Article

Effect of an iron fulvate on quality and production of 'Serrano' chili fruits

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Abstract

Fresh green chilli, in Mexico, are of importance not only because they are part of the food diet, but because of the workforce that generates their production; however, the soils of the producing states have alkaline pH and this causes iron fixation (Fe), which is a vital element in the quality of the fruits. Therefore, the objective of the study was to determine the effect of an iron fulvate (FFe), on the quality of 'serrano' chili fruits for which increasing doses of a mixture of fulvic acids and ferrous sulfate (FFe) were used to 200, 400, 600, 800, 1 000 and 1 200 mg kg^{-1} added four times to the soil: at the time of transplantation, at 15, 45 and 60 ddt and a nutritive solution (SN) as a control. The performance and quality variables measured to the fruit: fresh weight (PFF), dry weight (PSF), length (LF), diameter (DF), firmness (FI), total soluble solids (SST) and iron (Fe) and calcium (Ca), to the plant tissue of foliage. With the high dose of 1 200 mg kg^{-1} the highest value of PFF, LF and DF was obtained, while with the dose of 1 000 mg kg^{-1} the highest value of PSF was obtained, FI obtained the highest value high with the dose of 400 mg kg^{-1} and with the lowest dose of the organic-mineral complex the highest values of SST and NF were obtained. With respect to the concentration of nutrients in foliar tissue the dose of 1000 mg kg^{-1} caused optimal Fe values and close to the optimum of Ca, while with the lowest doses of 200 and 400 mg kg^{-1} the concentration of both minerals was in excess.

Keywords: *Capsicum annum*, humic substances, iron fulvate, serrano chilli.

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Introduction

The ‘Serrano’ chili is used fresh and dry because it contains a quantity of nutrients and antioxidants that provide protection against free radicals, so they are associated with health promoting properties (Velioglu *et al*., 1998). The chillis are considered as an excellent source of nutrients, as well as ascorbic acid (vitamin C), carotenoids and phenolic compounds that are its main antioxidant constituents, whose levels depend on several factors that include cultivating, type of production (organic or conventional), cultural practices, fruit maturity and storage conditions (Lee and Kader 2000).

According to Mafla and Pérez (2016), only the fruits of the genus *Capsicum* contain capsicin (8-methyl-N-vanillil-6-nonenamicide) and is used in the pharmaceutical industry in medications that are used against arthritis and as an anti-inflammatory. In addition, the chillis are considered within the basic food of the Mexican people and their cultivation is an important source of employment since it requires up to 150 wages per hectare (Martínez-Magdaleno *et al*., 1998; Inifap, 2006).

Mexico ranks third worldwide in green chili production, after China and Turkey since they produce 50.4 and 7.1%, respectively (FAO-STAT, 2017). The soils of the Mexican states producing 'Serrano' chili such as Sinaloa, Tamaulipas, San Luis Potosí and Jalisco are mainly Calcisoles (SIAP, 2015; World Reference Base, WRB-FAO/UNESCO, 2015), which are characterized by having pH alkaline from 7.5 to 8, organic matter contents that oscillate around one percent, more than 2 dS m^{-1} of electrical conductivity (EC), between 17 and 22 percent calcium carbonate, silt-clay or loam texture and the exchange phase is dominated by the Illitas clays, the above causes the iron (Fe) to be fixed in this type of soil and the plants because of this, among other factors, present deficiencies of this nutrient, these can be corrected with inorganic salts (fertilizers), synthetic chelates and addition of organic matter, both solid and liquid, enriched with this element (Lucena, 2004).

The functions of Fe in the plant, according to Marschner (1995) are: protein synthesis, such as peroxidase for the formation of lignin and suberine; chlorophyll molecule formation together with calcium, inhibits the formation of ethylene and intervenes in photorespiration and depending on the characteristics of the soil, especially pH, plants develop physiological mechanisms for the absorption of this element, where organic acids intervene generated by the root (phytosiderophores). One way to provide Fe to plants is through the addition of chelates to this element; however, these compounds are synthetic, difficult to obtain and not economical (Salisbury and Ross, 1995).

In recent years, with the rise of sustainable agriculture, the use of organic compounds as complexing agents, is increasing, thus the use of humic substances (SH) that are composed of humic acids (AH), fulvic acids (AF) and residual humines (HR) are the most significant constituents of soil organic matter that are defined as organic macromolecules with a complex and stable chemical structure (Schnitzer, 2000; Sutton and Sposito, 2005) is very widespread and in a large amount from countries around the world (Schnitzer, 2000).

The researchers of the SH have devoted a great deal of effort, to demonstrate the positive effect of these on the plants and have found that the mixing of the mentioned substances with nutrients, cause positive effects on the crops from the point of view of nutrition and plant physiology since they have a relevant role in the cycle of mineral elements in the soil (Senesi *et al*., 1996) and the increase in stem, root, leaf length, fresh and dry mass and size and quality has been reported of fruits, as well as yields on crops (Veobides-Amador *et al*., 2018).

Within the organic matter of the soil, the AF are an important fraction (Van-Hess *et al*., 2005) and compared with the AH they generally show a greater chemical and physicochemical activity (Stevenson, 1994) so they are considered as an important part of the buffering capacity of the soil and of the retention, release, biological availability and mobility of metal ions in the soil (Senesi and Miano, 1995).

For example, Abros'kin *et al.* (2016), compared the addition of the humic acid complex with Fe (AH-Fe) with the Fe-EDTA complex, measured the Fe contents added to the soil and foliar route, at the root and stem of the wheat plants and establish that, this last complex remains longer in the soil solution and probably the complex AH with Fe at the root surface.

Likewise, the synergistic effect of the joint application of fulvic substances with Fe chelate has been demonstrated, improving plant nutrition (Cerdan *et al*., 2007). Fulvic acids in the presence of iron produce an increase in chlorophyll a and b with the dose of 5 µg mL^{-1} in tomato plants. Fe is directly responsible for the synthesis of chlorophyll, Chen *et al*. (2001); Pinton *et al*. (1999) suggest that increases in total leaf chlorophyll are more evident with iron deficiency since fulvic substances improve the solubility of Fe in the environment by increasing their assimilation by plants.

Therefore, for the production of crops and obtaining quality fruits, it is necessary to search for economically and ecologically feasible techniques to simply provide nutrients to the root of the plant and that it does not invest too much energy to absorb the nutrients, especially in soils with alkaline pH, but in an orderly manner and in the appropriate proportions for each crop. AF have greater total acidity, a greater number of carboxy functional groups and greater capacity to chelate and exchange cations than AH (Bocanegra *et al*., 2006) and take them to the root cell wall to be absorbed by the root to be transported For the xylem towards the demand points of the plants (López-Salazar *et al*., 2014), therefore, the objective of this work was to determine the effect of an iron fulvate (FFe), on the quality of 'Serrano' chili fruits.

Materials and methods

Study area

The present investigation was carried out in medium-tech greenhouse conditions, since it has mobile curtains, anti-aphids mesh, extractors and heater, located at the Autonomous Agrarian University Antonio Narro, in Saltillo, Coahuila, Mexico (25° 21' latitude north and 101° 02' west longitude, with the altitude of 1 742 meters above sea level). During the experiment, temperatures fluctuated on the day from 21 to 35 °C and at night between 15 and 18 °C.

Obtaining the fulvate of iron

It was used, leonardite (fossil coal ore), provided by GrowMate International LLC of Houston, Texas, USA, ground and sieved to a millimeter diameter mesh, dried in an oven (Lab Oven, Quincy Laboratory Inc. Model 30GC, Series G3-5572) at 70 °C for 24 hours and allowed to cool for one hour, in a glass dryer. Subsequently, 5 g of the 1N potassium hydroxide (KOH, 1N) (CTR Scientific, Monterrey, Nuevo Leon, Mexico) was added to 5 g of the fossil mineral and placed in 'Baño Maria' (Water Bath, Yamato brand, Model BM 100, Japan) at 60 °C for 120 min (López *et al*., 2014).

The solution was allowed to cool for 60 min at room temperature of the laboratory (25 °C), decanted and with anhydrous citric acid, 1 N grade reagent at 99.7% purity (technical control and representations-CTR Scientific, Monterrey, Nuevo León, Mexico) (López *et al*., 2014), the solution was brought to pH 4 in order to separate humic acids (AH) from fulvic acids (AF) (López *et al*., 2014).

The first were discarded and to these latter organic compounds, two percent iron was added and as a source of this element, ferrous sulfate (Fe_2SO_4) was used. In this way, the fulvate of Fe (FFe) was elaborated, in addition, both humic substances were measured total acidity (Schnitzer and Gupta, 1965) and the degree of humification, using the E4/E6 Ratio (Kononova, 1981) (thermo spectronic spectrophotometer, Genesys 20, model 4001/4, series LR45227, USA).

Crop management

Seeds of 'Serrano' chili, variety 'Tampiqueño 74' (Agro Delta, Saltillo, Coahuila), were sown in 200-cavity polystyrene trays, with the substrate 'peat moss' (Premier Horticulture Inc. Quakertown, PA USA) and 'perlita' (Hortiperl, SAPI Termolita from CV Santa Catarina, Nuevo Leon, Mexico) (1: 1 v/v ratio); at 35 days after sowing (dds), when the seedlings had three pairs of true leaves and 15 to 20 cm in length, they were transplanted into plastic pots containing 25 kg of the horizon Ap of a Calcisol soil obtained from the state of Coahuila. The main characteristics of the land used are presented in Table 1.

Table 1. Physical and chemical characteristics of the Ap horizon of the Calcisol soil used in the experiment. OM= organic matter; CO_3= carbonates; CE= electrical conductivity; CIC= cation exchange capacity.

Characteristic	Sand (%)	Clay (%)	Silt (%)	OM (%)	pH (1:2 water)	CO_3 (%)	CE ($dS\ m^{-1}$)	CIC ($cmol_c\ kg^{-1}$)
Ap horizon	37.48	22.52	40	3.41	8.57	52.7	1.1	78.1

The plants were distributed at a distance of 60 cm between them and 80 cm between rows. Three days after the transplant (ddt), the potted plants were fertilized with the nutritive solution (SN) Steiner (Steiner, 1961) which was prepared based on a chemical analysis of the irrigation water (Table 2) and using soluble fertilizers technical grade such as phosphoric acid (H_3PO_4), boric acid (H_3BO_3), ferrous sulfate ($FeSO_4$), copper sulfate ($CuSO_4$) and zinc sulfate ($ZnSO_4$) (CTR Scientific, Monterrey, Nuevo Leon, Mexico), nitrate potassium (KNO_3), calcium nitrate ($Ca(NO_3)_2$), magnesium nitrate ($Mg(NO_3)_2$) (Keswick SA de CV, Saltillo, Coahuila, Mexico).

Table 2. Characteristics of irrigation water (A 1) and nutritional solutions, solution 1 (SN 1) and solution 2 (SN 2) added to the 'Serrano' chili, variety 'Tampiqueño 74'.

	pH	CE (dS m^{-1})	NO_3	H_2PO_4	Cl	SO_4	HCO_3	K	Ca	Mg	Fe	Cu	Zn	B
A 1	7.1				0.7	0.16	0.78	0.28	1.14	0.2				
SN 1	5.7	1.3	7.2	1.3		4.4	0.7	4.3	4.7	2.4	2	1.9	2	0.3
SN 2	5.5	2.6	14.3	2.6		8.9	0.7	8.8	10.6	5	2.5	2.2	2.5	0.5

The units of the anions: nitrates (NO_3); phosphates (H_2PO_4); chlorides (Cl); sulfates (SO_4); bicarbonates (HCO_3) and that of cations: potassium (K), calcium (Ca) and magnesium (Mg) are meq L^{-1}. And those of iron (Fe), copper (Cu), zinc (Zn) and boron (B), are in mg L^{-1}.

The FFe treatments added to the soil were: 200, 400, 600, 800, 1 000 and 1 200 mg kg^{-1} per liter of nutrient solution with five repetitions and as a control only the complete SN Steiner was applied with an electrical conductivity of 2 dS m^{-1}. The amount of nutrient solution that was added in each irrigation was according to the amount lost by evapotranspiration using the weight difference in 24 h which was measured every week to make the corresponding adjustments due to the increase of the plant and consequently to the increase of evapotranspiration.

To avoid accumulation of salts in the growth medium, a wash fraction was added to each irrigation, which resulted in a 25% drain in each irrigation. The treatments were added four times: at the time of transplant, at 15, 45 and 60 ddt. The crop management of the crop was through a biweekly preventive applications calendar using environmentally friendly products such as garlic extract, neem oil and copper sulfate entahydrate.

Methods used for determinations: OM by Walkey-Black; pH by the metric potency method; CE by conductimeter electrode; CIC method of 1N ammonium acetate, pH 7 and CO_3 Bernard's method due to the release of CO_2 in calcimeter, percentages of silt sand and sand by means of the sedimentation rate of the particles.

Table 3 shows the high total acidity (AT) of fulvic acids (AF); that is, a greater number of oxygenated functional groups, with little condensed structure and a greater amount of aliphatic chains.

Table 3. Total acidity (AT), carboxyl functional groups (-COOH), oxhydryls and absorbance ratio at 465 and 665 nm (E_4/E_6) of fulvic acids obtained from leonardite.

Humic substance	AT ($cmol_c$ kg^{-1})	$-COOH^-$ ($cmol_c$ kg^{-1})	$-OH^-$ ($cmol_c$ kg^{-1})	Ratio E_4/E_6
AF	1277	561	716	5.7

AF= fulvic acids.

Quantified quality variables

The fruits of chilli, were harvested at commercial maturity, three cuts were made spaced for 25 days each, being the first cut at 117 ddt. The measured variables of performance and quality were: fresh weight (PF), length (LF), equatorial diameter (DE) (Vernier Stainless-Steel, Truper Brand)

and firmness (FF) (penetrometer, fruit hardess tester, model FHT 200. Extech, instruments), total soluble solids (SST) (Master Refractometer, Atago Brand), number of fruits (NF), dry weight (PSF) and in the foliage plant tissue, Fe and Ca contents (wet digestion-microwave-based digester, Cem brand, Model MARS 6 One Touch Technology, USA and measurement with an atomic absorption spectophotometer, Varian brand, model A5) (Lorenzo *et al*., 2010).

The experiment was established in a completely randomized experimental design, with seven treatments and five repetitions. The results obtained were analyzed by means of an analysis of variance (Anva) and for the separation of means the Tukey test ($p \leq 0.05$) was used, using the statistical package Minitab, version 17 in Spanish for Windows.

Results and discussion

For fruit weight (PF), no significant statistical differences were found; however, numerically (Table 4), it can be seen that by adding the doses of 200 to 800 mg kg^{-1} of the FFe, as the quantity increased the values decreased; but, by adding 1 200 mg kg^{-1} of the FFe, the PF was presented numerically, since it exceeded 84% to the control plants which were grown only with nutrient solution (SN). This was possibly due to the fact that the plants with which they received this treatment were larger fruits with greater diameter and length, but in quantity they were less as seen in Table 4, which suggests that having less quantity reached greater size and weight of fruit.

Table 4. Quality of fruits of serrano chilli, variety 'Tampiqueño 74' with the addition of a fulvate of iron at different concentrations.

Treatment	PF (g)	PSF (g)	LF (cm)	DF (cm)	FI (N)	SST (°Brix)	NF (N°)
FFe2	380.3^{a}	18.17^{ab}	9.32^{a}	1.2^{a}	11.88^{c}	6.85^{a}	35.58^{a}
FFe4	430.4^{a}	19^{ab}	11.26^{a}	1.47^{a}	17.33^{a}	6.37^{a}	23.74^{ab}
FFe6	376.9^{a}	14.7^{ab}	9.86^{a}	1.3^{a}	13.43^{bc}	6.7^{a}	31.66^{ab}
FFe8	342.9^{a}	15.92^{ab}	9.48^{a}	1.47^{a}	13.9^{bc}	6^{a}	22.25^{ab}
FFe10	421.3^{a}	23.66^{a}	10.79^{a}	1.46^{a}	13.57^{bc}	6^{a}	17.55^{b}
FFe12	452.3^{a}	14.32^{b}	11.53^{a}	1.6^{a}	13.2^{bc}	6.18^{a}	21.95^{ab}
SN	245.2^{a}	13.67^{b}	9.67^{a}	1.37^{a}	14.98^{ab}	6.39^{a}	25.16^{ab}

PF= fresh fruit weight; PSF= dry weight fruit; LF= fruit length; DF= fruit diameter; FI= fruit firmness; SST= total soluble solids; NF= number of fruits and SN= nutritive solution. Means values of each treatment with superscripts of equal letters within each column are not statistically different (Tukey $p \leq 0.05$).

The treatments did not cause a significant effect on the length of the fruit (LF), however, for this variable, from the lowest dose to the penultimate, the values ranged by 2.2 units; that is, very little variation; however, when applying the higher dose of FFe, it was numerically exceeded 23%. For the diameter of the fruit (DF) the behavior was similar to that in the previous variable; that is, the treatments did not cause significant effect; however, the dose of FFe at 1 200 mg kg^{-1} exceeded the SN by 33%.

Firmness (FI) measured in Newtons is a very important quality variable, since the shelf life depends largely on it; in this response variable to the addition of the treatments, the addition of 400 mg kg^{-1} of the FFe stands out, since it exceeded the control 16% and the dose of 200 mg kg^{-1} exceeded 45%, this difference being highly significant.

For total soluble solids (SST), no significant difference was found in the application of the treatments; however, numerically the highest value in this variable was obtained with the addition of 200 mg kg^{-1} which exceeded the control with 7% more. In general, commercial serrano chillis are harvested with values between 5 to 6 ºBrix (Gómez and Gómez *et al*., 2017) and the values obtained in the present study ranged from 6 to 6.8.

In Table 4, it was observed that in the number of fruits (NF) the treatments had a significant effect, with the addition of the lower dose of the FFe of 200 mg kg^{-1} the highest value was obtained, being higher in 41% compared with the SN. Also, the lowest dose of 200 mg kg^{-1} significantly exceeded the dose of 1 000 mg L^{-1} by 102%. The values with the other treatments were not different from each other. For the variable dry weight of the fruit (PSF), the treatments had a significant effect, by adding the treatment with the dose of 1 000 mg kg^{-1}, the control (SN) was exceeded by 73%. The rest of the treatments, although they were not significantly different, numerically all were superior to the control and it is important to mention that the low doses of 200 and 400 mg kg^{-1} exceeded the control 33 and 38% respectively.

In the Table 5 shows the iron (Fe) and calcium (Ca) content of plant tissue, where treatments significantly affected these nutrients. With the lowest dose of FFe, higher values were presented in both elements and as the dose was increased, the values decreased considerably. The plants where 200 and 400 mk kg^{-1} of the FFe were added were not deficient in Fe; however, with the rest of the treatments, if they were (Reuter and Robinson, 1997), they indicate that the adequate amounts of this element in the plant tissue of foliage ranges between 60 and 80 mg kg^{-1}.

Table 5. Nutritional analysis of Fe and Ca of the foliage plant tissue of 'Serrano' chilli, variety 'Tampiqueño 74'.

Treatment	FFe2	FFe4	FFe6	FFe8	FFe10	FFe12	SN
Fe^{2+} (mg kg^{-1})	145^a	137.5^a	45^b	42.5^b	60^b	45^b	50^b
Ca^{2+} (%)	3.34^a	3.13^a	1.53^b	0.99^b	1.27^b	0.96^b	0.97^b

Means values of each treatment with superscripts of equal letters within each column are not statistically different (Tukey $p \leq 0.05$).

The main antagonistic element with Fe is Ca and in this experiment by adding 200, 400 and 600 mg kg^{-1} of FFe the plants showed values within sufficient ranges of 1.3%, according to the same authors, while with the rest of the treatments were deficient.

The results found in this study in particular with the high dose of 1 200 mg kg^{-1} contrast with the results of (Adani *et al*., 1998), who reported that with the application of humic and fulvic substances the availability of iron in the growth medium increases due to a reduction of Fe3+ to Fe2+ which causes an increase of this element in the plant.

Authors such as Bocanegra *et al*. (2006), established that fulvic acids (AF) have high total acidity, large number of carboxyl functional groups, high adsorption capacity and exchange cations, greater than humic acids (AH), so that the AF are the responsible for the chelation and mobilization of metal ions, which includes Fe and aluminum (Al) in addition, the ability to chelate nutrients such as Fe and move it; through, the membrane suggests that they play a role as natural chelating agents in the mobilization and transport of Fe and other micronutrients.

This is consistent with the characteristics of the AF mixed with the Fe, added in this work. Alvárez-Fernández *et al*. (2006), indicate that the deficiency of Fe in crops, causes a decrease in the size of the fruits and their firmness, which results in the appearance that is, affects the shelf life of the fruits and therefore the quality, by what, the most commonly used way to correct this deficiency is the use of iron chelates; however, these products are expensive and the amount to be added to the soil and foliar route is high and their effectiveness depends on various factors.

The price of one pound of an iron chelate ranges between 40 and 50 US dollars and depending on the crop they must be added two to three times during the cycle, while the cost of a gallon of an FFe varies between 20 and 22 dollars. Americans and should only be added between one or two times maximum.

Given this situation, the use of humic substances (SH) is outlined as something viable, since, as a fundamental characteristic, they have oxygenated (-COOH-, -OH-, -COO-) and nitrogen (NH^-, NH_2) functional groups. Of these two types of functional groups, the former form more than 80% of the molecule of the mentioned organic substances and with the capacity to exchange cations up to 1 200 cmolc kg^{-1} (Schnitzer, 2000), which have the particularity of complexing and chelating to nutrients (cations).

Given their small molecular size, AF can pass through micropores of biological systems or artificial membranes and AH cannot because of their larger size. The combined ability of AF to chelate nutrients such as Fe and move; through the membranes, it suggests that these compounds may play a role similar to natural chelators in the mobilization and transport of Fe and other micronutrients. In a study in sunflower (*Helianthus annus*) applying a Hoagland solution with isotope ^{59}Fe the AF functioned as chelating agents and it was found that Fe presented greater availability and increase for the plant (Bocanegra *et al*., 2006).

Research conducted by Aminifard *et al*. (2012), applied AF to chilli to determine the effect on quality and found that especially organic compounds, they also increase antioxidant activity, total soluble solids, total carbohydrates and capsaicin. In treatment of rice with AF in calcareous soils, Fe availability and the efficiency of the Fe-AF mixture increase, as fertilizer it was greater than $FeCl_3$ (Pandeya *et al*., 1998); Sánchez-Sánchez *et al*. (2002), reported in lemon trees an increase in the foliar availability of Fe and Cu when they applied twice SH that contained 90.7% AF.

On the other hand, Abros'kin *et al*. (2016), added Fe with EDTA and humic acids (AH) to wheat seeds and found that when applying AH with Fe, the chlorophyll contents of the leaf increased and the Fe contents were higher in the root than in the stem and on the sheet; this was possibly due to the fact that the Fe-AH complex accumulated on the surface of the root, which limited the absorption and subsequent translocation of the element and this resulted in the limitation of lipid metabolism.

In the present work, it was found that in the foliage plant tissue with the addition of the two lowest doses of 200 and 400 mg kg^{-1} of the FFe, the Fe concentration was presented in excessive amounts of 145 and 137.5 mg kg^{-1} respectively since, according to Reuter and Robinson (1997), the adequate concentration of Fe is 60 to 80 mg kg^{-1}, and when applying 1 000 mg kg^{-1} of the FFe, the amount of Fe was within the range optimal with 60 mg kg^{-1}. In reference to calcium according to Reuter and Robinson (1997) the appropriate concentration is 1.3 to 2.5% and with this same dose of 1 000 mg kg^{-1} of the FFe, the concentration of Ca was close to the optimum with 1.27% and with the low doses of 200 and 400 mg kg^{-1} the concentrations were 3.34 and 3.13%.

The foregoing indicates that with the addition of fulvic acids, at the low concentrations studied, the mineral contents increase which suggests that it could bring benefits as in shelf life, as Luchsinger *et al*. (2006) that when increasing the concentration of calcium, the firmness of fruits increases.

The foregoing denotes that the Fe increase in foliage when the two lowest doses of the organic-mineral complex were added as reported by Karakurt *et al*. (2009), as well as Ertani *et al*. (2015). In addition, Aminifard *et al*. (2012) report that with the lowest dose of 25 mg kg^{-1} fulvic acids applied to chilli (*Capsicum annuum* L.) they obtained higher quality of harvested fruit and higher content of antioxidant compounds in fruits and with the highest dose of 250 mg kg^{-1} higher capsicin content was obtained in chili fruits.

This coincides with what was reported by Oliver-Albert (2012) who reports that with the addition of SH with Fe, the concentration in leaf tissue of this element increases considerably above the optimum when there is low availability of it in the growth medium. With this, the effect of the low applied concentrations of the FFe is revealed when evaluating the quality variables measured to the ‘Serrano’ chili fruit, with the exception of the fresh weight, dry weight and fruit length, since, in these measured variables, who caused a significant effect was the higher dose of the organic-mineral compound.

Conclusions

The iron fulvate (FFe), caused a positive effect on the quality variables measured to the ‘Serrano’ chili, grown in a calcisol soil, since with the addition of the FFe10 dose the highest dry weight of fruits was obtained, with the lowest number of fruits per plant and the lowest value in Brix degrees, in contrast to the lowest dose FFe2, the highest number of fruits with the smallest size was obtained, but the highest value in Brix degrees. For the mineral content in plant tissue, the highest Fe and Ca values were found with the two lower doses FFe2 and FFe4.

The use of fulvic substances in combination with inorganic products are obtained by a simple and low cost procedure since raw materials such as leonardite are abundant, cheap and susceptible to chemical modification, so it is a promising way to improve the quality of the harvests of serrano chilli by means of growth stimulation, increasing the efficiency of some mineral nutrients.

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