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Influence of exotic rootstocks and cultivars of apple on seasonal nutrient dynamics

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Abstract
A study was aimed to investigate the influence of leaf nutrient concentrations among different exotic cultivars on various rootstocks and fruit quality parameters for two consecutive years. The other goal of the experiment was to precise the time of leaf sampling in four apple cultivars. Among rootstocks MM_{106} had the highest level of nutrient concentrations whereas M_9 had the lowest. Cooper IV recorded the maximum leaf magnesium content and minimum leaf magnesium content was observed in Vista Bella, where as highest leaf boron content was recorded in Vista Bella and minimum was recorded in Cooper IV. 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 June, thereafter the trend decreased, while as the mid-season cultivars viz. Starkrimson and Cooper IV observed a similar trend upto 15th July and decreased thereafter.
The seasonal variation of nutrients in leaves indicate stability period of leaf magnesium and boron in early maturing cultivar *viz*, Vista Bella was observed on 15th of June to 15th of July and in Mollies Delicious was observed on 30th of June to 30th of July, while as in mid season cultivars like Starkrimson and Cooper IV it was observed on 15th of July to 15th of August, indicating proper time for leaf sampling in early and mid season cultivars with respect to leaf magnesium and boron content. It was also observed that fruit L/D ratio, fruit volume, total sugar, TSS and TSS acid ratio was significantly influenced by rootstocks and cultivars. Whereas, titrable acidity didn't showed any significant variation.

Keywords: Apple, rootstock, cultivar, seasonal variations, nutrient concentrations

Introduction
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. In the last decades rootstocks brought about a revolution in fruit growing, completely changing the shape and methods of cultivation of apple orchards. These changes gradually appear also in the plantations of other species. The use of dwarf rootstock solved the issues connected with the too strong growth of trees, too late cropping and low yields from a surface area. The interest in breeding and use of new rootstocks constantly increases. The most popular and commonly used apple rootstock is M.9. It unites well with most cultivars, the trees grafted on it begin the stage of fruit bearing very early and the obtained apples are of very good quality. It should be used as a model in comparing the growth and yield of different rootstocks. Rootstocks directly affect the ability of plants to uptake the water and nutrients from the soil. They are also able to significantly affect the pattern of canopy development and functions such as photosynthesis (Richardson *et al.,* 2003). 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. More than twenty horticultural characteristics are affected by the rootstock including leaf nutrient status, vigor and size, depth of rooting, cold tolerance, adoption to adverse soil conditions, disease resistance and fruit quality (Castle, 1987) [8]. Mineral nutrients are greatly influenced by rootstocks, similarly different scion varieties exhibit variable quantities of nutrients from different rootstocks.
Leaf is the principle site of metabolism and the optimum concentrations of nutrient in the leaf at specific growth stage have positive relationship with the leaf nutrient content and yield. Among various approaches, leaf analysis has proved to be best for formation of proper fertilizer scheduling (Bould, 1966; Bhargava and Chadha, 1993) [5, 4] and it gives accurate guide than soil analysis for predicting the nutrient needs of fruit trees (Sparks, 1968) [26].

Material and Methods

The study was conducted at Central Institute of Temperate Horticulture Srinagar, India during the years 2013 and 2014. Four apple cultivars viz., 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 (15th of May, 30th of May, 15th of June, 30th of June, 15th of July, 30th of July, 15th of August and 30th 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 kept at 65±5°C until they reached to stable weight. Calcium and zinc concentrations were determined using atomic absorption spectrophotometry (Kacar and Katkat, 1995) [17]. Fruit volume was measured by water displacement method and expressed as cubic centimetres. The volume of fruit samples was measured with the help of measuring cylinder and recorded for (Mazumdar and Majumder, 2003) [20]. The TSS of fruit were determined with the help of a Bausch and Lamb hand refractomemter and subsequent corrections were made with the help of temperature correction chart at 20 °C room temperature (AOAC, 1990) [1]. Titratable acidity was estimated by titrating 2 ml of juice against N/10 NaOH solution using 0.1 per cent phenolphthalein solution as an indicator and the end point was determined by the appearance of persistence pink color for five seconds (AOAC, 1990) [1]. Total sugar was estimated by the method of (Harminder and Dhillon, 2007) [14]. 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

Magnesium

The comparison of leaf magnesium content between the two rootstocks depicted that significantly higher leaf magnesium content was recorded on MM_{106} rootstock compared to M_9. Similarly, among different cultivars significantly maximum leaf magnesium content was recorded in Cooper-IV, while as minimum leaf magnesium content was recorded in Vista Bella. 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) [19]. Similarly leaf magnesium content varied significantly within different sampling timings and recorded maximum leaf magnesium content on 30th of July and minimum on 15th of May during experimental period. An increasing trend in leaf magnesium content was recorded from 15th of May to 30th of July thereafter, it decreased slowly upto 30th of August. stability period of leaf magnesium in early maturing cultivar viz, Vista Bella was observed on 15th of June to 15th of July and in Mollies Delicious it was observed on 30th of June to 30th of July, while as in mid season cultivars like Starkrimson and Cooper IV it was observed on 15th of July to 15th of August, indicating proper time for leaf sampling in early and mid season cultivars with respect to leaf magnesium content fig.1. Tagliavini *et al.* (1992) reported that during vegetation the level of calcium and magnesium in leaves of apple trees increases. 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) [15]. This is the so-called the effect of chemical dilution, that is, reduction in the nutrient concentrations caused by the increase in fruit dry matter. According to Sadowski *et al.* (1990) [23] effect of rootstock is due to the genetically determined ability of absorption of a particular nutrient.

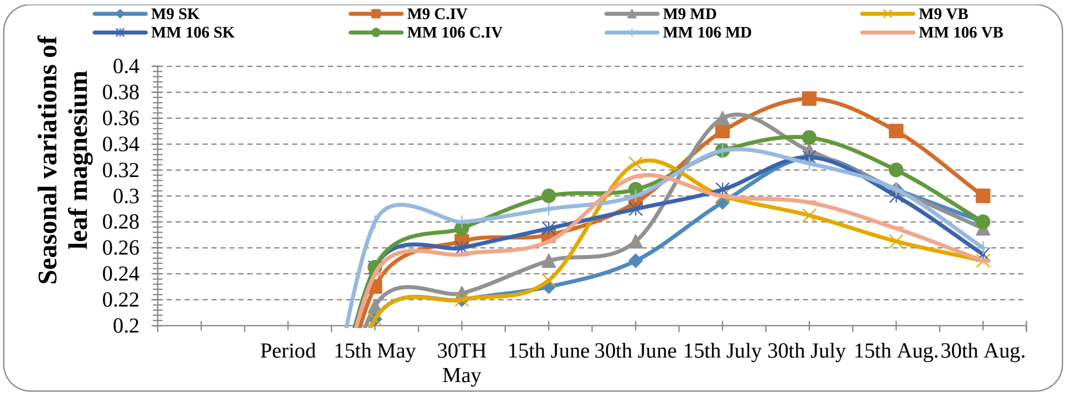

Fig 1

Boron

The comparison of leaf boron content between the two rootstocks depicted that significantly higher leaf boron content was recorded on MM_{106} rootstock compared to M_9 rootstock. Leaf boron content also exhibited significant variation among cultivars with maximum in Vista Bella and Mollies Delicious and minimum in Cooper-IV during both the years respectively. Among rootstocks it is clearly seen that semi dwarf rootstock, MM_{106} and strong rootstock MM_{111}, had significantly higher mineral nutrients, compared to dwarf rootstocks M_9 and M_{26}. This could be attributed to the fact that there could be lower leaf nutrient concentrations due to less vigor of trees on M_9 and M_{26} rootstocks (Fallahi *et al.*, 2001) [12]. Poling and Oberly, (1979) [22] also reported that trees on MM_{106} rootstock generally had higher concentrations of boron in their leaves than trees on M_9 rootstock whose concentrations were variable among years. Similarly leaf boron content varied significantly within different sampling dates and recorded maximum leaf boron content on 15th of July and minimum on 15th of May during both the years respectively. Leaf boron content increased from 15th of May to 15th of August thereafter, it decreased upto 30th of August during the vegetation season. Buwalda and Meekings (1990) [7] reported that the depletion in leaf boron around anthesis has been linked to boron mobilization from the leaves to supply boron requirements of flowers and fruits and utilization of this element for proper growth and development of apple and pear fruits in their later stages.

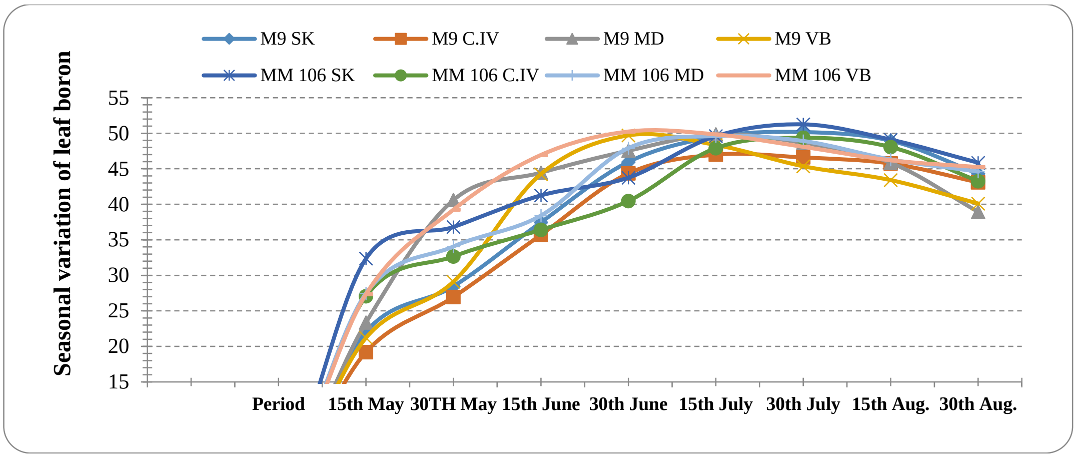

Fig 2

The stability period for leaf boron content in early maturing cultivar like Vista Bella was observed from 15th of June to 15th of July and in Mollies Delicious from 30th of June to 30th of July whereas in mid season cultivars viz, Starkrimson and Cooper- IV showed from 15th of July to 15th of August during both the years of studies which gives an indication of proper leaf sampling time for boron analysis in early and mid season cultivars. whereas, mid season maturing cultivars Starkrimson and Cooper IV showed the nutrient stability from 15th July to 15th of August on both rootstocks fig.2. The present findings are in line with those of Boynton and Cain (1943) [6] who recommended that nutrient content of apple leaves follows stability during June to August and with those Kamboj *et al.* (1987) [18].

Fruit length diameter

Fruit L/D ratio was highly influenced by various cultivars, whereas, the 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) [3] 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) [2] 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 volume

Among the rootstocks 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) [13], and Jaskani, *et al.* (2006) [16] who observed that rootstocks widely affect the fruit volume and size in citrus. EL. Sabagh (1999) [10] 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.

Rootstock and varietal effect on chemical parameters of apple Total Sugar, Total soluble solids (TSS), Titrable acidity and TSS acid ratio: 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%) where as minimum was recorded in Vista Bella (8.96 and 9.16%) on both rootstocks during both the years of study. Dolp and Probsting (1989) [9] observed a significant variation on both rootstocks, these results are in agreement with Orazem *et al.*, (2011) [21] in respect of sugars and acids a balanced sugar to acid ratio in apple fruit could provide sweet but refreshing taste. The total soluble solid content of various cultivars of apple showed a significant difference among rootstocks. 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. Among the rootstocks MM_{106} 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). Titrable acidity showed a non significant effect of rootstocks among the cultivars Vista Bella recorded the maximum acidity (0.16 and 0.15%) were as the Cooper IV showed the lowest acidity on both the rootstocks during both the years of studies. Sekse (1992) [24] and Skrzynski and Gastol (2007) [25] reported that *Malus* (vigorous) rootstock significantly increased acidity in comparison to MM_{106} semi vigorous rootstock in both the seasons. EL. Sabagh (2012) [11] reported that the lower fruit acidity was obtained from Anna apple trees grown on two different rootstocks, while several fruit quality parameters were enhanced by Polish rootstocks, the latter may occur only when appropriate acid content is maintained. Zekri (2000) [28] also reported that higher the Brix acid ratio the earlier is the fruit maturity. The perusal of data reveals that rootstocks had no significant influence on TSS acid/ ratio whereas, the cultivars recorded a significant effect during both the years of studies. MM_{106} rootstock produced the highest TSS acid ratio as compared with M_9 rootstock. Among the cultivars Cooper IV produced the maximum TSS acid ratio (114.0%) on M_9 rootstock and Starkrimson (104.1%) on MM_{106}. Whereas, the Vista Bella produced the lowest TSS acid ratio (77.5 and 79.95%) on both rootstocks. Our results are in agreement with Zekri (2000) [28] who reported that TSS / acid ratio is a flavoring factor, so these results depicted that with increase in the ratio there was a decrease in the acidity so with low TSS / acid ratio, quality of fruit is poor and taste of fruit becomes watery and insipid. Again the ratio is used to determine the fruit maturity standards, so where the ratio is high, fruit will mature earlier.

Table 1: Rootstock effect on fruit quality parameters in various exotic cultivars of apple

Treatment	Fruit L/D ratio						Fruit volume (cm^3)					
	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	0.91	0.95	0.93	0.94	0.91	0.92	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	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	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	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	150.99	183.83	167.41	180.49	190.99	186.00

CD ($p \leq 0.05$)
2013= R NS V 0.04 RXV NS 2013= R 13.57 V 19.19 RXV 27.14
2014= R NS V 0.03 RXV NS 2014= R NS V 11.57 RXV 16.36
Legend= SK= Starkrimson, C.IV= Cooper IV, MD= Mollies Delicious, VB= VistaBella, R= Rootstock, V= variety,

Table 2: Rootstock and varietal effect on Chemical parameters of apple

Treatment	Total sugar (%)						Total soluble solids (ºB)					
	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	13.20	14.03	13.61	14.20	14.50	14.35	14.50	15.63	15.06	14.16	15.00	14.58
C.IV	10.96	11.50	11.23	11.20	12.0	11.6	13.46	13.93	13.69	12.90	13.23	13.06
MD	11.16	12.03	11.59	12.40	12.50	12.45	14.16	15.03	14.59	14.36	15.00	14.68
VB	9.70	8.23	8.96	9.36	8.96	9.16	11.96	13.56	12.76	11.36	12.63	11.99
Mean	11.25	11.44		11.79	11.99		13.52	14.53	14.02	13.19	13.96	13.57

CD ($p \leq 0.05$)
2013= R NS V 1.32 RXV Ns 2013= R 0.75 V 1.06 RXV 1.50
2014= R NS V 1.24 RXV 1.75 2014= R NS V 1.33 RXV 1.88
Legend= SK= Starkrimson, C.IV= Cooper IV, MD= Mollies Delicious, VB= VistaBella, R= Rootstock, V= variety,

Table 3: Rootstock and varietal effect on Chemical parameters of apple

Treatment	Titrable acidity (%)						TSS /acid ratio (%)					
	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	14.58	0.14	0.15	0.15	0.14	0.14	103.5	104.2	103.8	101.1	107.1	104.1
C.IV	13.06	0.12	0.12	0.12	0.13	0.13	112.1	116.0	114.0	99.2	101.7	100.4
MD	14.68	0.14	0.14	0.14	0.15	0.14	101.1	107.3	104.2	95.7	107.1	101.4
VB	11.99	0.15	0.18	0.16	0.15	0.15	79.7	75.3	77.5	75.7	84.2	79.95
Mean	13.57	0.14	0.15	0.14	0.15	0.14	99.1	100.7		92.92	100.02	

CD ($p \leq 0.05$)
2013= R NS V NS RXV NS 2013= R NS V 24.18 RXV NS
2014= R NS V NS RXV NS 2014= R NS V 30.01 RXV NS
Legend= SK= Starkrimson, C.IV= Cooper IV, MD= Mollies Delicious, VB= VistaBella, R= Rootstock, V= variety,

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