Int.J.Curr.Microbiol.App.Sci (2018) *7*(1): 10-19

International J. Current Microbiology and Applied Sciences
***ISSN: 2319-7706* Volume 7 Number 01 (2018)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2018.701.002

Stionic Effect and Seasonal Nutrient Dynamics in Some Exotic Apple Cultivars

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Keywords

Apple, Rootstock, Cultivar, Seasonal variations, Nutrient concentrations

Article Info

Accepted:
04 December 2017
Available Online:
10 January 2018

A B S T R A C T

The present studies entitled "Rootstock effects on seasonal nutrient dynamics and horticultural characteristics in some exotic apple cultivars" aimed to investigate differences of nutrient concentrations among different exotic cultivars on various rootstocks growing in the same conditions. During the investigation it was observed that leaf nutrient concentrations significantly varied with rootstocks during both the seasons. The exotic cultivars like Vista Bella on MM_{106} recorded highest leaf P (0.21, 0.20%) and highest K content (1.54, 1.55%) recorded in Starkrimson on both rootstocks. However, the maximum Mg content (0.30, 0.30%) was observed in Cooper IV on both rootstocks. Similarly lower concentration of P and potassium content (0.16, 0.15%) and (1.47%) recorded in Cooper IV, and minimum Mg nutrient content (0.25, 0.27%) recorded in Vista Bella indicating a definite effect of rootstocks on translocation of nutrients within the plant system. The seasonal variation of leaf nutrient concentrations during growth period indicate that early maturing cultivars *viz.*, Vista Bella and Mollies Delicious recorded increase in nutrient content upto 30th of June, thereafter the trend decreased, while as the mid-season cultivars like Starkrimson and Cooper IV observed a similar trend upto 15th of July and decreased thereafter. The seasonal variation of nutrients in leaves indicate stability period of various nutrients like P, K and Mg in early maturing cultivars like Vista Bella and Mollies Delicious from 15th of June to 15th of July, while as in mid-season cultivars Starkrimson and Cooper IV the stability in nutrient concentration was recorded from 30th June to 30th of July indicating the appropriate leaf sampling period for these exotic cultivars as against the sampling time of existing cultivars which is from mid-July to mid-August under similar conditions.

Introduction

Mineral nutrients are greatly influenced by rootstocks, similarly different scion cultivars exhibit variable quantities of nutrients from different rootstocks. Wide fluctuation in nutrient concentration occur in tissues during growth period, however, most suitable leaf position and sampling time are those which gave rise to least variation in its mineral concentration, the nutrient accumulation curves of apple trees are good indicators of nutrient requirement in each plant development stage (Hirzel and Best, 2009).

The knowledge of seasonal variation in leaf nutrient concentrations is necessary in order to understand the physiology of apple nutrition, and helpful in the interpretation of leaf analysis. It will used to strength the knowledge of seasonal variations in nutrient levels of leaf that would be important to accurate prescription of subsequent fertilizer additions and will play theoretical and basic roles in practical steps for production (Nachtigall *et al.,* 2006). Nutrients are essential for the productivity and quality of different fruits; hence the determination of nutritional needs for efficient production of high quality fruit is an important aspect of nutrient management for the orchardists. Besides giving anchorage to the tree, rootstock is also responsible for the absorption of water and nutrients, storage of photosynthates and synthesis of hormones making the scion part more tolerable.

Materials and Methods

The study was conducted at Central Institute of Temperate Horticulture Srinagar, India during 2013-2014 growing seasons. Starkrimson, Cooper IV, Mollies Delicious and Vista Bella grafted on M_9 dwarf and MM_{106} semi vigrous rootstock was used in the study. Leaf samples were taken in eight different seasons (15^{th} of May, 30^{th} of May, 15^{th} of June, 30^{th} of June, 15^{th} of July, 30^{th} of July, 15^{th} of August and 30^{th} of August). Before analysis, samples were washed thoroughly with fountain water, dilute acid (0.2 N HCl) and distilled water to remove surface residues, then they were kept at 65±5°C until they reached to stable weight Phosphorus was estimated by vandate-molybdate colorimetric method as outlined by Jackson (1973). Potassium was determined by flame photometer and Mg concentrations were determined using atomicabsorption spectrophotometry Kacar *et al.,* (1998). Statistical analysis of nutritional statues of apple plants was evaluated depending on the values given by Jones *et al.,* (1991). Analysis of variance was performed on the data obtained from the treatments. The level of the significance (LSD at $P< 0.05$) was used in the SAS to test significance.

Results and Discussion

Phosphorous

Comparing the leaf phosphorous content of trees between two rootstocks it was observed that significantly higher leaf phosphorous content (0.20 and 0.19%) was recorded in trees on MM_{106} rootstocks compared to leaf phosphorous content (0.18 and 0.17%) of trees on M_9 rootstocks during the study period (table 01). Among rootstocks it was observed that semi vigrous rootstock, MM_{106} had significantly higher phosphorous content compared to dwarf rootstocks M_9. The lower leaf nutrient concentrations in trees of M_9 rootstock could be due to less vigor of these trees Kucukyumuk and Erdal (2009), the observations are also in accordance with the findings of Wustcher and Shull (1976).

Among different cultivars maximum leaf phosphorous content (0.20 and 0.19%) was recorded in Vista Bella whereas minimum leaf phosphorous content (0.16 %) was recorded in Cooper IV during both the years respectively. Trees of 'Delicious' and 'Golden Delicious' growing on MM_{106} rootstocks had higher phosphorous levels than similar trees on MM_{111} rootstock (Schneider *et al.,* 1978). However, the rootstock and variety effects on nutrient concentration of apple trees can be explained with the genetic effect leading to different nutrient uptake capacity Jimenez *et al.,* (2007). Leaf phosphorous content recorded a significant difference on both the rootstocks at different sampling dates between spring and autumn season flushes, the highest leaf phosphorous content (0.24 and 0.22%)

was observed on 30th of June and 15th of July whereas, minimum leaf phosphorous content (0.13 and 0.12%) was recorded on 15th of May during both the years. The higher concentration of phosphorous during the initial growth of the apple plant may be due to current absorption and also as a result of remobilization of the phosphorous and in persimmon phosphorous content of leaves decreased with the advancement of growing season Rehalia and Sandhu (2005).

Seasonal variation

Least variation period in early maturing cultivars Vista Bella and Mollies Delicious was observed on 15th of June to 15th of July because there is a relative nutrient concentration stability from 8th to 12th week after full bloom in early maturing cultivars where as in mid maturing cultivars Starkrimson and Cooper IV observed on 30th of June to 30th of July, 10th to 14th week after full bloom and might be due to least requirement of phosphorous by the growing fruit during this period and minimum changes in fully developed leaves (Fig. 1). The variation in nutrient stability period in the cultivars of apple may be due to genotypic effect.

The variation in the stability period in different crops and varieties may be due to the requirement of phosphorous during different periods of crop growth Kamboj *et al.*, (1987).

Potassium

As for as rootstocks are concerned significantly higher leaf potassium content (1.52 and 1.54%) was recorded in trees on MM_{106} rootstock compared to leaf potassium content (1.46 and 1.50%) on M_9 rootstock. Among rootstocks it was clearly seen that semi vigrous rootstock, MM_{106} had significantly higher mineral nutrients, compared to dwarf rootstocks M_9. Dwarf rootstocks such as M_9 and M_{26} have smaller root systems, so it can be the major reason for having lower nutrients compared to others (Erdal *et al.*, 2008). Among cultivars significantly maximum leaf potassium content (1.52 and 1.54%) was recorded in Starkrimson and minimum (1.47%) and (1.50%) was recorded in Vista Bella and Mollies Delicious (table 02). Leaf potassium content showed a significant difference on various sampling dates, maximum leaf potassium content (1.68 and 1.71%) was recorded on 15th of July and minimum leaf potassium content (1.24 and 1.30%) was recorded on 15th of May during both the years respectively. Leaf potassium content of different cultivars on M_9 and MM_{106} rootstocks depicted an increasing trend from 15th of May to 15th of July, thereafter, it decreased gradually upto 30th of August indicating a significant difference between spring and autumn season flushes. In July and August sampling seasons potassium concentrations had the highest level compared to the other sampling dates during the season Roca-Perez *et al.*, (2006). Potassium content of leaves sampled from different cultivars of apple increased steadily during initial period of growth and reached to maximum on 15th of July and there after declined towards the end of sampling season Kucukyumuk *et al.*, (2012). The decline in potassium content is associated with growth dilution effects and also due to utilization of potassium by growing points (Kotur and Singh, 1993).

Seasonal variation

The nutrient stability period with regard to early season maturing cultivars was recorded from 30th of May to 30th of June in Vista Bella and 15th of June to 15th July in Mollies Delicious whereas mid maturing cultivars Starkrimson and Cooper IV showed least variation period from 30th June to 30th July (Fig. 2).

Table.1 Rootstock and cultivar effect on seasonal variation of leaf Phosphorous (%) content of exotic apple cultivars

Rootstock	Year 2013										Year 2014									
	M_9					MM_{106}					M_9					MM_{106}				
variety period	SK	C.IV	MD	VB	Sub mean	SK	C.IV	MD	VB	Sub mean	SK	C.IV	MD	VB	Sub mean	SK	C.IV	MD	VB	Sub mean
15th May	0.13	0.11	0.12	0.14	0.13	0.14	0.11	0.15	0.16	0.14	0.12	0.10	0.13	0.14	0.12	0.14	0.10	0.15	0.16	0.14
30TH May	0.15	0.13	0.15	0.24	0.16	0.16	0.14	0.17	0.16	0.15	0.14	0.11	0.14	0.15	0.13	0.15	0.11	0.16	0.24	0.16
15th June	0.17	0.15	0.25	0.27	0.21	0.20	0.16	0.24	0.25	0.21	0.15	0.12	0.22	0.21	0.17	0.18	0.13	0.23	0.26	0.20
30th June	0.21	0.19	0.29	0.24	0.23	0.23	0.20	0.30	0.29	0.25	0.21	0.17	0.24	0.23	0.21	0.23	0.19	0.25	0.23	0.22
15th July	0.23	0.21	0.23	0.22	0.22	0.25	0.22	0.26	0.25	0.24	0.23	0.20	0.23	0.22	0.22	0.24	0.21	0.24	0.21	0.22
30th July	0.21	0.20	0.20	0.19	0.20	0.23	0.20	0.22	0.22	0.21	0.21	0.20	0.21	0.20	0.20	0.23	0.20	0.22	0.19	0.21
15th Aug.	0.20	0.17	0.18	0.16	0.17	0.21	0.18	0.21	0.21	0.20	0.19	0.17	0.16	0.15	0.16	0.20	0.18	0.18	0.17	0.18
30th Aug.	0.15	0.13	0.16	0.15	0.15	0.16	0.16	0.17	0.16	0.15	0.15	0.13	0.15	0.15	0.14	0.18	0.16	0.18	0.14	0.16
Mean (V)	0.18	0.16	0.18	0.20		0.19	0.17	0.21	0.21		0.18	0.15	0.18	0.18		0.19	0.16	0.20	0.20	
Mean (S)	0.18					0.20					0.17					0.19				
Factor mean varieties SK= 0.18 C.IV= 0.16 MD= 0.20 VB= 0.20											Factor mean SK= 0.18 C IV= 0.16 MD= 0.19 VB= 0.19									
CD (p≤0.05) Timing (T)= 0.005 Rootstock(S)= 0.002 Varieties(V)= 0.003 TXS 0.006 VXT= 0.009 VXS 0.005 VXSXT= 0.01 Legend SK= Starkrimson C.IV= Cooper IV MD= Mollies Delicious VB= Vista Bella											CD (p≤0.05) Timing (T)= 0.00 Rootstock(S)= 0.002 Varieties(V)= 0.003 TXS 0.007 VXT= 0.010 VXS NS VXSXT= NS										

Table.2 Rootstock and cultivar effect on seasonal variation of leaf Potassium (%) content of exotic apple cultivars

Rootstock	Year 2013										Year 2014									
	M_9					MM_{106}					M_9					MM_{106}				
variety period	SK	C.IV	MD	VB	Sub mean	SK	C.IV	MD	VB	Sub mean	SK	C.IV	MD	VB	Sub mean	SK	C.IV	MD	VB	Sub mean
15th May	1.28	1.15	1.27	1.25	1.24	1.31	1.32	1.37	1.38	1.34	1.30	1.28	1.27	1.35	1.30	1.37	1.43	1.45	1.44	1.42
30TH May	1.36	1.27	1.52	1.52	1.41	1.41	1.40	1.43	1.41	1.41	1.47	1.36	1.39	1.59	1.45	1.47	1.51	1.51	1.55	1.51
15th June	1.49	1.42	1.54	1.62	1.51	1.52	1.50	1.59	1.70	1.57	1.53	1.49	1.58	1.77	1.59	1.53	1.54	1.56	1.80	1.60
30th June	1.52	1.45	1.75	1.59	1.57	1.57	1.54	1.74	1.73	1.64	1.57	1.49	1.75	1.58	1.59	1.62	1.63	1.80	1.65	1.67
15th July	1.73	1.71	1.60	1.52	1.64	1.74	1.72	1.69	1.59	1.68	1.75	1.70	1.55	1.53	1.63	1.81	1.77	1.65	1.62	1.71
30th July	1.62	1.52	1.55	1.49	1.54	1.62	1.62	1.56	1.59	1.59	1.66	1.61	1.55	1.48	1.57	1.61	1.63	1.55	1.53	1.58
15th Aug.	1.55	1.47	1.32	1.35	1.42	1.56	1.51	1.54	1.57	1.54	1.61	1.50	1.51	1.41	1.50	1.51	1.47	1.52	1.51	1.50
30th Aug.	1.52	1.50	1.20	1.15	1.34	1.57	1.49	1.16	1.17	1.35	1.51	1.48	1.27	1.20	1.36	1.46	1.48	1.20	1.21	1.34
Mean (V)	1.51	1.44	1.47	1.44		1.54	1.51	1.51	1.50		1.55	1.47	1.48	1.49		1.54	1.56	1.53	1.54	
Mean (S)	1.46						1.52				1.50					1.54				
Factor mean varieties SK= 1.52 C.IV= 1.47 MD= 1.49 VB= 1.47											Factor mean SK= 1.54 C IV= 1.52 MD= 1.50 VB= 1.51									
CD (p≤0.05) Timing (T)= 0.018 Rootstock(S)= 0.009 Varieties(V)= 0.013 TXS 0.025 VXT= 0.036 VXS 0.018 VXSXT= 0.051 Legend SK= Starkrimson C.IV= Cooper IV MD= Mollies Delicious VB= Vista Bella											CD (p≤0.05) Timing (T)= 0.019 Rootstock(S)= 0.010 Varieties(V)= 0.014 TXS 0.027 VXT= 0.038 VXS 0.019 VXSXT= 0.054									

Table.3 Rootstock and cultivar effect on seasonal variation of leaf magnesium (%) content of exotic apple cultivars

Rootstock	Year 2013										Year 2014									
	M_9					MM_{106}					M_9					MM_{106}				
variety period	SK	C.IV	MD	VB	Sub mean	SK	C.IV	MD	VB	Sub mean	SK	C.IV	MD	VB	Sub mean	SK	C.IV	MD	VB	Sub mean
15th May	0.21	0.22	0.21	0.20	0.21	0.26	0.24	0.27	0.26	0.26	0.21	0.24	0.22	0.20	0.22	0.23	0.25	0.29	0.22	0.24
30TH May	0.22	0.27	0.22	0.22	0.22	0.26	0.30	0.27	0.27	0.27	0.22	0.26	0.23	0.22	0.23	0.26	0.25	0.29	0.24	0.26
15th June	0.22	0.24	0.25	0.23	0.23	0.28	0.33	0.29	0.28	0.29	0.24	0.30	0.25	0.24	0.29	0.27	0.27	0.29	0.25	0.27
30th June	0.24	0.26	0.26	0.32	0.27	0.29	0.31	0.29	0.30	0.29	0.26	0.33	0.27	0.33	0.29	0.29	0.30	0.31	0.33	0.30
15th July	0.28	0.33	0.35	0.30	0.31	0.29	0.32	0.32	0.29	0.30	0.31	0.37	0.37	0.30	0.33	0.32	0.35	0.35	0.31	0.32
30th July	0.32	0.36	0.33	0.27	0.32	0.31	0.33	0.30	0.29	0.30	0.34	0.39	0.34	0.30	0.34	0.35	0.36	0.35	0.30	0.34
15th Aug.	0.29	0.35	0.30	0.26	0.30	0.29	0.30	0.29	0.28	0.29	0.32	0.35	0.31	0.27	0.31	0.31	0.34	0.32	0.27	0.31
30th Aug.	0.27	0.30	0.27	0.24	0.27	0.25	0.26	0.24	0.23	0.25	0.29	0.30	0.28	0.26	0.28	0.26	0.30	0.28	0.27	0.28
Mean (V)	0.26	0.28	0.27	0.25		0.28	0.30	0.29	0.27		0.27	0.32	0.28	0.27		0.28	0.30	0.31	0.27	
Factor mean varieties SK= 0.27 C.IV= 0.29 MD= 0.28 VB= 0.27 CD (p≤0.05) Timing (T)= 0.13 Rootstock(S)= 0.007 Varieties(V)= 0.009 TXS 0.01 VXT= NS VXS NS VXSXT= NS Legend SK= Starkrimson C.IV= Cooper IV MD= Mollies Delicious VB= Vista Bella											Factor mean SK= 0.28 C IV= 0.31 MD= 0.30 VB= 0.27 CD (p≤0.05) Timing (T)= 0.015 Rootstock(S)= NS Varieties(V)= NS TXS 0.020 VXT= NS VXS 0.015 VXSXT= NS									

Table.4 Rootstock effect on fruit yield, yield efficiency in various exotic cultivars of apple and relationship between leaf nutrients with fruit quality parameters

Treatment	Yield (kg/tree)						Yield efficiency (kg/cm^{-2})					
	Year 2013			Year 2014			Year 2013			2014		
	Rootstock		Mean	Rootstock		Mean	Rootstock		Mean	Rootstock		Mean
	M_9	MM_{106}		M_9	MM_{106}		M_9	MM_{106}		M_9	MM_{106}	
SK	13.83	19.43	16.6	20.93	23.90	22.41	0.17	0.24	0.20	0.24	0.27	0.25
C.IV	8.30	6.26	7.2	15.00	10.63	12.81	0.18	0.08	0.13	0.31	0.14	0.22
MD	18.71	15.56	17.1	15.96	21.76	18.86	0.29	0.23	0.26	0.21	0.29	0.25
VB	14.33	24.93	19.6	22.70	24.46	23.58	0.33	0.32	0.32	0.27	0.37	0.32
Mean	13.79	16.55		18.65	20.19		0.24	0.21		0.25	0.26	
CD (p≤0.05) **2013= R 1.47 V 2.08 RXV 2.94** **2014= R NS V 2.55 RXV 3.60** **Legend= SK= Starkrimson C.IV= Cooper IV MD= Mollies Delicious VB= VistaBella** **R= Rootstock, V= variety,**							2013= R 0.00 V 0.00 RXV 0.00 2014= R 0.006 V 0.008 RXV 0.012					

Rootstock and cultivar effect on seasonal variation of leaf nutrient content of exotic apple cultivars

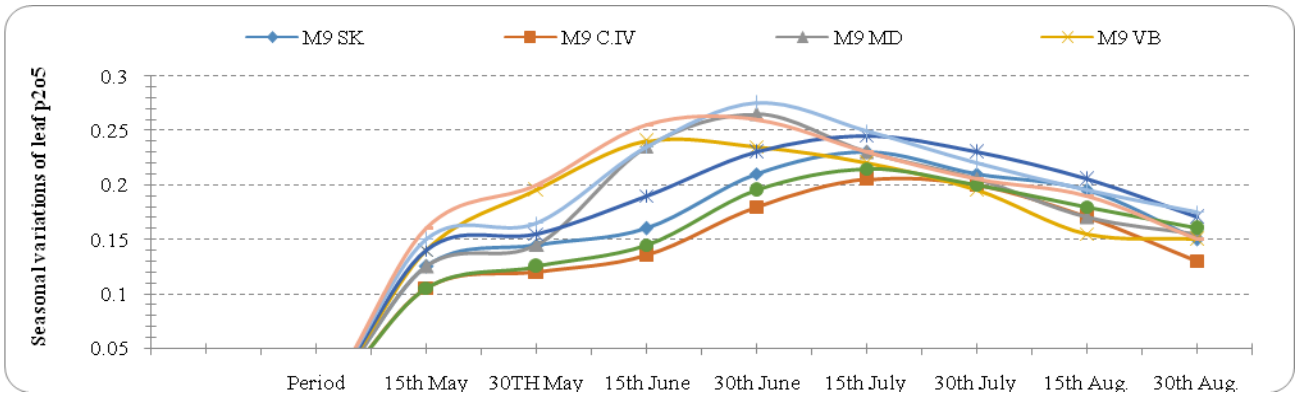

Fig.1

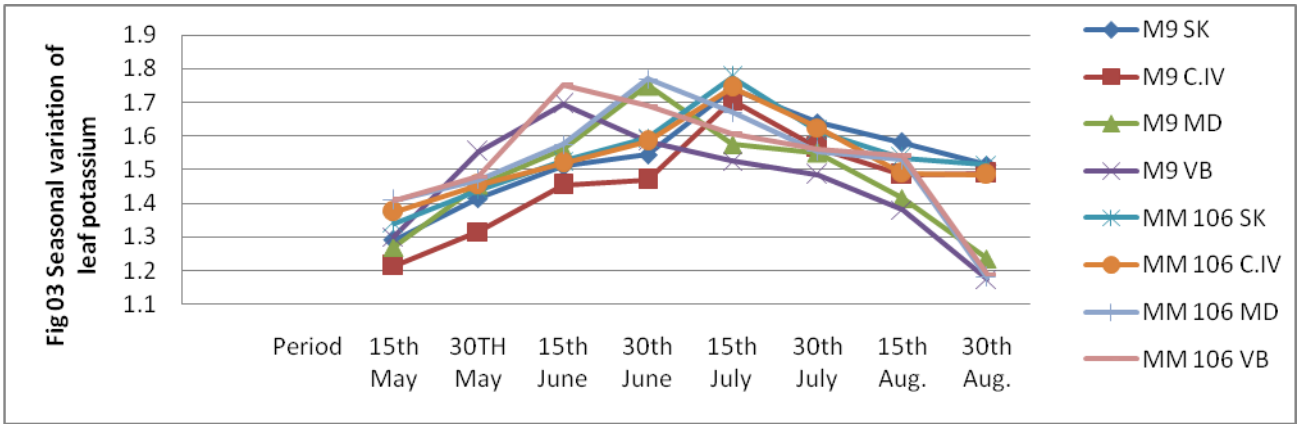

Fig.2

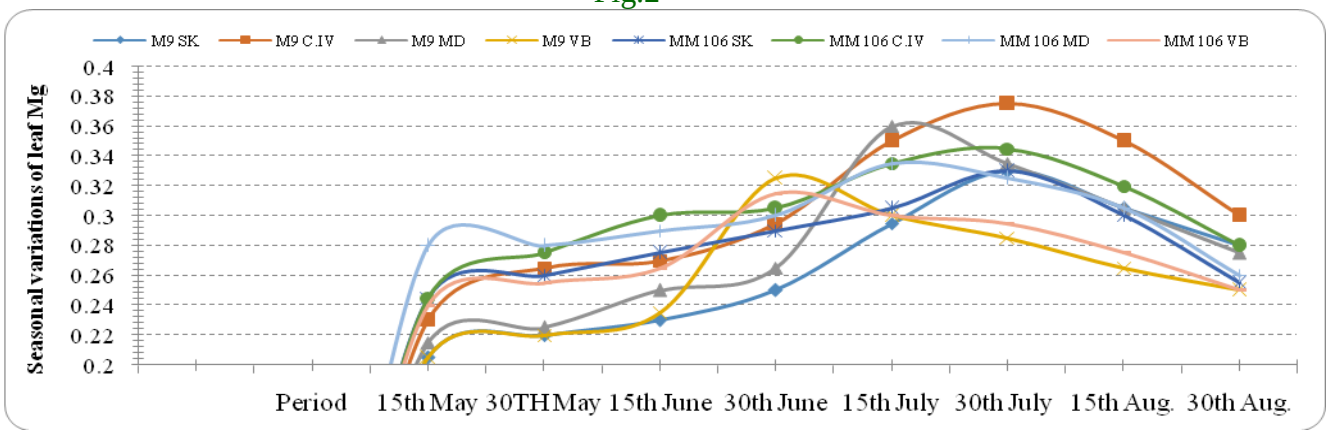

Fig.3

Magnesium

The comparison of leaf magnesium content between the two rootstocks depicted that significantly higher leaf magnesium content (0.29 and 0.29%) was recorded on MM_{106} rootstock compared to M_9 (0.27 and 0.28%) during the study period. Rootstock and variety effects on nutrient concentration of apple trees can be explained with the genetic effect leading to different nutrient uptake capacity (Kucukyumuk and Erdal, 2009). Among

different cultivars significantly maximum leaf magnesium content (0.29 and 0.31%) was recorded in Cooper-IV, and minimum leaf magnesium content (0.27%) was recorded in Vista Bella during both the years (table 03). Leaf magnesium content varied significantly among different sampling timings with maximum leaf magnesium content (0.32% and 0.34%) recorded on 30th of July and minimum (0.21% and 0.22%) was recorded on 15th of May during both the years of experiment. There was an increasing trend in leaf magnesium content from 15th of May to 30th of July thereafter, decreased slowly upto 30th of August. The nutrient content of leaves is subject to variation during the vegetation season and the level of calcium and magnesium in leaves of apple trees increases Tagliavini *et al.,* (1992). The first phase occurs during the cellular division period, while the other phases are associated with the period of cellular expansion (Hilmelrick and McDuffie, 1983).

Seasonal variation

The obtained leaf magnesium content distribution, in practical terms, allowed to infer that leaf sampling for nutritional diagnosis might be anticipated for 30 days in relation to the period used in the present experiment and reported in the literature (14th to 18th week after full bloom), because there is a relative nutrient concentration stability in early maturing cultivar Vista Bella from 15th of June to 15th of July and Mollies Delicious showed the nutrient stability from 30th of June to 30th of July.

Whereas in mid-season maturing cultivars (Starkrimson and Cooper IV) from the 15th July to 15th of August. As the results indicated that the highest levels of magnesium concentrations were reached in July, mid-season of vegetation, but through the end of the season, they began to decrease (Fig. 3).

Fruit yield/plant (kg) and yield efficiency

Fruit yield is prime concern to orchardists they grow the plants for better yield and good quality fruit production. The maximum fruit yield (16.55 kg/tree and 20.19 kg/tree) was recorded on MM_{106} rootstock were as the lowest (13.79 kg/tree and 18.65 kg/tree) was records in M_9 rootstock (table 04). Among the cultivars Vista Bella produced highest fruit yield (19.63 and 23.58 kg/tree) and Cooper IV produced the lowest (7.28 kg/tree and 12.81 kg/tree). Among the genotypes M_9 rootstock produced highest yield efficiency (0.24 kg/cm^{-2}, 0.25 kg/cm^{-2}) as compared lowest value (0.21 kg/cm^{-2}, 0.26 kg/cm^{-2}) was recorded in MM_{106} rootstock. Vista Bella recorded the highest yield efficiency (0.32 kg/cm^{-2}) and Cooper IV recorded the lowest yield efficiency (0.13 kg/cm^{-2}) during both the years.

Fruit yield is of prime concern to orchardists they grow the plants for better yield and good quality fruit production. Yield is linearly related to light interception (Robinson, 2007). The linear relationship between yield and fruit count per tree and the sink strength of an apple crop is almost proportional to the number of fruit per tree (Hampson *et al.,* 2002). Cultivars grafted on M_9 had a more yield efficiency than MM_{106} increased photosynthesis and yield efficiency in grafted cultivars on dwarfing rootstock deriving from reduction of shoot growth Dorin *et al.,* (2015).

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How to cite this article:

Rather, J.A., F.A. Misgar, Z.A. Bhat, S. Sami Ullah, G.A. Dar and Javeed, K. 2018. Stionic Effect and Seasonal Nutrient Dynamics in Some Exotic Apple Cultivars. *Int.J.Curr.Microbiol.App.Sci.* 7(01): 10-19. doi: https://doi.org/10.20546/ijcmas.2018.701.002