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Nutrimental diagnosis of avocado (*Persea americana* Mill.) "Haas", soil fertility and water quality in Cuernavaca, Morelos, Mexico

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ABSTRACT

In two contrasting agricultural ecohabitats (agrohabitats) in the avocado production area in the municipality of Cuernavaca, Morelos, an analysis of nutrimental status, soil fertility and water quality was conducted to measure soil fertility levels and to determine the nutrimental state of the trees. The "Hass" variety avocado groves studied had an average age of 8 years; the first grove was planted in an acrisol soil (1700 to 1900 meters above mean sea level [mamsl]); the second, in an andosol soil (1200 to 1700 mamsl). In each agrohabitat, tests were performed to determine the soil's physical and chemical characteristics. The physical and chemical characteristics of the soils of this zone differ as do the nutrimental states of the avocado trees in the two agrohabitats. The trees showed excessive concentration of Ca, Fe, S, Z and Mg. The indices of Deviation from Optimal Percentage (DOP) in the two agrohabitats showed different nutrimental requirements; nevertheless, they were low and very near to zero, 14.218 and 13.350 respectively. The water used for the agricultural irrigation was low in salinity and sodium content and thus may be used for the agricultural irrigation without restrictions.

Keywords: Avocado; Nutrimental Imbalance Index; Diagnosis; Nutrimental Status; Nutrients

1. INTRODUCTION

The world production of avocado (*Persea americana* Mill.) var. Hass, is estimated as 3.8 million tons annually, produced on a surface area of 436,280 ha. which is distributed in more than 65 countries, of which 64% are located in the Americas and the remaining 36% in other continents [1]. Mexico is considered the world's principal producer of avocado, providing 43% of the world production [2]. Of the 28 avocado producer states in Mexico, the principal ones are Michoacan, Morelos, Nayarit, Puebla, Mexico (the state), Guerrero and Jalisco, which together account for 95% of the planted surface and 97% of the produced tonnage. Morelos occupies the fourth place as regards cultivated surface and production volume [3]. This market fruit species is the most important one in the state of Morelos, representing a cultivated surface of 3348 ha., 1580 producers and an average yield of 9.6 $t \cdot ha^{-1}$ [4], distributed in 13 municipalities, of which the most important are: Ocuituco (43.51%), Tetela del Volcán (27.53%), Tlalnepantla (6.69%) and Cuernavaca (3.58%). The production is grown under conditions of rainfall and irrigation, the latter on a much reduced surface area, highlighting in both modalities the scarce technical methods that affect the productivity and quality of the avocado fruit, above all the nutrimental aspect. Sixty percent of the avocados cultivated in the state (entity) are native varieties; the rest are improved varieties (Haas and Fuerte). These varieties are grown in family groves or commercial operations [3]. The Mexican Service for Agricultural Food Production and Fishery Information (Servicio de Información Agroalimentaria y

Pesquera, SIAP) [5] reports a production of 25,390 t, with an average yield of 10 t·ha^{-1}, a price of $10.92 per ton, and value of production of 227 million pesos.

Despite the importance of this crop in the state of Morelos, reliable scientific-technical information is lacking on the quality and quantity of irrigation water. Furthermore, studies on soil fertility and the nutrimental status of the trees themselves are few in numbers. Various investigations have shown the importance of these foliar nutrimental indices for the optimal fruit production [6], on top of the influence of soil type and climate, the nutritional status of the tree [7], the effect of the soil moisture upon nutrients' availability and nutrimental condition of the tree [8] since the soil's physical characteristics influence the water-air ratios of the soil and therefore the growth of roots that translate into a larger biomass of the aerial parts of the plant. Although soil origin affects the concentrations of nutrients in the different tissues of the plant, the absorption of nutrients should be in large measure more important to the plant's biomass [9].

In regard to this type of studies, Salazar-Garcia and Lascano-Ferrat [6], in research done in Nayarit, related that the majority of the groves under rainfall and medium irrigation would contain levels of potassium (K), boron (B), and sulfur (S) below normal, levels of nitrogen (N) near the lower limit of normal and levels of phosphorus (P), calcium (Ca), iron (Fe), maganese (Mn) and zinc (Zn) at normal. While in the Purepecha region of Michoacan, they reported that the diagnostics of soil fertility showed strongly acidic pH, low to very low levels of organic material, P, Mn and inorganic N, high to very high concentrations of Cu, Fe, K, Ca, B, and Zn, and medium levels of magnesium (Mg), while for the leaf nutrimental concentration levels, the order from higher to lower was as follows: Ca > N > K > Mg > P > B > Mn > Fe > Zn > Cu. That is to say that the foliage accumulates higher levels of Ca, N and K, with respect to Mg and P, and that the accumulation of Mn and Fe are higher in respect to Zn and Cu [10]. The present management of fertilization in the region is done in an empirical manner. The lack of a nutrimental diagnostic that permits knowing the necessity of fertilization provides the objective of the present effort to determine the nutrimental status of the avocado trees, soil fertility and irrigation water quality.

2. MATERIALS AND METHODS

The present investigation was conducted in the municipality/county of Cuernavaca, Morelos, located geographically at latitude 18˚55′N and longitude 99˚14′W, and with an average elevation of 1480 meters above mean sea level (mamsl). The municipality is bordered to the north by the Huitzilac municipality, to the south by Jiutepec and Emiliano Zapata, on the east by Jiutepec and Tepoztlán and on the west by the state of México. In Morelos, there are two well-defined harvest periods for Hass avocados. The first, from October to March, and the second, from June to August, represent 70% and 30% of the production respectively [11].

To accomplish the studies of soil fertility and arboreal nutrimental state in the product zone of the municipality of Cuernavaca, Morelos that covers an area of 210 ha., two active agricultural ecohabitats (or preferably agrohabitats) were selected on the basis of climate, soil and physiography [12]. In each agricultural habitat or agrohabitat, a representative grove of Hass avocados was selected, taking into account grove age (8 years), management and irrigation use. Sample taking, analysis and interpretation of the soil results followed the guidelines of NOM-021-SEMARNAT-2000 [13]. The analyses for soil fertility and their procedures were as follows: color, by Munsell tables; texture, by the Bouyoucos method [14]; apparent (bulk) density (Da), by the graduated measuring cylinder method; true (particle) density (Dr), by pycnometer; electrical conductivity (EC), by saturated paste extract procedure [15]; activity of hydrogen ions (pH) [16]; organic material (OM), by the Walkley-Black method [14]; cation-exchange capacity (CEC), by percolation method with ammonium acetate pH 7.0; total nitrogen (TN), by Kjedldahl method [14]; assimilable phosphorus, by Bray P-I method [16]. The phosphorus retention capacity was examined by Blakemore procedure [17]; quantifications of assimilable Fe,Cu, Mn and Zn, by atomic absorption spectrophotometry [18].

For the study of the nutrimental state of the trees in the chosen groves, 14 trees (for each grove) were selected in a random manner. From each tree, the following was collected: 8 complete perfectly developed leaves (leaf blade and petiole) which were mature but not senescent, from terminal buds without fruiting that came from the winter and spring vegetative growth spurts, healthy (without physical and chemical damage nor affected by infestations or diseases), from four to six months old, from the middle part of the tree and from each one of the four cardinal points. The leaves were placed in paper bags and then in a portable ice cooler for their conservation, prior to their preparation and analysis. The leaf sample, collected in February, 2013, was done in accordance with the procedure indicated by Maldonado [19].

In the laboratory, the samples were washed with distilled water, dried at 70˚C for 48 hours in convection ovens and afterwards grounded in a stainless steel mill until passable through a 20 mesh [20]. The following elements were measured: N, P, Ca and Mg; Fe, Cu, Mn and Zn in an acid solution coming from wet digestion; S and B, by ashing [16].

The interpretation of the leaf analysis of the avocado cultivars from each of the agrohabitats was accomplished taking in account the ranks of adequacy reported by

Rowley [21] and the Deviation from Optimal Percentage (DOP), a tool to evaluate simultaneously the intensity (level) and quality of nutrition [22].

In regard to the irrigation water quality, a sample was taken from the supply source in each of the agrohabitats. The following characteristics were determined: pH, electrical conductivity (EC), concentrations of Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, CO_3^{2-}, HCO_3^-, SO_4^{2-}, NO_3^- and B, as recommend by Richards [15].

3. RESULTS AND DISCUSSION

3.1. Characteristics of the Agrohabitats

In the community of Buenavista del Monte of the Cuernavaca municipality, Morelos, two agrohabitats were selected: III-C-2 and II-B-2. The first is characterized by a temperate subhumid climate [C(w_2)], an uneven (mountain) topography, acrisol soils, an altitude between 1700 and 1900 mamsl, an annual average precipitation of 1200 mm and an annual average temperature of 18˚C. The second habitat has a semi-hot (warm) climate [A(C)], uneven (hilly) topography, andosol soils, an altitude between 1200 to 1700 mamsl, an annual average precipitation of 1000 mm and an annual average temperature of 22˚C [12]: very similar conditions are those reported for the state of Michoacan where an area of 94045.28 ha. has been planted with avocado. These conditions for Michoacan are altitudes between 1100 and 2900 mamsl, seven soil types, 10 climate types, average temperatures between 16˚C and 24˚C, annual precipitation between 800 and 1500 mm, and a predominant relative humidity of 90% [23]. On this manner, Wolstenholme mentions that the temperatures of 17.9˚C to 19.7˚C with stable temperate environmental conditions free of stress are considered as the best conditions for the production of the 'Hass' avocados while the temperature limits for gaining a reasonable yield from this cultivar are from 19.5˚C to 21˚C which corresponds to the hot and humid subtropical climates [24].

3.2. Soil Fertility

The soils are acidic since the pH varied from 5.46 to 5.91. The electrical conductivity (EC) was from 0.53 to 0.82 $dS \cdot m^{-1}$ at 25˚C. The cation-exchange capacity (CEC) in Agrohabitat 1 was 20.33 $cmol(+) \cdot kg^{-1}$; it was 15.00 in Agrohabitat 2. The values encountered for organic material (OM) were 3.77% for Agrohabitat 1; 2.42%, for Agrohabitat 2. The total nitrogen (TN) had values of 0.11 $mg \cdot kg^{-1}$ in Agrohabitat 1; 6.72, in habitat 2. Assimilable phosphorus (P) varied between 23.00 and 12.41 $mg \cdot kg^{-1}$ in the two experimental sites respectively. K varied from 695.00 to 312.00 $mg \cdot kg^{-1}$ in both agricultural habitats (1 and 2 respectively). With regard to Ca and Mg, the concentrations obtained for Ca were 2585.00 $mg \cdot kg^{-1}$ in Agrohabitat 1 to 1887.97 in site 2; the concentrations for Mg were 533.00 $mg \cdot kg^{-1}$ in site 1; 424.20, in site 2. For the micronutrients, the concentration of B varied from 0.77 to 0.35 $mg \cdot kg^{-1}$ in both sites (agrohabitats) respectively. In the case of Cu, Fe and Mn, the concentrations present in the soil of the two agrohabitats were for Cu 0.90 $mg \cdot kg^{-1}$ for area 1; 1.41 $mg \cdot kg^{-1}$ for area 2. The results for Fe were 11.93 and 20.82 $mg \cdot kg^{-1}$ for area 1 and area 2 respectively. In the case of Mn, the values were 12.33 and 34.34 $mg \cdot kg^{-1}$ for area 1 and area 2 respectively (**Table 1**).

The obtained values in this effect coincide with the reports by Alcalá [25], Campos [26], Cruz [27] and Aguilar [28] that found pH values from 4.9 to 6.9, from 4.8 to 6.6, 5.4 and 5.3 in andisols for the Tarasca Mesa and Tarasca Mountains of the state of Michoacan, the volcanic mountain of Cofre de Perote and the Veracruz Mountains respectively. The previous values indicate the necessity to incorporate emendations to increase the pH to bring the soils to the minimal required by the avocado tree.

Electrical conductivity (EC) was low, meaning that the soils do not have problems with salinity since the values

Table 1. Fertility of the soils in the agrohabitats located in the municipality Cuernavaca, Morelos, Mexico.

Characteristics	Agrohabitat 1[z]	Agrohabitat 2[y]	Unit
Organic Material	3.77	2.42	%
pH	5.91	5.46	
Electrical Conductivity	0.53	0.82	$dS \cdot m^{-1}$ at 25˚C
CEC	20.33	15.21	$Cmol(+) \cdot kg^{-1}$
Depth	30	30	Cm
Apparent Density	1.06	1.04	$g \cdot cm^{-3}$
Total Nitrogen	0.11	6.72	
P	23.00	12.41	
K	695.92	312.00	
Ca	2585.00	1887.97	
Mg	533.23	424.20	
S	21.13	51.50	
B	0.77	0.35	$mg \cdot kg^{-1}$
Cu	0.90	1.41	
Fe	11.93	20.82	
Mn	12.33	34.34	
Na	271.14	331.00	
Zn	2.10	1.44	
Cl	0	0	

[z]Agrohabitat 1: subhumid temperate climate [C(w_2)], uneven (mountain) topography and andolsol soils; [y]Agrohabitat 2: semi-hot climate [A(C)], uneven (hilly) topography and andosol soils.

are lower than 1.0 dS·m^{-1} a 25˚C.

The cation-exchange capacity (CEC) in Agrohabitat 1 was medium, being in the range of 15 to 25 cmol(+)·kg^{-1}; that measurement in Agrohabitat 2 was low, its value (15.00) varying from 5 to 15 cmol(+)·kg^{-1}. This CEC range is common in acrisol and andisol soils since, as mentioned in Wada [29], this property varies from one soil horizon to another and, in each one of those, depends upon on the composition and type of minerals, the clay and organic components. The values for organic material were very low in the soils of the Agrohabitats 1 and 2 since the values were lower than 4. Those values are similar to those found by Venegas [30] and Alcalá [25], who found quantities of 0.70, 1.10, 1.90 and 2.0% for soils in the localities of San Felipe, Paracho, Santa Cruz and Puente Q in the Tarasca Mountains of Michoacan, and 0.4 and 2.2% in the Tarasca plateau in the same state.

The total nitrogen (TN) was very low in both agrohabitats, being 0.11 mg·kg^{-1} in No. 1, and 6.72 in No. 2 since Vázquez [31] notes that the concentration of TN is considered very low when the values are between 0 and 10 mg·kg^{-1}. Thus the soils are considered poor in inorganic nitrogen in terms of the cultivation of avocado. Nevertheless the quantities encountered in the present investigation are higher than the reports for the andisol soils of the Tarasca Mountains in the state of Michoacan by Venegas [30] and Rodas [32], who note concentrations from 0.08% to 0.07% and of 0.42% respectively.

Assimilable P fluctuates between 23.00 and 12.41 mg·kg^{-1} which is considered as medium since in the two experimental sites the values do not exceed 30 mg·kg^{-1}. The P concentrations in the soils of the two evaluated agrohabitats are superior to those found by Venegas [30], Rodas [32] and Aguilar [28] in various andisols of the Tarasca Mountains (Michoacan) and the Veracruz Mountains, where the values varied from 15.0 to 6.0 mg·kg^{-1} in the former and were at 0.62 mg·kg^{-1} in the later. The elevated values for the retention of P, as well as the availability of this element in andisols, have been attributed fundamentally to the content of aluminum (Al) and Fe in the organic-mineral complex of humus-Al related to allophane [28,29,33]. The P concentrations in the evaluated sites probably are due, in part, to the contribution of organic fertilizers.

K (potassium) varied from 695.00 to 312.00 mg·kg^{-1}, considered as very high (*i.e.*, greater than 234 mg·kg^{-1}) in both agrohabitats respectively. This factor indicates to us that extra K is not required.

In regards to Ca and Mg, the concentrations obtained were from 2585.00 to 1887.97 mg·kg^{-1} for Ca and from 533.00 to 424.30 mg·kg^{-1} for Mg. These values for Ca are considered very high (greater than 2000 mg·kg^{-1}) for Agrohabitat 1 (A1) and normal (*i.e.*, between 1000 to 2000 mg·kg^{-1}) for Agrohabitat 2 (A2). In the case of Mg, the value was high (greater than 360 mg·kg^{-1}) in the two experimental sites (A1 and A2). These previously highlighted results indicate that Ca and Mg should be eliminated in the fertilizer formulas to be applied in both agrohabitats, being already in high doses in both cases.

3.3. Nutrimental Status of the "Hass" Avocado

Nitrogen (N) was found in concentrations of 3.015% (A1) and 2.570% (A2) respectively. P was in quantities of 1.126 and 1.101% in all the trees of Agrohabitat 1 and Agrohabitat 2 respectively. The concentrations of K were 0.0 and 0.746% in A1 and A2 respectively. In the case of Mg, the values were 0.410% (A1) and 0.542% (A2). Nevertheless, Ca measurements were 1.064% for Agrohabitat 1 and 0.542% for Agrohabitat 2. Those for S were 0.134% in Agrohabitat 1 and 0.183% in Agrohabitat 2.

Cooper (Cu) was found in the quantities 38.11 mg·kg^{-1} in the trees of Agrohabitat 1 and 26.66 mg·kg^{-1} in those of Agrohabitat 2. For Zn, the values were 160.140 mg·kg^{-1} in A1 and 47.330 mg·kg^{-1} in A2. Fe was encountered in values of 48.330 mg·kg^{-1} in A1 and 48.33 mg·kg^{-1} in A2. For Cl, the values were 0.248 mg·kg^{-1} and 0.195 mg·kg^{-1} in Agrohabitats 1 and 2 respectively (**Table 2**).

According to the index DOP, the trees of Agrohabitat 1 show the order of requirements S > Fe > Mg. In Agrohabitat 2, the requirements are encountered in the following order: Ca > Fe > Mg > S > Zn > K.

The Nutrient Imbalance Index (NII) was 14.218 in Agrohabitat 1 and 13.350 in Agrohabitat 2. The nutrimental condition of the "Hass" avocado trees in the two Agrohabitats located in Cuernavaca, Morelos was determined on the basis of the concentration of the macro and micro nutrients found in **Table 2**, the sufficiency range given in Rowley [21] and nutrimental indices determined by the Deviation from Optimal Percentage (DOP) presented in **Table 3**.

P was found in high quantities (1.126% and 1.101%) in all the trees of Agrohabitats 1 and 2 respectively (the standard for normal is from 0.35% to 0.74%). The excess of this element is corroborated by the DOP index.

The trees of the "Hass" avocado groves exhibited different nutrimental states in the two agrohabitats. N was encountered in a concentration of 2.650%. Following the standard DOP, N is over the optimum in all the trees, independently of the area of investigation.

According to the foliar chemical analysis, the concentrations of K (0.0 to 0.746) was low in Agrohabitat 1 and normal in Agrohabitat 2; Mg levels (0.410 and 0.542 in A1 and A2 respectively) were in the normal range of sufficiency in the avocado trees of the two agrohabitat. Nevertheless, Ca was normal (1.145) in Agrohabitat 1 and low in Agrohabitat 2 (the optimal range being 1.00% to 3.00%). The sulfur levels were low in both agrohabitats

Table 2. Nutrimental Status of the "Hass" avocado in each one of the agrohabitats studied in Cuernavaca, Morelos, Mexico.

Element	Cultivars in Agrohabitat 1[z]	Cultivars in Agrohábitat 2[y]	Sufficiency Range (Rowley, 1992)
N (%)	3.015	2.570	1.6% to 2.20 %
P (%)	1.126	1.101	0.05% to 0.30 %
K (%)	0.000	0.746	0.35% to 2.9 %
Ca (%)	1.064	0.542	0.50% to 4.0 %
Mg (%)	0.410	0.242	0.15% to 1.0 %
S (%)	0.134	0.183	0.05% to 1.0 %
B ($mg·kg^{-1}$)	142.540	142.070	20 to 100 $mg·litro^{-1}$
Cu ($mg·kg^{-1}$)	38.114	26.684	3 to 16 $mg·litro^{-1}$
Fe ($mg·kg^{-1}$)	48.330	48.330	40 to 200 $mg·litro^{-1}$
Mn ($mg·kg^{-1}$)	302.015	595.650	15 to 500 $mg·litro^{-1}$
Zn ($mg·kg^{-1}$)	160.140	47.330	
Cl ($mg·kg^{-1}$)	0.248	0.195	unknown

[z]Agrohabitat 1: subhumid temperate climate [C(w_2)], uneven (mountain) topography and andosol soils; [y]Agrohabitat 2: semi-hot climate [A(C)], uneven (hilly) topography andosol soils.

Table 3. Nutrimental Index by the Deviation from Optimum Percentage in the cultivation of "Hass" avocado in the agrohabitats located in Cuernavaca, Morelos, México.

Element	Agrohabitat 1[z]	Agrohabitat 2[x]
N	0.5968	0.3455
P	6.0375	5.8812
K	1.0000	−0.4554
Ca	0.4680	−0.7290
Mg	0.2115	−0.5288
S	−0.6650	0.5125
B	0.9000	0.8942
Cu	2.8100	1.6684
Fe	−.6133	−0.6133
Zn	0.7793	−0.4747
Cl	0	0
NII[w]	14.2180	13.350

[z]Agrohabitat 1: subhumid temperate climate [C(w_2)], uneven (mountain) topography and andosol soils; [y]Agrohabitat 2: semi-hot climate [A(C)], uneven (hilly) topography and andosol soils.

since the range varied from 0.134% to 0.183% and the normal range would be from 0.05% to 0.19%.

Cu were encountered in quantities very above normal: 38.11 $mg·kg^{-1}$ in the trees of Agrohabitat 1 and 26.66 $mg·kg^{-1}$ in those of Agrohabitat 2, on the basis of high ranges being greater than 16 $mg·kg^{-1}$. For Zn, the trend was toward excess in Agrohabitat 1 with a value of 160 $mg·kg^{-1}$ and to a normal level in Agrohabitat 2 with a value of 47.3 $mg·kg^{-1}$, if we start from the position that the standard for us marks normal values as those going from 30 to 150 $mg·kg^{-1}$.

Fe was encountered in the trees in low values in both Agrohabitats 1 and 2, 48.33 $mg·kg^{-1}$ and 48.32 $mg·kg^{-1}$ respectively, compared to the optimal range of 50 to 200 $mg·kg^{-1}$.

For Cl, the range of sufficiency is not well known for avocado. In this respect, Lemus [34] says the interval from 2500 to 5000 $mg·kg^{-1}$ corresponds to excessive concentrations, which indicates that problems of toxicity is not present in the avocado trees in the two agrohabitats since their values were from 0.248 to 0.195 $mg·kg^{-1}$ respectively.

On the basis of the index DOP, the trees of Agrohabitat 1 show the requirement order S > Fe > Mg while the rest of the nutrients are encountered in condition of excess. In Agrohabitat 2, the deficiency of nutrients was greater than in the previous case, the requirements being in the following order: Ca > Fe > Mg > S > Zn > K.

The Nutrient Imbalance Index (NII) was greater in the trees of Agrohabitat 1 (14.218), followed by those of Agrohabitat 2 (13.350). Such indices are not too elevated. Considering that the NII is correlated negatively with the yield of the cultivars and positively with the susceptibility to attack by blights and diseases [35,36], it is to be hoped that upon decreasing the said indices so they approach zero, the yield will increase in the avocado production zone in Cuernavaca, Morelas.

3.4. Water Quality

The pH of the irrigation water of the Agrohabitats 1 (6.160) and 2 (5.970) is neutral, being in the range of 5.88 to 6.5. The alkalinity of the water is possibly due to the joint effect of the concentration of bicarbonates with the presence of sodium (Na), calcium (Ca) and magnesium (Mg). In this sense, Coras says that if the pH is greater than 7, being between 7.5 and 8.5 approximately denotes distinct content level of soluble salts, which in

Table 4. Irrigation water quality in the agrohabitats located in Cuernavaca, Morelos.

Agrohabitat	pH	CE[w]	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3^{-}	Cl^{-}	SO_4^{2-}	B[v]
						$mol_c \cdot m^{-3}$					
A1[z]	6.160	0.042	0.080	0.041	0.331	0.000	0.000	0.100	0.200	0.020	0.000
A2[y]	5.970	0.090	0.330	0.149	0.349	0.028	0.003	0.500	0.200	0.010	0.000

[z]A1, subhumid temperate climate [C(w_2)], uneven (mountain) topography and andosol soils; [y]A2, semi-hot climate [A(C)], uneven (hilly) topography and andosol soils.

turn will be able to be influenced by the cation sodium, which is alkaline in the extreme and induces the value of pH toward higher figures above the limit 7 [37] (**Table 4**).

The electrical conductivity (EC) of the water used for the irrigation of the Agrohabitats 1 and 2 was encountered in the range of 0.10 to 0.25 $dS \cdot m^{-1}$. According to the standards of Riverside [37], the type of water for the two agrohabitats is C2. Waters of type C2 are of medium salinity, suitable for irrigation; in certain cases it may be necessary to employ excessive water volumes and use cultivars tolerant to salinity.

The sodium adsorption ratio was 0.331 for Agrohabitat 1 and 0.349 for Agrohabitat 2. According to the standards of Riverside [38], the water used for agricultural irrigation in the avocado region of Cuernavaca is of type S1: with low sodium content, suitable for irrigation in the majority of cases; nevertheless, problems with cultivars very sensitive to sodium may appear.

The avocado being a species sensitive to the presence of B in irrigation waters, the concentration should be less than 0.33 $mg \cdot L^{-1}$ [38]. In the region of Cuernavaca, it is at 0 $mg \cdot L^{-1}$, consequently there should be no problems with this element.

The water for agricultural irrigation contained chloride in concentrations of 7.09 $meq \cdot L^{-1}$, which are considered good [15].

The level of residual sodium carbonate is an indicator of the danger of soil sodification, given that it takes into account the precipitation of calcium and magnesium by the carbonates and bicarbonates and in consequence the drop in its antagonistic effect over sodium. The measurements were 0.00 in both agrohabitats. Those values being below 1.25 $me \cdot L^{-1}$ indicate that the water quality is good [39].

The chemical characteristics described above show that available agricultural irrigation water in the muncipality of Cuernavaca, Morelos is of good quality and may be used for the cultivation of avocado without causing toxicities by some specific ion or leading to salinity in the soil. Furthermore if done, a good program of irrigation may control tree growth. Little salt accumulation is produced when the irrigation intervals are long since the large quantities of water supplied in each irrigation leaches the salt steadily [40].

4. CONCLUSIONS

Based on the results obtained in this study, the following may be concluded:

The diagnosis of soil fertility in the study area indicated that, in the two agrohabitants, the pH is slightly acidic and the levels of organic material content are low to very low (2.42%).

The physical characteristics and soil fertility of the two agrohabitats in which the Hass avocado is cultivated in the municipality of Cuernavaca are appropriate for this cultivation. However, it is found that the soil fertility and nutrimental status of the "Hass" avocado were different in those two agrohabitats. This variation should be considered in determining the more adequate fertilization dosage to nourish the avocado cultivars in each one of the encountered agrohabitats. With this consideration, certain nutrimental problems, specifically nitrogen, may be corrected.

The water available for agricultural use in each one of the agrohabitats has the adequate chemical characteristics for use in the irrigation of the avocado groves without any restrictions. This area specifically permits relief irrigations being implemented with which, on one hand, the stressing of plants can be avoided and, on the other hand, a good program of fertilization especially in the dry season may be implemented which will give, as a result, good production in the season (June-August) in which the best prices are gained.

REFERENCES

[1] FAOSTAT (2011) Avocados. Food and agriculture organization of the United Nations. http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor

[2] FAO (2007) Food and agriculture organization of the United Nations. La producción mundial deaguacate. www.fao.org/es/esc/common/ecg/226/esavocadoTF_web_s.pdf

[3] SIAP Servicio de información agroalimentaria y pesquera (2011) 2010 Producción agrícola. Ciclo: Cíclicos y perennes 2010. Modalidad: riego + temporal. Aguacate. http://www.siap.aguacate.gob.mx/index.php?portal=aguacate

[4] Secretaría de Agricultura Ganadería Desarrollo Rural

Pesca y Alimentación (Sagarpa)-Morelos (2010) Avancedesiembrasciclos P.V. 2009-2009 y O.I. 2009-2010. Perennes, 6 p.

[5] SIAP Servicio de Información Agroalimentaria y Pesquera (2010) 2007 Estadode Morelos. Ciclo: Perennes 2007. Modalidad: Riego + temporal. http://www.siap.gob.mx/index.php?option=com_wrapper&view=wrapper&Itemid=350

[6] Salazar-García, S. and Lazcano-Ferrat, I. (1999) Diagnóstico nutrimental delaguacate "Hass" bajocondicionesde temporal. *Revista Chapingo Serie Horticultura*, **5**, 173-184.

[7] Aguilera-Montañez, J.L., Tapia-Vargas, L.M., Vidales-Fernández, I. and Salazar-García, S. (2005) Contenido nutrimental en suelo y hojas de aguacate en huertos establecidos en Michoacán y comparación de métodos para interpretación de resultados. INIFAP, Campo Experimental Uruapan. Uruapan, Michoacán, México. *Folleto Técnico*, **2**, 28 p.

[8] Tapia-Vargas, L.M., Rocha-Arroyo, J.L. and Aguilera-Montañez, J.L. (2003) Mantenga altos niveles nutrimentales en su huerto con fertiriego sin afectar el ambiente. *Boletín el Aguacatero*, **34**, 7-15.

[9] Gil, P.M., Bonomelli, C., Schaffer, B., Ferreyra, R. and Gentina, C. (2012) Effect of soil water-to-air ratio on biomass and mineral nutrition of avocado trees. *Journal of Soil Science and Plant Nutrition*, **12**, 609-630.

[10] Maldonado-Torres, R., Álvarez-Sánchez, M.E., Almaguer-Vargas, G., Barrientos-Priego, A.F. and García-Mateos, R. (2007) Estándares nutrimentales para aguacatero "hass"-Revista Chapingo. *Serie Horticultura*, **13**, 103-108.

[11] Osorio, A.F. and García, D.J.J. (2005) Cadena agroalimentaria aguacate. Fundación Produce Morelos, 239-244.

[12] Ornelas, R.F., Ambriz, C.R. and Bustamante, O.J.D. (1990) Delimitación y definición de agrohábitats del estado de Morelos. Folleto técnico no. 8. Secretaría de Agricultura y Recursos Hidráulicos, Instituto Nacional de Investigaciones Forestales y Agropecuarias, Centro de Investigaciones Forestales y Agropecuarias del Estado de Morelos Campo Experimental Zacatepec, Zacatepec, 18 p.

[13] Semarnat (2002) Norma Oficial Mexicana NOM-021-SEMARNAT-2000. Que establece las especificaciones de Fertilidad, Salinidad y Clasificación de suelos, Estudio, Muestreo y Análisis. http://www.profepa.gob.mx/innovaportal/file/3335/1/nom-021-semarnat-2000.pdf

[14] Sparks, D.L. (1996) Methods of soil analysis. Part. 3. Chemical methods. Soil Science Society of America, Madison, 8 p.

[15] Richards, L.A. (1954) Diagnóstico y rehabilitación de suelos salinos y sódicos. Limusa, México D.F., 812 p.

[16] Jackson, L.M. (1982) Análisis químico de suelos. Omega, Barcelona, 34 p.

[17] Blakemore, L.C., Searle, P.L. and Daly, B.K. (1987) Methods for chemical analysis of soils. N. Z. Soil Bureau Scientific Report 80, Soil Bureau, Lower Hutt, 38-41.

[18] Lindsay, W.A. and Norvell, W.A. (1978) Development of a DTPA soil tets for zinc, iron, manganese and copper. *Soil Science Society of America Journal*, **42**, 421-428. doi:10.2136/sssaj1978.03615995004200030009x

[19] Maldonado, T.R. (2002) Diagnóstico nutrimental para la producción de aguacate Hass. Informe de investigación. UACH, Texcoco, 167 p.

[20] Etchevers, B.J.D. (1988) Manual de métodos de análisis de suelos, plantas, aguas y fertilizantes. Colegio de Postgraduados en Ciencias Agrícolas, Montecillos, 125 p.

[21] Rowley, D.F. (1992) Soil fertillity and the mineral nutrition of avocado, circular No. CAS-92/1. California Avocado Development Organizacion (CADO) and California Avocado Society, 30 p.

[22] Montañés, L., Heras, L., Abadia, J. and Sanz, M. (1993) Plant analysis interpretation based on a new index: Deviation from optimum percentage (DOP). *Journal of Plant Nutrition*, **16**, 1289-1308. doi:10.1080/01904169309364613

[23] Gutiérrez-Contreras, M., Lara-Chávez, M.B.N., Guillén-Andrade, H. and Chávez-Bárcenas, A.T. (2010) Agroecología de la franja aguacatera en Michoacan, México. *Interciencia*, **35**, 647-653.

[24] Wolstenholme, B.N. (2007) Ecología: El Clima y el ambiente edáfico. In: Whinley, A.W., Schaffer, B., Wolstenholme, B.N., Eds., *El Palto. Botánica, Producción y Usos*, Ediciones Universitarias de Valparaiso, 75-101.

[25] Alcalá, J.M., Ortiz, S.C. and Gutiérrez, C.M. (2011) Clasificación de los suelos de la meseta Tarasca, Michoacán. *Terra*, **19**, 227-239.

[26] Campos, C.A., Oleschko, K., Cruz, H.J., Etcheveres, B.J.D. and Hidalgo, M.C. (2001) Estimación de alófano y su relación con otros parámetros químicos de Andisoles de montaña del Volcán Cofre de perote. Terra, **19**, 105-116.

[27] Cruz-Flores, G., Tirado, T.J.L., Alcantar, G.G. and Santizo, R.J.A. (2001) Eficiencia de uso de fósforo en triticale y trigo en dos suelos con diferente capacidad de fijación fósforo. *Terra*, **19**, 47-54.

[28] Aguilar-Acuña, J.L., López-Morgado, R., Núñez-Escobar, R. and Khalil-Gardezi, A. (2003) Encalado y fertilización fosfatada en el cultivo de papa en un andosol de la Sierra Veracruzana. *Terra*, **21**, 417-426.

[29] Wanda, K. (1985) The distinctive properties of andisoles. *Advances in Soil Science*, **2**, 173-229. doi:10.1007/978-1-4612-5088-3_4

[30] Venegas, G., Cajuste, J.L., Trinidad, A.S. and Gavi, F.R. (2000) Correlación y calibración de soluciones extractantes del fósforo aprovechable en andisoles de la sierra Tarasca. *Terra latinoamericana*, **17**, 287-291.

[31] Vazquez, A.A. (1999) Guía para interpretar el análisis químico del agua y suelo. Universidad Autónoma Chapingo, Chapingo.

[32] Rodas, C.A., Núñez, E.R., Espinosa, H.V. and Alcántar, G.G. (2001) Asociación lupino-maíz en la nutrición fosfatada en un andosol. *Terra*, **19**, 141-154.

[33] Shoji, S.M., Dahlgren, R.A. and Quantin, P. (1996) Evaluation and proposed revisions of criteria for andosols in the world reference base for soil resources. *Soil Science*,

161, 604-615. doi:10.1097/00010694-199609000-00005

[34] Lemus, S.G., Ferreyra, R.E., Gil, P.M., Maldonado, P.B., Toledo, C.G. and Barrera, C.M. (2005) El cultivo del palto. Boletín 129. Instituto de Investigaciones Agropecuarias, Valparaíso, 12 p.

[35] Medina, Q.F. (2005) Incidencia del barrenador grande del hueso del aguacate Heilipus lauri Boheman (Coleoptera: Curculionidae) en Tepoztlan, Morelos, Tesis de Licenciatura. Facultad de Ciencias Agropecuarias, Universidad Autónoma de Morelos, 39 p.

[36] Damián-Nava, A., González-Hernández, V., Sánchez-García, P., Peña-Valdivia, C. and livera-muñoz, M. (2006) Dinámica y diagnóstico nutrimental del guayabo en Iguala, Guerrero, México. *Terra Latinoamericana*, **24**, 125-132.

[37] Coras, M.PM. (2000) Calidad química del agua para riego. Temas didácticos No. 6. Departamento de Fitotecnia, Universidad Autónoma Chapingo, Chapingo, 123 p.

[38] Cadahía, L.C. and Lucena, M.J.J. (2005) Diagnóstico de nutrición y recomendaciones de abonado. In: Cadahia, L.C., Ed., *Fertirrigación*. *Cultivos Hortícolas*, *Frutales y Ornamentales*. Tercera Edición Revisada, Actualizada y Ampliada. Mundi-Prensa, Madrid, 185-257.

[39] Aceves, E. (1979) El ensalitramiento de los suelos bajo riego. Colegio de Postgraduados, Chapingo, 381 p.

[40] Kalmar, D. and Lahav, E. (1977) Water requirements of avocado in Israel. I. Tree and soil parameters. *Australian Journal of Agricultural Research*, **28**, 859-868. doi:10.1071/AR9770859

