree size and performance necessitates the use of these size controlling rootstocks, which are known for their specific influence on scion vigour and productivity. In a composite plant rootstock and cultivars are the main factors affecting plant growth. Numerous study has shown that beside affecting growth and production, rootstocks can also affect the photosynthetic parameters and nutritional status of the scion grafted on them. The photosynthetic efficiency and nutrient uptake and translocation ability of the different cultivars and rootstock must also be taken in account for plant growth, because these differences can affect yield and quality.

Rootstocks have also been reported to influence transpiration rate and stomatal conductance of scion cultivars thereby affecting tree water balance and various physiological processes of composite tree (Giulivo and Bergawini, 1981). In Himachal Pradesh, Delicious group of apple cultivars occupies about 80 per cent of total area .They are characterized by excessive vigour, low fruitfulness and acute biennial bearing tendency. Further, most of Delicious cultivars have similar maturity duration causing glut in market. The growth and productivity of apple in Indian conditions can be optimized by adopting the improved high yielding cultivars, clonal rootstocks and management practices. Recently, some of the cultivars like Scarlet Gala and Red Fuji have been introduced and being commercialized in state. Besides adding to the diversification of Delicious, these cultivars have promise to increase productivity of apple as these are heavy bearer and good pollinizers for Delicious apple. Therefore, an attempt was made to study the effect of clonal rootstock on photosynthetic efficiency and nutritional status of apple cultivars Scarlet Gala and Red Fuji.

RESEARCH METHODS

The experiment was laid down on 12- year- old plants of cultivar Scarlet Gala and Red Fuji raised on five clonal rootstocks *viz*., EMLA 9, EMLA 26, EMLA 7, EMLA106 and EMLA111. The present studies were carried out during two consecutive years, 2008 and 2009.The experiment was laid out in a Split Plot Design with 5 rootstocks and two cultivars with the treatment combination of 10 and replicated five times. Stomatal rate, transpiration rate and photosynthetic rate were recorded, between 9.00 to 11.00 AM, with the help of LICOR-6200 portable photosynthesis system. The stomatal conductance, transpiration rate and photosynthetic rate were expressed in mol/m^2/s, m mol/m^2/s and u mol/m^2/s, respectively. The nitrogen was determined with Kjeltech 2300 analyser unit using digestion, titration and distillation methods, whereas other nutrients were determined with digestion in diacid mixture. Total phosphorus was determined by Vanadomolybedo-Phosphoric yellow colour method Jackson (1967) in double beam UV-Vis spectrophotometer at 470 nm wave length. Potassium was determined using flame photometer. Calcium and magnesium were determined by atomic absorption method using model atomic absorption spectrophotometer-4141.Data on N, P, K, Ca and Mg were expressed in per cent on dry weight basis.

RESEARCH FINDINGS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarised under following heads:

Stomatal conductance, transpiration rate and photosynthetic rate:

The data presented in the Table 1 indicate that the rootstocks, cultivars and their interaction had a significant effect on the stomatal conductance, transpiration rate and photosynthetic rate of the scion cultivars grafted on them during two years of study. Among the rootstock EMLA 7 rootstock recorded maximum stomatal conductance (0.17 and 0.20 mol/ m^2/s),transpiration rate(3.88 and 3.93 m mol/ m/s) and photosynthetic rate (11.08 and 11.16 µ mol/ m^2/s) during 2008 and 2009, respectively, which was significantly higher than all other rootstocks. However, the minimum stomatal conductance (0.10 in 2008 and 0.12 mol/m^2/s in 2009), transpiration rate (2.73 and 2.81m mol/m^2 /s in 2008 and 2009), and photosynthetic rate (9.85 and 9.95 µ mol/ m^2/s in 2008 and 2009, respectively) was recorded in EMLA 26 rootstock, which was least among the rootstocks. So far as the effects of cultivars were concerned, during both of the years Red Fuji recorded maximum values of stomatal conductance (0.15 and 0.20 mol/m^2/s), transpiration rate (3.41 and 3.47 m mol/m^2/s) and photosynthetic rate(10.65 and 10.77µ mol/ m^2/) as compared to Scarlet Gala. Among the rootstocks and scion interaction, maximum stomatal conductance (0.18 and 0.22 mol/m^2/s), transpiration rate (3.92 and 3.99 m mol/m^2/s) and photosynthetic rate (11.32 and 11.39 µ mol/m^2/s) was recorded in Red Fuji grafted on EMLA 7 rootstock during 2008 and 2009, respectively, which was significantly higher than all other stionic combinations. However, Scarlet Gala on EMLA 26 rootstock exhibited significantly minimum rate of stomatal conductance (0.07 and 0.08 mol/m^2/s during 2008 and 2009), transpiration rate (2.70 and 2.75 m mol/m2 /s during 2008 and 2009,) and photosynthetic rate (11.32 and 11.39 µ mol/m^2/s during 2008 and 2009), respectively. These findings are in accordance with the findings of Baugher *et al*.(1994) who also observed minimum photosynthetic rate, transpiration rate and stomatal conductance on dwarfing rootstocks. These results are also in line with the findings of Bhardwaj (2010) and Chandel (1989), who observed the highest stomatal conductance in apple plants on MM 111 followed by M 7 and MM 106 rootstocks.

Leaf nutrient status:

The effect of clonal rootstocks on the macronutrient status of apple cultivars Scarlet Gala and Red Fuji are given in Table 2.

Leaf nitrogen:

Data presented in Table 2 indicated a significant effect of rootstock and scion cultivars on the leaf nitrogen content. During 2008 and 2009, significantly, higher leaf nitrogen (2.23% and 2.26%) was recorded in EMLA 111 rootstock, which was significantly higher than those on all other

Table 1 : Effect of clonal rootstocks on stomatal conductance and Transpiration rate of apple cultivars Scarlet Gala and Red Fuji

Cultivars	Stomatal conductance ($mol/m^2/s$)						Transpiration rate ($m\ mol/m^2/s$)						Photosynthetic rate ($\mu\ mol/m^2/s$)					
	2008			2009			2008			2009			2008			2009		
Rootstocks	Scarlet Gala	Red Fuji	Mean	Scarlet Gala	Red Fuji	Mean	Scarlet Gala	Red Fuji	Mean	Scarlet Gala	Red Fuji	Mean	Scarlet Gala	Red Fuji	Mean	Scarlet Gala	Red Fuji	Mean
EMLA 9	0.10	0.14	0.12	0.14	0.16	0.15	2.86	2.93	2.90	2.92	2.97	2.95	10.18	10.28	10.23	10.27	10.38	10.32
EMLA 26	0.07	0.13	0.10	0.08	0.15	0.12	2.70	2.77	2.73	2.75	2.87	2.81	9.79	9.91	9.85	9.85	10.05	9.95
EMLA 7	0.15	0.18	0.17	0.17	0.22	0.20	3.84	3.92	3.88	3.87	3.99	3.93	10.85	11.32	11.08	10.94	11.39	11.16
EMLA 106	0.11	0.16	0.14	0.14	0.19	0.16	3.60	3.77	3.69	3.74	3.82	3.78	10.72	10.81	10.76	10.77	10.91	10.84
EMLA 111	0.14	0.16	0.15	0.15	0.19	0.0.17	3.56	3.68	3.62	3.56	3.70	3.64	10.76	10.94	10.85	10.90	11.12	11.01
Mean	0.11	0.15		0.14	0.20		3.31	3.41		3.37	3.47		10.46	10.65		10.54	10.77	
$CD_{0.05}$																		
	Rootstock	=	0.01			0.01	Rootstock	=	0.01			0.02	Rootstock	=	0.02			0.01
	Cultivar	=	0.01			0.01	Cultivar	=	0.01			0.01	Cultivar	=	0.01			0.01
	Rootstock x Cultivar	=	0.02			0.02	Rootstock x Cultivar	=	0.03			0.03	Rootstock x Cultivar	=	0.03			0.03

Table 2 : Effect of clonal rootstocks on leaf nitrogen, phosphorus and potassium content of apple cultivars Scarlet Gala and Red Fuji

Cultivars	Nitrogen (%)						Phosphorus (%)						Potassium (%)					
	2008			2009			2008			2009			2008			2009		
Rootstocks	Scarlet Gala	Red Fuji	Mean	Scarlet Gala	Red Fuji	Mean	Scarlet Gala	Red Fuji	Mean	Scarlet Gala	Red Fuji	Mean	Scarlet Gala	Red Fuji	Mean	Scarlet Gala	Red Fuji	Mean
EMLA 9	1.94 (1.39)	2.09 (1.45)	2.02 (1.42)	2.01 (1.42)	2.11 (1.45)	2.06 (1.43)	0.119 (0.346)	0.129 (0.359)	0.124 (0.353)	0.123 (0.350)	0.133 (0.364)	0.128 (0.357)	1.30 (1.14)	1.35 (1.16)	1.33 (1.15)	1.33 (1.15)	1.39 (1.18)	1.36 (1.17)
EMLA 26	1.89 (1.37)	1.92 (1.38)	1.90 (1.38)	1.91 (1.38)	1.99 (1.41)	1.95 (1.40)	0.117 (0.342)	0.121 (0.348)	0.119 (0.345)	0.118 (0.343)	0.123 (0.351)	0.121 (0.347)	1.26 (1.22)	1.31 (1.15)	1.29 (1.13)	1.30 (1.14)	1.34 (1.16)	1.32 (1.50)
EMLA 7	2.07 (1.44)	2.18 (1.48)	2.13 (1.46)	2.11 (1.45)	2.18 (1.48)	2.15 (1.47)	0.123 (0.350)	0.131 (0.361)	0.127 (0.356)	0.124 (0.352)	0.139 (0.374)	0.132 (0.363)	1.49 (1.22)	1.56 (1.25)	1.52 (1.23)	1.51 (1.23)	1.59 (1.26)	1.56 (1.25)
EMLA 106	2.13 (1.46)	2.22 (1.49)	2.18 (1.48)	2.15 (1.47)	2.23 (1.50)	2.19 (1.48)	0.136 (0.369)	0.142 (0.377)	0.139 (0.372)	0.140 (0.374)	0.146 (0.382)	0.143 (0.378)	1.60 (1.27)	1.64 (1.28)	1.62 (1.27)	1.64 (1.28)	1.66 (1.29)	1.65 (1.28)
EMLA 111	2.18 (1.48)	2.27 (1.50)	2.23 (1.49)	2.20 (1.48)	2.32 (1.52)	2.26 (1.50)	0.151 (0.389)	0.157 (0.397)	0.154 (0.392)	0.157 (0.397)	0.161 (0.401)	0.159 (0.399)	1.63 (1.28)	1.66 (1.29)	1.64 (1.28)	1.63 (1.28)	1.67 (1.29)	1.65 (1.28)
Mean	2.04 (1.43)	2.14 (1.46)		2.08 (1.44)	2.17 (1.47)		0.129 (0.359)	0.136 (0.368)		0.132 (0.363)	0.141 (0.375)		1.46 (1.21)	1.50 (1.22)		1.48 (1.22)	1.53 (1.24)	
$CD_{0.05}$																		
Rootstock			0.01			0.01	Rootstock		0.002			0.003	Rootstock		0.01			0.01
Cultivar			0.01			0.01	Cultivar		0.002			0.001	Cultivar		0.01			0.004
Rootstock x Cultivar			0.03			0.02	Rootstock x Cultivar		0.003			0.004	Rootstock x Cultivar		0.02			0.01

(Figures in parenthesis are arc sign transformed values) rootstock during both the years of study. However, the lowest nitrogen content (1.90 % and 1.95 %) during 2008 and 2009 was observed in EMLA 26 rootstock, which was significantly lowest among all other rootstocks. Among the cultivars Red Fuji recorded maximum leaf nitrogen (2.14% in 2008 and 2.17% in 2009) as compared to the Scarlet Gala which recorded (2.04% in 2008 and 2.08% in 2009). So far as the variety and rootstock interaction was concerned Red Fuji on EMLA 111 rootstock recorded maximum values of leaf nitrogen (2.27% in 2008 and 2.32% in 2009), This suggest that EMLA 111 rootstock had better uptake capacity of these nutrients than other rootstock. However, the minimum leaf nitrogen (1.89% in 2008 and 1.91% in 2009) was recorded in Scarlet Gala on EMLA 26 rootstock, which was significantly lowest among all other stionic combinations. The result confirms the findings of Awad and Kenworthy (1963) who found higher N in Red Delicious than Northern Spy, Jonathan and McIntosh cultivars on MM 111 rootstock.

Phosphorus:

The data pertaining to the leaf phosphorus content as influenced by the clonal rootstocks are presented in Table 2. The maximum leaf phosphorus content (0.154 % and 0.159% in 2008 and 2009, respectively) was recorded in EMLA 111 rootstock, which was significantly higher than those on all other rootstocks. However, the minimum leaf phosphorus (0.119% in 2008 and 0.121 % in 2009) was recorded in EMLA 26 rootstock, Irrespective of rootstocks, significantly higher amount of leaf phosphorus (0.136% and 0.141% in 2008 and 2009, respectively) was recorded in Red Fuji as compared to Scarlet Gala (0.129% in 2008 and 0.132% in 2009).So far as the interactions between rootstock and cultivars were concerned, the maximum amount of leaf phosphorus content (0.157% in 2008 and 0.161% in 2009) was recorded in Red Fuji raised on EMLA 111 rootstock. However, the minimum leaf phosphorus (0.117% in 2008 and 0.118% in 2009) was recorded in Scarlet Gala on EMLA 26 rootstock, which was statistically at par with Scarlet Gala on EMLA 9 rootstock during 2008 but differed significantly during 2009. The above findings are in line with the findings made by West and Young (1981), who observed maximum concentration of P in Golden Delicious on MM 111 and MM 106 rootstocks.

Potassium:

The perusal of the data tabulated in the Table 2 reveals that leaf potassium varied significantly in plants raised on different rootstocks. The maximum leaf K content (1.64% and 1.65% during 2008 and 2009, respectively) was recorded in EMLA 111 rootstock, which was significantly superior to all other rootstocks. This was closely followed by EMLA 106 rootstock, which was at par with EMLA 111 rootstock during 2008 and 2009, respectively. However, minimum leaf K (1.29 % in 2008 and 1.32% in 2009) was recorded in EMLA 26 rootstock. Among the cultivars, the significantly higher leaf potassium content (1.50% and 1.53% during 2008 and 2009, respectively) was recorded in Red Fuji as compared to Scarlet Gala (1.46% in 2008 and 1.48% in 2009). The Interaction between rootstock and cultivars were also found to be significant during both the years of study. The maximum leaf K (1.66 % and 1.67% during 2008 and 2009, respectively) was recorded in Red Fuji raised on EMLA 111

Table 3 : Effect of clonal rootstocks on leaf calcium and magnesium content of apple cultivars Scarlet Gala and Red Fuji

Cultivars	Calcium (%)						Magnesium (%)					
	2008			2009			2008			2009		
Rootstocks	Scarlet Gala	Red Fuji	Mean	Scarlet Gala	Red Fuji	Mean	Scarlet Gala	Red Fuji	Mean	Scarlet Gala	Red Fuji	Mean
EMLA 9	1.53	1.50	1.51	1.57	1.53	1.55	0.26	0.32	0.29	0.30	0.35	0.33
	(1.24)	(1.22)	(1.23)	(1.25)	(1.24)	(1.25)	(0.50)	(0.60)	(0.54)	(0.55)	(0.59)	(0.57)
EMLA 26	1.47	1.38	1.43	1.50	1.39	1.45	0.23	0.35	0.33	0.34	0.38	0.36
	(1.21)	(1.17)	(1.19)	(1.22)	(1.18)	(1.20)	(0.60)	(0.61)	(0.58)	(0.58)	(0.61)	(0.60)
EMLA 7	1.63	1.56	1.60	1.67	1.60	1.64	0.47	0.55	0.51	0.51	0.60	0.56
	(1.28)	(1.25)	(1.12)	(1.29)	(1.27)	(1.28)	(0.71)	(0.80)	(0.71)	(0.72)	(0.77)	(0.65)
EMLA 106	1.66	1.60	1.63	1.69	1.63	1.66	0.44	0.49	0.47	0.48	0.51	0.50
	(1.29)	(1.27)	(1.28)	(1.30)	(1.28)	(1.28)	(0.70)	(0.71)	(0.68)	(0.69)	(0.72)	(0.70)
EMLA 111	1.69	1.63	1.66	1.73	1.65	1.69	0.35	0.41	0.38	0.41	0.45	0.43
	(1.30)	(1.28)	(1.29)	(1.32)	(1.29)	(1.30)	(0.63)	(0.70)	(0.61)	(0.72)	(0.67)	(0.75)
Mean	1.60	1.53		1.63	1.56		0.37	0.42		0.41	0.46	
	(1.26)	(1.24)		(1.28)	(1.25)		(0.60)	(0.65)		(0.69)	(0.67)	

$CD_{0.05}$							
Rootstock	=	0.01	Rootstock	=	0.02		0.02
Cultivar	=	0.01	Cultivar	=	0.01		0.01
Rootstock xCultivar	=	0.010	Rootstock x Cultivar	=	0.03		0.03

(Figures in parenthesis are arc sign transformed values) rootstock, which was significantly higher than all other stionic combinations, except Red Fuji on EMLA 106 rootstock, which was at par with Red Fuji on EMLA 111 rootstock during both the years of study. However, the minimum leaf potassium content (1.26 % and 1.30% during 2008 and 2009, respectively) was recorded in Scarlet Gala on EMLA 26 rootstock. The maximum content of N, P and K on EMLA 111 rootstock might be due to the larger root system of vigorous rootstock as compared to dwarf rootstock, which utilize maximum N and K available in soil as suggested by Hirst and Ferree (1995). Poling and Oberly (1979) also recorded maximum K content on EMLA 111 rootstock than MM 106 and M 7.

Calcium:

It is depicted from the Table 3 that rootstocks and cultivars had significant effect on leaf calcium content of apple trees. Among the rootstocks, the maximum leaf Ca content (1.66% and 1.69% in 2008 and 2009, respectively) was recorded in EMLA 111 rootstock, which was significantly higher than those on all other rootstocks. However, the minimum leaf Ca (1.43% and 1.45% in 2008 and 2009, respectively) was recorded in EMLA 26 rootstock , which was significantly lower than any other rootstocks. So far as the effects of cultivars were concerned, significantly higher leaf calcium content (1.60% in 2008 and 1.63% in 2009) was recorded in Scarlet Gala as compared to Red Fuji (1.53% and 1.56 % during 2008 and 2009, respectively). Irrespective of the rootstocks and cultivars, interaction between rootstocks and cultivars were also found to be significant during two years of study. The maximum leaf calcium (1.69% and 1.73% during 2008 and 2009, respectively) was recorded in Scarlet Gala grafted on EMLA 111 rootstock, which was significantly higher than all other stionic combinations. However, the minimum leaf calcium (1.38% and 1.39% during 2008 and 2009, respectively) was recorded in Red Fuji grafted on EMLA 26, which was significantly lower than any other stionic combinations. The present findings are in agreement with the observations of Bould and Campbell (1970) and Lockard and Schneider (1981) who reported that trees on MM 106 had highest Ca content.

Magnesium:

It is clear from the data depicted in Table 3 that rootstocks exhibited significant influence on the foliar magnesium content in both the years of study. Among the different rootstocks, maximum amount of leaf magnesium (0.51% in 2008 and 0.56 % in 2009) was recorded in EMLA 7 rootstock, which was significantly higher than any other rootstocks. This was closely followed by EMLA 106 rootstock (0.47 % and 0.50 % in 2008 and 2009, respectively). However, the minimum amount of leaf Mg content (0.29% in 2008 and 0.33% in 2009) was recorded in trees raised on EMLA 9 rootstock, which was significantly lower than all other rootstocks in this respect. Regardless of rootstocks, higher amount of leaf Mg (0.42% in 2008 and 0.46% in 2009) was recorded in the cultivar Red Fuji as compared to Scarlet Gala (0.37 % and 0.41 % during 2008 and 2009, respectively).The interaction effects of rootstocks and cultivars were also found to be significant during both the years of study. The maximum leaf Mg (0.55% in 2008 and 0.60% in 2009) was recorded in Red Fuji on EMLA 7 rootstock, which was significantly higher than all other stionic combinations, but closely followed by Red Fuji grafted on EMLA 106 rootstock (0.49 % and 0.51% in 2008 and 2009, respectively). The minimum amount of leaf Mg (0.23%) was recorded in Scarlet Gala on EMLA 26 rootstock during 2008, whereas during 2009, the minimum leaf Mg content (0.30%) was recorded in Scarlet Gala grafted on EMLA 9 rootstock, which was significantly lowest among all other stionic combinations. From the present findings, it is evident that rootstocks have a preference for the certain nutrient elements, although this depends upon soil fertility, climatic factors, tree age and possibly cultivar x rootstock interactions (Tukey *et al.*, 1962).

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