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Micronutrient Status and their Deficiency Diagnosed through DRIS in Tomato Growing Areas

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ABSTRACT

The nutritional imbalances in tomato plants determined on the basis of soil and plant tests with interpretations on the critical nutrient level are less well correlated with the corresponding crop yields. Nutrient imbalance in tomatoes yield was assessed using Diagnosis and Recommendation Integrated System (DRIS) approach was more efficient. The study objectives were to evaluate micronutrient status in tomato growing areas and determine the nutrient(s) limiting tomato yield and establish DRIS norms for micronutrients for tomato crop. Twenty-six tomato fields from Chatter plain (Khyber Pakhtunkhwa), and Sheikupura (Punjab) were collected with soil, accompanying leaf index tissue and tomato yield was recorded. Tomato yield data were recorded and divided into high- (≥3.90 kg per 10 plants) and low- yield (<3.95 kg per 10 plants) populations. DRIS analysis identified a deficiency of iron in the tomato production areas. Norms established through DRIS can be used for potential tomato yield.

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INTRODUCTION

Tomato (*Lycopersicon esculentum* L.) is an economically attractive short duration crop. Plant growth and potential yield depend on a balanced supply of nutrients (Fageria, 2011). In tomato plants, the nutrient responses are generally measured in terms of growth and yield. Different test methods for soil and plant nutrients are available. The nutritional needs of the plants are commonly determined by the chemical analysis of the soil. Tomato plant growth depends on both major and micronutrients (Sainju *et al*., 2003). Plants' enzymatic activity is directly related to micronutrients availability and the deficiency of the nutrients results in poor yield (Patil *et al*., 2008) and also affects post-harvest storage quality (Passam *et al*., 2007). Fertilizer management can be done by leaf analysis (Wadt, 2009). Diagnosis and Recommendation Integrated System (DRIS), which relates the nutrient contents and analyzes them in pairs, on the grounds of Physiological Diagnosis (Beaufils, 1977). In DRIS diagnoses assessment, the ratios of nutrients in the index tissue are considered instead of the absolute value of individual nutrients and developed as a means to organize and interpret plant tissue analysis data. The nutrient ratios in the high yield population provide reference values also called norms to compare the ratios found in the low yielding population of the same variety of crops. The DRIS approach provides a valid analytical tool independent of plant aging, cultivar grown, local conditions, tissue sampling method, or the time of sampling. The field survey approach is adopted in DRIS, and diagnosis is through a comparison of nutrient ratios in the low and the high yielding population (Walworth and Sumner, 1987; Hockman *et al*., 1989). In many countries, DRIS models have been established to diagnose nutrient deficiencies and plant nutrition requirements of many crops. The study objectives were to evaluate micronutrient status in tomato growing areas and determine the nutrient(s) limiting tomato yield and establish DRIS norms for micronutrient for tomato crop.

MATERIALS AND METHODS

Soil and Plant Sampling

A total of 26 tomato fields were sampled from Sheikupura (Punjab) and Chatter Plain (Kyber Pakhtunkhwa). 26 soil samples were collected from different tomato-growing fields of Sheikupura (Punjab) and Chattar plain (Khyber Pakhtunkhwa). The soils were stored in polyethylene bags in the field and kept cool till returning to the lab. Soil samples were air-dried, and plant material was removed from them and ground to sieved through a 2mm sieve. The composite sample of tomato plant, first early mature leaves which is metabolically very active were randomly collected from each tomato field and form composite sample, washed with distilled water, oven dried at 65^oC and ground for nutrient analysis.

Soil and Plant Analysis

Soil pH was determined by Mettler multi pH meter in 1:1 soil/deionized water suspension (Watson and Brown 1998), organic matter by loss, and ignition method (Combs and Nathan, 1998). Soil Cu, Fe, Mn, and Zn were determined by DTPA (di-ethylene tri-amine Penta acidic acid) method and measured by using an ICP-AES (Whitney, 1998; Fassel and Kniseley, 1974). Zinc, copper, iron, and manganese in plants were determined by dry ashing and measured on an ICP-AES (Munter and Grande 1981; Fassel and Kniesly, 1974). Tomato yield data were collected from 26 selected fields.

DRIS Calculation

In order to establish the DRIS norms, the first step is to calculate the nutrient concentration of plant index tissue and respective yields that differentiate between high and low yielding populations. Nutrient pair ratios of both low and high yielding populations were calculated from the data bank. Mean and the coefficient of variation of each ratio of low and high yielding populations were calculated. After the establishment of the DRIS norms, the second step is a calculation of DRIS indices which are calculated by using functions of ratios, using the following equation (Bailey *et al*., 1997):

$$\text{I index} = [f(I/A) + f(I/B) + \cdots - f(I/X) - f(I/X) - \cdots]/Z$$

$$fI/A \begin{cases} \left(\frac{I/A}{i/a} - 1\right) \times \frac{1000}{CV} & when\, \frac{I}{A} > \frac{i}{a} \\ 0 & when\, \frac{I}{A} = \frac{i}{a} \\ \left(1 - \frac{I/A}{i/b}\right) \times \frac{1000}{CV} & when\, \frac{I}{A} < \frac{I}{a} \end{cases} \quad \text{........Equation 1}$$

Z is no. of nutrients under study. I/A is the ratio of concentrations of nutrients I where, f (I/A) are functions of all the nutrient pairs of nutrient I. Function calculations depended upon whether I/A was greater than i/a, was equal to i/a, or was lower than i/a. Where I/A was the nutrient ratio of low yielders and i/a was nutrient ratio of high yielders. The study objectives were to establish DRIS indices for tomato crop to choose the best fertilization formula to obtain maximum tomato crop yield.

RESULTS

Soil-Plant nutrient status and correlation

The soils were mostly neutral to slightly alkaline except for the three sites from Chatter plain which had pH in the acidic range. Overall, soil pH varied from 5.50 to 7.60. Soil organic matter content ranged from 1.5 % to 3.8 % in Chatter plain (Khyber Pakhtunkhwa) and 1.5 % to 2.2 % in Sheikupura district (Punjab). The critical values suggested by Soltanpour, 1985; Soil and Plant Analysis Council, 1992 were used to categorize soil Cu, Fe, Mn, and Zn in Table 1, and sites categorized into low, medium, and high levels of the nutrient are presented in Table 2. The data revealed that all the soils were at an adequate level of Cu, Fe, Mn, and Zn in all 26 soils. The soils had copper > 0.5 mg kg^{-1}, iron > 4.5 mg kg^{-1} and manganese >2.0 mg kg^{-1}.

Table 1. Critical values for the DTPA extractable soil nutrients (Soltanpour, 1985; Soil and Plant Analysis Council, 1992).

Soil Nutrient	Low	Medium	High
	----------------------------mg kg^{-1}-----------------------------		
Zinc	<0.5	0.5-1.0	>1.0
Iron	<4.5	-	>4.5
Copper	<0.2	0.2-0.5	>0.5
Manganese	<1.0	1.0-2.0	>2.0

Zn, Fe, Cu and Mn were extracted by 0.005M DTPA and analyzed by an ICP-AES.

Table 2. The soil frequency is categorized as low, medium, and high level of plant available nutrients.

	Low	Medium	High
	------------------------Frequency(n/26)---------------		
Zinc (DTPA)	1	5	20
Iron (DTPA)	0	0	26
Copper (DTPA)	0	0	26
Manganese (DTPA)	0	0	26

n, the number of samples under the categories out of the total number of soils analyzed.

The critical values for the tomato plant suggested by Campbell (2000) were used to categorize nutrients as deficient, sufficient, and excess in Table 3. Tomato leaves contained copper ranging from 9 to 26 mg kg^{-1} with a mean value of 18 mg kg^{-1}, Iron from 240 to 860 mg kg^{-1} with a mean value of 457 mg kg^{-1}, Manganese from 38 to 251 mg kg^{-1} with a mean value of 98 mg kg^{-1} and Zinc from 19 to 63 mg kg^{-1} with mean values of 35 mg kg^{-1} (Table 4). Iron was in excess (>300 mg kg^{-1}) in the majority of samples and few had iron in the sufficient range within 45-300 mg kg^{-1}.

Table 3. Critical nutrient ranges for the essential nutrients in tomatoes index tissue (Campbell, 2000).

Plant Nutrient	Deficient	Sufficient	Excess
	-------------------------------mg kg^{-1}------------------------------		
Zinc	<18	18-75	>75
Iron	<45	45-300	>300
Copper	<5	5-30	>30
Manganese	<30	30-300	>300

Table 4. The tomato plants categorized as per critical ranges of Campbell (2000).

Plant Nutrient	Deficient	Sufficient	Excess
	------------Frequency(n/26)----------		
Zinc	0	26	20
Iron	0	6	22
Copper	0	26	0
Manganese	0	24	2

n, the number of samples.

Overall, plant manganese was sufficient in the range from 30 to 300 mg kg^{-1}. Zinc was also in the sufficient range from 18-75 mg kg^{-1} in plant tissue of Sheikupura and Chatter plain. The linear, positive and significant relationship was observed in the plant index tissue micronutrients and soil micronutrients as given in Figure 1.

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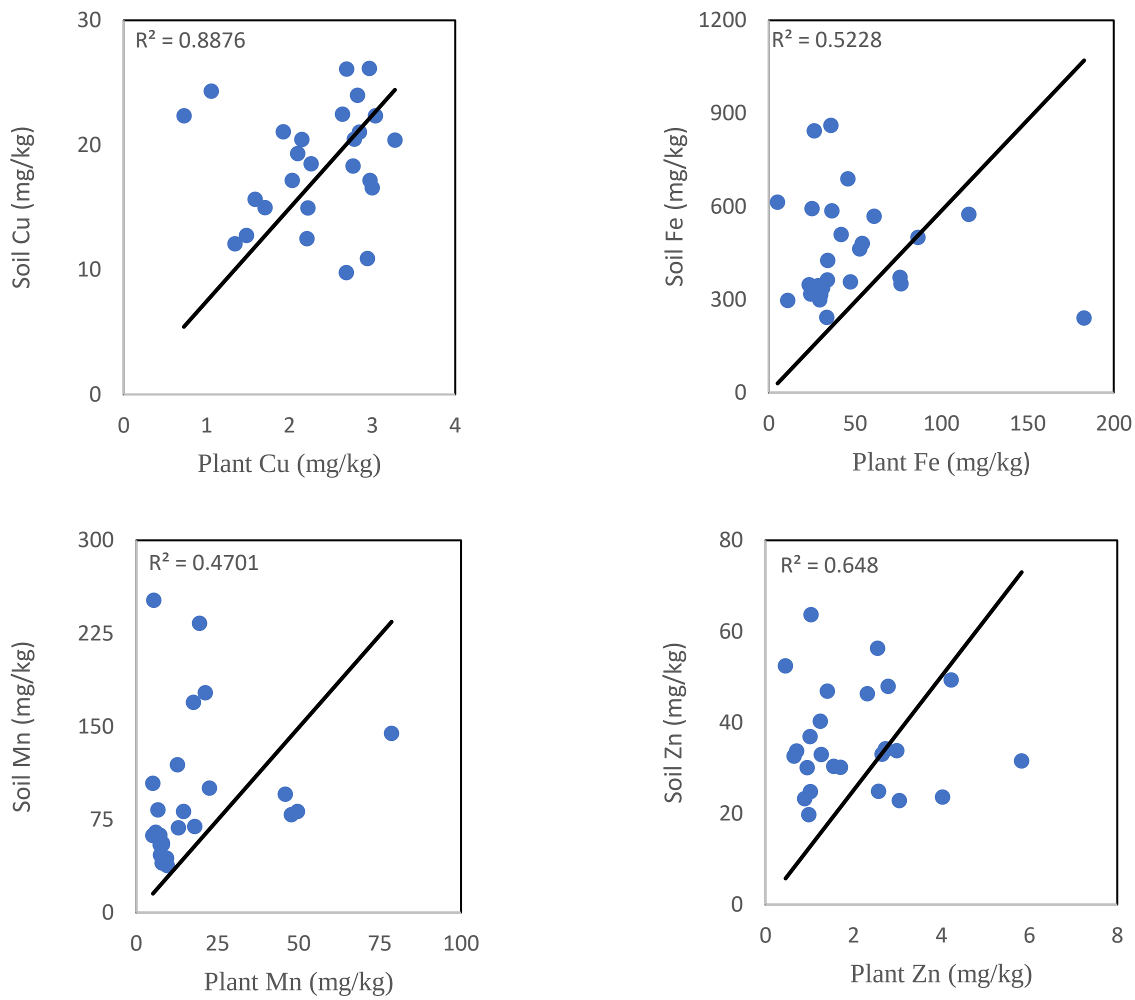

Figure 1. Relationship between the measured soil and plant micronutrients in tomato fields.

DRIS Calculations

Tomato yields were divided into high- (≥3.90 kg per 10 plants) and low- yield (<3.90 kg per 10 plants) populations. The ratios of pairs of nutrients were calculated from nutrient concentrations for both low and high yielding populations. The mean and coefficient of variation were calculated for low and high yielders segregated on the basis of principles given by Walworth and Sumner (1987). Diagnosis of nutrient deficiency through DRIS requires reference nutrient ratios called "norms" which are the nutrient ratios in the high yielding population presented in Table 5. DRIS function estimates the sufficiency or deficiency of a specific nutrient against other nutrients individually. A function value for each nutrient is given in Table 6. The nutrient balance index was calculated using Beaufil's methodology. The individual nutrient indices imbalance gave a more comprehensive association for the four micronutrients on the deficiency to excess scale given in Table 7.

Table 5. Plant nutrient ratios mean, C.V and range in the high and low yielding population.

	Low Yielders				High Yielders			
	Mean		CV%	Range	Mean		CV%	Range
Cu/Fe	0.05	44.49	0.02	0.09	0.05	76.28	0.02	0.11
Cu/Mn	0.24	61.41	0.05	0.56	0.38	55.11	0.12	0.69
Cu/Zn	0.53	39.09	0.33	1.03	0.67	43.59	0.27	1.05

Fe/Cu	25.88	42.89	10.76	54.08	29.73	54.14	9.18	45.62
Fe/Mn	5.80	64.75	1.19	14.37	9.90	66.63	4.16	18.58
Fe/Zn	13.19	48.57	5.27	29.99	17.17	51.46	9.34	28.02
Mn/Cu	5.91	66.14	1.78	18.30	3.68	75.09	1.45	8.46
Mn/Fe	0.25	67.45	0.07	0.84	0.14	57.08	0.05	0.24
Mn/Zn	2.74	51.92	1.18	7.16	1.93	28.16	1.3	2.69
Zn/Cu	2.11	31.54	0.97	3.06	1.85	60.56	0.95	3.77
Zn/Fe	0.09	45.90	0.03	0.19	0.07	47.20	0.04	0.11
Zn/Mn	0.45	46.27	0.14	0.85	0.55	27.04	0.37	0.74

Table 6. The values of DRIS functions for micronutrients.

Function	Value
Cu/Fe	-0.73
Cu/Mn	-9.90
Cu/Zn	-5.87
Fe/Cu	-2.75
Fe/Mn	-10.61
Fe/Zn	-5.87
Mn/Cu	8.09
Mn/Fe	12.81
Mn/Zn	15.04
Zn/Cu	2.32
Zn/Fe	6.18
Zn/Mn	-8.26

Table 7. DRIS indices for the nutrients and diagnosis for the tomato grown in the studied area.

Nutrient	Index	Diagnosis
Copper	-4.02439	Adequate
Iron	-6.2481	Deficient
Mn	10.78304	High/Excess
Zinc	-0.51055	Adequate
Sum of imbalances	21.56609	
Mean Imbalance	5.391521	

DISCUSSION

Most soils from Sheikupura had low organic matter content which may be largely due to the climatic conditions that do not favor organic matter accumulation in soils. Soil zinc matched with the zinc content range of 0.13 to 2.04 mg kg^{-1} reported by Rafiq *et al*., (2006). Copper in tomato index tissue was mostly in the sufficient range (5-30 mg kg^{-1}). Plant copper found in these samples matched with copper in tomato index tissue ranging from 10 to 27 mg kg^{-1} reported by Memon *et al*., (2012). Plant copper was in sufficient range almost equally in both the tomato growing areas. Mousavi *et al*., (2012) stated that a higher concentration of Cu in the soil solution, relative to Zn, can reduce the availability of Zn to a plant (and vice versa) due to competition for the same sites for absorption into the plant root. Memon *et al*., (2012) reported plant zinc ranging from 13-191 mg kg^{-1} in tomato index tissue. Therefore, the micronutrient concentration was mostly within the critical sufficiency range for tomatoes given by Campbell (2000). Memon *et al*., (2012) reported plant manganese ranging from 40 to 86 mg kg^{-1}. Plant iron range matched with the iron in tomato index tissue 320-1180 mg kg^{-1} reported by Memon *et al*., (2012).

Soil and plant relationships found in this study are supported by many researchers. Significant positive correlations were reported between plant and soil zinc (Golia *et al*., 2008) and plant copper with soil copper (Arain *et al*., 2017) when both zinc and copper were in excess. Positive relations were observed for Fe and Mn in tomato by Memon *et al*., (2012), Zn in tomato, by Rafique *et al*., (2006).

Copper to iron ratios means were almost similar in the high yielding population than the low yielding population. Abd El Rheem *et al*., (2015) reported wider copper ratios with macronutrients than present data indicating more acquisition of macronutrients. Cu/Zn and Cu/Mn means were wider in the high yielding population. Copper ratios' mean i.e Cu/Fe and Cu/Mn reported by Abd El Raheem *et al*., (2015) were wider than Cu/Fe and Cu/Mn, found in the present study. Iron with copper, manganese, and zinc nutrient ratios were wider in high yielding population. Abd El Rheem *et al*., (2015) reported narrower iron to zinc, iron to copper, and iron to manganese ratios than these iron ratios in the present study. Manganese to copper, manganese to iron, and manganese to zinc were wider in the low yielding population. Abd El Rheem *et al*., (2015) reported narrower Mn/Zn and Mn/Cu ratios as compared to these ratios presented in Table 5. Zn/Cu and Zn/Fe were wider in low yielding population than high yielding population while Zn/Mn ratio means were wider in high yielding population than high yielding population. The copper functions Cu/Mn, Cu/Fe, and Cu/Zn had a negative sign with values -0.73, -9.90, -5.87 respectively which showed a deficiency of copper against iron, manganese, and zinc in low yielding population. Most of the iron functions had a negative sign suggesting a deficiency of iron against respective nutrients in the low yielders. All manganese functions were positive in signs suggesting an excess of manganese against these nutrients in low yielding population. Zinc functions had a positive sign with copper and iron suggesting sufficiency of zinc against these nutrients in low yielding population. DRIS index of copper and zinc indicated an adequate level -4.02, -0.51 respectively in low yielding populations. Soil test values of zinc extracted by 0.005M DTPA were mostly high in the soil samples. Solubility of zinc is largely dependent on pH and decreased at more pH levels (Rashid, 1996). Zinc was found to be 100 % insufficiency range based on tomato plant tissue analysis. It was reported that the tomato crop is sensitive to zinc deficiency (Rashid and Rayan, 2004). The manganese index was 10.78 suggests an excess of manganese in low yielding population. Soil analysis suggests manganese was high in soils. It was reported that probably no manganese deficiency was found in the Pakistani alkaline soils (Rashid, 1996; Shafiq *et al*., 2005). In the case of manganese, 92 % plant was in the sufficiency range. The most severe imbalance element is iron and showed deficit and supplementation of this nutrient in non-reference population. The average indices values for zinc and manganese designated high levels of these nutrients in the tomato plant tissue. DRIS indices reflected the luxurious uptake of zinc and manganese by the tomato plant. Copper and boron were sufficient to an excess level in the tomato index tissue. DRIS testing conclusion was dependent on the assessment of the nutrient deficiencies with the nutrient status to specify the additional benefits of DRIS. The order of nutrient deficiency observed in following order: Fe -6.24 > Cu -4.02 > Zn -0.51> Mn 10.78. Among the micronutrients soil zinc, manganese, copper, and iron extracted by the DTPA method above the sufficiency level, DIRS indicated manganese as an excess /High. Copper and zinc as an adequate while iron which diagnosed as deficient. Diagnosis through critical nutrient status and sufficiency ranges is restricted, as it covers the whole population which has both low and high yielders. DRIS comprehends this undulating nutrient status better.

CONCLUSION

The DRIS norms calculated in the present study could improve the nutritional diagnosis of tomato plants based traditionally on critical intervals of nutrient concentration. The DRIS index of Fe was -6.24, which is the quantitative difference from zero of balance nutrition indicated iron deficiency in low yielding population suggesting maximum yield potential achieved by correcting the deficiencies of this nutrient. DRIS model is best for evaluating micronutrient status in the tomato plant.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

AUTHOR CONTRIBUTIONS

Rabia Manzoor has made substantial contributions to the conception and designing of the study, performed index tissue analysis, and interpretation of data for the manuscript. Mohammad Saleem Akhtar has been supervising the entire work. He has guided from designing this study to the interpretation of data and ensuring the accuracy and integrity of every part of the work. Khalid Saifullah Khan has been involved in drafting the manuscript and revising it critically for important intellectual content. Carl Rosen helped during the analysis and thoroughly studied the manuscript and gave suggestions to improve the manuscript.

REFERENCES

Abd El-Rheem, K.M., M. Entsar, A. Hayam and A. Mahdy. 2015. Preliminary DRIS Norms for evaluating the nutritional status for tomato crop. Advances in Agriculture Biology, 4:50-53.

Arain, M.Y., K.S. Memon, M.S. Akhtar and M. Memon. 2017. Soil and plant nutrient status and spatial variability for sugarcane in lower Sindh (Pakistan). Pakistan Journal of Botany, 49:531-540.

Bailey, J.S., J.A.M. Beattie and D.J. Kilpatrick. 1997. The Diagnosis and Recommendation Integrated System (DRIS) for diagnosing the nutrient status of grassland swards: I. Model establishment. Plant and Soil, 197:127-135.

Beaufils, E. and M. Sumner. 1977. Effect of time of sampling on the diagnosis of the N, P, K, Ca, and Mg requirements of sugarcane by the DRIS approach. In Proceedings of The South African Sugar Technologists Association, 62-67.

Campbell, C.R. 2000. Sufficiency ranges for plant analysis: Tomato, Greenhouse. (SCSB #394).

Combs, S.M. and M.V. Nathan. 1998. Soil Organic Matter. In: Brown, J.R., Ed., Recommended Chemical Soil Test Procedures for the North Central Region, NCR Publication No. 221, Missouri Agricultural Experiment Station SB 1001, University of Missouri-Columbia, Columbia, 6:53-58.

Fageria, V. 2001. Nutrient interactions in crop plants. Journal of Plant Nutrition, 24:1269-1290.

Fassel, V.A., and R.N. Kniseley. 1974. Inductively Coupled Plasma Optical Emission Spectroscopy. Analytical Chemistry, 46:1110A-1120A.

Golia, E.E., A. Dimirkou and I.K. Mitsios. 2008. Influence of some soil parameters on heavy metals accumulation by vegetables grown in agricultural soils of different soil orders. Bulletin of Environmental Contamination and Toxicology, 81:80-84.

Hockman, J., J. Burger and D.W. Smith. 1989. A DRIS application to Fraser fir Christmas trees. Communications in Soil Science and Plant Analysis, 20:305-318.

Memon, M., G.M. Jamro, N.U.N. Memon, K.S. Memon and M.S. Akhtar. 2012. Micronutrient availability assessment of tomato grown in Taluka Badin, Sindh. Pakistan. Journal of Botany, 44:649-654.

Mousavi, S.R., M. Galavi and M. Rezaei. 2012. The interaction of zinc with other elements in plants: a review. International Journal of Agriculture Crop Science, 4: 1881-1884.

Munter, R.C. and R.A. Grande. 1981. Plant tissue and soil extract analysis by ICP-AES. In R. M. Barnes (ed.) Development in atomic plasma spectrochemical analysis, 4:653-673.

Passam, H.C., I.C. Karapanos, P.J. Bebeli and D. Savvas. 2007. A review of recent research on tomato nutrition, breeding and post-harvest technology with reference to fruit quality. European Journal of Plant Science and Biotechnology, 1:1-21.

Patil, B.C., R.M. Hosamani, P.S. Ajjappalavara, B.H. Naik, R.P. Smitha and K.C. Ukkund. 2008. Effect of foliar application of micronutrients on growth and yield components of tomato (*Lycopersicon esculentum* Mill.). Karnataka Journal of Agricultural Sciences, 21:428-430.

Rafique, E., A. Rashid, J. Ryan and A.U. Bhatti. 2006. Zinc deficiency in rainfed wheat in Pakistan: Magnitude, spatial variability, management, and plant analysis diagnostic norms. Communications in Soil Science and Plant Analysis, 37: 181-197.

Rashid, A. 1996. Soils: Basic concepts and principles. In: Soil oil Science. National Book Foundation, Islamabad, 4:3-23.

Rashid, A., and J. Ryan. 2004. Micronutrient constraints to crop production in soils with Mediterranean-type characteristics: a review. Journal of Plant Nutrition, 27:959-975.

Sainju, U.M., R. Dris and B. Singh. 2003. Mineral nutrition of tomato. Food, Agriculture and Environment, 1:176-183.

Shafiq, M., A. Mangrio and A. Shaheen. 2005. The nature and severity of nutrient deficiencies in typical water-eroded soils in Pothwar plateau. Soil and Environment, 24:75-83.

Soil, and Plant Analysis Council. (1992). Soil analysis: Handbook of reference methods, Athens, Gorgia, USA, 3:34-56.

Soltanpour, P.N. 1985. Use of ammonium bicarbonate DTPA soil test to evaluate elemental availability and toxicity. Communications in Soil Science and Plant Analysis, 16:323-338.

Wadt, P.G.S. 2009. Análise foliar como ferramenta para recomendação de adubação. In Congresso Brasileiro De Ciência Do Solo, 32.

Walworth, J. and M. Sumner. 1987. The diagnosis and recommendation integrated system (DRIS). In

Advances in Soil Science, 5:149-188.
Watson, M.E. and J.R. Brown. 1998. pH and lime requirement. In: Brown, J.R., Ed., Recommended Chemical Soil Test Procedures for the North Central Region. NCR Research Publication, University of Missouri, Columbia, 5:13-16.
Whitney, D.A. 1998. Micronutrient soil tests for zinc, iron, manganese and copper. In Recommended Chemical Soil Test Procedures for the North central region. 9:42-44.

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