Nutritional survey of kinnow orchards soil series at Rawatsar and Fatehgarh of Hanumangarh district of arid Rajasthan

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Summary

The present study was conducted to evaluate the fertility status of kinnow orchards at Rawatsar and Fatehgarh soil series of Hanumangarh district in irrigated area of arid Rajasthan. All kinnow orchards soils were found saline in nature, EC_2 of all the orchard soil samples was normal. The calcium carbonate content in soils showed increasing trend with depth, low in organic carbon and available N, low to medium in available P_2 O_5, medium to high in available K_2O content, majority of samples were found high in available Fe, available Mn and low to sufficient in available Cu and low in available Zn content. Leaf N content were found low in kinnow orchards, majority of leaf samples found medium to optimum in leaf P, Fe, and Mn content, whereas leaf K content and Zn content were found low to medium in kinnow orchards. The leaves Cu content were found optimum range in kinnow orchards. Fruit juice N, Fe and Mn content were found low to optimum, whereas fruit juice P, K and Cu content were found optimum and Zn content low at Rawatsar and Fatehgarh soil series of Hanumangarh district.

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INTRODUCTION

Kinnow (*Citrus nobilis* × *Citrus deliciosa*) is a highly preferred mandarin hybrid in North India. In Rajasthan, fruit crop covers an area of 57.50 thousand hectares and production is 995.59 thousand MT, whereas area under kinnow cultivation is 12.48 thousand hectare and production is 267.34 thousand MT (NHB, 2016-17),[21] indicated that still there is a scope to increase the area and productivity level of kinnow fruits cultivation in the state. Kinnow cultivation is becoming very popular among farmers of Hanumangarh district in Indira Gandhi canal command area of Rawatsar and Fatehgarh series. Hanumangarh district has approximately 3.65 lac hectare canal irrigated area which has great potential for expanding area under kinnow cultivation. Very little work has been done on soil environment and nutrient concentration and quality of kinnow growing particularly in Hanumangarh districts of arid Rajasthan. Hence, the research programme on kinnow was taken up to find out the probable reasons for the decline of kinnow orchards with respect to soil factors and leaf nutrient concentration that influencing yield and quality of fruits.

Materials and Methods

Study area: The present study was carried out at canal irrigated areas of semi-arid transitional plains, of Fatehgarh and Rawatsar soil series of Hanumangarh district of Rajasthan with an area of 296800 and 170600 ha, respectively. The studied area is situated in north Rajasthan having geographic position of Rawatsar (29˚16′N and 74˚22′E) and Fatehgarh (29˚32′N and 74˚14′E) in Hanumangarh district. According agro climatic zone Hanumangarh district comes under Ib *i.e.* Irrigated northwestern plain.

Characteristics of soil series and climate: Fatehgarh series is a member of fine, mixed (cal.) hyperthermic family of Ustic Torrifluvents, Typically Fatehgarh soils are very deep, moderately well drained with dark brown, clay

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loamy to clayey strongly alkaline A horizon and yellowish brown, clayey, strongly alkaline C horizon. Conspicuous stratification occurs between A and C horizon. Rawatsar series is a member of coarse loamy, mixed (cal.) hyperthermic family of Typic Haplocambids. Typically Rawatsar soils are very deep, well drained and have dark yellowish brown, loamy sand, occasionally sandy loam, mildly alkaline, A horizon and dark yellowish brown, sandy loam moderately alkaline, B horizon.[31] The climatic conditions of Semi-arid Transitional Plain in Fatehgarh and Rawatsar in Hanumangarh district, are almost the same as in the western plains marusthali (Bikaner district) except that the rainfall which is slightly higher. The annual rainfall ranges between 300 to 400 mm. Weather hazards of varying intensities are not uncommon in this region like; dust storms during summer, frosty winter nights and ground fog are some of the typical features of weather hazards. The cold waves in winter and dust storms in summer make the climate more severe unpleasant.

Soil sampling and analysis: Soil samples from surface (0-30 cm depth) and sub-surface (30-60 cm depth) from each orchard (10 Kinnow orchards) of selected soil series in Hanumangarh district were collected with the help of a wooden khurpi. Samples were completely air-dried and passed through 2 mm sieve and stored in properly labeled plastic bags for analysis. The pH and electrical conductivity of the soil samples were measures in 1: 2 soil water suspension described by Richards (1954).[29] The content of organic carbon in the soil samples was determined using the procedures described by Piper (1950)[25] and calcium carbonate was estimated by rapid titration method described by Hutchinson and McLennan (1914).[43] Available N was determined using alkaline permanganate method described by Subbiah and Asija (1956),[40] Available P was determined Extract by 0.5 M $NaHCO_3$ at pH 8.5 and development of color for colorimetric measurement by Olsen *et al.* (1956),[22] Available K was determined using flame photometer described by Metson (1956),[18] Available Zn, Fe, Cu and Mn contents in soil samples were determined using AAS described by Lindsay and Norvell (1978).[14]

Leaf sampling and analysis: The methodology for leaf sampling suggested by Singh *et al.* (1989)[33] for kinnow was followed. Composite leaf samples from four trees in each orchard of the soil series (recently mature leaves) was collected from third pair of leaf apex in the early morning or late evening hours during the month of March-April, 2015 from 10-15 years age old plants with a sample size of 60 leaves from all the four directions *viz*. North, East, West and South for nutritional diagnosis. Samples collected were kept in paper bag and quickly brought to the laboratory. These samples were washed thoroughly by using 0.2 per cent detergent solution to remove waxy coating on the leaf surface. Thereafter washed with N/10 HCl solution to remove heavy metals like Fe, Mn, Zn, etc., followed by distilled water to remove acid and detergent residue and finally in double distilled water. After cleaning samples were put in a new paper bag and placed in hot air oven at 70 ^{0}C for 24 hours. After drying sample were ground and stored in clearly labeled polythene bags for further analysis. Plant sample was digested by using H_2SO_4 and H_2O_2 carried out for nitrogen and determined N content by colorimetric method using spectrophotometer described by Snell and Snell (1949),[36] Plant P content determined by vanadomolybdo-phosphric acid yellow colour method described by Jackson (1973),[39] plant K content K was determined using flame photometer described by Bhargava and Raghupati (1993),[3] plant digest (using HNO3 and HClO4 mixture for digestion) were prepared and analyzed for Cu, Fe, Mn and Zn using the atomic absorption spectrophotometer described by Lindasy and Norvell (1978).[14]

Fruit sampling and analysis: A composite fully matured fruit samples were taken from four trees in each orchard of the soil series and packed in a plastic bag with sample label. Fruit samples for kinnow were collected during the month of December, 2015 to January, 2016. For studying the physical and chemical characteristics of kinnow fruits.

Results and Discussion

Physico-chemical and soil fertility status of kinnow orchards: Data presented in table 1 revealed that pH of soil depths *i.e.* 0-30 and 30-60 cm varied from 8.04-8.95 and 7.93 to 8.78 with mean value 8.43 and 8.17 in Fatehgarh series and 8.00 to 8.56 and 7.70 to 8.43 with mean value 8.38 and 8.20 in Rawatsar soil series. The EC_2 of 0-30 and 30-60 cm soil depths were ranged between 0.12 to 0.48 and 0.10 to 0.44 with mean value 0.21 and 0.19 in Fatehgarh series and 0.13 to 0.59 and 0.10 to 0.50 with mean value 0.36 and 0.28 in Rawatsar soil series. The $CaCO_3$ values of soil depths *viz*. 0-30 and 30-60 cm were ranged between 12.50 to 35.60 and 17.30 to 38.00 with mean value 22.05 and 26.91 in Fatehgarh soil series and 21.40 to 38.30 and 26.50 to 40.90 with mean value 29.30 and 33.45 in Rawatsar series. Serieswise, range and mean values of organic carbon content of different soil layers were recorded 0.84 to 3.62 g kg^{-1} with the mean value 1.90 in 0-30 cm, 0.52 to 2.10 with mean value 1.17

g kg^{-1} in 30-60 cm depth in Fatehgarh series, 0.69 to 3.12 with mean value 1.81 in 0- 30 cm and 0.45 to 1.85 with mean value 1.01 g kg^{-1} in 30-60 cm depths in Rawatsar series. The available N content of soils in 0-30 and 30-60 cm depths were ranged between 115.48 to 181.43 and 105.45 to 172.52 with mean value 150.66 and 140.30 in Fatehgarh series, 101.41 to 159.41 and 95.48 to 155.54 with mean value 131.25 and 124.61 in Rawatsar soil series. The available P content in soil depths of 0-30 and 30-60 cm were ranged between 18.31 to 31.49 and 18.12 to 28.22 with mean value 22.56 and 21.94 in Fatehgarh series, 18.31 to 31.49 and 18.12 to 23.11 with mean value 21.43 and 19.65 in Rawatsar series. The available K content of soils were varied from 119.84 to 355.84 and 115.47 to 251.45 with mean values 210.17 and 189.31 in Rawatsar series, 120.48 to 375.81 and 119.84 to 315.54 with mean values 216.62 and 202.13 in Fatehgarh series.

Table 1: Physico-chemical and soil fertility parameters of kinnow orchards at different soil series of Hanumangarh district

Soil Series	Depth (cm)	pH_2	EC_2 (dS m^{-1})	$CaCO_3$ (g kg^{-1})	Organic carbon (g kg^{-1})	Available macronutrients (kg ha^{-1})		
						Nitrogen	Phosphorus (P2O5)	Potassium (K_2O)
Fatehgarh Series								
Range	0-30	8.04-8.95	0.12-0.48	12.50-35.60	0.84-3.62	115.48-181.43	18.31-31.49	120.48-375.81
	30-60	7.93-8.78	0.10-0.44	17.30-38.00	0.52-2.10	105.45-172.54	18.12-28.22	119.84-315.54
Mean	0-30	8.43	0.21	22.05	1.90	150.66	22.56	216.62
	30-60	8.17	0.19	26.91	1.17	140.30	21.94	202.13
C.V.	0-30	3.59	54.20	34.80	62.27	13.81	23.51	34.77
	30-60	3.57	54.43	26.27	49.53	15.41	18.94	28.42
Rawatsar Series								
Range	0-30	8.00-8.56	0.13-0.59	21.40-38.30	0.69-3.12	101.41-159.41	18.31-31.49	119.84-355.84
	30-60	7.70-8.43	0.10-0.50	26.50-40.90	0.45-1.85	95.48-155.54	18.12-23.11	115.47-251.45
Mean	0-30	8.38	0.36	29.30	1.81	131.25	21.43	210.17
	30-60	8.20	0.28	33.45	1.01	124.61	19.65	189.31
C.V.	0-30	2.05	42.29	2148	52.88	13.66	19.69	33.16
	30-60	3.01	44.61	14.87	43.23	14.46	8.49	22.82

The relative high pH of these orchard soils might be due to dominance of CO^{2-}+ HCO^{-} of Ca^{2+}_3, Mg^{2+}providing OH^{-1} ions. The pH_2 of study area were varied from normal to alkaline. Accumulation of bases especially Na^{+} under low rainfall conditions seen to be the primary reason for alkaline soil reaction. The EC values of surface soils were slightly higher as compared to subsurface soils. The higher values of EC of surface soils might be due to high evaporation demand of the arid-ecosystem due to prevailing high temperature and low rainfall and irrigating soils with poor quality underground waters. Increase in the $CaCO_3$ content with increased soil depths indicates that the calcium leached down from surface soil to sub surface soils and accumulated in the form of calcium carbonate as secondary carbonate by the precipitation. Low content of organic carbon in the soils of all the soil series appears to be mainly due to the type of climate of region. It is difficult to build up organic matter in the soils of arid regions on account of high temperatures which causes rapid oxidation of organic matter. The results of investigation are in close agreement with the findings Singh and Kumar (2012),[34] Bhatnagar and Singh (2014),[5] Rathod *et al.* (2016)[28] and Yadav and Gupta (2018).[42] The cause of low available nitrogen content in all these soils had been due to the absence of natural vegetation, low organic carbon, low precipitation and high temperature which aggravates decomposition of organic matter by enhancing oxidation and aeration. The soils of the study area were found to be low to medium in available phosphorus content. A satisfactory potassium status of the studied area might be due to potash bearing minerals (muscovite, biotite and feldspar) which on weathering slowly release potash. The results of present study are in confirmation with those reported by Singh and Kumar (2012),[34] Haldhar *et al.* (2013),[9] Srivastava and Patil (2016)[38] and Bagdi *et al.* (2017).[2]

Soil micronutrient (mg kg-1) status of kinnow orchards: Data presented in table 2 revealed that the available Fe content of soils in 0-30 and 30-60 cm depths were varied from 3.55 to 7.22 and 3.31 to 6.83 with average values 5.19 and 4.91 in Fatehgarh series, 4.32 to 7.43 and 4.09 to 7.01 with average values 5.51 and 5.24 in Rawatsar series. The available manganese content of 0-30 and 30-60 cm soil layers were varied from 2.19 to 3.85 and 2.09

to 3.76 with average values 2.87 and 2.78 in Fatehgarh series and 2.28 to 3.95 and 2.20 to 3.84 with average values 2.98 and 2.80 in Rawatsar series. The available copper content of soils were ranged between 0.12 to 0.38 and 0.11 to 0.38 with average values 0.26 and 0.22 in Fatehgarh series and 0.10 to 0.38 and 0.10 to 0.38 with average values 0.29 and 0.23 in Rawatsar series. The available Zn content of soils in 0-30 and 30-60 cm depths were varied from 0.24 to 0.53 and 0.19 to 0.50 with an average values 0.40 and 0.34 in Fatehgarh series, 0. 30to 0.54 and 0.27 to 0.52 with an average values 0.44 and 0.40 in Rawatsar series of Hanumangarh district.

Table 2: Soil micronutrient status of kinnow orchards at different soil series of Hanumangarh district

Soil Series	Depth (cm)	DTPA extractable micronutrients (mg kg soil^{-1})			
		Fe	Mn	Cu	Zn
Fatehgarh soil series					
Range	0-30	3.55-7.22	2.19-3.85	0.12-0.38	0.24-0.53
	30-60	3.31-6.83	2.09-3.76	0.11-0.38	0.19-0.50
Mean	0-30	5.19	2.87	0.26	0.40
	30-60	4.91	2.78	0.22	0.34
C.V.	0-30	25.58	20.35	29.34	30.18
	30-60	26.16	20.84	36.48	35.02
Rawatsar soil series					
Range	0-30	4.32-7.43	2.28-3.95	0.10-0.38	0.30-0.54
	30-60	4.09-7.01	2.20-3.84	0.10-0.38	0.27-0.52
Mean	0-30	5.51	2.98	0.29	0.44
	30-60	5.24	2.80	0.23	0.40
C.V.	0-30	21.92	22.01	33.88	20.55
	30-60	22.30	22.45	40.49	21.38

The soils of study area were found low to medium in available iron content due to calcareous soil. A satisfactory available Mn status were found in studied area. The available copper status of orchard soils were found low to sufficient might be due to high pH, calcareousness, organic carbon status and light texture of soil. Calcareous nature and low organic matter are some of the other properties where low levels of Zn are anticipated. Sharma and Choudhary (2007)[30] also reported decreasing trend of available iron from surface to sub surface layers of soil.[37, 32, 38, 23]

Nutrient contents status in kinnow leaves: A study of the data in table 3 showed that the leaf N content in kinnow leaves were collected during the month of March-April, 2015 ranged from 0.43 to 1.19 with a mean value 0.92 per cent in Fatehgarh series, 0.52 to 1.25 with a mean value 1.00 per cent in Rawatsar series. The P content in kinnow leaves varied from 0.13 to 0.38 with mean value 0.25 per cent in Fatehgarh series, 0.11 to 0.55 with mean value 0.25 percent in Rawatsar series. The K content in leaves showed a range of 0.29 to 0.64 with mean value 0.48 per cent in Fatehgarh series, 0.32 to 0.55 with mean value 0.43 per cent in Rawatsar series. The Fe content in the leaves varied from 267.76 to 449.76 with mean value 350.03 mg kg^{-1} in Fatehgarh series, 238.43 to 425.54 with mean value 314.29 mg kg^{-1} at Rawatsar series. The Mn content in kinnow leaves ranged from 23.87 to 67.82 with mean value 46.20 in Fatehgarh series, 22.94 to 65.34 with mean value 51.50 in Rawatsar series. The Cu content in leaves of kinnow orchards were ranged between 15.67 to 34.87 with the mean value 23.72 mg kg^{-1} in Fatehgarh series, 14.85 to 32.83 with the mean value 25.13 mg kg^{-1} in Rawatsar series. The Zn content in leaves of kinnow orchards were ranged from 10.32 to 26.47 with mean value 16.44 mg kg^{-1} in Fatehgarh series, 9.32 to 22.67 with mean value 14.51 mg kg^{-1} in Rawatsar series of Hanumangarh district.

The low concentration of nitrogen in leaves of these plants might be due to low nitrogen status of soils, poor organic matter content, high pH and less application of nitrogen. Besides, soils of the study area are loamy in nature; therefore, leaching of nitrogen was more which might cause reduction in its uptake. The content of P in kinnow leaves might be due to medium to high P status of orchard soils and it proper uptake and utilization by plant tissues. The leaves samples which were found low to optimum in potassium content; might be due to sufficient availability of potassium in soils of studied area.

Table 3: Nutrient contents in kinnow leaves at different soil series of Hanumangarh district

Soil Series	Macronutrients (per cent)			Micronutrients (mg kg^{-1})			
	N	P	K	Fe	Mn	Cu	Zn
Fatehgarh soil series							
Range	0.43-1.19	0.13-0.38	0.29-0.64	267.76-449.76	23.87-67.82	15.67-34.87	10.32-26.47
Mean	0.92	0.25	0.48	350.03	46.20	23.72	16.44
C.V.	30.30	37.98	34.38	15.76	31.11	31.02	33.05
Rawatsar soil series							
Range	0.52-1.25	0.11-0.55	0.32-0.55	239.43-425.54	22.94-65.34	14.85-32.83	9.32-22.67
Mean	1.00	0.25	0.43	314.29	51.50	25.13	14.51
C.V.	24.19	61.06	19.98	20.17	26.59	30.18	34.66

The results of present investigation are in accordance with Srivastava and Patil (2016),[38] Kuchanwar *et al.* (2017)[10] and Kumar *et al.* (2017)[12] who reported that nitrogen content decreased with plant or leaf age too. The orchards of study area had 100 per cent samples sufficient in Mn content in leaves and optimum to high in Fe content in leaves. It might be due to sufficient quantity of DTPA iron in soil. The evaluation of leaf samples of kinnow collected from all the soil series orchards showed higher range of Mn content. It may be due to low mobility as Mn presented a continuous leaf concentration increase over the time. Majority of leaf samples of kinnow orchards in all the soil series orchards showed optimum to high leaf Cu content. The low to high Zn content in leaves might be due to low status of available Zn in the soil, poor status of organic matter content. The results of present investigation are in accordance with Rastogi and Chandra (1987),[27] Maia (2007),[16] and Srivastava and Patil (2016).[38]

Physical and chemical characteristics of kinnow fruit: Data in table 4 showed that the fruit yield was ranged from 38.11 to 61.11 with average value 49.36 kg plant^{-1} in Fatehgarh series, 39.24 to 51.94 with average value 44.66 kg plant^{-1} in Rawatsar series. The fruit volume was ranged from 158.41 to 251.47 with average value 199.15cc in Fatehgarh series and 182.24 to 210.15 with average value 197.28 cc in Rawatsar series. The total soluble solids (TSS) were ranged from 10.48 to 12.15 with average value 11.32 ^{0}Brix in Fatehgarh series, 9.98 to 11.52 with average value 10.72 ^{0}Brix in Rawatsar series. The ascorbic acid content of kinnow fruits were ranged from 22.01 to 25.19 with average value 23.24 mg 100 g^{-1} pulp in Fatehgarh series, 21.23 to 24.35 with average value 22.66 mg 100 g^{-1} pulp in Rawatsar series. The total acidity of kinnow fruits were ranged from 0.95 to 1.12 with average value 1.03 per cent in Fatehgarh series, 0.47 to 1.07 with average value 0.95 per cent in Rawatsar series. The total sugars were ranged from 2.85 to 6.05 with average value 4.76 per cent in Fatehgarh series, 3.68 to 5.10 with average value 4.28 in per cent Rawatsar series. The reducing sugars were ranged from 2.10 to 3.02 with mean value 2.46 per cent in Fatehgarh series, 1.26 to 2.99 with mean value 2.32 per cent in Rawatsar series of Hanumangarh district.

Table 4: Physical and chemical characteristics of kinnow fruits at different soil series of Hanumangarh district

Soil Series	Fruit yield (kg plant^{-1})	Fruit volume (cc)	TSS (^{0}Brix)	Ascorbic acid (mg 100 g^{-1} pulp)	Total acidity (%)	Total sugar (%)	Reducing sugar (%)
Fatehgarh series							
Range	38.11-61.11	158.41-251.47	10.48-12.15	22.01-25.19	0.95-1.12	2.85-6.05	2.10-3.02
Mean	49.36	199.15	11.32	23.24	1.03	4.76	2.46
C.V.	13.46	13.97	4.80	4.01	4.90	10.14	11.33
Rawatsar series							
Range	39.24-51.94	182.24-210.15	9.98-11.52	21.23-24.35	0.47-1.07	3.68-5.10	1.26-2.99
Mean	44.66	197.28	10.72	22.66	0.95	4.28	2.32
C.V.	8.38	4.19	4.27	4.66	17.33	12.20	19.34

The physical characters of fruits *i.e.* fruit volume and fruit yields were found relatively higher due to better nutrient management, water availability and quality along with appropriate management might have resulted in better fruit volume and yield similar findings reported by Nasreen *et al.* (2013)[20] and Desai *et al.* (2014).[7] The chemical characteristics of fruits like total soluble solids, total acidity, reducing sugar and total sugar content

series wise differences due to variation in soil nutrient status of the orchards. These results get support from the findings of Kaul *et al.* (2014)[44] who studied the response of soil nutrient status on leaf nutrient content and fruit yield of kinnow at different locations of seven kinnow orchards at Sriganganagar district of Rajasthan, India, during 2005-06. The results showed that average fruit weight, T.S.S., acidity, ascorbic acid, juice content and fruit yield varied between 108.96 to 151.39 g, 10.40 to 11.60 °Brix, 0.98 to 1.02%, 32.93 to 36.02 mg $100g^{-1}$ pulp, 51.80 to 55.70 ml and 47.53 to 71.33 kg $plant^{-1}$, respectively. Similar results were also reported by Bhatnagar and Singh (2014),[5] Bhatnagar *et al.* (2015)[4] and Pawar *et al*. (2017).[24]

Nutrient content status of kinnow fruit juice: Data presented in table 5 indicated that the N content in kinnow fruit juice at ranged from 724.58 to 1269.45 with mean value 1016.89 in Fatehgarh series, 819.48 to 1389.84 with mean value 994.57 in Rawatsar series. The P content of kinnow fruits ranged from 103.58 to 173.65 with mean value 135.05 at Fatehgarh series, 112.61 to 159.62 with mean value 125.81 in Rawatsar series. The K content in kinnow fruit juice was ranged from 1172.54 to 1505.22 with mean value 1246.84 at harvest in Fatehgarh series, 1075.14 to 1206.21 with mean value 1185.17 in Rawatsar series. The Fe content in the kinnow fruit juice varied from 0.22 to 1.29 with mean value 0.58 ppm at Rawatsar series, 0.22 to 1.21 with mean value 0.50 in Rawatsar series. The kinnow juice Mn content varied from 0.11 to 0.42 with mean value 0.24 at Fatehgarh series, 0.11 to 0.38 with mean value 0.22 in Rawatsar series. The variation in Cu content of kinnow fruit juice was observed from 0.28 to 0.57 and 0.27 to 0.50 with mean value 0.43 and 0.35 ppm at Fatehgarh and Rawatsar series. The kinnow fruit juice Zn content varied from 0.27 to 0.65 and 0.18 to 0.54 with mean values of 0.38 and 0.34 ppm at Fatehgarh and Rawatsar series of Hanumangarh district.

Table 5: Nutrient contents in kinnow fruit juice of different soil series of Hanumangarh District

Soil Series	Juice nutrient contents (ppm)						
	N	P	K	Fe	Mn	Cu	Zn
Fatehgarh series							
Range	38.11-61.11	158.41-251.47	10.48-12.15	22.01-25.19	0.95-1.12	2.85-6.05	2.10-3.02
Mean	49.36	199.15	11.32	23.24	1.03	4.76	2.46
C.V.	13.46	13.97	4.80	4.01	4.90	10.14	11.33
Rawatsar series							
Range	39.24-51.94	182.24-210.15	9.98-11.52	21.23-24.35	0.47-1.07	3.68-5.10	1.26-2.99
Mean	44.66	197.28	10.72	22.66	0.95	4.28	2.32
C.V.	8.38	4.19	4.27	4.66	17.33	12.20	19.34

Singh *et al*. (2015)[35] reported the concentrations of macronutrients (N, P, K, Ca and Mg) and micronutrients (Fe, Zn, Mn and Cu) in the fruit peel and pulp from grapefruit cv. Star Ruby fruits at monthly intervals during fruit development. Similarly, results were also reported by Li-ying *et al.* (2008),[15] Rangel (2010),[26] Tufuor *et al.* (2011)[41] and Lado *et al.* (2016).[13]

Correlation coefficients between leaf nutrients and fruit quality of kinnow: The estimates of correlation between different variables measured from two different soil series under irrigated area of Rajasthan is given in table 6.

In Fatehgarh series the leaf N content was positively correlated with total acidity (r = 0.602*), ascorbic acid (r = 0.632*), fruit volume (r = 0.846**) and fruit yield (r= 0.809**); leaf K content negatively correlated with TSS (r = -0.610*), reducing sugar (r = -0.808**) and positively correlated with total acidity (r = 0.803**), ascorbic acid (r = 0.576*) and fruit volume (r =0.508*); leaf Fe content correlated positively with total sugar (r= 0.589*) and ascorbic acid (r= 0.702*); leaf Mn content with total acidity (r = 0.658*) and fruit yield (r = 0.510*); leaf Cu content with TSS (r = 0.868**), fruit volume (r= 0.897**), fruit yield (r = 0.557*) and negatively correlated with total acidity (r = -0.748*) and reducing sugar (R = -0.873**); leaf Zn content with reducing sugar (r = -0.572*) and fruit yield (= 618*).

In Rawatsar series the leaf N content was correlated positively with total acidity (r = 0.559*), fruit volume (r = 0.840**) and fruit yield (r = 0.803**); leaf P content with total sugar (r = 0.571*); leaf K content with total acidity (r = 0.785**), ascorbic acid (r = 0.501*), fruit volume (r = 0.980**) and fruit yield (r = 0.502*); leaf Fe content with total sugar (r = 888**) and ascorbic acid (r = 0.738*); leaf Mn content with total acidity (r = 0.822**); leaf Cu content negative correlated with total sugar (r = -0.588*) and

positive correlated with fruit volume (r = 0.633*); leaf Zn content with TSS (r = 0.883**) and fruit yield (= 0.631*).

Table: 6: Correlation coefficients between leaf nutrients concentration and fruit quality and yield of kinnow

Leaf nutrients	Fruit yield and quality parameters						
	TSS (°B)	Total acidity (%)	Reducing sugar (%)	Total sugar (%)	Ascorbic acid (mg/100^{-1}g pulp)	Fruit volume (cc)	Fruit yield (kg plant^{-1})
Fatehgarh series							
N (%)	-0.746	0.602*	-0.130	0.018	0.632*	0.846**	0.809**
P (%)	0.323	0.377	-0.398	0.472	0.135	0.277	0.384
K (%)	-0.610*	0.803**	-0.808**	0.156	0.576*	0.508*	0.436
Fe (ppm)	0.117	0.278	0.171	0.589*	0.702*	0.341	0.442
Mn (ppm)	-0.124	0.658*	0.182	0.239	0.030	0.434	0.510*
Cu (ppm)	0.868**	-0.748*	-0.873**	-0.144	-0.272	0.897**	0.557*
Zn (ppm)	0.533*	-0.540	-0.572*	0.038	-0.209	0.278	0.618*
Rawatsar series							
N (%)	-0.690	0.559*	-0.415	0.175	0.160	0.840**	0.803**
P (%)	0.095	0.07	0.212	0.571*	0.365	0.158	0.049
K (%)	-0.132	0.785**	-0.399	0.095	0.501*	0.980**	0.502*
Fe (ppm)	0.347	0.104	0.273	0.888**	0.738*	0.166	0.017
Mn (ppm)	-0.335	0.822**	0.334	-0.116	-0.205	0.060	0.103
Cu (ppm)	0.144	-0.475	-0.195	-0.588*	-0.370	0.633*	0.380
Zn (ppm)	0.883**	-0.512	-0.295	0.404	-0.148	0.298	0.631*

Perusal of the data revealed a positive and significant correlation coefficient between leaf N, P, K Cu and Zn with fruit volume and fruit yield. Since all the characteristics depend upon vegetative growth of the plant which are influenced by nitrogen. These results are in accordance with the findings of Kumar *et al.* (1998)[11] and Mukherjee *et al.* (1981).[19] Significant positive correlation was observed between kinnow leaf macronutrients content and fruit yield while leaf Zn content with both yield and quality of fruits (Marathe *et al.* 2012).[17] Positive and significant relationship of leaf N with acidity is in agreement with that of Awasthi *et al.* (1998),[1] Desai and Phadnis (1987)[8] and Dalal *et al.* (2011).[6]

Suggested nutrient management recommendations for kinnow orchards: On the basis of soil series, potentialities and limitations, following nutrient management recommendations are being suggested for obtaining optimum kinnow fruit production from the orchards at Fatehgarh and Rawatsar soil series of Hanumangarh districts in irrigated area of Rajasthan. The Soils of kinnow orchards were found low in organic carbon and available N, low to medium in available P and medium to high in available K. Therefore, well decomposed 100 kg F.Y.M. along with 2.00 kg urea and 1.80 kg single super phosphate per plant must be applied before planting. Full dose of single super phosphate and potash and half dose of urea should be applied during the month of February and the remaining dose of urea applied in the month of August. If we use vermicompost then apply 100 kg well decomposed vermicompost along with 1 kg urea. The SSP dose will remain same as above for kinnow plants. Micronutrient status in kinnow orchards at Fatehgarh and Rawatsar soil series were found low in available Fe, sufficient in available Cu, high in available Mn and majority of soil samples were found low in available Zn. The foliar application of $FeSO_4$, $CuSO_4$ and $ZnSO_4$@ of 150 g each for Fe, Cu and Zn content should be applied per plant per annum.

Conclusion

The high pH_2 values, $CaCO_3$ content and EC_2 in soil samples were observed at kinnow orchards in Rawatsar and Fatehgarh series of Hanumangarh district. The low in organic carbon, available N and low to medium in available P_2O_5 and low to medium in available K_2O, low in available Fe, high in available Mn, medium to sufficient in available Cu and low in available Zn contents. Leaf samples of kinnow were found low in N, high in P, optimum in K, high in Mn, optimum too high in Cu and low in Zn content, whereas, Fe content was found optimum

too high in kinnow of the studied area. The fruit yield, quality and nutrient status of kinnow fruits were found superior in Fatehgarh as compared to Rawatsar soil series. Fruit juice samples of kinnow were found optimum in N, P and K, optimum to high in Fe, Cu and Mn contents and the Zn content in kinnow fruit juice was found low to optimum range of the studied area.

Declaration of interests

The authors have no conflict of interest to declare.

Data sharing

All relevant data are within the manuscript.

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