International Journal of Economic Plants

https://ojs.pphouse.org/index.php/IJEP

IJEP May 2024, 11(2): 111-116

Article IJEP5278a

Full Research

Doi: HTTPS://DOI.ORG/10.23910/2/2024.5278a

Critical Ranges of Zinc in Soils and Leaves in Relation to Visual Symptoms in Apple Orchards of Temperate Jammu and Kashmir, India

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Article History

Received on 03rd March, 2024
Received in revised form on 28th April, 2024
Accepted in final form on 11th May, 2024

Abstract

A comparative study of leaf and soil Zn in healthy and unhealthy apple orchards was undertaken to diagnose Zn deficiency in major apple growing blocks of district Doda, Jammu and Kashmir, India during July–August, 2014. Available Zn content in healthy orchards ranged from 1.0–3.6 mg kg^{-1} in surface soils and from 0.67–2.90 mg kg^{-1} in sub surface soils of entire district with respective mean values of 1.54 and 1.21 mg kg^{-1}. The corresponding ranges for unhealthy orchards were found to be 0.50–0.99 mg kg^{-l} and 0.40–0.83 mg kg^{-1} with respective mean values of 0.70 and 0.59 mg kg^{-1}. The overall Zn content in leaves of normal healthy orchards ranged from 24.6–37.5 mg kg^{-1} whereas in unhealthy orchards, the range was 12.7–28.4 mg kg^{-1} with respective mean values of 30.36 and 19.25 mg kg^{-1}. Higher Zn status of healthy orchards was ascribed to relatively better management practices being followed in these orchards when compared to others where absentee farming was prevalent. Available Zn showed significant positive correlations with leaf Zn and OC content, both in surface and sub surface soils, whereas its relationship with soil pH was negative. The proposed critical levels of Zn, both in soil and leaf could effectively differentiate the healthy and unhealthy orchards. However, in some cases symptom development could only be attributed to hidden hunger/interactions with other nutrient elements/environment or some external factors.

Keywords: Apple, critical limits, visual symptoms, Zn

1. Introduction

Apple (*Malus domestica* Borkh.) is the principal fruit crop of Jammu and Kashmir and accounts for 51% of total area under temperate fruit crops in the state (Anonymous, 2022). However, many of the apple orchards growing in the region suffer from low plant vigour and poor yield and quality of fruits due to lack of proper mineral nutrition. Such orchards have often been associated with the development of visual nutrient deficiency symptoms. These symptoms/ disorders have pattern specific to nutrient element, which makes visual diagnostics as one of the popular methods to identify nutritional deficiencies in plants (Fageria, 2009). This approach is simple, fast and inexpensive. However, nutrient deficiency symptoms are extremely complex since each nutrient has numerous physiological and metabolic activities, each of which may interact with environmental circumstances. Many nutrient deficiencies may look similar as the same symptoms may be caused by multiple nutrient deficiencies as well as other biotic and abiotic factors and their interactions (McCauley et al., 2009, Fageria et al., 2011, Mia, 2015, Kathpalia and Bhatla, 2018). Interference by pests and pathogens may obscure accurate identification of the problematic nutrient (de Mello Prado, 2019, de Mello Prado and Rozane, 2020). Diseases, insects, drought, excess water, soil compaction, genetic abnormalities, insecticides (Stevens et al., 2002, Chatterjee and Dube, 2004, McCauley et al., 2009) and heavy metal toxicity (Ranganathswamy et al., 2019, Zafar-ul-Hye et al., 2020) may produce symptoms similar to those of nutrient deficiencies. Plants may suffer from hidden hunger (Afghani and Hashimi, 2015). Furthermore, visual diagnostic does not quantify the level of deficiency or excess, therefore it should be supplemented with plant and soil analysis.

Zn, the 'metal of life' is a micronutrient essential for maintaining life process both in animals and plants (Chellan and Sadler, 2015). As per criteria of Arnon and Stout (Osman, 2013), Zn is essential for plant growth and development (Brady and Weil, 2016). It is involved in the production of growth hormones and many crucial metabolic

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processes from photosynthesis to chlorophyll synthesis and plant reproduction . It has a role in fruit/grain yield, seed development, protection against plant pathogens (Cabot et al., 2019). Zn deficient plants show deformity (de Mello Prado, 2021) and delayed seed development (Khan et al., 2018). Interveinal chlorosis (mottling) in young leaves is the initial Zn deficiency symptom with short internodes, small leaves (Barker and Pilbeam, 2015) and rosetting (Karthika et al., 2018, Gulzar et al., 2020, Hashimi, 2021). Older leaves under severe Zn deficiency display leaf bronzing, limited growth, rolling and wilting (Mattiello et al., 2015, Zhao and Wu, 2017, Xie et al., 2019). For proper growth and fruiting, essential nutrients must remain within optimum limits defined by site-specific nutrient ranges/critical limits. Comparison of healthy and unhealthy trees is one of the methods to standardize critical ranges/limits of nutrient elements as used by Smith (1966) and Beyers (1962). The underlying hypothesis is that maximum plant performance is associated with an optimum range of nutrient concentration with specific upper and lower limits. So, if leaf analysis data are available from a large number of such orchards in different localities representing a wide range of nutrient supply, the highest and the lowest values may be considered to represent a close approximation of limits required for maximum performance. Although nutritional aspect of temperate fruit crops in Jammu and Kashmir has been studied widely (Wani et al., 2016, 2017, Nabi et al., 2020), no information is available regarding nutritional ranges in apparently healthy and unhealthy orchards. Present study attempts to propose critical Zn ranges based on visual symptoms, soil and plant analysis for apple growing areas of district Doda.

2. Materials and Methods

A diagnostic survey of the major apple growing localities concentrated in five blocks of district Doda (33.13^0 N latitudes, 75.57^0 E longitudes with an average altitude of 1107 m above mean sea level) in Jammu and Kashmir, India, namely Bhaderwah, Ghatt, Marmat, Thathri and Bhalessa was conducted during July–August, 2014. In each locality normal, healthy looking orchards at one site were compared with unhealthy orchards (exhibiting abnormal symptoms) in adjoining site having comparable site characteristics i.e. slope and aspect. However, if there seemed much variation in slope or aspect, more than one set of healthy and unhealthy orchards were taken into consideration for one locality. In this way, out of a total of 105 apple orchards surveyed, 60 orchards (26 healthy and 34 unhealthy) were finally selected in 20 localities to meet the objectives of present investigation. A sample of 50 leaves from each of five selected trees in each orchard was taken at random from the middle of terminal shoots of current year's growth on the periphery of the tree at shoulder height (Kenworthy, 1964). A composite leaf sample for each category of orchards at each site was prepared. These samples were sequentially washed in tap water, distilled and double distilled water, dried at 60±5^{0}C for 72 hours, ground in a stainless steel grinder and digested in di-acid mixture (nitric acid, perchloric acid in 4:1 ratio). Soil samples were taken at 0–20 cm (surface soils) and 20–40 cm (sub surface soils) depths from drip line of the tree. For this, four borings on all sides of the tree were made and a composite, representative sample was drawn in the month of October/November prior to the application of fertilizers by the farmers. Various physico-chemical characteristics of soils were determined following standard analytical methods (Jackson, 1973). Available Zn in soil samples was extracted with the help of DTPA extractant (Lindsay and Norvell, 1978). All Zn determinations were done using atomic absorption spectrophotometer. All statistical analyses were computed using Microsoft Excel software.

3. Results and Discussion

3.1. Soil characteristics

Soil reaction ranged between 4.71–8.26 (surface soils) and 4.76–8.31 (sub surface soils) in healthy and between 6.0–8.36 (surface soils) and 6.15–8.42 (sub surface soils) in unhealthy orchards (Table 1). Healthy orchard soils had relatively higher contents of organic carbon (OC) both in surface (mean 1.85% and range 1.27–2.17%) and sub surface soils (mean 1.38% and range 0.71–1.87%) as compared to unhealthy ones (mean 1.38% and range 0.49–2.10% for surface soils with mean 1.05% and range 0.30–1.73% for sub surface soils).

Table 1: Important soil characteristics of studied orchards

Soil characteristics	Soil depth (cm)	
	0-20	20-40
Healthy		
pH (1:2)	4.71-8.26	4.76- 8.31
OC (%)	1.27-2.17 (1.85)	0.71-1.87 (1.38)
Unhealthy		
pH(1:2)	6.0-8.36	6.15-8.42
OC (%)	0.49-2.10 (1.38)	0.30-1.73 (1.05)

Figures in parentheses denote mean values

3.2. Soil Zn content

The data given in table 2 indicated that available Zn content of healthy orchards of Bhaderwah, Ghatt, Marmat, Thathri and Bhalessa blocks ranged from 1.52–3.6, 1.05–1.3, 1.70–2.0, 1.0–1.4 and 1.0–1.25 mg kg^{-1} respectively in surface soils and from 1.36–2.90, 0.75–1.20, 0.67–1.68, 0.87–1.30 and 0.71–1.12 mg kg^{-1} in sub surface soils. In unhealthy orchards, it ranged from 0.52–0.95, 0.50–0.90, 0.6–0.99, 0.84–0.88 and 0.81–0.92 mg kg^{-1} in surface soils and from 0.43–0.83, 0.40–0.72, 0.5–0.61, 0.72–0.75 and 0.65–0.76 mg kg^{-1} in sub surface soils for above five apple growing blocks, in order. Surface soils of all orchards contained higher contents of this micronutrient element, which may be attributed to their higher OC content and favourable pH (Lindsay, 1972).

Table 2: Status of zinc in soil and leaves of plants in apple orchards

Block	Locality	Status of orchard	No. of ochards	Zn ranges (mg kg^{-1})		
				Leaf	Surface soil (0-20 cm)	Sub surface soil (20-40 cm)
Bhaderwah	Sartangal, Puneja, Seri, Drudhu, Neota, Bhallara, Dugga, Chhanni	Healthy	7	28.7-37.5 (33.21)	1.52-3.6 (2.34)	1.36-2.90 (1.94)
		Unhealthy	17	14.0-27.2 (20.03)	0.52-0.95 (0.67)	0.43-0.83 (0.60)
Ghatt	Troun, Droundi	Healthy	5	27.4-32.1 (29.26)	1.05-1.3 (1.19)	0.75-1.20 (0.86)
		Unhealthy	7	14.0-28.4 (17.56)	0.5-0.9 (0.6)	0.4-0.72 (0.47)
Marmat	Humbal, Malhori, Goa	Healthy	3	28.1-30.1 (28.97)	1.7-2.0 (1.83)	0.67-1.68 (1.07)
		Unhealthy	3	12.9-25.8 (21.3)	0.6-0.99 (0.79)	0.50-0.61 (0.57)
Thathri	Chirala, Bhella	Healthy	3	25.3-28.3 (26.47)	1.0-1.4 (1.15)	0.87-1.30 (1.03)
		Unhealthy	3	18.2-20.1 (19.47)	0.84-0.88 (0.86)	0.72-0.75 (0.73)
Bhalessa	Bhatyas, Jhakyas, Tilogra, Kilotran, Kahljugasar	Healthy	8	24.6-36.2 (30.54)	1.0-1.25 (1.09)	0.71-1.12 (0.91)
		Unhealthy	4	12.7-24.4 (17.2)	0.81-0.92 (0.85)	0.65-0.76 (0.68)
Overall/total		Healthy	26	24.6-37.5 (30.36)	1.0-3.60 (1.54)	0.67-2.90 (1.21)
		Unhealthy	34	12.7-28.4 (19.25)	0.50-0.99 (0.70)	0.40-0.83 (0.59)

Figures in parentheses denote mean values

This contention finds support from the significant positive correlation coefficients of available Zn with OC (r=0.56 in surface soils and r=0.57 in sub surface soils) and also negative correlations with soil pH (r=-0.17 in surface soils and r=-0.25 in sub surface soils) as given in table 3. Organic matter besides being a direct source of Zn, also to some extent, reduces soil pH which increases Zn solubility. Also, it effects weathering of Zn containing minerals and favours the formation of chelated Zn. The results are in accordance with those of Muftuoglu et al. (2004). On the whole, available soil Zn content in healthy orchards ranged from 1.0–3.6 mg kg^{-1} in surface soils to 0.67–2.90 mg kg^{-1} in sub surface soils with respective mean values of 1.54 and 1.21 mg kg^{-1}. The respective ranges for unhealthy orchards varied from 0.50–0.99 mg kg^{-1} and 0.40–0.83 mg kg^{-1} having mean values of 0.70 mg kg^{-1} and 0.59 mg kg^{-1}. Unhealthy orchard soils contained less amount of available Zn than healthy ones. Soils containing less than 0.5 mg of DTPA extractable Zn kg^{-1} of soil are generally classified as Zn deficient soils (Mertens and Smolders, 2013). Some studies define critical Zn deficiency in the range of 0.6–2.0 mg kg^{-1} depending on the extraction method (Singh and Singh, 2005). Taking 1.0 mg kg^{-1} as the critical limit for available Zn (Viets and Lindsay, 1973), 61.7% of the studied orchards fell in deficient category while 39.3% belonged to sufficient category. These figures are very close to the actual proportion of unhealthy (56.7%) and healthy (43.3%) orchards selected for the present studies. Healthy orchards were better managed with respect to plant basin preparation, weed control, inter-cropping, mulching and balanced fertilizer application of macro and micro nutrients. However, unhealthy ones were found to be poorly managed and neglected due to majority of the orchardists practising absentee farming. Fertiliser applications, especially of micronutrients in these orchards were negligible. Thus, continuous removal of Zn by plants in the absence of adequate replenishment might have led to the deficient levels of Zn in these soils.

3.3. Leaf Zn content

Leaf Zn content in healthy orchards of Bhaderwah, Ghatt, Marmat, Thathri and Bhalessa blocks ranged from 28.7–37.5, 27.4–32.1, 28.1–30.1, 25.3–28.3 and 24.6–36.2 mg kg^{-1} with respective mean values of 33.21, 29.26, 28.97, 26.47 and 30.54 mg kg^{-1} (Table 2). The unhealthy orchards of these respective blocks contained Zn in the range of 14.0–27.2, 14.0–28.4, 12.9–25.8, 18.2–20.1 and 12.7–24.4 mg kg^{-1} with mean values of 20.03, 17.56, 21.3, 19.47 and 17.2 mg kg^{-1}. The overall leaf Zn in normal healthy orchards ranged from 24.6–37.5 mg kg^{-1} whereas in unhealthy orchards, the range was from 12.7–28.4 mg kg^{-1} with corresponding mean values of 30.36 and 19.25 mg kg^{-1}. Considering 28.0 mg kg^{-1} (lower limit of leaf Zn for healthy orchards associated with the onset of visual symptoms) as critical leaf Zn level, 61.7% of the studied orchards (same proportion as in case of available Zn critical limit of 1.0 mg kg^{-1}) could be categorised as Zn deficient. Sharma and Bhandari (1995) reported average leaf Zn content of 31.7 mg kg^{-1} to be sufficient for apple orchards of Himachal Pradesh. Leaf Analysis Service Program in New York State uses levels of 35–50 ppm as adequate and 20–35 ppm as low leaf Zn status. The Zn content in leaves seems to vary according to available Zn content in soils as revealed by highly significant and positive correlation of leaf Zn with soil Zn content both in surface (r=0.77) and sub surface (r=0.75) soils (Table 3, Figure 1). Healthy orchards were found to have higher leaf Zn status as compared to unhealthy ones. Similar results were reported by Chaudhary and Sharma (2007) for apple orchards of Himachal Pradesh.

Variations in Zn content in different orchards may be ascribed to the different orchard management practices being followed by the orchardists in different areas and also to some extent, to the variations in soil physico-chemical properties. Leaf Zn content was significantly correlated with soil OC (r=0.74 for surface soils and r=0.61 for sub surface soils) and pH (r=-0.35). A higher pH soil has less availability of Zn than a lower pH soil (Sadeghzadeh, 2013). Walter (1961) attributed such variations to certain factors like age of tree, season, year, size of crop and different cultural treatments of the orchards.

Table 3: Correlation coefficients among studied parameters

Parameter		pH		OC		Available Zn		Leaf Zn
		(0–20 cm)	(20–40 cm)	(0–20 cm)	(20–40 cm)	(0–20 cm)	(20–40 cm)	
pH	(0–20 cm)	1.00	0.99**	-0.11	-0.15	-0.17	-0.25*	-0.35**
	(20–40 cm)	0.99**	1.00	-0.12	-0.16	-0.17	-0.26*	-0.35**
OC	(0–20 cm)	-0.11	-0.12	1.00	0.89**	0.56**	0.57**	0.74**
	(20–40 cm)	-0.15	-0.16	0.89**	1.00	0.52**	0.60**	0.61**
Available Zn	(0–20 cm)	-0.17	-0.17	0.56**	0.52**	1.00	0.96**	0.77**
	(20–40 cm)	-0.25*	-0.26*	0.57**	0.60**	0.96**	1.00	0.75**

$^{**}p$=0.01, $^{*}p$=0.05, n=60

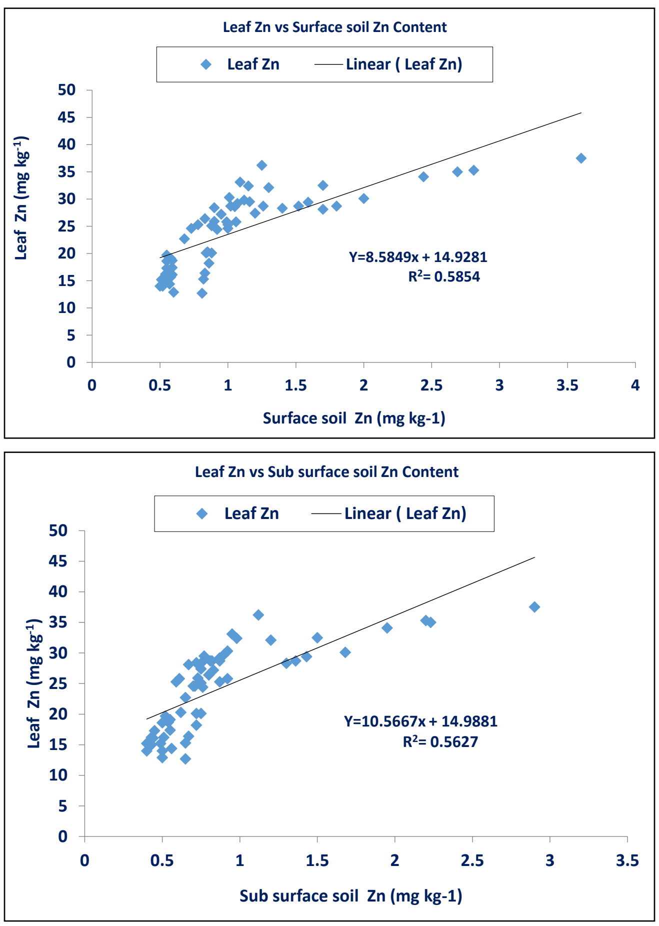

Figure 1: Correlation between soil and leaf Zn content

Some apparently healthy trees had Zn levels lower than those in unhealthy trees, as evidenced by lower limit of Zn in these healthy trees being lower than the upper limit of unhealthy trees. This might be probably a reflection of hidden hunger for Zn (McCauley et al., 2009, Afghani and Hashimi, 2015) due to interaction of Zn with other nutrient elements like P, both in soil and plants and with environmental factor like temperature or it could be some factor other than Zn that was effecting symptom expression. Sivaraman and Mukherjee (1970) reported that lower temperatures could induce severe Zn deficiency in plants.

4. Conclusion

Healthy orchards showed higher Zn content as compared to unhealthy ones, varying widely with locality. Zn content in leaves correlated well with that in soils. Zn content in soil and leaves was sufficiently reflected in the condition of plants apparent as healthy or unhealthy. Levels of 1.0 mg kg^{-1} available Zn and 28.0 mg kg^{-1} leaf Zn could closely differentiate apparently healthy and unhealthy orchards and may be used as tentative Zn standards for study area.

5. Authors' Contribution

Conceptualization of research work and designing of experiment (SKC, NK, MK); Execution of field/lab experiments and data collection (SKC, MK, SKS); Analysis of data and interpretation (SKC, NK, MK, NS, SKS); Preparation of manuscript (SKC, NK, MK, NS, SKS).

6. Acknowledgement

Authors acknowledge the supports from Regional Horticultural

Research Sub Station-Bhaderwah, Sher-e-Kashmir University of Agricultural Sciences and Technology-Jammu (Jammu and Kashmir).

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