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Full Length Research Paper

Soil fertility and nutritional status of Kinnow orchards grown in aridisol of Punjab, India

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The present study was aimed at evaluating the fertility status of Kinnow orchards in aridisol order of Punjab. The soil texture of different productive Kinnow orchards was loamy sand in nature. All Kinnow orchards soils were found alkaline to saline in nature, with pH value ranging from 8.4 to 9.5 and deficient of macronutrients while sufficient in most of the micronutrients. Foliar analysis suggested that percent samples of different locations were nearly sufficient of manganese (Mn), copper (Cu), iron (Fe) and zinc (Zn) and deficient of potassium (K) and nitrogen (N). Sand and silt content significantly and positively correlated with soil pH and electrical conductivity (EC). Soil properties showed antagonistic effect with most of soil and foliar macro-micronutrients and fruit yield. Available N showed a significant and positive correlation with soil P, K and Cu. Moreover, foliar N was positively related with foliar P and Zn, while foliar P with foliar Cu, Fe and Zn concentrations.

Key words: Aridisol, foliar, Kinnow orchards, macronutrients, micronutrients, Punjab.

INTRODUCTION

Kinnow, a hybrid between King Sweet orange and Willow Leaf mandarin, is one of the most promising hybrid not only for the plains of northern India, but also in the valleys and hilly tracts of medium altitude. Kinnow trees, like other plants, need different nutrients in varying quantities to achieve optimum growth and fruiting. Ordinarily, the elements which need constant replenishment are mainly nitrogen (N), phosphorus (P) and potassium (K), as these are used up in considerable quantities by crops. Soil fertility and its productivity are mainly affected by soil properties and nutrient status. Soil texture is basic to many other soil properties and serves as an indicator of water holding capacity, cation exchange capacity and aeration.

One of the major deficiencies in most of the Kinnow orchards in aridisol is an acute shortage of organic matter and is commonly low in both macro and micronutrients, which can limit tree function. In addition, micronutrients deficiency occurs in trees growing in such alkaline soils (Amberger, 1982). Kinnow mandarin is extensively grown in aridisol, although the fertility is low and pH values ranges from 8.4 to 9.5; proper nutrients management is required to grow mandarin successfully on such soils. In the past, research has been mainly focused on macro-nutrients such as N and P. Kinnow trees do much better in good nutrition and controlled nutrient supply during different seasons, and can produce higher yield. Average recommendation will result in high yielding or large trees in the grove receiving relatively less fertilizer than they require, and low yielding or small size tree areas receiving relatively more fertilizer than necessary (Zaman et al., 2005). Local over fertilization may decrease ground water quality, reduce profit margins, induce deficiency of other elements and interfere with metabolic processes, while unsuitable fertilization may restrict Kinnow yield and quality. Hence, there is need for variable rate of application to avoid these problems by having knowledge of the scale of variability of soil and tree characteristics

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Table 1. Soil physico-chemical properties of Kinnow orchards grown in aridisol.

Parameter	HYO		LYO		CD at (5%)
	Range	Mean	Range	Mean	
pH	8.4 - 9.2	8.82	8.5 - 9.5	9.2	0.2
EC (dS m^{-1})	0.06 - 0.32	0.14	0.13 - 0.84	0.39	0.1
$CaCO_3$ (%)	2.7 - 5.2	4.1	3.6 - 7.6	5.9	0.5
Sand (%)	46.8 - 72.4	57.7	47.2 - 55.1	62.4	3.5
Silt (%)	20.4 - 39.2	31.0	28.0 - 37.8	34.8	0.3
Clay (%)	9.5 - 15.0	12.6	11.6 - 17.7	14.4	1.1

HYO = high yielding orchards; LYO = low yielding orchards.

within each field. Soil and leaf analysis can be used to evaluate the nutritional status of the trees and nutrient availability in the soil to supply the trees with nutrients requirement (Embleton et al., 1996). The objective of this study was, therefore, to evaluate the nutrients and their relationship with soil properties, so as to use such knowledge as a tool in optimizing fertilizers use for higher yield.

MATERIALS AND METHODS

A survey was carried out to investigate the causes of Kinnow orchards (rootstock *Jatti khatti*) deterioration in aridisol order of Punjab. Twenty-eight Kinnow orchards (13 years old) were selected and 112 soil samples were collected from them. Fourteen Kinnow orchards were selected each for high yielding and low yielding orchards on the basis of yield. Four sites were selected in each Kinnow orchard; each site was a crossing point of four plants. The samples were so composited that four samples were taken from each orchard upto 15 cm. These soil samples were brought to laboratory, air dried, ground and passed through a 2-mm sieve and analyzed for physical, chemical characteristics and various nutrient levels were determined.

One hundered and twelve Kinnow leave samples were collected from 5 to 7 months old spring flush immediately above the node, from the same orchards from where soil samples were collected. Each plant sample was a composite of four sub-samples. Leaves were collected from 8 - 10 plants haphazadarly from an orchard and a total of 100 leaves were taken from each sample. All the leaves were sampled from non-fruiting twigs 3 - 6 feet above the ground level. No Kinnow plant was sampled from the borderlines. Leaf samples were washed with distilled water and oven dried at 60 - 70°C to a constant weight. The oven-dried plant samples were ground and analyzed for varoius nutrients.

Analysis of soil and plants samples

Soil and plant samples were analyzed using the following methodology: soils were analyzed for their physico-chemical properties such as soil texture (Koehler et al., 1984), soil pH (1:2) (Mclean, 1982) using 105 Ion Analyzer pH meter, Soil electrical conductivity (EC; 1:2) (Richards, 1954) and calcium carbonate content (Nelson and Sommers, 1982). AB-DTPA extracts of soils (Soltanpour and Schwab, 1977) and plant digest (using HNO_3 and $HClO_4$ mixture for digestion) were prepared and analyzed for copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) using the Atomic Absorption Spectrophotometer 'Perkin Elmer' model No.2380, while potassium (K) was analysed using 'Perkin Elmer' Flame Photometer model No.2380 and phosphorus (P) by spectro-photometer "Spectronic Lmbda (λ) 35" using required standard solutions. Available nitrogen in soils and plants were determined using Kjeldahl distillation procedure as described by Subbiah and Asiza (1956). The data were subjected to complete randomized block design, linear and multiple correlation analyses in order to diagnose the optimum leaf and available soil nutrients in relation to soil properties.

RESULTS AND DISCUSSION

Physico-chemical properties of soil

The soil pH of soil suspension (1:2) of all the representative soils was mostly alkaline and saline in nature (Table 1). The mean EC observed highest in low yielding orchards was 0.39 ± 0.3 dS m^{-1} (Table 1). The results suggested that these soils were low (<2-4 dSm^{-1} at 25°C) in electrolyte concentration due to leaching induced by heavy rainfall. Such low EC value is a matter of concern with respect to maintaining the required levels of bases on sustainable basis, indicating the susceptibility of soils to nutrient leaching in the absence of adequate levels of soil organic matter. A similar trend was found in calcium trioxocarbonate ($CaCO_3$) content.

Furthermore, the soil texture of high and low yielding Kinnow orchards was loamy sand and dominated with high content of 57.7 and 62.4% sand content (Table 1). Silt and clay content were found to be higher in high yielding Kinnow orchards soils than that of low yielding (Table 1). On the whole, the particle size analysis suggested that the soils of orchards being loamy sand in nature are best suited for Kinnow orchards. However, being well drained in nature, the chances of nutrient leaching are always more if the level of organic matter is not maintained. Thus, it is very important to add organic and chemical fertilizer to maintain adequate fertility status of these soils.

Table 2. Soil available N and AB-DTPA- P, K, Cu, Fe, Mn and Zn in Kinnow orchards grown in aridisol.

Nutrient	HYO		LYO		Evaluation	CD at (5%)
	Range	Mean	Range	Mean		
N (Kg/ha)	120 - 202	148.2	69 - 89	80.89	Low	2.1
P (Kg/ha)	1.21 - 5.47	2.69	1.21 - 1.46	1.26	Low	0.6
K (Kg/ha)	103.2 - 121.4	*114.5*	51.0 - 103.2	73.52	Low	3.5
Mn (Kg/ha)	1.78 - 3.80	3.03	1.89 - 2.94	2.50	Medium	0.2
Cu (ppm)	0.52 - 2.36	1.75	1.07 - 1.56	1.20	High	0.1
Fe (ppm)	1.79 - 5.68	3.50	1.76 - 2.20	2.04	Low	1.2
Zn (ppm)	0.86 - 2.56	1.39	0.80 - 1.60	1.17	Low	0.9

HYO = high yielding orchards; LYO = low yielding orchards.

Table 3. Foliar macro and micro-nutrients of Kinnow orchards grown in aridisol.

Nutrient	HYO		LYO		Evaluation
	Range	Mean	Range	Mean	
N (%)	2.18-2.89	2.32	2.11-2.53	2.28	Low
P (%)	0.06-0.13	0.09	0.10-0.17	0.15	Medium
K (%)	0.46-1.43	1.04	0.58-1.78	1.09	Medium
Mn (ppm)	16.78-36.78	23.34	17.14-32.42	24.94	Medium
Cu (ppm)	42.00-118.7	73.64	14.70-57.80	35.30	High
Fe (ppm)	249.0-549.2	369.7	191.3-362.4	242.3	High
Zn(ppm)	13.61-41.60	18.90	12.9-39.1	16.12	Low

HYO = high yielding orchards; LYO = low yielding orchards.

Soil analysis

The available N, P and K concentrations in Kinnow orchard grown in aridisol of Punjab ranged from 69 to 202, 1.20 to 5.47 and 51.0 to 121.4 kg/ha in different Kinnow orchards (Table 2). The highest mean available N (148.2 kg/ha) was recorded in high yielding orchards than that of low yielding (80.89 kg/ha). The P varied from 1.21 - 5.47 and 1.21 - 1.46 kg/ha in two different productive orchards. Exchangeable K ranged from 103.2 - 121.4 and 51.0 - 103.2 kg/ha in high and low yielding Kinnow orchards in aridisol (Table 2). Similarly, Mn varied from 1.78 - 3.80 and 1.89 - 2.94 in high and low yielding orchards. Fe and Zn varied from 1.76 - 5.68 and 0.80 - 2.56 in different productive Kinnow orchards grown in aridisol (Table 2). The data also showed that all samples contained low N, P and K (Table 4) as compared with the values reported by Subbiah and Asiza (1956), Olsen et al. (1954) and Jackson (1967).

Soils of Kinnow orchards in aridisol order are well drained in nature, hence the chances of nitrogen leaching if the level of organic matter is not maintained. The low P and K concentrations in the soils of Kinnow orchards might be due to high pH and faulty cultural practices followed by orchardists. Micro-nutrients showed large variation in concentrations in the study sites with high concentrations of Cu and Mn (Table 2). The concentrations of Cu, Mn and Zn concentrations in the soils of Madison country, Missouri (USA), ranged from 1 to 450, 17 to 1227 and 14 to 142 mg kg^{-1}, respectively (Davies and Wixon, 1985). The data showed that most of soil samples were deficient of Zn and Fe but sufficient in Cu and Mn (Table 2) when compared with previously reported values (Foliet and Lindsay, 1970; Peryea, 2000; Lindsay, 1979; Jones, 1972) (Table 4).

Plant analysis

It is well known that mandarin trees are very sensitive of nutrient deficiencies in the soil and foliar. Foliar N, P and K in Kinnow orchards of aridisol ranged from 2.11 - 2.89, 0.06 - 0.17 and 0.46 - 1.78% in the different Kinnow orchards (Table 3). Nitrogen concentration in the leaves ranged between 2.18 - 2.89 and the mean was 2.32% on dry matter basis, and was found to be low in high yielding Kinnow orchards (Table 3). This may be due to the high leaching of ammonium nitrate in such soil with 57.7% sand (Table 1). It is, therefore, recommended to add nitrogen as ammonium sulphate, which is less

Table 4. Index values for available N and AB-DTPA- P, K, Cu, Fe, Mn and Zn in soils reported by various sources.

Soil nutrient	Soil fertility class			References
	High	Medium	Low	
N (kg/acre)	> 543	271 - 543	< 271.0	Subbiah and Asiza (1956)
P(kg/acre)	> 9.0	5 - 9	< 5.0	Olsen et al. (1954)
K (kg/acre)	> 138.7	54.8 - 138.7	< 54.8	Jackson (1967)
Mn (ppm)	> 7.0	3.5 - 7.0	< 3.5	Foliet and Lindsay (1970)
Cu (ppm)	> 0.4	0.2 - 0.4	< 0.2	Jones (1972)
Fe (ppm)	> 9.0	4.5	< 4.5	Lindsay (1979)
Zn (ppm)	> 1.2	0.6 - 1.2	0.6	Peryea (2000)
N (%)	> 2.80	2.80	< 2.30	Chahil et al. (1991)
P (%)	> 0.15	0.15	0.09	Chahil et al. (1991)
K (%)	> 1.57	1.57	< 0.72	Chahil et al. (1991)
S (%)	> 0.34	0.34	< 0.17	Chahil et al. (1991)
Mn (ppm)	> 38.0	38.0	< 20.50	Chahil et al. (1991)
Cu (ppm)	> 9.83	9.83	< 3.96	Chahil et al. (1991)
Fe (ppm)	> 102.7	102.7	61.20	Chahil et al. (1991)
Zn(ppm)	> 62.0	62.0	18.8	Chahil et al. (1991)

susceptible to leaching and more efficient at sandy and high pH conditions. In this respect, Johnston (2004) reported that when ammonium sulphate is applied, one pH unit can be decreased and this pH change is important for P availability supply and may be also for micronutrient availability supply. P-concentrations in the mature leaves of high and low yielding orchards ranged between 0.06 - 0.13 and 0.10 - 0.17% and ranged between low and sufficient levels (Table 3). Potassium concentrations in the leaves ranged in different orchards (0.46 - 1.78%) with medium fertility status (Table 3). Fe and Cu concentrations can be higher than or equal to those in normal trees. The mean Fe-concentration ranged from (249.0 - 549.2 ppm) in high yielding orchards. Moreover, foliar Mn ranged from 16.78 - 36.78 ppm and 17.14 - 32.42 ppm in the high and low yielding orchards evaluated. Conversely, the Zn concentration in this study was low in most cases; the Zn concentration had low levels (13.61 - 41.60 ppm) in the fertility status in Kinnow orchards. Zinc deficiency is widespread in citrus trees in India; Srivasatava and Singh (2004), mentioned that in soils with very high pH matter, availability of Zn to plant roots is extremely low. In addition, Srivastava and Singh (2009) found that when severe Zn deficiency symptoms appear, early spring foliar sprays could increase the micronutrient concentration in the targeted organs.

Relationship between soil/foliar nutrient status and physio-chemical properties

The data presented in Table 5 revealed that sand, silt and clay improved the fruit yield but non-significantly. On the other hand, sand and silt significantly correlated with soil pH (r = 0776**) and (r = 0.412*), but significantly and negatively related with available N (Table 5). Fruit yield was also significantly and positively correlated with available N (r = 0.460*), P (r = 0.830**), K (r = 615**) and Mn (r = 0.549**) as shown in Table 5. However, significant and negative relationship was observed with soil pH (r = -0.548**), EC (r = -0.491**) and $CaCO_3$ (r = -0.448*) content. Available N showed a significant but negative relationship with soil pH (r = -0.469*) as shown in Table 5. Similar results were also reported by Srivastava and Singh (2004).

Additionally, a highly significant and negative correlation was observed between soil N and EC (r = -0.522**), and it may be concluded that the increase in pH and EC resulted in decreased availability of N in the soil. Available P significantly and negatively correlated with soil pH (r = - 0.567**) (Table 5). Exchangeable K like other macro-nutrients decreased with increase in soil pH and EC (r = -0.633**, r = -0.589**) as shown in Table 5. Similar results were reported by Chinchmalatpure et al. (2000). Available Mn showed non-significant but negative relationship with soil properties viz; pH and $CaCO_3$, but significant and negative relationship with EC (Table 5). Available Cu, Fe and Zn showed non-significant and negative relationship with pH, EC and $CaCO_3$ content (Table 5). Available N improves the availability of P (r = 0.533**), K (r = 0.622**) and Cu (r = 0.437*) (Table 5). Sand and silt significantly but negatively correlated with foliar N and foliar P. Foliar N, Cu Fe and Zn significantly increased the fruit yield of Kinnow orchards (Table 6).

Table 5. Relationship among macro and micronutrients with soil properties of the tested soil samples of aridisols.

Parameter	Sand	Silt	Clay	Yield	Soil pH	EC	$CaCO_3$	N	P	K	Mn	Cu	Fe	Zn
Sand	1	0.046	0.196	0.312	0.776**	0.134	0.479*	-0.471*	-0.315	-0.355	-0.041	0.321	-0.123	0.133
Silt			0.124	0.081	0.412*	0.236	-0.235	-0.374*	-0.113	0.041	0.051	0.118	0.123	-0.127
Clay				0.228	0.223	0.109	-0.145	0.143	0.071	-0.005	0.073	0.081	0.119	0.094
Yield					-0.548**	-0.491**	-0.448*	0.460*	0.830**	0.615**	0.549**	0.313	0.375	0.223
Soil pH						0.435*	0.212	-0.469*	-0.567**	-0.633**	-0.046	-0.138	-0.276	-0.151
EC							0.213	-0.522**	-0.241	-0.589**	-0.446*	-0.323	-0.156	-0.274
CaCo3								-0.273	0.036	-0.109	-0.320	-0.318	-0.288	-0.140
N									0.533**	0.622**	0.365	0.437*	0.088	0.253
P										0.457*	-0.110	0.184	0.221	0.165
K											0.205	0.265	0.101	0.365
Mn												0.171	0.187	-0.092
Cu													0.226	0.400*
Fe														0.507**
Zn														1

* = Significant at 5% level; ** = significant at 1% level; n= 18.

Table 6. Relationship among foliar macro and micro-nutrients with soil properties of the tested samples of aridisol order.

Parameter	N	P	K	Mn	Cu	Fe	Zn
Sand	-0.372*	0.776**	0.134	-0.079	-0.071	0.315	0.355
Silt	-0.381*	-0.412*	0.236	-0.235	-0.089	0.113	0.041
Clay	0.228	0.223	0.109	-0.145	-0.143	0.071	-0.005
Yield	0.855**	-0.581**	-0.079	-0.134	0.649**	0.627**	0.588**
Soil pH	-0.532**	-0.392*	0.202	-0.477*	-0.272	-0.265	-0.456*
EC	-0.573**	-0.583**	0.416*	-0.061	-0.334	-0.275	-0.451*
CaCo3	-0.471*	-0.394*	0.096	-0.038	-0.387*	-0.360	-0.214
N		0.605**	-0.057	-0.096	0.328	0.356	0.688**
P			0.004	0.196	0.574**	0.398*	0.453*
K				0.168	0.224	0.304	-0.055
Mn					-0.087	-0.011	0.042
Cu						0.432	0.481*
Fe							0.491**
Zn							1

*= Significant at 5% level; ** = Significant at 1% level; n= 18.

The data presented in Table 6 showed that foliar N and P significantly and negatively correlated with pH EC and $CaCO_3$. However, non-significant and negative relationships were found with foliar Mn, Cu and Fe. Foliar Zn showed a significant and negative relationship with soil pH (r = -0.456*) and EC (-0.451*) as shown in Table 6. Foliar N positively and significantly related with foliar P (r = 0.605**) and foliar Zn (r = 0.688**). Similarly, foliar P with foliar Cu (r = 0.574**), foliar Fe (r = 0.398*) and foliar Zn (r = 0.453*) (Table 6).

Conclusion

The results obtained herein suggest that the soil texture of high, medium and low yielding Kinnow orchards were loamy sand in texture. The soil pH of soil suspension (1:2) of all the representative soils was mostly alkaline and slightly neutral in reaction. This study showed that there is nutrient deficiency and imbalance nutrition in Kinnow mandarin orchards. Nutrient concentration in mandarin leaves was greatly affected by soil characteristics. However, Kinnow mandarin trees have the ability to accumulate nutrients in higher concentrations in their leaves relative to their soils. Therefore, the orchard's nutrient requirement should be considered when preparing a fertilizer recommendation. The fruit yield was significantly improved with available macronutrients and Mn, but showed a strong antagonism with soil properties. Hence, soil and foliar nutrient contents should also be consider when improving fruit yield.

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