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# Nutrient Content in Avocado Fruits: Effect of Climate, Water Management, and Flowering Type
# Contenido de Nutrientes en Frutos de Aguacate: Efecto del Clima, Manejo de Agua y Tipo de Floración

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## SUMMARY

Avocado is a fruit (*Persea americana*), that has increased its consumption worldwide. Mexico is the main producer and exporter of avocado in the world, representing more than 30% of the world harvest, of which 73.2% of the total avocado production in Mexico was concentrated in the state of Michoacán. In the state of Michoacán, there is a constant production of avocado fruit throughout the year, but this production is affected by the variation in climate, water management and flowering type, putting agricultural production and sustainable development at risk. The objective of this study was to evaluate the climatic effect, water management, and flowering type on fruit nutrient content in six orchards in the state of Michoacan. Six orchards were evaluated in the towns of Basilia, Cheranguerán, Tecario, Araparicuaro, Peribán and Patamburu in the state of Michoacan, which represent 90% of the climate types (TC), predominant in the state (ACW1, ACW2 and CW1)., with 100% of the water regime (irrigated and seasonal, RH) and 97% of the type of fruit produced (loca and normal, FF). The dry matter contents and total mineral content of the fruit were evaluated. The arrangement of treatments was a factorial [A= water regime (RH); B= type of climate (TC); C= floral flow (FF)], distributed completely randomly with 20 repetitions taking each tree as a repetition. The results indicated that the dry matter content is affected by TC, but not by RH and FF, FF affects the nutritional content more than TC and RH. The type of climate is the factor with the least impact on the mineral content of the fruit. In floral flow, the total nutritional content was significant in four elements with higher values for N, Cl, and Zn in crazy fruit and Na in normal fruit.

***Index words:*** *environment conditions, mineral composition, nutritional relationship*.

## RESUMEN

El aguacate (*Persea americana*), es un fruto que ha incrementado su consumo a nivel mundial. México es el principal productor y exportador de *aguacate* en el mundo que representa más del 30% de la cosecha mundial, del cual el 73.2% de la producción total de aguacate en México se concentra en el estado de Michoacán, pero dicha producción es afectada por la variación del clima, poniendo en peligro la producción agrícola y el desarrollo sostenible. El objetivo del fue evaluar el efecto climático, manejo de agua y el tipo de floración sobre el contenido nutrimental

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del fruto en seis huertas del estado de Michoacán. Se evaluaron seis huertos de las localidades de la Basilia, Cheranguerán, Tecario, Araparicuaro, Peribán y Patamburu del estado de Michoacan, que representan un 90% de los tipos de clima (TC), predominantes en el estado (ACW1, ACW2 y CW2), con un 100% del régimen de agua (riego y temporal, RH) y un 97% del tipo de fruto producido (loca y normal, FF). Se evaluaron los contenidos de materia seca y el contenido mineral total del fruto. El arreglo de tratamientos fue una factorial [A= régimen hídrico (RH); B= tipo de clima (TC); C= flujo floral (FF)], distribuido completamente al azar con 20 repeticiones tomando cada árbol como una repetición. Los resultados indicaron que el contenido de materia seca es afectado por TC, pero no por RH y FF, FF afecta más el contenido nutricional que TC y RH. El tipo de clima es el factor de menor impacto en el contenido mineral del fruto. En flujo floral el contenido nutricional total fue significativo en cuatro elementos con mayor valor para N, Cl, y Zn en fruto loca y Na en fruto normal.

***Palabras clave:*** *condiciones ambientales, composición mineral, relación nutrimental*

## INTRODUCTION

Avocado is a fruit that has increased its consumption worldwide in recent years (Reyes *et al.*, 2021), especially in countries such as the United States, France, Germany, and Spain, among others, which has resulted in a large increase in planted areas in all the countries that produce it, such as Mexico, Chile, Spain, South Africa, New Zealand, Australia, Peru, Israel, and the United States, among others: Chile, Spain, South Africa, New Zealand, Australia, Peru, Israel and the United States among others (Madero and Castro, 2019). In Mexico 253 000 hectares are sowed with avocado crop, more than 70% of the established area is located in the state of Michoacan, Jalisco in the western region, represents almost 12%, the State of Mexico has a planted area of 3611 hectares in 21 municipalities and Nayarit with more than 4350 hectares (Zuleta and Hurtado, 2022[1]).

In the state of Michoacán, there is a constant production of avocado fruit throughout the year, showing a difference with other producing regions such as the state of Nayarit in Mexico and worldwide in other regions such as Israel, Spain, California, Chile, South Africa and Australia (Cruz-Lopez, 2021[2]). Avocado production in Michoacan is affected by the variation of climate and microclimate along the avocado belt, depending on the topography, the topological arrangement of the orchards, their exposure to the sun and prevailing winds, as well as their altitude concerning sea level, which affects the biochemical characteristics of the fruit (Shezi, Magwaza, Mditshwa, and Tesfay, 2020). These climatic variations jeopardize agricultural production, potentially worsening malnutrition, poverty, and sustainable development, especially in developing countries (Peng *et al*., 2020).

In this context, avocado (*Persea americana* Mill., Lauraceae) is a highly nutritious fruit crop that is becoming a global commodity. However, current avocado plantations are highly dependent on temperature and humidity (Rodríguez *et al*., 2020). In the long term, these plantations may become unsustainable due to inadequate management and these in turn may not be able to respond to biotic and abiotic stresses in the face of climate change (Ingvarsson and Dahlberg, 2019). Therefore, the objective of the present study was to evaluate the climatic effect, water management, and flowering type on fruit nutrient content in six orchards in the state of Michoacán.

## MATERIALS AND METHODS

### Selection of Orchards and Trees

The vegetative material used was avocado (*Persea americana*). The study was conducted during the cycle (2022-2023) in six adult commercial orchards of cv. Hass, accidentally generated by Rudolph Hass in 1926 (Llambias, 2023), established La Basilia (1680 m of altitude), Cheranguerán (1740 m of altitude), Tecario (1798 m of altitude), Araparicuaro (1941 m of altitude), Peribán (1550 m of altitude) and Patamburu (1985 m of altitude). The climates considered represent more than 90% of the climate types (CT) of the area established with avocado in Michoacán (Rocha-Arroyo, Salazar, Bárcenas, González, and Cossio, 2011).

[1] Zuleta, S. A., & Hurtado, C. A. G. (2022). *Políticas fiscales sobre incentivos tributarios para el sector agropecuario de Colombia y México en la producción de aguacate Hass.* Tesis para obtener el grado de Doctor en Ciencias. Corporación Universitaria Minuto de Dios. Disponible en https://repository.uniminuto.edu/bitstream/10656/16833/1/AcevedoSantiago-G%C3%B3mezC%C3%A9sar_2022.pdf

[2] Cruz-López, D. F. (2021). *Análisis de la competitividad y ventaja comparativa revelada del aguacate hass de México en el mercado mundial*. Tesis para obtener el grado de doctor en Ciencias en Economía Agrícola. Universidad Autónoma Chapingo. Disponible en https://hdl.handle.net/20.500.12098/1016

These regions are distributed in three climates (Table 1); Semi-warm sub-humid ((A)C($W_1$)), found in the localities of Patamburu and Tecario in the municipality of Tancítaro and Tecario, with a climate that represents 46.2% of the planted area. Semi-warm humid ((A)C (m)($W_2$)), found in Cherangueran and La Basilia, municipality of Uruapan, with 22.8% of the area planted. Temperate humid (C(w2) (w)), of Peribán and Araparícuaro, municipality of Peribán and Tancítaro, respectively, with 22.3% of the planted area (Gutiérrez-Contreras, Lara, Guillén, and Chávez, 2010). The relation of these climates represents 94% of the planted area in the state (Table 1). Regarding water management, the two basic climates were irrigated (48% of the planted area) and non-irrigated (rainfed) (52% of the remaining area). The soil type of the six orchards corresponds to the Andept classification (Alcalá-de Jesús, Ortiz, and Gutiérrez, 2001). The main soil units found by locality are presented in Table 2.

In each orchard, 20 trees were selected without canopy crossing, in orchards of the same age and at similar phenological stages of development and size following the methodology of Hofman and Jobin (1999) and Ferguson, Thorp, Barnett, and Triggs (2003), to avoid failures in the evaluation of the results. They were also from similar geographic orientation and from indeterminate flowers, as well as a composite sampling of each component of each fruit to avoid variations in nutritional (Ashton *et al*., 2006), longitudinal (Boyd *et al*., 2007), and equatorial fruit content.

## Variables Evaluated

### Maturity

Avocado fruits from the field were weighed fresh on an analytical scale (Uline, H-9984), and their length and width were measured with a vernier (Jiavarry, F-20). Likewise, the parts of the avocado were separated with a knife (Caledonia) into peel, pulp, tegument, and stone in 0.5 mm thick slices, which were weighed fresh on an analytical balance (Uline, H-9885), to be introduced in an oven (Ecosel, 9030) at 64 °C until a constant weight was obtained.

### Nutrient Extraction

Samples of plant tissue were weighed on an analytical balance (Uline, H-9885) to obtain the nutritional content of the fruit (peel, pulp, tegument, and seed) using various techniques; total nitrogen was obtained by semi-microKjeldahl digestion modified to include $NO_3$ (Bremner, 1965). For the elements phosphorous (P), calcium (Ca), magnesium (Mg), iron (Fe), cupper (Cu), manganese (Mn), zinc (Zn), and boron (B) it was done by wet digestion with a mixture of $HNO_3$ and $HClO_4$. Ca, Mg, Fe, Cu, Mn, and Zn were determined directly from the digestion in atomic absorption equipment, an AA. Spectrometer M Series (Thermo, Electron Corporation). Boron was determined from the digestion by the Azomethine-H spectrophotometric method (Enríquez, 1989), with a Spectronic 21D Spectrophotometer (Milton Roy). P was determined by the ascorbic acid method (Anderson and Ingram, 1994) using a Spectronic 21D Spectrophotometer (Milton Roy). K and Na were extracted in water (Jaimes, Severiche, and Colpas, 2015). K and Na were determined directly in the AA Spectometer M Series Atomic Absorption equipment. Thermo brand (electron Corporation). Cl was determined by titration with silver nitrate (Morh method) (Chávez-Cury, 2006). Subsequently, the results obtained were added to obtain the total extraction of nutrients per fruit.

**Table 1. Average annual temperatures and total rainfall in the studied locations.**

| Location | Minimal | Main | Maxima | Rainfall |
|---|---|---|---|---|
| | - - - - - - - - - - - | ° C | - - - - - - - - - - - | mm |
| La Basilia | 7.9 | 16.2 | 27.9 | 2171.6 |
| Cherangueran | 8.4 | 17.5 | 31.2 | 1442.2 |
| Araparicuaro | 9.0 | 15.8 | 26.2 | 1650.3 |
| Patamburu | 11.5 | 17.5 | 28.1 | 919.4 |
| Periban | 8.1 | 17.7 | 30.2 | 1507.4 |
| Tecario | 13.8 | 18.4 | 25.8 | 910.8 |

**Table 2. Main soil groups in the avocado area of locations of Michoacan.**

| Location | Andosol | Leptosol | Luvisol | Otro |
|---|---|---|---|---|
| | % | | | |
| La Basilia | 52.4 | 15.9 | 13.9 | 18.1 |
| Cherangueran | 52.4 | 15.9 | 13.9 | 17.8 |
| Araparicuaro | 45.2 | 32.7 | 16.4 | 5.7 |
| Patamburu | 83.4 | 10.4 | 3.5 | 2.7 |
| Periban | 45.2 | 32.7 | 16.4 | 5.7 |
| Tecario | 36.1 | 19.3 | 14.7 | 29.9 |

### Statistical Analysis

Data were evaluated by analysis of variance under a factorial design with completely randomized distribution and comparison of means with Tukey's test ($P \leq 0.05$) using STATISTICA software version 10.0 (Statsoft, 2011).

## RESULTS AND DISCUSSION

The variable fresh and dry fruit weight analyzed for each factor studied indicated that there is a significant effect in the factors RH (5.4*) and FF (4.4*), while the effect of these factors disappears when the dry matter of the fruit is analyzed. Conversely, TC was not significant in fresh fruit, but it was significant in dry fruit (5.8** $P < 0.01$). This indicates that, although the type of flowering and water management influence fresh weight, climate has a greater effect on fruit dry matter, which is ultimately the most important and proves the homogeneity of the fruit studied about FF and RH (Table 1). This is probably due to the altitudinal gradient, topography, sun exposure, and prevailing winds; such variability can affect the production and quality of 'Hass' avocado fruit (Lobell, Cahill, and Field, 2007). In addition, orography, tree phenology (mainly flowering time) and the quality of the infrastructure for fruit handling also affect fruit production and postharvest behavior (López-López and Cajuste-Bontemps, 1999; Salazar-García, Zamora, and Vega, 2005; Salazar-García, Cossio, and González, 2007a[3]; Salazar-García, Cossio, González, and Lovatt, 2007; Rocha-Arroyo *et al.*, 2011).

The statistical analysis carried out on the nutritional content of the fruit is also presented in (Table 3). As can be seen, only the nutrient macroelements N and Cl showed significant effects concerning FF. Ca in RH, as well as in TC. No other macroelement showed a significant difference. Regarding microelements, a greater significant response was found, in fact, twice as many nutrients were significant, Cl, Na, Mn and Zn showed significance due to the effect of flowering type: Cl (26.4**; $P < 0.001$), Na (9.7**; $P < 0.01$) and Zn (5.8**; $P < 0.01$); for the water regime, Mn (8.7**; $P < 0.001$); TC was the factor that did not show statistical significance in micronutrients. According to Salazar-García, González, and Tapia (2011), the type of climate and flowering time of 'Hass' avocado in Michoacán affected the weight of the different fruit tissues, such as skin (exocarp), pulp (mesocarp), testa (endocarp+tegmen) and embryo (cotyledons+embryonic axis), as well as their nutrient composition.

The origin of the fruit, concerning the three factors studied, showed significant differences depending on whether the fruit was fresh or dry (Table 3). In fresh fruit, there was an effect on water management (5.4*; $P < 0.05$), and on floral flow (4.4*; $P < 0.05$), while in fruit dry matter the effect was climatic (5.8**; $P < 0.01$). Fresh fruit weight was higher in rainfed fruit (220.9 g) than in irrigated fruit (190.2 g), likewise, normal flowering flow produced higher fresh fruit weight (223.2 g), than mad flowering flow (203.2 g). However, when PS was analyzed, these two variation factors (FF and RH) were not significant (Table 3), because they produced the same amount of dry matter in both irrigated and rainfed conditions and both normal flowering and crazy flowering. In this variable, the type of climate was significant (5.8**; $P < 0.001$), being the SH climate the one with the highest fruit dry matter weight (61 g) different from TS and SS with (52.8 g and 50.1 g), respectively. Dry matter weights in rainfed (56.6 g) and irrigated (51.2 g), and those of normal (55.7 g) and crazy (53.9 g) flower flow were statistically equal.

[3] Salazar-García, S., Cossio-Vargas, L. E., & González-Durán, I. J. L. (2007a). Reciclamiento de nutrimentos por las hojas de aguacate 'Hass'. En *Actas VI Congreso Mundial de la Palta-Aguacate-Avocado* (pp. 12-16). Nayarit, México: INIFAP.

**Table 3. F-statistic values for fresh fruit, dry fruit, and mineral content from each factor studied climate (TC), water management (RH), and flowering flow (FF).**

| Variable | Water management | Climate type | Flow of flowering |
|---|---|---|---|
| | RH | TC | FF |
| Fresh Fruit | 5.4* | 2.2 | 4.4* |
| Dried Fruit | 2.4 | 5.8** | 0.3 |
| N | 0.1 | 1.4 | 8.6** |
| P | 2 | 1.2 | 0.9 |
| S | 1.1 | 0.3 | 1.9 |
| K | 3.6 | 0.4 | 2.3 |
| Ca | 5.5* | 7.9** | 0 |
| Mg | 1.1 | 0.1 | 2.4 |
| Cl | 0 | 2.5 | 26.4** |
| Na | 0 | 0.6 | 9.7** |
| Fe | 0 | 0.5 | 0.1 |
| Cu | 3.2 | 0.4 | 0.9 |
| Mn | 8.7** | 1.8 | 1.7 |
| Zn | 2.3 | 1.4 | 5.8* |
| B | 0.1 | 1.7 | 1.5 |

* Significant ($P < 0.05$), ** highly significant ($P < 0.01$); according to Tukey's test.

This is because soil moisture can influence in affecting yield and fruit quality (Kaneko, Gould, Campbell, Snelgar, and Clearwater, 2022), which is a price factor in the market (Van Rooyen and Bower, 2005), this variable can be altered by water management (Moreno-Ortega, Pliego, Sarmiento, Barceló, and Martínez, 2019), sun strike, hormone homeostasis (Taylor and Cowan, 2001), rootstock type, fruit load (Kaneko *et al*., 2022), type and position of the branch containing fruit (Boyd *et al*., 2007), fruit size (Hofman and Jobin, 1999), tie-up, fruit maturity (Bhuyan *et al*., 2019), flowering type (Arpaia, Collin, Sievert, and Obenland, 2015) and the presence of pests and diseases (FAO, 2023).

The lowest water contents correspond to the SH climate fruit with 72.6 (±1.6), not different from SS with 74.6% (±1.4), but from TS with 75.8% (±0.9), in the other factors (RH and FF) the water contents and therefore dry matter were equal with values between (73.1 - 75.1%) (Figure 1), thus demonstrating that both water management and type of flowering do not affect the dry matter content of the fruit, as was already pointed out for the case of the water factor by Kaneko *et al*. (2022), also agrees with Arpaia *et al*. (2015), who points out that for fruits of different floral flow, the contents are equal in the dry matter provided that they are similar in maturity stage. In this work, the homogeneity of dry matter in the factors of water regime and floral flow allows the assumption that the fruits had similar maturity stages (Moreno *et al*., 2019). Likewise, the flow of crazy or late summer flowering has been reported to have a higher dry matter content of the fruit and even higher quality than normal flowering at equal stages of harvest maturity (Licona-Vargas, 2007[4]), however, in this work both types of fruit have similar dry matter contents, although the crazy flowering fruit has a better nutritional condition in N, Cl, Na and Zn, which were significant concerning normal flowering.

Nutrient removal by water regime effect was analyzed and is shown in (Figure 2). The concentration of some macronutrients was different by the RH effect. K concentration was higher in rainfed (3.6 kg $Mg^{-1}$; ±0.12) than in irrigated (3.2 kg $Mg^{-1}$; ±0.18), a similar effect was found for Ca with 0.152 kg $Mg^{-1}$ (±0.009) in rainfed and 0.12 kg $Mg^{-1}$ (±0.0.01). Mg was the only macronutrient that had a higher concentration in irrigation with 0.28 kg $Mg^{-1}$ (±0.012) than in rainfed with 0.266 kg $Mg^{-1}$ (±0.008). Regarding micronutrients, significant effects were also detected in three elements. Cu concentration was higher in rainfed with 3.71 g $Mg^{-1}$ than in irrigated (±0.24) 3.03 (±0.21), with similar trends in Mn (1.61 g $Mg^{-1}$; ±0.087) versus (1.2 g $Mg^{-1}$; ±0.094). Zn was the micronutrient with

[4] Licona-Vargas, A. L. (2007). *El papel de la clasificación local de tierras en la generación y transferencia de tecnología: El caso del policultivo café-plátano para velillo-sombra en Veracruz, México.* Tesis para obtener el grado de doctor en ciencias. Colegio de Postgraduados. Disponible en http://hdl.handle.net/10521/1601

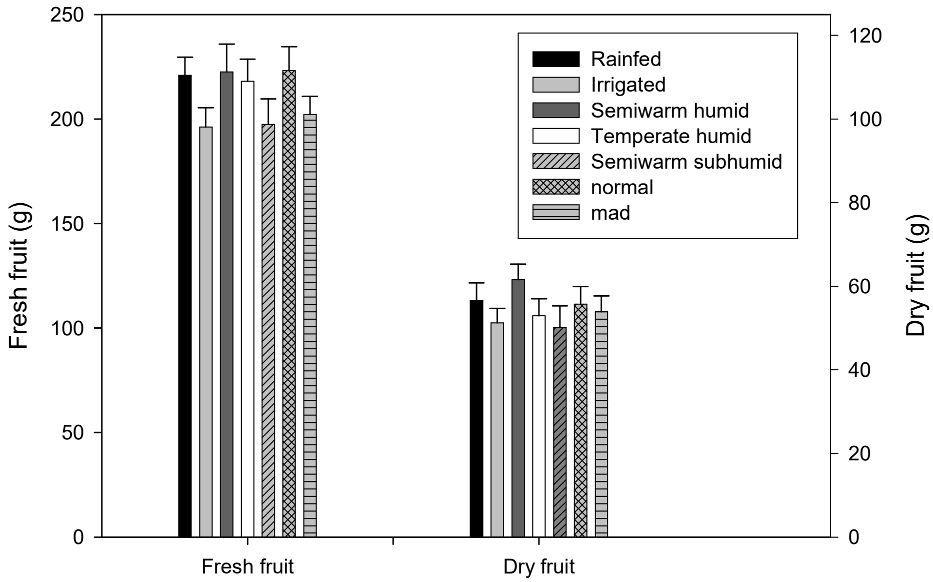


**Figure 1. Effect of climate, water management, and type of flowering on the fresh and dry weight of "Hass" avocado fruit in Michoacán. (SH = semi-warm humid; TS = temperate sub-humid; SS = semi-warm sub-humid).**

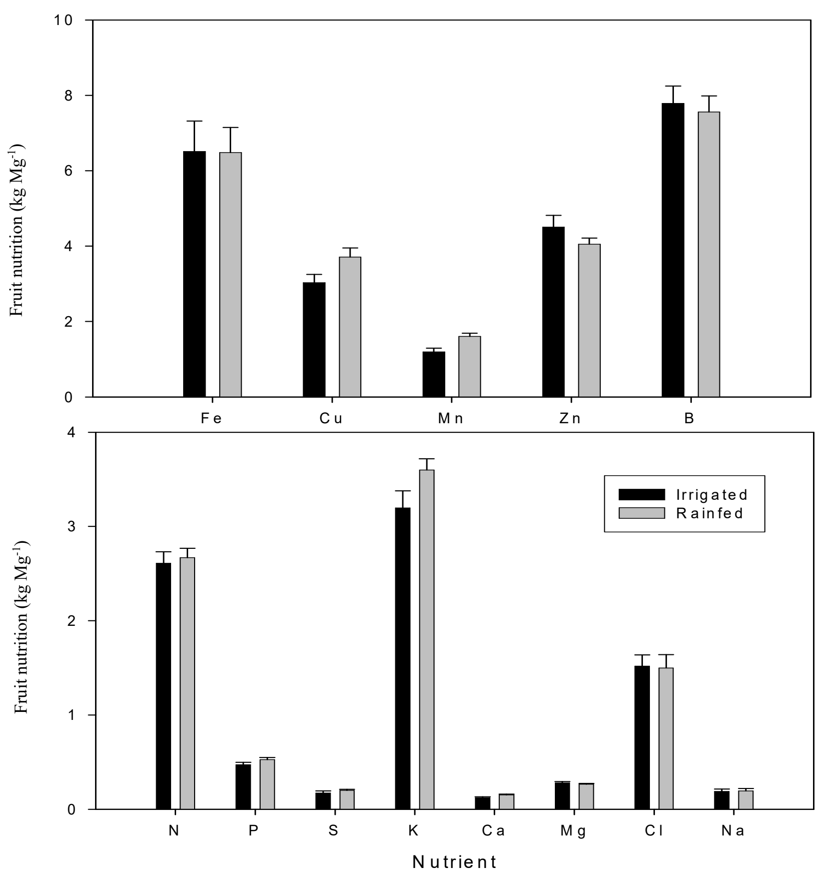


**Figure 2. Nutrient removal of macro and micronutrients in "Hass" avocado fruit due to the effect of the water regime.**

a higher concentration in irrigated than in rainfed conditions, with a concentration of 4.5 g $Mg^{-1}$ (±0.31) versus only 4.05 g $Mg^{-1}$ (±0.16), respectively. According to Serrano *et al*. (2022), orchard climate can influence the time it takes for the fruit to reach physiological maturity from the anthesis stage, with warmer and sub-humid climates [A(C)W] generally reaching legal harvest maturity earlier. One of the advantages of avocados is the possibility of remaining longer on the tree once maturity is reached, however, the chemical content of the fruit can be modified.

The study of nutrient removal due to TC, RH, and FF (Figure 2), showed that it presents a differential effect, depending on the nutrient element, and that it is not constant in the three factors evaluated. RH presented a response in K, Ca, and Mg, which at a given moment can be the least available cations in irrigation (Tapia, Marroquín, Cortés, Anguiano, and Castellanos, 2007), this could be verified since rainfed orchards presented higher concentrations of K (3.6 kg $Mg^{-1}$; ±0.12) and Ca (0.152 kg $Mg^{-1}$ ±0.009), than in irrigation with 3.2 kg $Mg^{-1}$ (±0.18) for K and 0.12 kg $Mg^{-1}$ (±0.0.01) for Ca (Figure 2). This may be important for proper nutritional management and scheduling of cultivation practices, which can affect postharvest quality (García-Martínez *et al*., 2021).

The different soil moisture management did not present problems of vascular damage and pulp staining, so a possible blockage of K to Ca and subsequent damage by malformation of cell membranes by increased permeability and leaching of phenols from the vacuole to the cytoplasm, as argued by Bangerth (1979). However, the results obtained in this work are below the normal fruit contents for calcium and magnesium reported by Boyd *et al*. (2007), with 0.2 and 0.4 kg $Mg^{-1}$, respectively. The values found for Ca, Mg, and K indicate that local research is needed to adjust the coefficients found in other reports for nutrient ratios in fruit.

About climate, the three types analyzed in this work (Figure 3), produced contrasting results. In general, the temperate sub-humid climate (TS) showed a visible tendency to obtain a higher concentration of nutrients. However, in macronutrients, there was a wider response than the RH factor, since in three cases the differences were significant. Therefore, climate can affect the external characteristics of 'Hass' avocado fruits (size, shape, and roughness of the skin), phytochemical and oil content (Salazar-González, Castro, Martínez, Casson, and Urrea, 2022) climate change can affect avocado production mainly due to its effect on temperature-sensitive phenological stages, such as floral differentiation, anthesis, fruit set and fruit development.

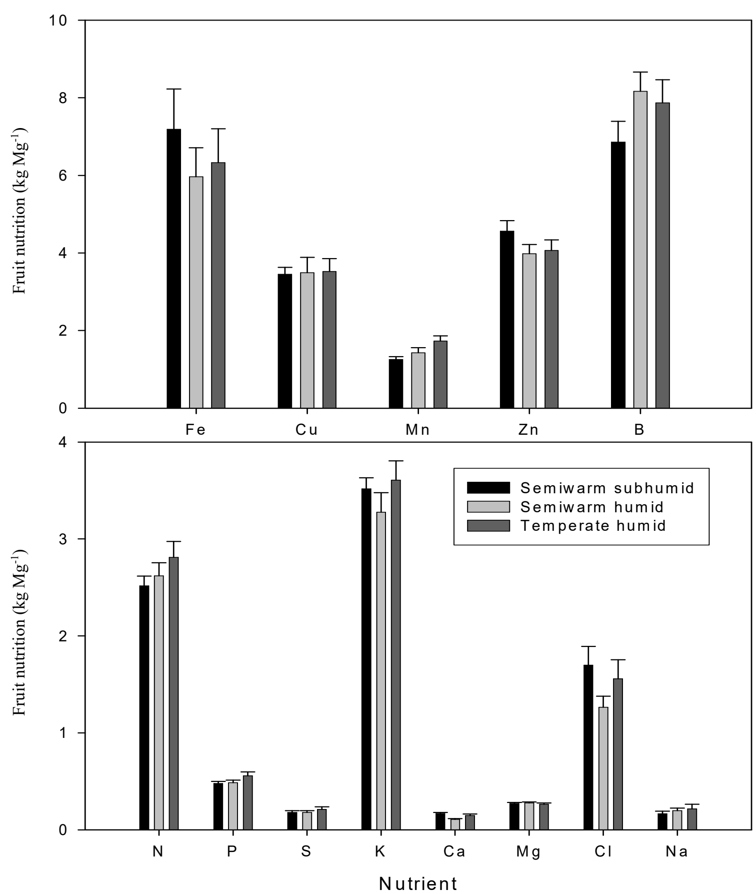


**Figure 3. Effect of climate type on the nutritional removal of avocado fruit var 'Hass' in Michoacán.**

According to Figure 3, in N, TS had a higher concentration (2.81 kg $Mg^{-1}$; ±0.17), than SS (2.62 kg $Mg^{-1}$; ±0.13), but it was only significant concerning SH (2.52 kg $Mg^{-1}$; ±0.1). In Ca the climates TS (0.17 kg $Mg^{-1}$; ±0.01), and SH (0.15 kg $Mg^{-1}$; ±0.02) were equal, but both are different from SS which had only 0.11 kg $Mg^{-1}$ (±0.008). The same response was had in Cl only that climate SH had 1.70 kg $Mg^{-1}$ (±0.2) and TS recorded 1.56 kg $Mg^{-1}$ (±0.2), both were different from SS which stood at 1.26 kg $Mg^{-1}$ (±0.11). For micronutrients, there was no difference in Na, Fe, Cu, and B, but there was a difference in Mn and Zn. In Mn, the TS climate (1.73 g $Mg^{-1}$; ±0.13) was the one with the highest removal, surpassing both the SH climate (1.25 g $Mg^{-1}$; ±0.07) and SS (1.43 g $Mg^{-1}$; ±0.13), the latter two presenting the same statistical value. About Zn, the best response was obtained in the SH climate with 4.56 g $Mg^{-1}$ (±0.27), different from the other two climates with 4.06 g $Mg^{-1}$ (±0.28) for the coldest climate (TS) and only 3.98 g $Mg^{-1}$ (±0.23) for the driest climate (SS).

In general, the better performance of the TS climate in the content of N, Ca, Cl, and Mn in fruit, which is the freshest of the three, can be explained because low temperatures limit the volatilization of N (Zhang *et al*., 2021) and this can be better absorbed and subsequently expressed in the fruit, as occurred in this work. Regarding the other elements it may be due to the lower water temperature that reduces its viscosity and reduces the leaching of nutrients such as N, Ca, and Cl, however, the low concentration of Zn in fruit has been associated with low temperatures (Newett, Rigden, and Carr, 2018), due to this the SH climate presented the highest level of Zn in fruit with 4.56 g $Mg^{-1}$ (±0.27) different from TS with 4.06 g $Mg^{-1}$ (±0.28).

Nutrient analysis of the two fruit flows (crazy or normal fruit) produced significant results for six nutrient elements (Figure 4). N, K Cl, Na, and Zn, showed significant differences, but except Na, there was a consistent superior trend in the crazy flowering flow for all these elements, with a higher concentration. Thus, for N the difference was better for the August or crazy flow with 2.9 kg $Mg^{-1}$ (±0.11) versus 2.4 g $Mg^{-1}$ (±0.09) of the winter or normal flow, this same trend was found for the K elements with 3. 6 g $Mg^{-1}$ (±0.15) versus 3.3 kg $Mg^{-1}$ (±0.13), in Cl it was 1.9 kg $Mg^{-1}$ (±0.14) versus 1.1 kg $Mg^{-1}$ (±0.08), in Zn it was 4.5 g $Mg^{-1}$ (±0.22) versus 3.9 g $Mg^{-1}$ (±0.19). The trend of the superiority of the August flowering was broken with the extraction obtained in the Na element, being favorable for the normal flow with values of 252 g $Mg^{-1}$ (±31.5) and 135 g $Mg^{-1}$ (±16.8), for the crazy flow.

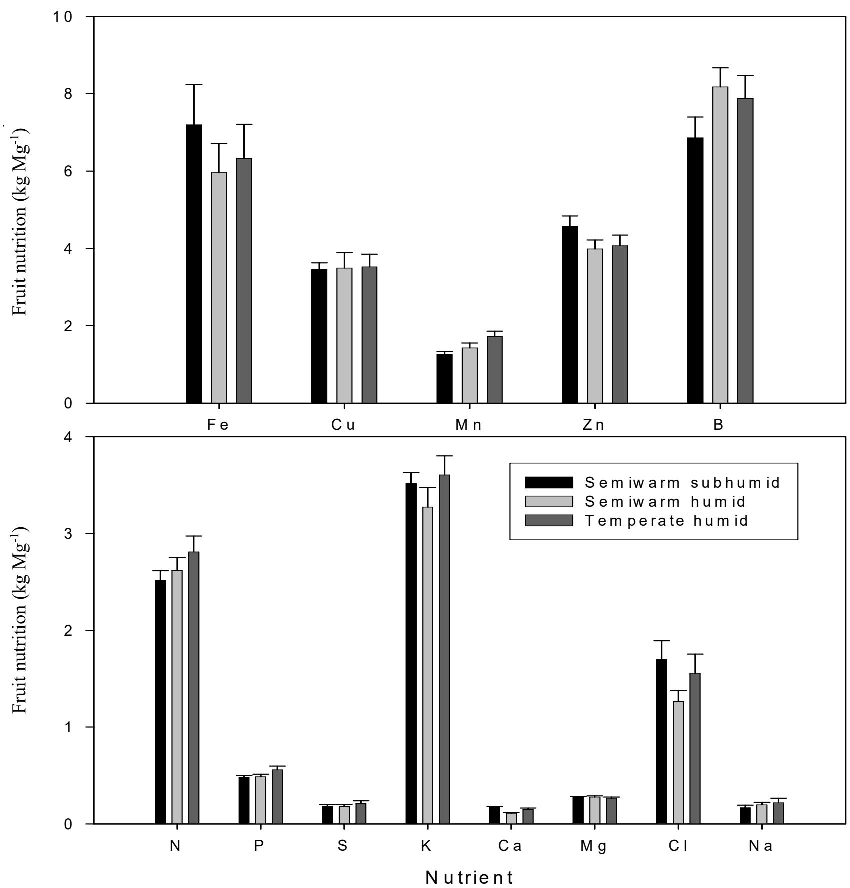


**Figure 4. Nutritional removal of minerals in 'Hass' avocado fruit due to the effect of flowering flow origin.**

The crazy flowering fruit also presented the highest amount of significant elements, concerning the normal flowering (as well as all the other factors studied), since, respectively, crazy and normal fruit: N 2.9 kg $Mg^{-1}$ (±0.11) vs. 2.4 g $Mg^{-1}$ (±0.09); K with 3.6 g $Mg^{-1}$ (±0.15) vs. 3.3 kg $Mg^{-1}$ (±0.13); Cl was 1.9 kg $Mg^{-1}$ (±0.14) vs. 1.1 kg $Mg^{-1}$ (±0.08); Zn was 4.5 g $Mg^{-1}$ (±0.22) vs. 3.9 g $Mg^{-1}$ (±0.19); the only element found higher in normal than in crazy blossom was Na. These elements are associated in the case of N with higher protein content and K with higher fruit quality, although at high concentrations they can cause fruit disorders, which did not occur in this study even with high concentrations (Figure 4). Likewise, low concentrations of Zinc have been associated with pulp spots (Vorster and Bezuidenhout, 1988), although in this work the concentrations obtained here are high so that the problem described could not occur in any flowering.

## CONCLUSIONS

The climate type is the factor with the least impact on fruit mineral content, with effect only on N, Ca, Cl, Mn, and Zn. Dry matter content is affected by TC, but not by RH and FF, affecting nutritional content more than TC and RH. In flower flow, the total nutrient content was significant in four elements with higher values for N, Cl, and Zn in crazy fruit and Na in normal fruit. However, more research is needed to obtain for each flowering stage the relationships applicable to this region for pulp quality and shelf life, resistance to physiological malformations and pathogenic organisms, as well as the content of oils and fats and their persistence over time.

## ETHICS STATEMENT

Not applicable.

## CONSENT FOR PUBLICATION

Not applicable.

## AVAILABILITY OF SUPPORTING DATA

Data sets used or analyzed during the current study are available from the corresponding author upon reasonable request.

## COMPETING OF INTERESTS

The authors declare that they have no competing interests.

## FINANCING

Not applicable.

## AUTHORS' CONTRIBUTIONS

Project management, fund acquisition: L.M.T.V., and H.D.G.S. Research formulation: L.M.T.V. Field execution: L.M.T.V. Data analysis: H.D.G.S. Original draft preparation, journal submission, and follow-up: R.Z.V., and L.M.T.V. Participated in the field phase, data organization and draft review: A.S.H.V. Responsible for field phase, data organization, and draft review: H.D.G.S. Responsible for soil sampling planning, lab analysis, and draft review: J.L.G.M. Responsible for soil sampling planning, lab analysis, and draft review: J.L.G.M. Responsible for soil sampling, lab analysis, and draft review: J.L.G.M. Responsible for soil sampling planning, lab analysis, and draft review: J.L.G.M. Responsible for field phase and draft review: H.D.G.S. Responsible for data tabulation and analysis and draft review: L.M.T.V. Planning soil sampling, lab analysis, and draft review: J.L.G.M. Responsible for data analysis and draft review: J.M.G.D., and P.P.R. Assisted in original draft preparation, review and final editing for submission: P.P.R.

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