Nutritional Diagnosis of "Hass" Avocado (*Persea Americana* Mill.) Soil Fertility and Water Quality, In Tepoztlán, Morelos

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Abstract— *In recent years, the avocado has become an important fruit species in Mexico, where it is distributed in six states, among which there is the state of Morelos. For the study, two agrohabitats with eight-year-old avocado orchards located in Tepoztlán, Morelos were selected. Soil fertility of the orchards was evaluated, as well as the quality of irrigation water, and the nutritional state of the leaves; sufficiency ranges were calculated, and the Deviation from Optimum Percentage method was used to interpret the results. Soils and the quality of irrigation water showed different chemical characteristics that had an influence on nutrient concentration in avocado leaves. The Deviation from Optimum Percentage (DOP) method allowed us to identify requirements of N, Zn, Mn, Fe and B in agrohabitat one, and deficiencies of P, K, Ca, S, Zn and Mn in agrohabitat two, which must be taken into account to implement a fertilization program in the studied orchards.*

I. INTRODUCTION

In 2010, world production of avocado (*Persea Americana* Mill.) cv. Hass was estimated at 3.8 million metric tons per year, obtained from a surface area of 462,661.50 ha, which were distributed in 65 countries; 64.23% of these countries were located in the Americas, and the remaining 35.77% in the rest of the world (FAOSTAT, 2012). In the same year, Mexico was the main producer of avocado in the world, with 28.44%, followed by Chile (8.47%), the Dominican Republic (7.41%), Indonesia (5.76%), and Colombia (5.81%) (FAOSTAT, 2012).

In 2013, 168,155 ha, were established in Mexico, with a global production of 1,109,000 metric tons of fruit. Just six states of the country (Michoacán, Jalisco, Nayarit, Mexico state, Guerrero, and Morelos) concentrated 92.27% of the cultivated surface, with yields of 3 – 11 t ha^{-1}, and a national average of 8.7 t ha^{-1} (SIAP, 2013).

In recent years, the avocado has become the most important fruit species of Morelos, represented by a surface of 3,617.00 hectares, distributed in 13 municipalities, the most important of which are Ocuituco, Tetela del Volcán, Yecapixtla, Tlalnepantla, and Cuernavaca (SIAP, 2013). However, in this region of Mexico there are not enough studies about soil fertility, which is added to the presence of acidic pH (4.8-5.2), low organic matter content, and high levels of microelements, especially copper and zinc, besides the nutritional state of avocado trees, and the levels of extraction of nutrients from the fruit to better define the best fertilization method to have an optimal nutrition and production, aspects that are addressed in this study (Sotelo-Nava *et al*., 2013).

On the other hand, the water quality that is determinant for good harvests under irrigation conditions has not been determined, and this can lead to low of avocado fruit quality, low yields and an increase in pests and diseases (Sotelo-Nava *et al*., 2013). In the face of this situation, the objective of this research was to analyze the nutritional state of avocado trees and soil fertility in commercial orchards, and determine the quality of the water used for agricultural irrigation.

II. MATERIALS AND METHODS

2.1 Description of the area of study

Tepoztlán is located at 18°59’07’’ latitude North, and 99°05’59’’ longitude West with respect to Greenwich meridian. The municipality has a population of 41,629 inhabitants according to the Population and Housing Census 2010 (INEGI, 2015). The total surface of the municipality is 292 square kilometers, and its north border is with Mexico City (Milpa Alta borough), its northeast border is with Tlalnepantla, its east border is with Tlayacapan, its southeast border with Yautepec, the south border is with Yautepec, Jiutepec, and Cuernavaca, and the northeast with Cuernavaca (the capital city of the state of Morelos) and Huitzilac (Secretaría de Gobernación, 2001).

The zone of study of Tepoztlán a semi warm, humid and temperate climate, and on the hillsides and mountains of Tepoztlán a sub humid climate. The rainy season occurs during summer and at the beginning of autumn; the lowest levels of rain occur in the valleys, where they reach up to 1,000 mm per year, and the highest occur in the mountains, where they surpass 1,200 mm per year (Secretaría de Gobernación, 2001).

To carry out studies of soil fertility, quality of irrigation water, and the nutritional diagnosis of "Hass" avocado trees, two experimental plots were selected, based on two agrohabitats present in the region under study, based on climate, soil, and physiography (Ornelas *et al*., 1990). In each agrohabitat a representative orchard of "Hass" avocado was selected, taking into account the age of the crop (eight years), management, and presence of irrigation.

The first agrohabitat had a semi cold climate, C (w2)b, with annual mean temperatures between 5 – 12 °C, and temperatures of the coldest month between -3 – 18 °C, with a long, fresh summer, and temperatures of the hottest month between 6.5 – 22 °C, ratio P/T 55.0. Soils are of type Andosol, derived from volcanic ashes, which tend to be acidic, with fixation of phosphates, with rough topography and easily eroded; these soils are generally considered unsuitable for agricultural activities; their most appropriate use being forestry and grasslands (Ornelas *et al*., 1990).

The second agrohabitat had a climate that is temperate sub humid [C(w2)], with annual mean temperatures between 12–18°C, and temperatures of the coldest month between -3 – 18 °C. It is the most humid of the temperate, with rains during summer, and rain of the driest month less than 40 mm, ratio P/T >55.0. The topography is rough (mountainous), with Andosol soils derived from volcanic ashes, which tend to fix phosphates, and are easily eroded and generally considered unsuitable for agricultural exploitation. Their most appropriate use is forestry and grasslands (Ornelas *et al*., 1990). The altitude is between 2,000 and 2,400 meters above sea level, the mean annual rainfall is 1,300 mm and the mean annual temperature is 16 °C.

2.2 Determination of soil fertility

Sampling, analysis and interpretation of the results were carried out according to NOM-021-SEMARNAT-2000, "that establishes specifications, study, sampling and analysis of fertility, salinity and soil classification".

Determination of soil fertility was carried out considering the following parameters: texture, by means of Bouyoucos method (Sparks, 1996); bulk density (BD), by means of a graduated cylinder; real density (RD), with a pycnometer; electric conductivity (EC), in the extract of saturation soil paste (Richards, 1954); activity of Hydrogen ions (pH) Jakson, 1982); organic matter content (OM) using the Walkley and Black method (Sparks, 1996); cation exchange capacity (CEC), using the percolation method with ammonium acetate pH 7.0; total nitrogen content (TN), using the Kjeldahl method (Sparks, 1996); absorbable phosphorus, using the Bray P-I method (Jakson, 1982). Phosphorus retention capacity was examined using the method of Blakemore *et al*. (1987); absorbable iron (Fe), copper (Cu), manganese (Mn) and zinc (Zn) were quantified using atomic absorption spectrophotometry.

2.3 Determination of water quality for agricultural use

To study the water quality for irrigation of avocado orchards in each of the agrohabitats in Tepoztlán, a sample from the supply source, which consists of water reservoirs that capture rain water, was taken, and the pH, EC, concentration of Ca2+, Mg2+, Na+, K+, CO32-, HCO3-, Cl-, SO42-, and B was measured according to the method proposed by Richards (1954).

2.4 Determination of the nutritional condition of avocado trees cv. Hass

In each experimental plot, which was representative of the two agrohabitats, 14 trees were selected, and their whole leaves were taken (leaf sheet and petiole), completely developed, mature but not senescent, from terminal buds without fructification, from winter and spring flow, healthy, from three to four months old, from the middle part of the tree and the four cardinal points. Leaf samples were placed inside paper bags and kept in a portable ice box to be transported to the laboratory of chemical analysis the same day (Maldonado, 2002).

Samples were washed with distilled water and dried at 70 °C for 48 hours in an oven with forced air flow. They were subsequently ground in a stainless steel grinder until a mesh 20 particle size was achieved (Etchevers, 1998). Concentration of Ca, Mg, N, and P was calculated (Jakson, 1982); Fe, Cu, Mn, and Zn in an acidic solution from a humid digestion; and S and B by ash formation (Jakson, 1982).

Interpretation of leaf analyses from the avocado crop in each of the agrohabitats was carried out taking into account sufficiency ranges reported by Rowley (1992) and the method of Deviation from Optimum Percentage (Montañés *et al*., 1991).

III. RESULTS AND DISCUSSION

3.1 Soil fertility

Soil fertility of the soils of the agrohabitats that are present in the municipality of Tepoztlán was determined based on the results of the chemical analyses of the soils, which are specific for each parameter, shown in Table 1, and the ranges mentioned in the Mexican Official Norm NOM-021-SEMARNAT-2000 (SEMARNAT, 2002).

pH values found in the soils under study were between 6.2 and 7.1, which indicate that these soils are moderately acidic to neutral (Etchevers, 1988), and represent ideal pH conditions except in the case of the Andosols (Castellanos, 2005). These results are similar to those reported by Méndez-García *et al*. (2008) in soils of "Hass" avocado orchards in the state of Mexico, with pH higher than 6.4.

Electric conductivity (EC) ranged from 0.48 to 0.63 dS m^{-1} in the soils of both agrohabitats, which shows that there are no salinity problems (Castellanos, 2005), and thus, there is no restriction to the development of the avocado crop (Méndez-García *et al*., 2008).

Cation Exchange Capacity (CEC) was lower than 21.97 cmol kg^{-1}. These values are considered in the middle of the range from 15 – 25 cmol kg^{-1}. In general, CEC increases with depth, as a result of the increment of the percentage of clay; this has an influence on the level of saturation of bases, which increases with depth (Méndez *et al*., 2008), and varies from horizon to horizon, and within each of them depending on the content and type of minerals, clay and organic components Wanda (1985).

The values of organic matter (OM) in the soils of the studied agrohabitats were between 2.55 – 3.23%, which are above the results reported by Méndez *et al*. (2008) in soils destined to the growth of avocado in the state of Mexico, where poor reports of OM were found, with values of 0.04 and 2.02% respectively. These values, according to the authors, are due to anthropogenic activity derived from overexploitation of the natural vegetation, in addition to the type of soil, as Tapia *et al*. (2007) showed in the avocado-growing zone of Michoacán, where they found differences in the content of OM, with 4 – 6, 4.5 – 5.5, and 2.1 – 3.0 ppm in soil types Andosol, Luvisol, and Regosol, respectively.

Total nitrogen (TN) was 4.36 – 4.38 mg kg^{-1}. These values are considered to be very low. The concentration of TN is considered low when the values are between 0 and 10 mg kg^{-1}, which is a characteristic of this type of soils (Andosols) because they are poor in inorganic nitrogen (Vázquez, 1999). However, these values are higher than those reported by Méndez *et al*. (2008), who obtained values from 0.01 to 0.12% of TN.

Absorbable P varied from 15.00 to 20.32 mg kg^{-1}. These values are normal for the agrohabitats under study, since they are in the medium range (15 – 30 mg kg^{-1}) established in the NOM-021-SEMARNAT (2002). These results are higher than those reported by Salazar (2002), who found values of 6.5 and 9.58 mg kg^{-1} of P in soils with "Hass" avocado in the state of Nayarit, which is classified as low and moderately low, respectively. Although values of absorbable P can be reduced as the depth increases and retention values of P increase (Méndez *et al*., 2008).

K varied between 435.00 and 711.31 mg kg^{-1}. According to Sánchez and Mijares (2000), considered these amounts of K to be high. In addition, these results are higher than those mentioned by Salazar (2002), who reports values of 300.5 and 368 ppm in soils of avocado orchards. Other researchers (Tapia *et al*., 2007) found values from 200 – 600 ppm, 300 – 1250 ppm, and 250 – 400 ppm in soils used for cultivation of avocado.

Regarding Ca, the concentrations obtained in the studies of Tepoztlán soils were 2,855.10 and 3,078.53 mg kg^{-1}, respectively. These values are considered high in both agrohabitats because they are higher than 2000 mg kg^{-1}. Therefore, application of Ca in fertilizers is not recommended in either case. The results obtained in this study are higher than those found by Salazar (2002) in soils destined to the culture of avocado, which he classified as low and moderately low with values of 687 and 1204.4 ppm, respectively. For his part, Tapia *et al*. (2007) mentions values from 500 – 3000 ppm, 600 – 1200 ppm, and 1800 – 2600 ppm in soil types Andosol, Luvisol, and Regosol, respectively.

Values of Mg found in the soils of the agrohabitats of Tepoztlán were 364.78 and 500.84 mg kg^{-1}, which indicates that fertilization with this element must be avoided because it is already abundant (higher than 360 mg kg^{-1}) in both sites. These values are similar to those found by Salazar (2002), who reported values of 17 and 420.5 ppm in soils of the avocado-growing zone of Nayarit, which are considered to have low and medium Mg content. However, the amount of Mg depends on the type of soil, and it can be present in ranges of 20 – 150 ppm (Andosol), 50 – 350 ppm (Luvisol), and 10 – 200 ppm (Regosol), as determined by Tapia *et al*. (2007) in soils from the avocado-growing region of Michoacán.

Regarding micronutrients, concentrations of B varied in both soils, with 0.080 mg kg^{-1} in agrohabitat one, which, according to the NOM-021-SEMARNAT (2002), it is considered to be a low value. In agrohabitat two, the value was 0.73 mg kg^{-1}. The values of B found in this research are lower than those indicated in soils from Nayarit by Salazar (2002), where values of 0.64 and 0.90 ppm were found, and classified as medium.

In the case of Cu, Fe, and Mn, the concentrations found in the soils of both agrohabitats were high (Table 1) because the concentration of Cu was higher than 0.8 mg kg^{-1}, Fe was above 6.0 mg kg^{-1}, and Mn was higher than 3.0 mg kg^{-1} (NOM-021-SEMARNAT, 2002). Due to that, it is not recommended to use fertilizers with Cu, Fe, and Mn in order to avoid continually increasing the amount of these elements in the soil. In other soils destined to the culture of avocado, concentrations of Cu of 0.30 and 0.77 ppm have been found, both values are considered to be low (Salazar, 2002).

The amounts of Fe found differ from those found by Tapia *et al*. (2007), who detected values of 25 – 35, 12 – 18, and 50 – 62 in three types of soil. For his part, Salazar (2002) found values of 1.11 (low) and 3.61 of Fe in two soils from avocado orchards. With respect to Mn, the results were close to some values found in soils from the avocado strip of Michoacán, where values of 2.3 – 103 ppm, 9 – 20 ppm, and 4 – 8.5 ppm of Mn were found in Andosol, Luvisol and Regosol soils, respectively (Tapia *et al*., 2007). Salazar (2002) found 2.45 and 64 ppm of Mn in two soils from “Hass” avocado orchards.

On the other hand, the value of Zn found in the soil of agrohabitat one was adequate (NOM-021-SEMARNAT-2002). However, the presence of Zn in agrohabitat two was null (0.00 ppm), and thus, it is inferior to the values of 2.5 – 5.5, 8 – 12, and 5 – 9 ppm (Tapia *et al*., 2007) and to the results detected by Salazar (2002) in two soils of avocado orchards with 3.13 ppm (low) and 2.3 ppm (medium).

TABLE 1
SOIL FERTILITY IN AVOCADO ORCHARDS IN TEPOZTLÁN, MORELOS.

Characteristic	Agrohabitat 1	Agrohabitat 2
Organic Matter (%)	3.23	2.55
pH	7.01	6.00
Electric Conductivity (dS m^{-1} at 25 °C)	0.48	0.63
CEC (cmol$_c$ kg^{-1})	18.75	21.97
Depth (cm)	30	30
Bulk density (g cm^{-3})	0.88	0.01
Total nitrogen (mg kg^{-1})	4.38	4.36
P (mg kg^{-1})	15.00	20.32
K (mg kg^{-1})	435.00	711.31
Ca (mg kg^{-1})	2855.10	3078.53
Mg (mg kg^{-1})	364.78	500.84
S (mg kg^{-1})	16.15	161.00
B (mg kg^{-1})	0.08	0.73
Cu (mg kg^{-1})	2.36	21.50
Fe (mg kg^{-1})	16.26	11.00
Mn (mg kg^{-1})	5.17	28.00
Mo (mg kg^{-1})	0	0
Zn (mg kg^{-1})	1.06	0
Cl (mg kg^{-1})	0	0

3.2 Water quality for agricultural use

Regarding the chemical characteristics of water (Table 2) in the agrohabitats under study, pH values varied from 6.24 to 7.6, and EC was from 0.138 to 0.121 dS m^{-1}, which shows that the water is of excellent quality because EC was lower than 0.4 dS m^{-1}, and according to the classification proposed by Castellanos (2205), these indicators are low, and differ from the results of pH and EC reported by Méndez *et al*. (2008), who found values of 8.3 and 8.8, and 0.09 to 0.16 dS m^{-1}, respectively. In the case of avocados, this crop is sensitive to EC, so when irrigation water has values higher than 2.0 dS m^{-1}, the yield is affected by 10%, and as EC increases, yield diminishes considerably (Salgado *et al*., 1999). Despite the fact that the irrigation water analyzed in both studied sites belong to class C1S1, which indicates low salinity and sodium content, and it is thus suitable for irrigation of avocado crops, there could be problems caused by very low soil permeability and crop sensibility due to sodium accumulation (Ayers and Westcott, 1985).

TABLE 2
QUALITY OF WATER DESTINED FOR IRRIGATION OF "HASS" AVOCADO IN TEPOZTLÁN, MORELOS.

Water characteristics	Agrohabitat 1	Agrohabitat 2
pH	7.800	6.240
EC (dS m^{-1})	0.121	0.138
Ca^{2+} (meq L^{-1})	0.661	1.120
Mg^{2+} (meq L^{-1})	0.263	0.042
Na^{+} (meq L^{-1})	0.000	0.070
K^{+} (meq L^{-1})	0.245	0.132
$HCO3^{-}$ (meq L^{-1})	0.900	0.700
Cl^{-} (meq L^{-1})	0.200	0.600
SO_4^{2-} (meq L^{-1})	0.100	0.040
B (mg L^{-1})	0.410	0.020

Concentration of B was 0.410 and 0020 mg L^{-1}, and chlorides were in concentrations lower than 1 mg L^{-1}, which represents adequate conditions of both elements in the water used for irrigation of avocados in both agrohabitats, because avocados are sensitive to values of B and Cl^{-} higher than 1 and 8 ml L^{-1}, respectively (Salgado *et al*., 1999). Bicarbonate concentration varied between 0.700 and 0.900 meq L^{-1}, which is lower than what is reported by Méndez *et al*. (2008). They obtained 1.6 and 1.9 meq L^{-1} of bicarbonate in water used for irrigation of avocados, and according to Castellanos (2005), bicarbonate levels obtained in this research are low.

3.3 Nutritional condition of avocado cv. Hass

The nutritional state of avocado trees was different in both agrohabitats. There were variations in the concentrations in each of the studied nutrients in the leaves (Table 3), and some of them were outside the sufficiency ranges indicated by Rowley (1992) and Salazar (2002).

Concentration of N in agrohabitats one and two were 0.009 and 2.209. These values, according to Maldonado (2002), are considered deficient and optimal, respectively. For his part, Salazar-García (2002) mentions that sufficiency intervals for nutrition in "Hass" avocado vary between 2.2 and 2.6% of N. However, this also depends on leaf health, since the concentration of N diminishes when the leaves show symptoms of a disease (Hernández-Valdez *et al*., 2012).

With respect to concentration of P, its concentration in leaves from agrohabitat one was within the sufficiency range, while in the leaves from agrohabitat two, there was a deficiency of this element (Maldonado, 2002). According to Salazar-García (2002), the optimal concentration of P in the leaves of avocado must be between 0.08 and 0.25%. Also, similar to what occurs with the concentration of N, the concentration of P can be affected by the health status of the leaves (Hernández-Valdés *et al*., 2012) or by the variety, as Figueroa-Ruiz *et al*. (2001) showed. They detected 0.12, 0.19, and 0.14% of P in the varieties "Colín V-33", "Fuerte", and "Hass", respectively.

The levels of K found in the leaves of avocados in agrohabitat one were higher than the optimum (excess), while in agrohabitat two, the concentration of K was deficient (Maldonado, 2002). In this sense, Salazar-García (2002) mentions optimal values of K in leaves of Hass avocado from 0.71 to 2%. Other researchers found 1.12% of K in the leaves of five-year-old avocado trees; such concentrations vary depending on the variety and age of the tree, and the season of evaluation (Figueroa-Ruiz *et al*., 2001; Herrera-Basurto *et al*., 2008).

The values of Ca of the leaves from agrohabitat one were higher than the sufficiency range, and the amounts of Ca in the leaves from agrohabitat two were within the range. According to the classification of Maldonado (2002), the last value also coincides with the optimal range that Salazar-García (2002) mentions for the concentration of Ca in leaves of the Hass avocado.

In the case of Mg, the concentrations of this element in the leaves of avocado from both agrohabitats were within the sufficiency range. However, according to the classification of Maldonado (2002), the levels of Mg were slightly above the sufficiency range in both agrohabitats. On the other hand, with respect to the concentration of S in the leaves of avocado, the values varied from 1.175 to 0.234% in both agrohabitats. These values are not sufficient to the crop of avocado (Salazar-García, 2002). The values of Ca found in this research are higher than the value of 0.83% found by Figueroa *et al*., (2001) in "Hass" avocados.

As for micronutrients in the leaves, concentrations of B, Cu, and Mn were within the optimal range for each element in both agrohabitats. Content of Fe and Mo were insufficient. In the case of Fe, it is affected when the pH of the soil tends toward neutrality (Salazar, 1999). The levels of Zn in agrohabitat two were closer to the optimal, and in agrohabitat one, they were deficient, probably due to the long time necessary for the Zn to show an effect in avocado leaves (Salazar *et al*., 2008). On the other hand, levels of Cl were within the optimal according to the classification of Maldonado (2002).

TABLE 3
NUTRITIONAL STATE IN THE LEAVES OF "HASS" AVOCADO IN TWO AGROHABITATS IN TEPOZTLÁN, MORELOS.

Element	Agrohabitat 1	Agrohabitat 2	Sufficiency range*
N (%)	0.009 b	2.209 o	2.20 to 2.60
P (%)	0.400 a	0.010 b	0.08 to 0.25
K (%)	3.168 a	0.628 b	0.71 to 2.00
Ca (%)	7.570 a	2.070 o	1.00 to 3.00
Mg (%)	0.529 o	0.555 o	0.25 to 0.80
S (%)	1.175 a	0.234 o	0.20 to 0.69
B (ppm)	65.00 o	122.39 a	50 to 100
Cu (ppm)	9.200 o	40.660 a	5 to 15
Fe (ppm)	48.33 b	48.420 b	50 to 200
Mn (ppm)	92.37 o	223.00 o	30 to 500
Mo (ppm)	0.00	0.00	0.05 to 1.00
Zn (ppm)	20.08 b	33.080 o	30 to 150
Cl (ppm)	0.230	0.248	Unknown

According to Rowley (1992) and Salazar (2002); a = high; o = optimal; m = medium; n = normal; b = low

Table 4 shows the nutritional index calculated by the Deviation from Optimum Percentage (DOP) method for each element. According to this, the trees show a requirement of N>Zn>Mn>Fe>B>Cu, while the rest of the nutrients were in excess. With reference to this, the concentration of some elements such as N can vary depending on the months were sampling takes place, generating variation in the results (Damián *et al*., 2006). In addition, deficiency of N detected in this study is probably related to the lack of a fertilization program with this element, and thus, it is necessary to increase the supply of N to avoid possible future deficiencies (Salazar and Lazcano, 1999). The deficiency of B, Zn, and Mn detected in leaf analysis is possibly related to the excess of K, as Du Plessis *et al*. (1998) observed in other varieties of avocado.

TABLE 4
DOP INDEX FOR "HASS" AVOCADO IN TEPOZTLÁN, MORELOS

Element	Agrohabitat 1	Agrohabitat 2
N	-99.52	9.42
P	150.00	-93.75
K	131.24	-54.16
Ca	273.50	-3.50
Mg	1.73	-6.73
S	193.75	-41.50
B	-13.33	63.18
Cu	-8.00	306.33
Fe	-61.33	61.36
Mn	-65.14	-15.54
Mo	0	0
Zn	-77.68	-63.24
NII	1,080.00	718.71

NII: Nutritional Imbalance Index

In agrohabitat two, the nutritional deficiency was different with respect to agrohabitat one, since deficient elements in the leaves were P>Zn>K>S>Mn>Mg>Ca. Deficiency of P could be the result of a strong retention of P by allophanic minerals in the soil (Méndez *et al*., 2008). Also, the concentration of Zn led to a deficit, which is related to a lack of Zn found in agrohabitat two (Table 1), in addition to the slow response of avocado to the supply of this element; the effects on leaf content are observable three years after Zn fertilization (Salazar-García *et al*., 2008).

Deficiency of K was probably the result of the low absorption of this element by the plants (Méndez *et al*., 2008). Ca, Mg, S and Mn were also deficient, and thus, they need to be supplied through a fertilization program (Montañes *et al*., 1991).

IV. CONCLUSION

Studied soils tended to neutrality, and did not show salinity problems. However, CEC and nutrient concentration were different in both agrohabitats.

Irrigation water showed adequate pH values, low EC, and low concentrations of B, Cl^-, and $HCO3^-$, and thus can be considered suitable for irrigation without restrictions in both agrohabitats.

The nutritional state of "Hass" avocado leaves was different, where 30 and 46% of the elements analyzed were within the optimal sufficiency range for agrohabitats one and two, respectively.

DOP index allowed us to know the deficit of N>Zn>Mn>Fe>B>Cu in agrohabitat one, and P>Zn>K>S>Mn>Mg>Ca in agrohabitat two, which must be taken into account to carry out an adequate fertilization program in the orchards of "Hass" avocado in Tepoztlán, Morelos.

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