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ZINC FERTILITY OF RED DELICIOUS APPLE ORCHARDS AND ITS ASSOCIATION WITH SOIL PROPERTIES IN TEHSIL SANJAVI, BALOCHISTAN

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Abstract

Prevailing Zn issue at the country level and some studies of fruit orchards highlighting Zn deficiency gave rise to the evaluation of apple orchards in Sanjavi Tehsil. Soil and leaf tissue samples were collected from twenty-five apple orchards (eight trees from each) covering four union councils (Sanjavi, Mana, Warchm and Poi) of Sanjavi Tehsil. Four cores were dug under each tree to have a representative soil sample. Leaves were collected from the middle of each newly emerged twelve shoots of each tree. According to the critical nutrient level (CNL) approach, there was no deficiency of plant available Zn in soil. All the samples (100%) were above the adequacy limit of 1.5 mg kg^{-1}. Nonetheless, 7 out of 25 orchards had relatively less available Zn (1.8 to 3.0 mg kg^{-1}) over others. In contrast to available Zn, the leaf tissue samples were at the edge of adequacy level. In other words, 100% samples were marginal (25-150 mg kg^{-1}) and if no application is carried out in near future, soil available and leaf tissue Zn, both may further lower down. Positive and significant relationships illustrated that organic matter contributed to soil available and leaf tissue Zn

Key words: AB-DTPA Zn, Critical nutrient level (CNL), Organic matter, Altitude, Balochistan.

Introduction

Among micronutrients, the role of Zn in apple production is most significant and apples are highly inclined to this deficiency. Development of buds and flowers, elongation of shoots, synthesis of sugar, and the process of photosynthesis is not possible without this nutrient (Patil *et al*., 2018). It is part of several enzymes. Low or no supply of Zn directly affects the fruit outcome. To be specific, inadequate supply of Zn leads to restricted leaf growth, the buds and overall development, fruit setting and ultimately the apple yield. With no exception, fruit quality such as weight, and colour index are also associated with Zn application. In the absence of Zn, apples lose their original taste (Woodbridge, 1954; Gianguzzi *et al*., 2017).

Apple cultivation under higher altitudes of Balochistan and Khyber Pakhtunkhwa is obvious and about a century old. Tehsil Sanjavi is part of district Ziarat at 30^{o}17'0 North and 68^{o} 21'0 East. The Tehsil falls under the "tropical agro-ecological zone" and includes, Sanjavi, Mana, Warchm and Poi union councils. The soils are built from stones, and variable proportions of shingle and clay. Calcite is the main material but also contains coal, marble iron and aluminum (Shah *et al*., 1964). The fields in the form of terraces ultimately form plain lands. The flood lands are the result of floodwater depositing the mixed material. Zinc is a natural component of the earth's crust. It is part of rocks and therefore present in the soil. District Ziarat is 8343 feet above sea level. The properties of soil are directly related to the increase in altitude (Panthi, 2010 and Saeed *et al*., 2014). Zinc is normally present with other metals such as Cu, Au, Ag and preferably Pb. Zinc associated with Pb can be found either in ores or in rocks that have shale, sand and siltstone or even mixed in clastic rocks (Arain *et al*., 2021).

The apple yield of 6.9 tons ha^{-1} in the country is relatively much less than the yield of 15 tons ha^{-1} at the world level (Pakistan Bureau of Statistics, 2019). The supply of nutrients is based on the nutrient stocks in soil, further carried to different parts of a plant. Soil Zn tests provide basic information. Some growers also follow the foliar application of nutrients. Even otherwise, leaf tissue testing is a reliable way to confirm the adequacy level of Zn or any other nutrient. The critical nutrient level (CNL) is a traditional approach to compare the soil or leaf tissue nutrients (Ulrich and Hills, 1967) and may have its limitations from one region to another. But it is the most widely used one. The deficiency of Zn has been widely highlighted in soils of Pakistan (Rashid *et al*., 1997) or in the case of particular crops i.e. wheat (Rafique *et al*., 2006), tomato (Memon *et al*., 2012), sugarcane (Arain *et al*., 2017). There is very little work on the record related to Zn fertility evaluation of soil (Zia ul Haq *et al*., 2018) or coupled with leaf tissue analysis in apple orchards of Balochistan (Ahmad *et al*., 2010 and Hidayatullah *et al*., 2019). However, these studies have not defined the sampling sites, and that the sampling is not carried out at the union council level from each district except that by Ahmad *et al*., (2010) carried out for district Murree. As the soil characteristics may vary even at small distances (Raquel *et al*., 2016), there is a dire need to have a detailed evaluation of Zn fertility at the union council level from each Tehsil in the district.

Materials and Methods

Soil and leaf tissue sampling: Tehsil Sanjavi is part of district Ziarat. The average rainfall is 22 mm and temperatures vary between -1 to 22^{o}C. First three months of the year, it generally rains, while July and August experience higher temperatures. Twenty-five apple orchards were chosen from different locations of Tehsil Sanjavi covering 4 union councils (Sanjavi, Mana, Warchm and Poi). The details of geographical coordinates for the sampling of apple orchards are presented in (Fig. 1.) A total of 800 soil samples (0-30 cm) were collected in the month of August by digging 8 cores (at random) from every 25 orchards and 4 cores underneath each tree canopy and 2 feet away from the main trunk. The samples were first dried in shade, later in an oven at 68°C, and ground (2mm particle size) to preserve in plastic vials for analysis.

Leaf tissue samples were collected from the same locations as for soil samples. A total of 2400 shoots were selected from 25 orchards (Kelling *et al*., 2000). Twelve shoots were randomly selected around the whole canopy and four leaves were sampled from the middle of the selected shoot. In this manner, total of 48 shoots were composited from each orchard. Leaves rinsed with tap water, double distilled water, shade dried, oven-dried at 60-65°C (Chapman, 1964), and ground to fine particle size were used for Zn testing.

Analytical methods: For soil analysis, sand, silt, clay (Bouyoucos, 1962), EC, pH (McLean, 1982), organic matter (Walkley & Black, 1934), $CaCO_3$ (Jackson, 1962), and available Zn (Soltanpour & Schwab, 1977) were determined. Leaf tissue samples (0.25 g) were digested in $HClO_4$:HNO_3 (1:5) on a hot plate, maintaining the temperature in the range of 180-200°C and in accordance with the procedure reported by Zarcinas *et al*., (1987). The digests as well as the AB-DTPA extracts were run for Zn determination on atomic absorption spectrophotometer (Shimadzu AA-6300, Japan).

Results

Soil status for general properties: Out of 25 apple orchards, 20 orchards possessed silt loam texture with the highest silt content of 74.6% in Soor Shor. The remaining 4 orchards were sandy loam with the highest sand content of 73.7% in Killi Marea and Masoori 1 and 01 orchards were loam at Harni Road. Hill torrents carry the fine particles of soil, with the flow of water and add silt particles (Government of Balochistan, 2017). Calcium carbonate contents were highest in Shyaka (28.5%) and pH (8.3) in Pitao Sinjavi 1. Zinc values experienced a decrease where $CaCO_3$ was higher. Zinc can form calcium-Zn compounds by precipitation process. Increased $CaCO_3$ results in high pH, and reduces the solubility of Zn instead forms different calcium- Zn compounds i.e. calcium zincate. The carbonate is also added from bicarbonate-rich water, increasing the alkalinity (Bloom & Skyllberg, 2012). Highest EC (0.65 dS m^{-1}) was in Chnngi Mango and even other soils were in the non-saline range of 0.2 to 1.85 dS m^{-1} (Shirokova *et al*., 2000). The highest organic matter was in Masoori 2 (2.54%), but generally, the organic matter was more due to low temperatures and high rainfall (Hood, 2001). Detailed soil properties have been covered under (Table 1).

Latitude	Longitude
N30°18.107′	E068°13.848′
N30°17.883′	E068°14.461′
N30°17.945′	E068°14.601′
N30°17.891′	E068°14.787′
N30°17.859′	E068°14.962′
N30°17.783′	E068°15.167′
N30°17.464′	E068°15.726′
N30°17.191′	E068°16.544′
N30°17.157	E068°16.630′
N30°16.597′	E068°17.656′
N30°16.037′	E068°17.715′
N30°16.411′	E068°16.780′
N30°16.747′	E068°16.359′
N30°19.165′	E068°03.312′
N30°19.532′	E068°00.721′
N30°20.140′	E067°59.167′
N30°28.103′	E067°43.118′
N30°28.143′	E067°43.464′
N30°28.053′	E067°44.024′
N30°28.048′	E067°44.329′
N30°27.794′	E067°44.539′
N30°27.598′	E067°44.697′
N30°26.965′	E067°45.144′
N30°26.604′	E067°45.433′
N30°25.570′	E067°46.551′

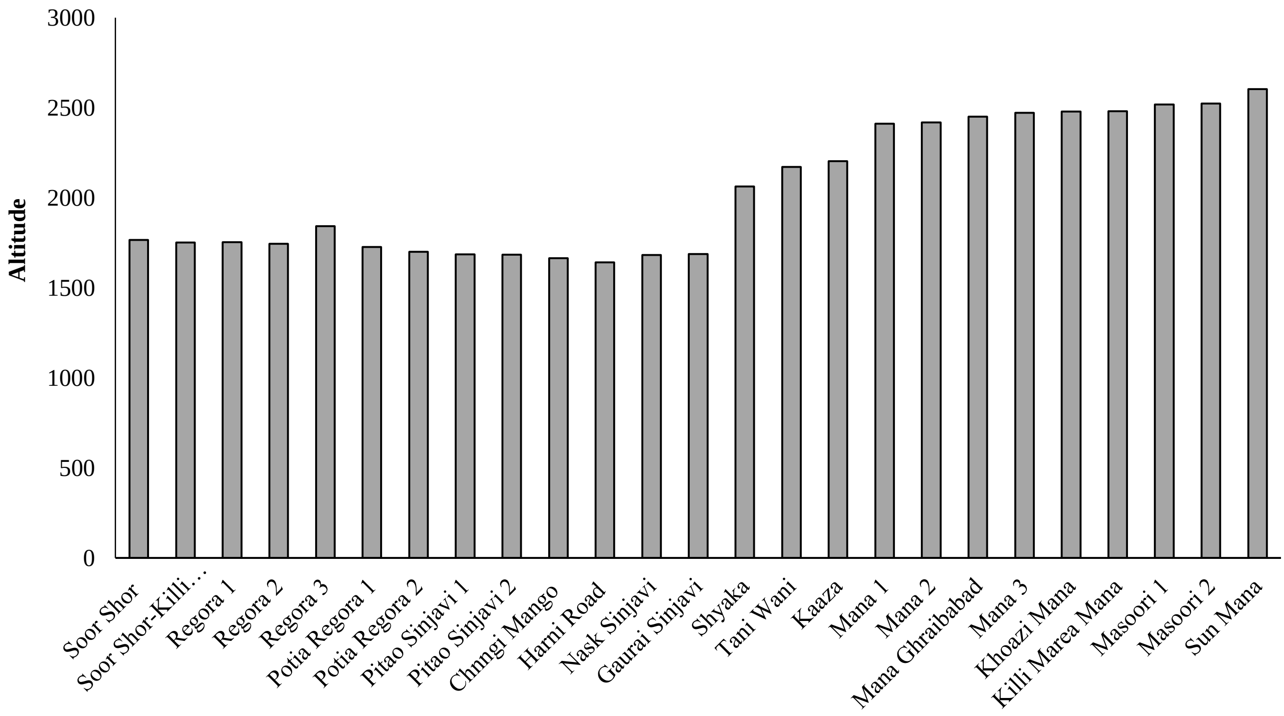

Fig. 1. Global positioning of apple orchards in Sanjavi Tehsil.

Table 1. Properties of apple orchard soils from Sanjavi Tehsil.

Location	Sand	Silt	Clay	EC	OM	$CaCO_3$	pH	Texture
	(%)							
Soor Shor	15.8	74.6	9.6	0.42	1.61	14.3	7.88	Silt loam
Soor Shor-Killi Boria	35.8	54.6	9.6	0.30	1.38	24.1	8.28	Silt loam
Regora 1	23.3	57.1	19.6	0.36	1.50	20.4	8.10	Silt loam
Regora 2	23.3	62.1	14.6	0.26	0.73	13.5	7.98	Silt loam
Regora 3	18.7	69.6	11.7	0.41	1.38	15.8	7.90	Silt loam
Potia Regora 1	18.7	72.1	9.2	0.43	1.00	18.9	8.16	Silt loam
Potia Regora 2	33.7	57.1	9.2	0.22	1.11	14.4	7.97	Silt loam
Pitao Sinjavi 1	18.7	67.1	14.2	0.51	1.18	25.9	8.30	Silt loam
Pitao Sinjavi 2	16.2	72.1	11.7	0.40	0.80	18.0	7.89	Silt loam
Chnngi Mango	11.2	67.1	21.7	0.65	1.08	24.1	8.21	Silt loam
Harni Road	41.2	44.6	14.2	0.30	0.91	27.9	8.28	Loam
Nask Sinjavi	53.7	37.1	9.2	0.34	0.66	24.9	8.25	Sandy loam
Gaurai Sinjavi	21.2	64.6	14.2	0.29	0.75	13.4	7.86	Silt loam
Shyaka	18.7	64.6	16.7	0.46	0.31	28.5	8.23	Silt loam
Tani Wani	18.7	69.6	11.7	0.35	0.93	13.9	7.99	Silt loam
Kaaza	16.2	72.1	11.7	0.50	2.18	21.3	8.25	Silt loam
Mana 1	20.6	53.7	26.7	0.26	1.86	18.0	8.09	Silt loam
Mana 2	8.7	67.1	24.2	0.31	1.24	27.9	8.32	Silt loam
Mana Ghraibabad	11.2	69.6	19.2	0.29	2.26	16.6	8.01	Silt loam
Mana 3	23.7	59.2	17.1	0.38	1.83	15.9	7.85	Silt loam
Khoazi Mana	33.7	51.7	14.6	0.35	1.42	13.7	7.71	Silt loam
Killi Marea Mana	73.7	9.2	17.1	0.23	1.58	13.7	7.88	Sandy loam
Masoori 1	73.7	11.7	14.6	0.42	2.27	18.7	8.07	Sandy loam
Masoori 2	61	27.2	11.8	0.32	2.54	23.4	8.29	Sandy loam
Sun Mana	33.7	54.2	12.1	0.36	2.12	19.8	8.04	Silt loam

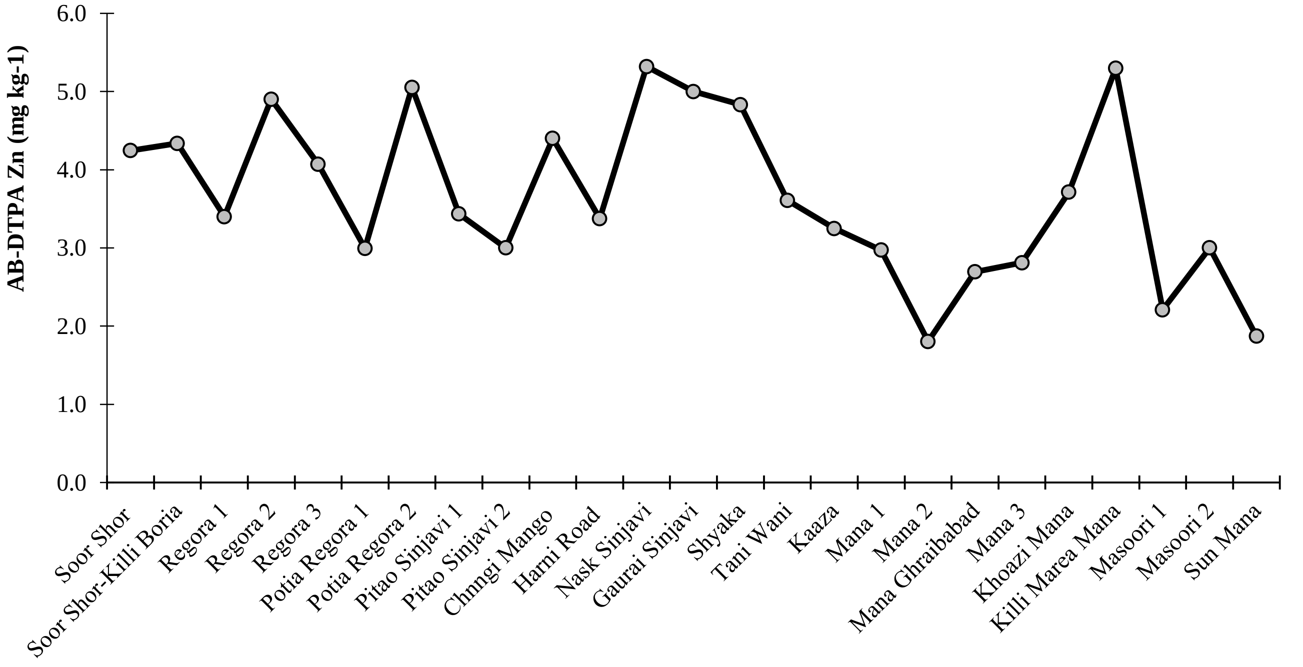

Fig. 2. AB-DTPA Zn content in apple orchard soils of Sanjavi Tehsil.

AB-DTPA Zn: The lowest concentration (1.80 mg kg^{-1}) was observed that in Mana 2, while the highest of 5.30 mg kg^{-1} in Killi Marea Mana (Fig. 2) with an average value of 3.66 mg kg^{-1}. Mode value of 3.0 confirms that most of the Zn values in Sanjavi Tehsil were close to the average value. All the apple orchards in Sanjavi possessed Zn concentration >1.5 mg kg^{-1} adequacy level as per categorization of AB-DTPA extractable Zn (Fig. 3) given by Soltanpour & Schwab (1977). The presence of Zn in association with Pb in different areas of Balochistan province (i.e. Saindak, Dirang Kalat, and Makki Chah) including Ziarat Balanosh are on the record and may be part of ores or rocks (Kazmi and Abbas, 2001; Arain *et al.*, 2021). There are very few studies related to Zn availability. Furthermore, the available Zn contents were adequate in the majority of the sites (21 out of 30 sites) tested from Qilla Saifullah (Zia ul Haq *et al.*, 2018). The AB-DTPA Zn contents of district Kalat, Killah Abdullah, Pishin, Quetta, and Ziarat were also greater than the critical limit of 1.5 mg kg^{-1} (Hidayatullah *et al.*, 2019). Unlike cited studies (Zia ul Haq *et al.*, 2018; Hidayatullah *et al.*, 2019), this study mentions the names of individual sites fulfilling the adequacy range. In addition, the number of samples should be taken at each union council. However, the study by Ahmad *et al*., (2010) was taken up at the union council level from Tehsil Murree. In contrast to our results, 38% of samples were reported to be deficient in AB-DTPA Zn content. This may be due to the difference in altitude of Murree (7516 ft) and Sanjavi Tehsil district Ziarat (8343 ft). The latter is relatively at a higher altitude which resulted in higher nutrient contents (Panthi, 2010).

Soil and leaf tissue Zn associated with soil properties: Unlike available Zn in soil, the leaf tissue Zn of all the orchards was under "marginal range" of 25-150 mg kg^{-1} (Fig. 4) as given by Neubert *et al*., (1970). None of the leaf tissue samples were either "low <25 mg kg^{-1}" or "adequate >150 mg kg^{-1}" in Zn but were rather in a marginal or critical range. It is the concentration of Zn, critical for the growth of apple trees (Nachtigall and Dechen, 2006). This means that the Zn contents were at the border and will require nutrition in no time. Examination of the leaf tissue data further showed that around 50% of orchards (12) had Zn content between 71 and 100 mg kg^{-1}, which is more towards the lower side of the marginal range (25-150 mg kg^{-1}). Consequently, the remaining 13 orchards were towards the higher end of the marginal level (25-150 mg kg^{-1}). Application of Zn fertilizer or even foliar spray may lead towards an adequate range of >150 mg kg^{-1}. Inadequate or no supply of Zn on the other hand will bring it in a lower category. The values were between 71 and 150 mg kg^{-1}, with a mean Zn content of 101 mg kg^{-1}. There was no association between soil and leaf tissue Zn contents.

Availability of Zn in soil may be related to some properties of soil. In this connection, sand (r = -0.184), pH (r = -0.172), EC (r = -0.126) and $CaCO_3$ (r = -0.195) had a negative and non-significant correlation with Zn content in soils of apple orchards of Sanjavi. The same has been highlighted by Alloway, 2009). A positive but non-significant relationship of available Zn with silt (r = 0.28) and clay (r = 0.141) was observed. Sandy soils have normally low Zn contents compared to those having more silt (Chinchmalatpure *et al*., 2000), which has more exchange sites. Sorption of $CaCO_3$ onto clay particles is very common under alkaline pH (Marschner, 1995; Holloway *et al*., 2008).

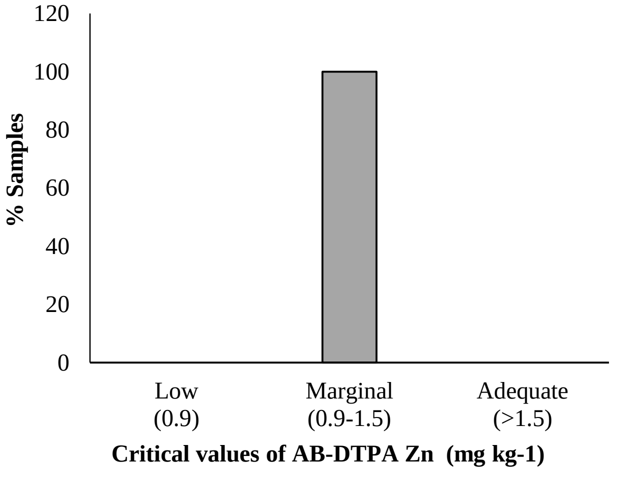

Fig. 3. Percent samples on the basis of critical values of AB-DTPA Zn in Sanjavi Tehsil.

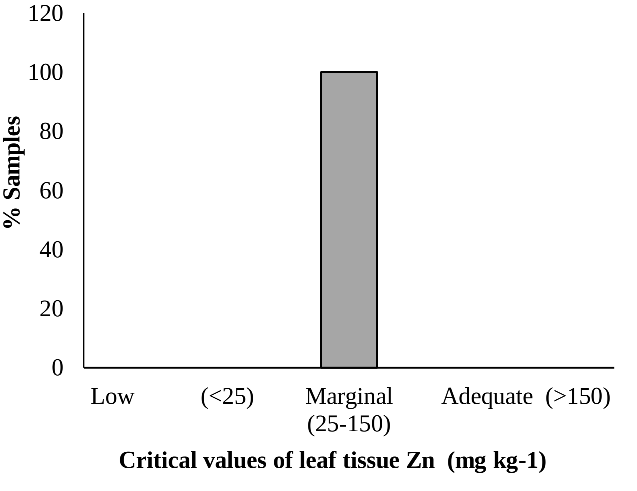

Fig. 4. Percent samples on the basis of critical values of leaf tissue Zn in Sanjavi Tehsil.

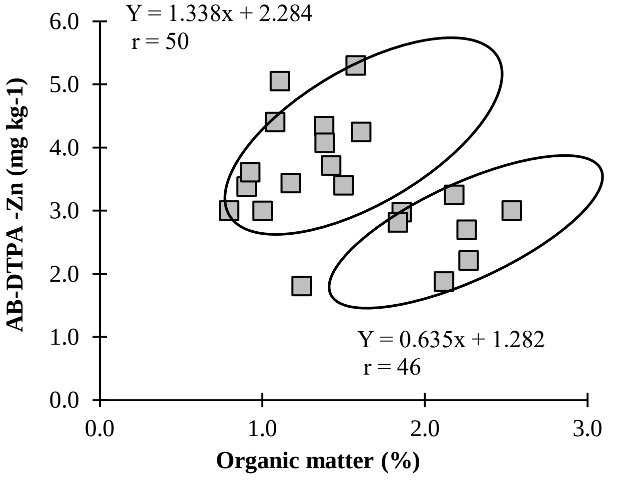

Fig. 5. Relationship between soil organic matter and AB-DTPA Zn content in apple orchards of Sanjavi Tehsil.

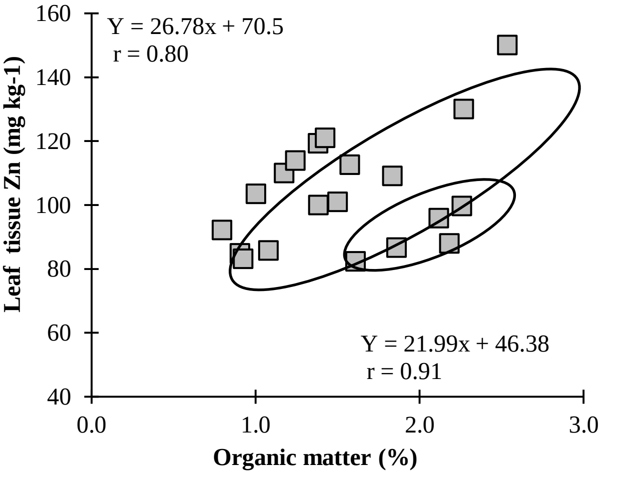

Fig. 6. Relationship between soil organic matter and leaf tissue Zn content in apple orchards of Sanjavi Tehsil.

In the case of organic matter, AB-DTPA extractable Zn and leaf tissue Zn, both were significantly and positively correlated with the organic matter content of the soil in apple orchards of Sanjavi (Figs. 5 & 6). Among metals (i.e. Cu, Cd, Ni, etc.), Zn has a relatively low affinity with soil organic matter content, therefore, it is effortlessly extracted from compounds that are organic in nature (Narwal & Singh, 1998). The significant influence of organic matter on available Zn has been also highlighted by Wei *et al*., (2006). The data in Fig. 5 described two groups of positive relationships. In one group, the soil organic matter content was relatively more (up to 2.5%), associated with AB-DTPA Zn contents (r = 46) under the adequacy range of 1.5 mg kg^{-1}. In another group (Fig. 5), the association is a bit stronger (r = 0.50), however, Zn values move above 5.0 mg kg^{-1} and organic matter content of around 1.75%. Both groups clearly prove the association of organic matter with available Zn. It has to do actually with available Zn content in the soil. The sites i.e. Potia Regora 1, Pitao Sinjavi 2, Mana 1, Mana 2, Mana Gharibabad, Mana 3, Masoori 1, Masoori 2, and Sun Mana had relatively less available Zn (1.80-3.00 mg kg^{-1}) in soil than the rest of the orchard soils. This also means that when critical limits report >1.50 mg kg^{-1} Zn, it does not really portray how much more. But this data does convey the message that Zn is not enough. However, the division into two groups may have to do with fertilizer management (type, quantity, and time of application) including Zn fertilization in that area. For instance, nitrogen fertilization in the form of ammonium sulphate, lowers the pH of soil by acidification, particularly in alkaline calcareous soils, and increases the availability of Zn in the soil as compared to other sources (Alloway, 2009). In addition, the quality of irrigation water testing, manure and foliar spray related information, even overall management of each orchard may be some relevant factors. The trend was the same as in the case of AB-DTPA Zn, when soil organic matter content was correlated with leaf tissue Zn. Nonetheless, the relationship was much stronger (r =0.8 and 0.91) as illustrated in Fig. 6. A little difference in relationships of organic matter with leaf tissue Zn may be that these orchards received some Zn through foliar application. In other words, along with organic matter from the soil, it may be the foliage spray of this nutrient that also contributed to Zn content in leaf tissue (Erdem & Sahin, 2021). Similar relationships were reported in apple (Ahmad *et al*., 2010), tomato (Memon *et al*., 2012), vegetables (Golia *et al*., 2008).

Conclusion

The leaf tissue Zn data of all the orchards in Sanjavi is an indication that orchards require foliar Zn application. Separation of the soil (AB-DTPA extractable) Zn data into two groups also support that some of the apple orchards i.e. Potia Regora 1, Pitao Sinjavi 2, Mana 1, Mana 2, Mana Gharibabad, Mana 3, Masoori 1, Masoori 2, and Sun Mana (1.8-3.0 mg kg^{-1} Zn), although falling under adequate category (>1.5 mg kg-1), require Zn nutrition boost. In addition, manure application along with regular macro- and micro nutrient supply including Zn fertilization through soil is recommended. Sources of fertilizers acidifying the soil will increase the plant available Zn from the soil pool. Future studies should include fertilizer, manure, irrigation water quality, yield scenario, and other management practices to have a better view of Zn contents in apple orchards.

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