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Comparative evaluation of soil physico-chemical and leaf nutritional status, and its effect on fruit quality characteristics in healthy versus declining Khasi mandarin (*Citrus reticulata* Blanco) in acid soils

Christy B. K. Sangma*[1] • A. Thirugnanavel[2] • D. J. Rajkhowa[1] • V. K. Mishra[3]

[1]ICAR-RC-NEHR, Nagaland Centre, Jharnapani, Medziphema, Nagaland 797 106
[2]ICAR- Central Citrus Research Institute, Amravati Road, Nagpur – 440 033, Maharashtra
[3]ICAR-RC-NEHR, Umiam, Umroi Road, Meghalaya- 793 103

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ABSTRACT

Considering the aggravated intensity of citrus decline and its drastic reduction in fruiting, a comprehensive study was undertaken to know the status of the soil health, management practices and age of the orchard affecting the fruit quality of Khasi mandarin grown in acid soils. Khasi mandarin (*Citrus reticulata* Blanco) orchards selected for the study were categorized into four types, *viz.* (1) Orchard type 1-young non-bearing orchards (2) Orchard type 2-bearing healthy orchards (3) Orchard type 3- bearing old orchards and (4) Orchard type 4- declining orchards in varying altitudes of <150 m to >1400 m amsl. The soil, plant and fruit samples were collected from these orchards, and were analysed for various physical, chemical, and quality parameters. The results of the soil analysis and survey revealed that most of the declining orchards (Orchard type 4) were located in the very low altitude and having a sandy clay loam soil textures. Other healthy orchards (Orchard type 1, 2 and 3) were all located above 1200 m amsl and soils were clay and clay loam types. Soil pH were significantly ($P \leq 0.05$) higher in healthy orchards than the declining orchards. Khasi mandarin fruit quality in Orchard type 2 was significantly ($P \leq 0.05$) better in terms of fruit weight (135.7 g), pulp weight (92.04 g), number of segments (11), juice content (59.5 ml) and number of fruits per tree (125 nos.). The size of the fruit and pulp content reduces significantly ($P \leq 0.05$) in the old age orchards. From the study it was clear that the soil health, management practices and altitude of the orchard has direct bearing on the fruit quality, and further, when the orchard aged the size and quality of fruit reduces.

1. Introduction

Mandarin (*Citrus reticulata* Blanco) is one of the premier citrus species, with global popularity under the family Rutaceae. Mandarin in India has four commercial cultivars *viz.* Nagpur mandarin- Central India, Kinnow mandarin- North West India, Coorg mandarin- South India, and Khasi mandarin- North-East India, which occupies nearly 41.5% of the total area (0.404 million hectares out of 0.923 million hectares with a production of 5 million tonnes) under citrus cultivation in India (www.agricoop.nic.in 2018-19). The crop in the present years has been receiving worldwide attention due to rapid decline which affects almost all citrus cultivar relatives *viz.* sweet orange (*Citrus sinensis*), tangelo (cross of *Citrus paradisi*×*Citrus reticulate*), lime (*Citrus aurantiifolia)*, pummelo (*Citrus maxima)*, trifoliate orange (*Poncirus trifoliate)* of which mandarin is the most susceptible (Knapp *et al.*, 2004). The decline has led to the death of millions of citrus trees all over the world fearing extinction and has rendered other millions useless for production. The causal factors for the decline are complex and might vary from one region to the other. Out of many causal factors, the region specific stress factors like soil physical and fertility

*Corresponding author: christysangma@gmail.com

constraints, nutritional disorder or multi-nutrient deficiencies was considered to be one of the contributory factors (Srivastava and Singh 2002; Wanshnong *et al.*, 2013) and another factor is the sensitivity of citrus crop to various diseases caused by a diverse range of pathogens like fungi, bacteria, viruses, and virus-like pathogens (Eskalen *et al.*, 2010).

Considering these aggravated intensity of decline, a survey was conducted and selected Khasi mandarin orchards located in hilly terrain with medium (<500 m mean sea level) to high altitudes (>1200 m above mean sea level) regions for the study. These regions received highly variable rainfall with extreme soil runoff conditions. In those selected orchards a comprehensive study on soil type, and nutritional status (macro- and micro- nutrients), in bearing and non-bearing healthy and declining Khasi mandarin was carried out to find out their effect on the fruiting behaviour.

2. Materials and Methods

Soil, leaf and fruit samples were collected from the major Khasi mandarin growing orchards located between 25°42.926' N to 25°47.475' N latitude and 93°48.213' E to 94°09.093' E longitude with altitude ranging from 141m to 1442m amsl in acidic soils of Northeast India (Table 1). Khasi mandarin orchards were categorized into four types, *viz.* (1) Orchard type 1- Young non-bearing orchards (0-7 years old), (2) Orchard type 2- Bearing healthy orchards (8-30 years old), (3) Orchard type 3- Bearing old orchards (30-45 years old) and (4) Orchard type 4- Declining orchards (any age-nutrient deficient, infested unhealthy plants). The plant growth conditions of Khasi mandarin in orchards were organically managed with minimum addition of nutrients through FYM. Soil samples collected were a random composite of 5 spots pooled from each orchard, collected within the radius of 60 cm of tree trunk of Khasi mandarin plant at two soil depths i.e. 0-15 cm and 15-30 cm, and air dried and sieved for physico-chemical analysis.

Six (6) types of leaf samples from Khasi mandarin plants at different stages of leaf discolouration were collected from the surveyed orchards. These leaf types are: Leaf type 1(LT 1): Healthy green leaves; Leaf type 2 (LT 2): Chlorotic initial stage; Leaf type 3 (LT 3): Chlorotic spotted leaves; Leaf type 4 (LT 4): Chlorotic mottled leaves; Leaf type 5 (LT 5): Interveinal chlorotic leaves and Leaf type 6 (LT 6): Full chlorotic leaves. The leaves were sampled following the zigzag pattern covering 15 trees or plants per orchard and each stage of leaves content 60-80 numbers. Three (3) replication orchards were taken for each stage of discoloured leaf samples. The selected leaves were 2^{nd} or 3^{rd} spring flush of non-fruiting shoots of 6-7 months old. The healthy leaves were collected from the healthy orchards and the discoloured or chlorotic leaves were collected separately from the declining orchards following the same pattern of sampling. The leaf samples were then air-dried and then oven-dried and grinded in the powder form for the chemical analysis.

2.1 Soil chemical parameters

Gravimetric soil moisture content (MC) was determined by oven drying at 105°C to constant weight. Water holding capacity (WHC) in soil was determined by filter paper method, in which the maximum amount of water retained (the known amount of water –e.g. 100ml) by soil lined with filter paper (Whatman no. 1 and Whatman no. 44) in a funnel, per unit of its dry weight after ceasing of gravitational flow was measured. The soil is then oven dried at 105°C till the constant weight is recorded (Pramer and Schmidt 1964).

The relative proportion of sand, silt, and clay (soil texture) in a soil sample was analysed by the hydrometer method (Buoyoucous 1927). Soil pH was analyzed using 1:2.5 soil/water suspensions (Jackson 1973). Soil organic carbon (SOC) was determined by the wet oxidation method as described by Walkley and Black, (1947). Available nitrogen (Avail. N) was determined by the alkaline permanganate oxidation method described by Subbiah and Asija (1956). Available phosphorus (Avail. P) was determined by the stannous chloride blue colour method (Bray and Kurtz 1945). The intensity of blue colour using Dickman Bray's reagent was measured at 660 nm. Available potassium (Avail. K) was determined by neutral normal ammonium acetate method (Hanway and Heidel 1952).

The DTPA (Diethylene triamine penta-acetic acid- 0.005M DTPA, 0.01M calcium chloride ($CaCl_2$) and 0.1M TEA (triethanolamine) adjusted at pH 7.3) extractable soil micronutrients *viz.* zinc (Zn), Iron (Fe), Manganese (Mn) and Copper (Cu) content were determined by atomic absorption spectrophotometer (AAS) method (Baker and Amacher 1982).

2.2 Leaf nutrient analysis

For leaf samples, total -nitrogen, -phosphorus, and -potassium (Total –N, -P, and –K) were determined in dried samples. Total -N was determined by digesting leaf sample in tri-acid in presence of digestion mixture followed by Kjeldahl distillation method (Bremmer and Mulvaney 1982). Total -P and total –K was determined by digesting the leaf sample with a di-acid mixture. Total –P was estimated in ammonium para-molybdate vanadate reagent (Walker and Adams 1958) and total –K in the flame photometer. The plant micronutrients *viz.* zinc (Zn), iron (Fe), copper (Cu), and manganese (Mn) content were analysed in atomic absorption spectrophotometer (AAS) after di-acid digestion.

2.3 Fruit quality characteristics

For Khasi mandarin fruit quality characterization, fruits were randomly collected from the different orchard types *viz.* bearing healthy orchards, bearing old orchards, and declining orchards. The physical characteristics of fruit *viz.* fruit diameter, fruit and peel weight, number of segments per fruit, *etc.* were recorded. Then the selected fruits were quantified chemically for total soluble solids (TSS) and titratable acidity (TA) as given by AOAC (2012). The TSS determination from the juice was performed by direct reading in an Abbe refractometer (ºBrix) and TA was measured as % citric acid, by carrying out titration with 0.1 N sodium hydroxide solution and phenolphthalein indicator.

2.4 Data analysis

Data generated from the laboratory analysis were subjected to the statistical analyses of variance appropriate to the experimental design. Data were assessed by Duncan's multiple range tests (Duncan 1955) with a probability $P \leq 0.05$. The least significant difference (LSD) between means was calculated using the SPSS program (SPSS version 21.0).

3. Result

3.1 Soil nutritional status and moisture related studies in different type of orchards

The healthy orchards mostly were located in the high altitude regions with clay and clay loam type soil textures, with moisture content (MC) ranging from 20.52% to 21.92% which is significantly higher ($P \leq 0.05$) than the declining orchards (13.49%), with sandy clay loam type of soil textures (Table 1). The water holding capacity (WHC) of the different orchard types under study varied from 43.80% to 60.81%. Higher WHC was observed in the clay and clay loam soil textures than in the sandy clay loam texture. The declining orchards under the study were mostly found in the low altitude areas and have light texture soils.

Soil chemical parameters at 0-15 cm soil depth *viz.* soil pH (5.40 to 5.82), SOC (1.17% to 1.72%), Avail. N (340.8 kg ha^{-1} to 422.0 kg ha^{-1}), Avail. P (6.30 kg ha^{-1} to 38.21 kg ha^{-1}) and Avail. K (161.3 kg ha^{-1} to 518.1 kg ha^{-1}) content in those healthy orchard soils was significantly ($P \leq 0.05$) higher than the other orchards (Table 2). The soil pH in the declining orchards was very low (4.69), Avail. N, Avail. P and Avail. K in declining orchards was also found to be low to moderate range *i.e.* 224.6 kg ha^{-1}, 7.03 kg ha^{-1} and 154.3 kg ha^{-1} respectively. The DPTA extractable micronutrient contents in soil *viz.* iron (Fe), zinc (Zn), manganese (Mn) and copper (Cu) are presented in Fig. 1. For Fe, Zn, Mn, and Cu (in mg kg^{-1}), the median values were 24.30 (range from 24.30- 49.83), 1.79 (range from 0.67-4.31), 3.86 (range from 0.83-5.43) and 1.09 (0.21-1.94), respectively. All four micronutrients were found to be significantly ($P \leq 0 .05$) higher in Orchard type 3: bearing old orchards, except for Fe, which was found higher in non-bearing orchards (Orchard type -1).

3.2 Leaf nutrient analysis

The leaf analysis (Table 3) for total –N and –P showed that the six types of leaf samples (LT1, LT2, LT3, LT4, LT5, and LT6) were found be deficient ($P \leq 0.05$) in element N (LT1 to LT6 with the value 0.39% to 0.18% respectively) and P content (LT1 to LT6 with the value 0.018% to 0.007% respectively). This showed that even though in healthy orchards the soil Avail. N and Avail. P were adequate but the uptake from the soil was low. Only total –K content in six types of leaves were in the range of moderate to a high level with significant ($P \leq 0.05$) higher content in LT1 with 2.18% and lowest in LT6 (0.88%). The micronutrient Zn content in leaf analysis (Table 3) showed that only in LT1 type of leaves (green leaves), the element is adequate (30.63 mg kg^{-1}), other leaf types from LT2 to LT6 were deficient which was similar to the reports of Shah et al. (2012). In LT4 (mottling), LT5 (interveinal chlorosis), and LT6 (full yellow) with Zn content 3.18 mg kg^{-1}, 2.98 mg kg^{-1}, and 2.16 mg kg^{-1} respectively, was found to be very low. The element Fe content (LT6 to LT1 with values 129.23 mg kg^{-1} to 307.69 mg kg^{-1}), Mn content (LT6 to LT1 with values 33.21 mg kg^{-1} to 192.86 mg kg^{-1}), and Cu content (LT6 to LT1 with values 27.45 mg kg^{-1} to 53.95 mg kg^{-1}) range were found to be moderate to a high level.

3.3 Fruit quality analysis of Khasi mandarin from different orchard types

The significant ($P \leq 0.05$) difference was seen in the physical characteristics of the Khasi mandarin fruit under different orchard types (Table 4). The physical fruit quality analysis showed that Khasi mandarin in Orchard type 2 was significantly ($P \leq 0.05$) better in terms of fruit weight (135.7 g), pulp weight (92.04 g), number of segments (11.25), number of fruits per tree (125 nos.) and juice content (59.5 ml). There was no significant difference in the chemical characteristics *i.e.* TSS (8.58-8.75 °Brix) among the difference orchards except for the TA which was found highest (0.956%) in the Orchard type 4 which is the declining orchards. This analysis showed that the size of the fruit and pulp content reduces significantly ($P \leq 0.05$) in the old age orchards (Orchard type 3). The fruit bearing ability reduces (6.3 nos.) significantly ($P \leq 0.05$) in declining orchards (Orchard type 4).

4. Discussion

4.1 Soil nutritional and moisture status and its effect on the leaf and fruit quality of Khasi mandarin in a different type of orchards

Nutritional disorders are considered as one of the important contributory factors to the citrus decline. Besides these factors, the soil and plant nutrients status and physico-chemical properties of soil play an important role in maintaining the health and vigour of the trees. Deep soils with a pH range of 5.5 to 7.5 are considered ideal for different citrus crop species. However, they can also be grown in a pH range of 4.0 to 9.0. In acidic soils high phosphorus (P) -fixation (as iron and aluminum phosphates) is the main problem making it unavailable for plant growth. P content in plants plays various important roles in metabolic processes, including photosynthesis, energy transfer, signal transduction, macromolecular biosynthesis, and respiration (Khan *et al.*, 2010) and it accounts for 0.2-0.8% of the plant dry weight. So, an adequate supply of P during the plant development phase is important for laying down the primordia of plant parts. Nitrogen content on the other hand plays an important role in the regulation of nutrient supply to the growing parts of the citrus tree, and an adequate amount of soil P and K were critical for citrus production (Mattos *et al.*, 2006). In the present study also, the soil pH was very low along with very low content of avail. -P and -N in the declining orchards with moisture stress conditions, which became the main contributory factor for the short lifespan of citrus trees in these locations (Shirgure *et al.*, 2014).

In citrus the nutrient requirement is in the order of potassium>nitrogen>phosphorus for macronutrients, whereas for the micronutrients it is Zn>Fe>B>Cu>Mn (Yaseen and Ahmad 2010). Various studies have shown that the nutrient content (nitrogen, phosphorus, and potassium) whether it is excessive or insufficient in the soil have a negative bearing on the yield and the fruit quality characteristics (both physical and chemical) of the citrus (Han *et al.*, 2008). The potassium (K) content in the soil greatly affects the citrus fruit enlargement, peel thickness, fruit weight, and overall yield of the citrus crop (Quaggio *et al.*, 2002), whereas, the flowering and fruit set, juice percentage, and TSS were favoured by optimum nitrogen (N) content in soil and TA to some extent are reduced by the optimum phosphorus (P) content which increases the soluble solids in citrus fruit (Alva *et al.*, 2006). The above researchers have shown that the optimum nutrition in the soil is the way to manage the yield and fruit quality in a citrus crop, and the addition of nutrients during the flowering and fruit set were found to increase the fruit retention in Khasi mandarin (El-Kobbia et al. 2011). The citrus crop has a long juvenile period of 2-5 years; therefore, the response to the nutrient management practices in terms of flowering and fruiting depends on the age of the citrus tree, cultivar, and environmental conditions (Monselise 1986). Research on soil nutrient related studies on citrus has been carried out extensively in various countries. Several reports highlighted the deficiency of both macro (N, P, K) and micro (Zn, Cu, Fe, Mn, B) nutrients in the citrus orchards (Zia *et al.*, 2006). In the present study also the deficiency of the nutrients (both macro and micro nutrients) was observed in the various citrus orchard types.

The leaf type characteristics analysis showed that the element Fe content, Mn content, and Cu content range were found to be moderate to a high level which is according to the study of Mattos *et al.* (2012). This showed that the results of Kidd and Proctor (2001) were similar to the current research that the low pH in acid soils (with an excess of H^+) can cause toxicity of some of the micronutrients like Fe, and the decline trees were associated with a high iron concentration of >40 mg kg^{-1} (ppm).

Another important criterion for the good production of the citrus crop is the water management practices. Optimum moisture with irrigation facilities is required during the critical stages of leaf expansion, bloom, fruit set, and fruit enlargement, and the water management alone can increase the fruit size and weight, juice content, and soluble solids in citrus. Water deficits can reduce the fruit sets and induced fruit abscission (Ginestar and Castel 1996). Soil moisture content and water holding capacity of the soil are largely dependent on the type of soil texture and organic matter content in the soil (Brady and Weil 2002). In the present study also the lack of management practices in terms of nutrients and water has led to the slow declined which is corroborated with the research of Chadha (2006). The marketability of the Khasi mandarin fruit depends on important quality parameters like the size of the fruit, weight, and juice content. Fruits are usually bright orange, loose skinned with medium to the thick rind, and easily separable rind and segment (Ngachan *et al.*, 2010). The quality (Table 4) and biochemical (TSS and TA) parameters of healthy as well as the declined Khasi mandarin fruit obtained in the present study corroborated with many researchers *viz.* Medhi *et al.* (2007) and Ullah *et al.* (2012).

5. Conclusion

The altitude of the place, soil pH, the type of soil, and the nutritional status, has a great role to play in growth and development as well as the longevity or economic lifespan of the Khasi mandarin in acid soils. Soil pH and type of soil determines the solubilization, uptake, and nutrient supplying capacity to the plant. This study also showed that the essential nutrient requirement of Khasi mandarin is in the order of potassium>nitrogen>phosphorus and Zn>Fe>Cu>Mn for macro and micro-nutrients respectively. The potassium (K) content in the soil greatly affects the fruit enlargement, peel thickness, fruit weight, and overall yield of the Khasi mandarin crop. Though the micronutrients were required in a small quantity, their deficiency affects the plant's growth and development to a great extent.

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7. Declaration of Interest

The authors declared that there is no conflict of interest relevant to this research article.

8. References

Alva AK, Paramasivam S, Obreza TA and Schumann AW (2006) Nitrogen best management practice for citrus trees: I. Fruit yield, quality, and leaf nutritional status. Scientia Horticulturae 109: 223-233.

AOAC (2012) Arlington Virginia. USA.

Baker DE and Amacher MC (1982) Nickel, Copper, Zinc and Cadmium. In: Page AL, Millers RH and Keeney DR (eds) Methods of Soil Analysis Part 2: Chemical and Microbiological Properties, 2nd ed. Agronomy Monograph No. 9, American Society of Agronomy, Madison, pp 323-334.

Bouyoucos GJ (1962) Hydrometer method improved for particle size analysis of soil. Agronomy Journal 54: 464-465.

Brady NC and Weil RR (2002) Soil organic matter. In: Brady NC and Weil RR (eds) The Nature and Properties of Soils, 13th ed. Prentice Hall, New Jersey, pp 498-541.

Bray RH and Kurtz LT (1945) Determination of total, organic and available form of phosphorus in soil. Soil Science 59: 39-45.

Bremmer JM and Mulvaney CS (1982) Nitrogen-Total. In: Page AL, Miller R and Keeny D (eds) Methods of soil analysis. Part-2, Chemical and Microbiological properties, 2nd ed., Agronomy Monographs, 9: 961-1010, ASA, SSSA, CSSA, Madison, WI, pp 595-613.

Chadha KL (2006) Mandarin. In: Handbook of horticulture. Published by Directorate of information and publications of Agriculture, ICAR, New Delhi, pp 291-298.

Duncan DM (1955) Multiple range and multiple F-test. Biometric 11: 1-42.

El-Kobbia AM, Kassem HA, Marzouk HA and Abo-Elmagd M (2011) Enhancing cropping of Navel orange by different agrochemicals foliar sprays. Emirates Journal of Food and Agriculture 23(1): 95-102.

Eskalen A, Vidalakis G and O'Connell N (2010) Citrus quick decline: A disease complex citrus research & technology, Cordeirópolis, v. 31, Suplemento, XVIII Conference of the IOCV, pp 1-129.

Ginestar C and Castel J (1996) Responses of young Clementine citrus trees to water stress during different phenological periods. The Journal of Horticultural Science and Biotechnology 71: 551-559. 10.1080/14620316.1996.11515435.

Han S, Chen L, Jiang H, Smith B, Yang L and Xie C (2008) Boron deficiency decreases growth and photosynthesis, and increases starch and hexoses in leaves of citrus seedlings. Journal of Plant Physiology 165: 1331-1341. doi:10.1016/j.jplph.2007.11.002.

Hanway JJ and Heidel H (1952) Soil analysis methods as used in Iowastate College, Soil Testing Laboratory. Iowa State College of Agriculture Bulletin 57: 1-31.

Jackson ML (1973) Soil Chemical Analysis. Prentice Hall of India (Pvt.) Ltd., New Delhi.

Khan I, Shah ZA, Saeed M and Shah HU (2010) Physico-chemical analysis of Citrus sinensis, Citrus reticulata and Citrus paradisi. Journal of the Chemical Society of Pakistan 32: 774-780.

Kidd PS and Proctor J (2001) Why plants grow poorly on very acid soils: are ecologists missing the obvious? *Journal* of *Experimental* Botany 52: 791–799.

Knapp JL, Halbert S, Lee R, Hoy M, Clark R and Kesinger M (2004) The Asian citrus psyllid and citrus greening disease. Agricultural IPM: Fruit (citrus) Florida. IFAS, University of Florida. http:/www. ipm. ifas.ufl.edu.

Mattos DJr, Quaggio J, Cantarella H, Alva A and Graetz D (2006) Response of young citrus trees on selected rootstocks to nitrogen, phosphorus, and potassium fertilization. Journal of Plant Nutrition 29: 1371–1385.

Mattos DJr, Quaggio JA, Cantarella H, Boaretto RM and Zambrosi FCB (2012) Nutrient management for high citrus fruit yield in tropical soils. Better Crops with Plant Food 96: 4-7.

Medhi BK, Saikia AJ, Bora SC, Hazarika TK and Barbora AC (2007) Integrated Use of concentrated organic manures, biofertilizers and inorganic NPK on yield, quality and nutrient content of Khasi mandarin (*Citrus reticulata* Blanco.). Indian Journal Agricultural Research 41(4): 235-241.

Monselise SP (1986) Growth retardation of shoot and peel growth in citrus by paclobutrazol. Acta Horticulturae 179: 529-536.

Ngachan SV, Roy SS, Sharma PK, Patel RK and Prakash N (2010) Citrus scenario in North Eastern India: issues and strategies. In: Shivankar VJ and Singh IP (eds) Citrus biodiversity: National seminar on citrus biodiversity for livelihood and nutritional security, Nagpur, India, October 4-5, pp 28-37.

Pramer DE and Schmidt EL (1964) Experimental soil microbiology burges publishing company Minneapolis, 15 Minnesota, USA. Sons Ltd. Beecles and London, pp 31-32.

Quaggio JA, Mattos JrD, Cantarella H, Almeida ELE and Cardoso SAB (2002) Lemon yield and fruit quality affected by NPK fertilization. Scientia Horticulturae 96: 151-162.

Shirgure PS, Srivastava AK and Huchche AD (2014) Water requirements in growth stages and effects of deficit irrigation on fruit productivity of drip irrigated Nagpur mandarin (*Citrus reticulata* Blanco). The Indian Journal of Agricultural Sciences 84(3): 317–22.

Srivastava AK and Singh S (2002) Soil analysis based diagnostic norms for Indian citrus cultivar. Communications in Soil Science and Plant Analysis 33(11&12): 1689-1706.

Subbiah BV and Asija CL (1956) A rapid procedure for estimation of available nitrogen in soils. Current Science 25: 259-260.

Ullah S, Khan AS, Malik AU, Afzal I, Shahid M and Razzaq K (2012) Foliar Application of boron influences the leaf mineral status, vegetative and reproductive growth, yield and fruit quality of Kinnow mandarin. Journal of Plant Nutrition 35(13): 2067-2079.

Walker TW and Adams AFR (1958) Studies on soil organic matter. Soil Science 85: 307-318.

Walkley A and Black IA (1947) An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science 37: 29-38.

Wanshnong RK, Thakuria D, Sangma CB, Ram V and Bora PK (2013) Influence of hill slope on biological pools of carbon, nitrogen, and phosphorus in acidic Alfisols of citrus orchard. Catena 111: 1–8.

www.agricoop.nic.in (2018-19 report)

Yaseen M and Ahmad M (2010) Nutrition management in citrus: effect of multinutrients foliar feeding on the yield of Kinnow at different locations. Pakistan Journal of Botany 42(3): 1863-1870.

Zia MH, Ahmad R, Khaliq I, Ahmad A and Irshad M (2006) Micronutrients status and management in orchards soils: applied aspects. Soil and Environment 25: 6-16.

Table 1. Orchard location and characterization along with soil texture, moisture content and water holding capacity in each Khasi mandarin orchard type

Sl. No.	Orchard type	Age	Latitude (N)	Longitude (E)	Altitude (m amsl)	Soil texture	Moisture content (%)	WHC (%)
1.	**Orchards type 1**: Young non-bearing orchards	0-7 years old	25˚47.461' to 25˚47.475'	94˚07.351' to 94˚07.366'	1000, 1300, 1313, 1315,	Clay loam	21.92[a]	51.79
2.	**Orchard type 2**: Bearing healthy orchards	8-30 years old	25˚42.926' to 25˚42.945'	94˚08.573' to 94˚09.093'	1204, 1433, 1436, 1442,	Clay and Clay loam	20.52[a]	60.81
3.	**Orchard type 3**: Bearing old orchards	30-45 years old	25˚43.230' to 25˚43.234'	94˚08.550' to 94˚08.552'	1245, 1240, 1311, 1313	Clay	20.80[a]	58.50
4.	**Orchard type 4**: Declining orchards	Any age-Infested un-healthy plants	25˚45.198' to 25˚45.248'	93˚48.213' to 93˚50.720'	284, 274, 255, 141	Sandy clay loam	13.49[b]	43.80
						CD ($P\leq0.05$)	3.13	NS

(m amsl: metre above mean sea level, WHC: water holding capacity)

In a column, figures with same letters do not differ significantly at $P\leq0.05$

Table 2. Basic soil parameters and soil microbial biomass -C, -N and -P for different Khasi mandarin orchard types

Sl. No.	Orchard type	Soil depth	pH	SOC (%)	Avail. N (kg ha^{-1})	Avail. P (kg ha^{-1})	Avail. K (kg ha^{-1})
1.	**Orchards type 1**: Young non-bearing orchards	0-15	5.41^{ab}	1.17	380.5^{a}	6.30^{c}	161.3^{b}
		15-30	5.01^{bc}	1.02	287.4^{abc}	5.57^{c}	129.5^{b}
2.	**Orchard type 2**: Bearing healthy orchards	0-15	5.40^{ab}	1.58	422.0^{a}	33.22^{ab}	518.1^{a}
		15-30	5.02^{bc}	1.15	345.0^{ab}	9.35^{c}	306.7^{b}
3.	**Orchard type 3**: Bearing old orchards	0-15	5.82^{a}	1.72	340.8^{abc}	38.21^{a}	184.8^{b}
		15-30	5.41^{ab}	1.54	316.7^{bc}	19.48^{bc}	261.0^{b}
4.	**Orchard type 4**: Declining orchards	0-15	4.69^{c}	1.32	224.6^{bc}	7.03^{c}	154.3^{b}
		15-30	4.15^{d}	0.85	209.1^{c}	6.06^{c}	140.3^{b}
	CD ($P \leq 0.05$)		0.25	NS	48.5	6.29	73.4

[SOC: Soil organic carbon, Avail. N: Available nitrogen, Avail. P: Available phosphorus, Avail. K: Available potassium]
In a column, figures with same letters do not differ significantly at $P \leq 0.05$

Table 3. Different leaf types and their macro and micro- nutrient content

Sl. No.	Orchard type	Total N (%)	Total P (%)	Total K (%)	Zn (mg kg^{-1})	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Cu (mg kg^{-1})
1.	Leaf type 1(LT 1): Healthy green leaves; Leaf type.	0.39^{a}	0.018^{a}	2.18^{a}	30.63^{a}	307.7^{a}	192.9^{a}	53.95^{a}
2.	2 (LT 2): Chlorotic initial stage	0.37^{b}	0.016^{b}	1.78^{b}	21.32^{b}	205.4^{b}	175.7^{b}	45.70^{b}
3.	Leaf type 3 (LT 3): Chlorotic spotted leaves;	0.25^{c}	0.009^{c}	1.41^{c}	12.08^{c}	196.9^{c}	157.1^{c}	33.52^{c}
4.	Leaf type 4 (LT 4): Chlorotic mottled leaves;	0.24^{c}	0.009^{c}	1.14^{d}	3.18^{d}	193.1^{c}	50.0^{d}	31.66^{c}
5.	Leaf type 5 (LT 5): Interveinal chlorotic leaves	0.21^{d}	0.008^{c}	1.05^{e}	2.98^{d}	140.8^{d}	41.4^{d}	28.86^{c}
6.	Leaf type 6 (LT 6): Full chlorotic leaves	0.18^{e}	0.007^{c}	0.88^{f}	2.16^{d}	129.2^{d}	33.2^{d}	27.45^{c}
	CD	0.02	0.002	0.08	2.52	7.04	30.92	7.31

[(Total N= total nitrogen, Total P= total phosphorus, Total K= total potassium, Zn= Zinc, Fe= Iron, Mn= Manganese and Cu= Copper content). The figures with same letters do not differ significantly at $P \leq 0.05$]

Table 4. Fruit characteristics of Khasi mandarin in different orchard types

Sl. No.	Orchard type	Fruit weight (g)	Peel weight (g)	Pulp weight (g)	Fruit Diameter (cm)	Peel thickness (mm)	No. of segments	No. of seeds	TSS (°Brix)	Juice content (ml)	TA (%)	No. of fruits per tree
1.	**Orchards type 1**: Young non-bearing orchards	-	-	-	-	-	-	-	-	-	-	-
2.	**Orchard type 2**:	135.7^{a}	39.62^{a}	92.04^{a}	7.125^{a}	2.875^{a}	11.25	12.00	8.75	59.5^{a}	0.652^{b}	125.5^{a}

	Bearing healthy orchards											
3.	**Orchard type 3**: Bearing old orchards	72.8^{c}	21.03^{b}	49.45^{b}	4.725^{c}	1.775^{b}	10.00	11.00	8.58	50.3^{b}	0.672^{b}	76.3^{b}
4.	**Orchard type 4**: Declining orchards	91.6^{b}	24.79^{b}	57.89^{b}	5.875^{b}	2.325^{ab}	9.75	10.25	8.73	26.3^{c}	0.956^{a}	6.3^{c}
	CD	5.2	3.29	5.91	0.500	0.370	NS	NS	NS	3.5	0.080	16.2

[TSS: Total soluble solids and TA: titratable acidity]

In a column, figures with same letters do not differ significantly at $P \leq 0.05$

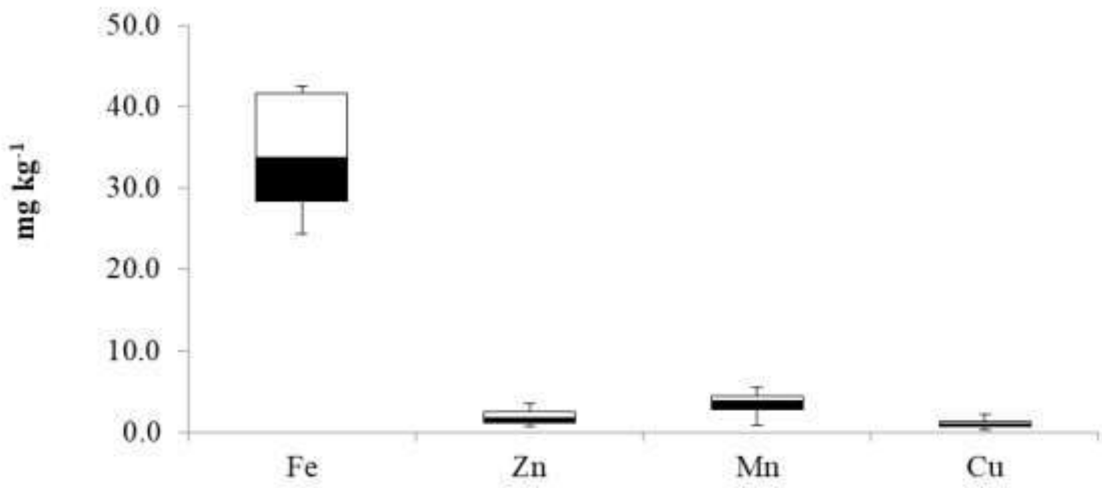

Fig. 1 Box-plot of DTPA extractable iron (Fe), zinc (Zn), manganese (Mn) and copper (Cu). The content is expressed in mg kg^{-1} (ppm). The lines within the boxes are median values. The box indicates the interquarter range, while the whiskers show non-outlier range.