Article

Nutritional regime in chilhuacle I: autumn-winter cycle

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Abstract

Due to the scarcity of information on the nutrition of chilhuacle, the objective of the research was to evaluate the growth, yield and physical quality of chilhuacle fruits in response to the nutritional regime in the autumn-winter cycle. Eight nutritional regimes were supplied considering the phenological stages of the species: vegetative, reproductive and fruiting. The experimental design was completely randomized, with five repetitions and one plant per experimental unit, which was a black polyethylene container with a capacity of 15 L with red tezontle as a substrate. The distance between plants was 50 cm in a staggered topological arrangement. Nutrient solutions were supplied by a drip irrigation system. The results indicated that, in the autumn-winter cycle, with a period of 168 days (average temperature of 20.2 °C) considered from transplantation to the last harvest, the nutritional regime that consisted of supplying 14 mEq L^{-1} of NO_3^- in the vegetative stage (duration 21 days), 10:0.75:9.25 mEq L^{-1} of NO_3^-:$H_2PO_4^-$: SO_4^{2-} in the reproductive stage (31 days) and 12:7 mEq L^{-1} of NO_3^-:K^+ in the fruiting stage (116 days) significantly increased the leaf area, dry matter of stem, of leaf, of fruit, of the whole plant, the number of fruits per plant and the yield of fresh and dry matter of fruits per plant, while the percentage of large fruits (> 4 g) was 63.64% and of medium fruits (2 to 3.9 g) was 36.36%.

Keywords: cultivation cycle, phenological stages, phenology.

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Introduction

Chilhuacle is one of the oldest dried chilis in Oaxaca (López *et al*., 2016) and is the main ingredient to prepare Oaxacan black mole (García-Gaytán *et al*., 2017; Martínez-Gutiérrez *et al*., 2021). In recent years, this variety has positioned itself commercially as one of the dried chilis of greatest economic value in regional and national markets. Its high price is due to the lack of improved cultivars, high susceptibility to pests and diseases, ignorance of nutritional requirements, low yield and high production costs (López *et al*., 2016; García-Gaytán *et al*., 2017). As for nutrition, it is relevant to satisfy the nutritional demand of chilhuacle in order to obtain high yields and the quality of the fruits demanded by the market.

In this way, the nutritional regime aims to provide essential nutrients in sufficient quantity and in the ionic form absorbed by plants in order to cover the requirements by phenological stage (Valentín-Miguel *et al*., 2013; Nieves-Gonzales *et al*., 2015; Siles, 2019), and increase productive potential, fruit quality (Valentín-Miguel *et al*., 2013) and appropriate development from seedling to fruit filling (Sieiro *et al*., 2020), in addition to reducing susceptibility to pests, diseases and deficiencies. By means of nutrient solutions, the supply of both macro and micronutrients can be manipulated (Steiner, 1984).

In relation to the former, Nitrogen (N), phosphorus (P) and potassium (K) are the most demanded by the plant. N is required in high quantities during the early stages of growth; if the demand is not met, the plant manifests chlorotic leaves and dwarfism, which affects the yield (Eguez *et al*., 2022). P is a constituent of adenosine triphosphate (ATP) (Siles, 2019), nucleic acid former and transfer of genetic information (Díaz-Durán *et al*., 2022). Deficiency symptoms are a purple coloration on stems and leaf ribs (Eguez *et al*., 2022). K is an element of fruit quality; the deficiency is manifested by the tendency of the plant to wither on dry and sunny days, short internodes and leaf fall (Eguez *et al*., 2022).

Calcium (Ca), magnesium (Mg) and sulfur (S) are elements required in less quantity than N, P and K; however, they have important functions in plants. Ca is the second messenger in signal transduction; the deficiency presents itself as apical rot (Sun *et al*., 2010), Mg is a constituent of chlorophyll, so it is related to the production of carbohydrates (Pinilla *et al*., 2011), in insufficiency, chlorotic leaves appear in the middle third of the leaf.

S in the form of SO_4^{2-} stimulates growth, increases the quality and uniformity of the fruits, favoring resistance to cold, tolerance to drought and salts (Nazar *et al*., 2011), the deficiency causes the young leaves to turn yellow and, in pepper, growth is reduced (Silva *et al*., 2017). The response of plants to the supply of nutrients during the production cycle is modified by the environment in which they grow, for this reason, the objective of the research was to evaluate the effect of different nutritional regimes on the yield and quality of chilhuacle fruits, grown in the autumn-winter cycle.

Materials and methods

Location of the experiment

The experiment was carried out in a greenhouse with a polyethylene plastic cover in the Experimental Field of the Faculty of Agricultural Sciences (18º 50' 51" west latitude, 1 868 masl) at the Autonomous University of the State of Morelos, Cuernavaca, Morelos, Mexico, from September 2019 to February 2020.

Plant material

Black chilhuacle seeds obtained from fruits from San Juan Bautista Cuicatlán, Oaxaca were used. The fruit is a trapezoidal-shaped berry of intense green color in immature state, bright brown with tender and soft exocarp in mature state and black in complete dehydration (García-Gaytán *et al*., 2017), the average size is 6 cm long by 5.2 cm wide, average weight in fresh of 40 g and in dry of 5.6 g, the average yield per plant is 1 400 g of fresh matter and 250 to 434 g of dry matter (Urbina-Sánchez *et al*., 2020). In open field, chilhuacle grows to 1.45 m (López and Pérez, 2015) and in greenhouse, it has an average height of 1.78 m (López *et al*., 2016).

Nutritional regimes in the experiment

Eight nutritional regimes were designed to nourish the chilhuacle using the Universal Nutrient Solution (UNS) by Steiner (1984) as control and basis for making anion and cation modifications in the three phenological stages of the species. The vegetative stage, which lasted 21 days from transplantation until 50% of the plants showed the first flower bud (5 ±1 mm), two concentrations of NO_3^- in 12 mEq L^{-1} (control) and 14 mEq L^{-1} (modified UNS) were considered (Table 1). The reproductive stage, lasting 31 days from when 50% of the plants showed the first flower bud until 50% showed the first fruit (10 ±1 mm in length), the regimes 12:1:7 (control) and 10:0.75:9.25 mEq L^{-1} of NO_3^-: $H_2PO_4^-$:SO_4^{2-} were used.

Table 1. Supply of different nutrient solutions evaluated during the different phenological stages of chilhuacle (*Capsicum annuum* L).

Nutritional regime	Vegetative stage NO_3^-	Reproductive stage NO_3^-:$H_2PO_4^-$:SO_4^{2-}	Fruiting stage NO_3^-:K^+
	(mEq L^{-1})		
R1*	12	12:1:7	12:7
R2	12	12:1:7	14:9
R3	12	10:0.75:9.25	12:7
R4	12	10:0.75:9.25	14:9
R5	14	12:1:7	12:7
R6	14	12:1:7	14:9
R7	14	10:0.75:9.25	12:7
R8	14	10:0.75:9.25	14:9

*Control= nutritional regime based on the Universal Nutrient Solution by Steiner (1984).

The fruiting stage began with the presence of the first fruit (10 ±1 mm in length) in 50% of the plants until the last harvest, the ratios NO_3^-: K^+ were modified in 12:7 (control) and 14:7 mEq L^{-1} (Table 1). The nutrient solutions were supplied in different concentrations according to the phenological stage, considering the values shown in Table 1 as 100%: vegetative, 80%; reproductive, 90%; in fruiting until the topping of the plant, 90%; from the topping to physiological maturity of the last fruit, 70%; then at 50% until the harvest of the last fruit.

In each regime, the following micronutrients were provided (mg L^{-1}): Fe (Fe-EDTA), 7; H_3BO_3, 2.88; $MnCl_2$, 1.81; $ZnSO_4$, 0.22; $CuSO_4$, 0.18; H_2MoO_4, 0.02. The ions present in the water were considered and, before adding the fertilizers, the pH was adjusted to 5.5 with sulfuric acid. Eleven irrigations were made daily (8:00 am to 18:00 pm), 1 min for 21 days (vegetative stage), 2 min at the beginning of the reproductive stage (31 days) and 3 to 4 min in the fruiting stage (116 days). Temperature and relative humidity were considered to estimate irrigation time.

Experiment management

The management of the crop consisted of removing the axillary shoots by performing a Dutch-type pruning with four secondary stems from the first bifurcation, the flowers of the first two bifurcations were also removed to promote vigorous stems, maintain vegetative development, reduce flower abortion and increase fruit set from the third to the fifth internode. The plant was topped above the tenth internode with the purpose of stopping longitudinal growth. Pollination was carried out during flowering-fruiting manually by mechanical vibrations of the plants through the tutors.

Experimental design and response variables

The experimental design was completely randomized, with five repetitions per treatment. The experimental unit was a black polyethylene container with a capacity of 15.14 L, red tezontle as a substrate with granulometry ≤1 cm in diameter, with a plant. The data obtained were subjected to an analysis of variance and the variables that had the effect of treatments were performed the multiple comparison test of means LSD ($p\leq 0.05$); in both cases, the SAS program (Version 9.0) was used. The plant height was measured with a tape measure, from the base of the stem to the apex of the longest stem; the relative chlorophyll content was measured with a SPAD-502 (Konica Minolta®) considering the fifth leaf after the apex of each stem.

The leaf area was quantified with a leaf area integrator (Li-Cor, LI3100C®), the main stem diameter was measured 2 cm from the neck of the plant above the substrate, measured with a digital vernier (Stainless Hardened®). The root length was measured with a tape measure from the neck of the plant to the longest root. The root volume was determined by the water displacement technique with the use of a 2 L graduated cylinder, the root was introduced into a known volume of water and the increase corresponded to the volume of the organ. The dry matter of root, stem, leaf, fruit and total was obtained by dehydrating each of the organs in a forced circulation oven (Luzeren, DGH9070A®) at a temperature of 70 °C until the weight of the dry matter remained stable.

The fruit variables were obtained as they were harvested in the mature state: length and equatorial diameter were measured with a digital vernier from the peduncle to the apex of the fruit as well as the middle part of the fruit. The weight of fresh and dry matter of fruit were weighed with a digital scale (Ohaus Corporation USA CS 2000®), number of fruits as a result of the total fruits produced per plant, yield of fruits in fresh and dry weight obtained by the total sum of the fruits produced per plant.

The data were subjected to a test of normality and homogeneity of variance. The variables: number of fruits per plant, large and medium fruits were subjected to a test of goodness and fit. The variables show the original data, the separation of means, the transformation with the square root was used for large fruits (> 4 g) and with the logarithm for number of fruits/plant and for medium fruits (2 to 3.9 g).

Results and discussion

The cycle of chilhuacle from transplantation to harvest of the last fruit was 168 days, with an average temperature of 20.2 °C, average relative humidity of 73.83% and average luminous intensity of 2 252.1 lux. If the duration of the seedling phase is considered, which also belongs to the vegetative stage (44 days), the full duration of the crop was 212 days. López-López and Pérez-Bennetts (2015) reported for chilhuacle, 35 to 45 days of seedling stage, 90 days of growth-development and 60 days of harvest, to have a cycle of 185 to 195 days in open field.

The ideal average temperature to grow chilhuacle is 28 °C so that the phenological stages occur favorably. Mármol (2010) a temperature ±20 °C causes a delay in flowering, fruiting and anomalies in the fruits. In relation to morphological variables of chilhuacle plants, the different regimes supplied had a statistically similar effect ($p\leq 0.05$) on the relative concentration of chlorophyll, stem diameter and root volume (Table 2), the average values were 75.87 SPAD units, 16.97 mm and 97.75 cm^3, respectively. Regarding the stem diameter, in *Capsicum*, it represents the ability of the plant to support the weight of branches, flowers and fruits, as well as reducing the risk of breakage of the aerial part.

In pepper, the growth rate occurs at 6 cm per unit of time using complete nutrient solutions than in solutions with -N and -K that delay the stem diameter, leaf area and number of leaves (Eguez *et al*., 2022). In Chilhuacle, it is possible that the stems have the same mechanical strength regardless of the nutritional regime due to the statistically similar percentage ($p\leq 0.05$) of dry matter destined for this organ.

The nutritional regime (R7) with 14 mEq L^{-1} of NO_3^-, 10:0.75:9.25 mEq L^{-1} of $NO_3^-:H_2PO_4^-:SO_4^{2-}$ and 12:7 mEq L^{-1} of $NO_3^-:K^+$ in the vegetative, reproductive and fruiting stages, respectively, increased the leaf area by 110.35% in relation to that of the plants that received a regime (R6) with 14, 12:1:7 mEq L^{-1} of $NO_3^-:H_2PO_4^-:SO_4^{2-}$ and 14:9 mEq L^{-1} of $NO_3^-:K^+$ and even the control regime (R1:12, 12:17, 12:7), which showed the largest leaf area. In this sense, the requirements (R7: 10:0.75: 9.25 and 12:7 mEq L^{-1}) for flowering and fruiting with respect to the leaf area are lower to increase in this variable, as the formation of fruits.

Measuring leaf area and chlorophyll concentration can indicate the nutritional state of the plant, the interception of solar radiation, CO_2 exchange, evapotranspiration and photosynthetic efficiency (Misle *et al*., 2013). The regimes (R7) 14, 10:0.75:9.45, 12:7 and (R6) 14, 12:1:7, 14:9 mEq L^{-1} were statistically similar ($p \leq 0.05$) in the relative chlorophyll content, however, the leaf area was completely different, as was the height of the plant, and there were no statistical differences in root length. These data suggest different photosynthetic capacity, which may have been modified by the variation of nutrition in the reproductive and fruiting stages (Table 2).

Table 2. Effect of nutrition in the different phenological stages of chilhuacle (*Capsicum annuum* L.) on growth variables.

	Nutritional regime mEq L^{-1}								
	Vegetative stage NO_3^-	Reproductive stage $NO_3^-:H_2PO_4^-:SO_4^{2-}$	Fruiting stage $NO_3^-:K^+$	RCC (SPAD)	Leaf area (cm^3)	Plant height (cm)	Stem diameter (mm)	Root length (cm)	Root volume (cm^3)
R1	12*	12:1:7*	12:7*	78.34 a	5553.4 abc	140.8 abc	16.22 a	32.64 ab	88 a
R2	12	12:1:7	14:9	76.02 a	5851.7 abc	138.78 abc	15.94 a	28.66 b	94 a
R3	12	10:0.75:9.25	12:7	77.46 a	6381.1 ab	152.18 a	17.36 a	35.92 ab	104 a
R4	12	10:0.75:9.25	14:9	73.5 a	4968.4 c	131.18 bc	15.7 a	35.04 ab	104 a
R5	14	12:1:7	12:7	76.68 a	5279.3 bc	134 bc	18.56 a	32.58 ab	96 a
R6	14	12:1:7	14:9	74.02 a	3157.9 d	128.82 c	16.12 a	39.58 a	106 a
R7	14	10:0.75:9.25	12:7	76.1 a	6642.7 a	147.32 ab	18.12 a	32.22 ab	84 a
R8	14	10:0.75:9.25	14:9	74.9 a	5508.1 abc	128.3 c	17.76 a	31.6 ab	106 a
LSD	-	-	-	5.7	1280.5	18.03	3.18	8.92	43.16
CV (%)	-	-	-	5.83	18.34	10.16	14.54	20.65	34.27

Means with the same literal in columns are statistically equal according to the LSD test ($p \leq 0.05$). RCC= relative chlorophyll content; LSD= least significant difference; CV= coefficient of variation; *= control.

In plant height, the regime (R3) with 12 (NO_3^-), 10:0.75:9.25 ($NO_3^-:H_2PO_4^-:SO_4^{2-}$) and 12:7 ($NO_3^-:K^+$) mEq L^{-1} induced plants 18.62% higher than the regimes (R6) 14, 12:1:7, 14:9 and (R8) 14, 10:0.75:9.25, 14:9, which were statistically similar (Table 2). Chilhuacle has an average height of 128.30 to 152.18 cm with topping to 10 internodes, while to 20 internodes, it could reach values of up to ± 170 cm, this variation could be an effect of environmental conditions and a management without pruning, where the plant has a free growth of stems, leaves, flowers and fruits.

In *Capsicum*, nutrition particularly affects stem diameter and leaf number (Eguez *et al*., 2022). Therefore, knowing the phenological stages and identifying the ideal moment of application of nutrient solutions (Valentín-Miguel *et al*., 2013) would allow reaching the maximum yield potential of a crop.

Regarding the production of dry matter, in root it was statistically similar ($p \leq 0.05$) with any of the regimes evaluated, with an average of 16.80 g. In stem, in the regime (R3) with 12, 10:075:9.25, 12:7 and (R7) 14, 10:075:9.25, 12:7 mEq L^{-1}, an average value of 135.5 g was obtained, which represented an increase of 41.45% compared to plants with the lowest accumulation of dry matter (Table 3). The dry matter of leaf was similar in plants nourished with 12, 12:1:7, 14:9 (R2); 12, 10:0.75:0.95, 12:7 (R3); 14, 10:0.75:9.25, 12:7 (R7) and 14, 10:0.75:9.25, 14:9 (R8) mEq L^{-1}, with an average of 135.5 g; the increase was 80.91% compared to plants nourished with the regime (R6) 14, 12:1:7, 14:9 mEq L^{-1}.

Table 3. Effect of nutrition in the different phenological stages of chilhuacle (*Capsicum annuum* L.) on the production of dry matter.

	Nutritional regime mEq L^{-1}							
	Vegetative stage NO_3^-	Reproductive stage $NO_3^-:H_2PO_4^-:SO_4^{2-}$	Fruiting stage $NO_3^-:K^+$	DMR (g)	DMS (g)	DML (g)	DMF (g)	DMTOT (g)
R1	12*	12:1:7*	12:7	15 a	108.2 ab	45.6 ab	116.6 ab	285.4 abc
R2	12	12:1:7	14:9	13.8 a	95.6 b	53.2 a	110 ab	272.6 abc
R3	12	10:0.75:9.25	12:7	20.2 a	135.8 a	54.4 a	100.2 ab	310.6 ab
R4	12	10:0.75:9.25	14:9	17.2 a	96.2 b	35.4 ab	110 ab	258.8 ab
R5	14	12:1:7	12:7	16.2 a	97.4 b	45 ab	86 ab	244.6 bc
R6	14	12:1:7	14:9	18.2 a	94 b	29.6 b	54.6 b	196.4 c
R7	14	10:0.75:9.25	12:7	15.2 a	135.2 a	54.6 a	145.2 a	350.2 a
R8	14	10:0.75:9.25	14:9	18.6 a	106.8 ab	52 a	84.2 ab	261.4 abc
LSD	-	-	-	8.58	37.56	19.78	76.02	93.48
CV (%)	-	-	-	39.65	26.83	33.23	58.51	26.62

Means with the same literal in columns are statistically equal according to the LSD test ($p \leq 0.05$). DMR= dry matter of root; DMS= dry matter of stem; DML= dry matter of leaf; DMF= dry matter of fruits per plant; DMTOT= dry matter of the whole plant; LSD= least significant difference; CV= coefficient of variation; *= control.

By implementing all the indispensable elements in nutrition, the obtaining of fresh and dry matter increases in a balanced way between the aerial and root parts (Eguez *et al*., 2022). The lack of N (in root) and K (in leaf) significantly reduces the production of dry matter when these elements are insufficient. The dry matter of the fruits per plant and that of the whole plant increased 165.93% and 78.3%, respectively, with the regime (R8) 14, 10:0.75:9.25, 12:7 mEq L^{-1} compared to (R6) 14, 12:1:7, 14:9 mEq L^{-1}.

In both variables (R8 and R6), they were affected by the variation of the nutrient solution of the reproductive stage and the fruiting stage since the concentration of NO_3^- in the vegetative stage was 14 mEq L^{-1}. In the chili known as *chile de agua*, the production of dry matter (66.7 g $plant^{-1}$) increased according to the osmotic potential (0.09 MPa), being significant in the yield and the harvest index (Valentín-Miguel *et al*., 2013). In leaves such as roots, the accumulation of dry matter is found in a higher concentration of P than with -N and -K (Eguez *et al*., 2022). P, in addition to being a former of the ATP molecule (Siles, 2019), nucleic acids and transfer of genetic information (Díaz-Durán *et al*., 2022), its concentration of accumulable dry matter in the plant is higher.

Regarding the physical quality of the fruits, these were analyzed in two categories: large (> 4 g) and medium (2 to 3.9 g). In this study, 884 fruits of chilhuacle were evaluated, of which 64.03% corresponded to the first and 35.97% to the second. Studies conducted by Vázquez-Vázquez *et al*. (2011) in jalapeño pepper determined that the percentage of first quality fruits is from 46.1 to 50.5%, while the second from 43.4 to 46.9%, third of 7% and only from 0.2 to 0.9% of fourth quality. As for large fruits of chilhuacle, they had an average length of 50.35 mm, there were no significant differences between the nutritional regimes, the same happened for the diameter of the base of the fruit (42.85 mm), average weight of fresh matter (27.95 g) and dry matter (5.45 g) of the fruit (Table 4).

Table 4. Effect of nutrition in the different phenological stages of chilhuacle (*Capsicum annuum* L.) on the production of large fruits.

	Nutritional regime (mEq L^{-1})									
	Vegetative stage NO_3^-	Reproductive stage $NO_3^-:H_2PO_4^-:SO_4^{2-}$	Fruiting stage $NO_3^-:K^+$	FL (mm)	FD (mm)	WFMF (g)	WDMF (g)	NFP	YFMF (g)	YDMF (g)
R1	12*	12:1:7*	12:7*	52.46 a	42.49 a	28.09 a	5.49 a	16.2 a	449.2 ab	89.4 ab
R2	12	12:1:7	14:9	47.16 a	43.56 a	29.86 a	5.64 a	14.4 ab	477.8 ab	95.2 ab
R3	12	10:0.75:9.25	12:7	46.89 a	44.49 a	29.19 a	5.45 a	11.4 ab	342.8 ab	65.2 ab
R4	12	10:0.75:9.25	14:9	55.95 a	42.09 a	29.46 a	5.76 a	16.2 a	520 ab	98.6 ab
R5	14	12:1:7	12:7	53.76 a	43.88 a	30.51 a	5.67 a	12.2 ab	351.4 ab	66.6 ab
R6	14	12:1:7	14:9	46.43 a	42.43 a	29.75 a	4.84 a	6.6 b	197.3 b	37.3 b
R7	14	10:0.75:9.25	12:7	53.53 a	41.84 a	27.81 a	5.43 a	21 a	606.8 a	116.4 a
R8	14	10:0.75:9.25	14:9	46.61 a	41.84 a	24.97 a	5.33 a	15.2 ab	418.2 ab	84.6 ab
LSD				11.74	5.9	8.51	1.27	0.45	397.41	74.29
CV (%)				18.18	10.7	23.62	18.11	33.8	73.37	70.61

Means with the same literal in columns are statistically equal according to the LSD test ($p \leq 0.05$). FL= fruit length; FD= fruit base diameter; WFMF= weight of the fresh matter of the fruit; WDMF= weight of the dry matter of the fruit; NFP= number of fruits per plant; YFMF= yield of the fresh matter of fruits per plant; YDMF= yield of the dry matter of fruits per plant. LSD= least significant difference; CV= coefficient of variation; *= control.

The results present similarity in weight of fresh and dry matter of fruits, indicating the ability of the plant to maintain itself in different nutritional regimes; however, due to the impact on other components of the yield (number of fruits plant^{-1}, among others), it is possible to propose modifications in agronomic management that generate a higher yield, with fewer resources. Regarding the number of fruits per plant, the control (12, 12:1:7, 12:7 mEq L^{-1}) and the regimes (R4) 12, 10:0.75:9.25, 14:9 and (R7) 14, 10:0.75:9.25, 12:7 mEq L^{-1} had 171.71% more than the plants nourished with (R6) 14, 12:1:7, 14:9 mEq L^{-1} corresponding to the vegetative, reproductive and fruiting stages.

The ratio between the nutrient solution (15, 1.25, 8.75 mol of $NO_3^-:H_2PO_4^-:SO_4^{2}$, 11.25, 5 and 8.75 mol of $Ca^{2+}:Mg^{2+}: K^+$) and the osmotic potential (0.090 MPa) in chile de agua increased the fruits plant^{-1} (100.3) and the yield (2601.5 g plant^{-1}), recommending 0.036 MPa up to 75 dat, subsequently 0.054 MPa to harvest 2 kg plant^{-1} (Valentín-Miguel *et al*., 2013). Regarding the yield of fresh and dry matter of chilhuacle fruits, it increased by 207.5 and 212.06%, respectively, with the regime (R7) 14 (NO_3^-), 10:0.75:9.25 (NO_3^-:$H_2PO_4^-$:SO_4^{2-}) and 12:7 (NO_3:K^+) mEq L^{-1} compared to plants that received 14, 12:1:7, 14:9 (R6) mEq L^{-1} (Table 4).

From the above data, it is deduced that the yield component number of fruits plant^{-1} is the one that had the most influence on the yield of fresh and dry matter of large fruits. Considering this, it is convenient to implement and evaluate agronomic practices aimed at increasing this variable, such as manipulating the number of stems per plant, foliar fertilization with the aim of increasing the set and the size of flowers and fruits, among others.

In the category of medium fruits, the diameter of the base of the fruit, the weight of fresh and dry matter were statistically similar ($p\leq 0.05$), regardless of the nutritional regime; the average values were 34.46 mm, 15.35 g and 2.36 g. The opposite happened with the length of the fruit, number of fruits per plant and the yield of fresh and dry matter of fruits (Table 5). The first variable was favored 50.9% with the regime (R4) of 12, 10:0.75:9.25, 14:9 mEq L^{-1} compared to the fruit length of plants nourished with (R3) 12, 10:0.75:9.25, 12:7 mEq L^{-1}. In chilhuacle, the requirements of P (0.75 mEq L^{-1}) were lower during the course of the phenological stages.

Table 5. Effect of nutrition in the different phenological stages of chilhuacle (*Capsicum annuum* L.) on the production of medium fruits.

	Nutritional regime (mEq L^{-1})									
	Vegetative stage NO_3^-	Reproductive stage NO_3^-:$H_2PO_4^-$:SO_4^{2-}	Fruiting stage NO_3^-:K^+	FL (mm)	FD (mm)	WFMF (g)	WDMF (g)	NFP	YFMF (g)	YDMF (g)
R1	12*	12:1:7*	12:7*	42.58ab	33.83a	16.14a	2.36a	11.2ab	172ab	26 ab
R2	12	12:1:7	14:9	32.37bc	33.33a	13.94a	2.34a	6.8ab	89.6ab	15.8ab
R3	12	10:0.75:9.25	12:7	30.03c	37.14a	14.24a	2.32a	9.4ab	119.2ab	20.6ab
R4	12	10:0.75:9.25	14:9	45.32a	31.49a	16.86a	2.2a	4.2b	66.6b	9.6b
R5	14	12:1:7	12:7	40.92abc	35.16a	15.78a	2.4a	6ab	88.4ab	13.4ab
R6	14	12:1:7	14:9	38.35abc	35.46a	15.86a	2.36a	9.2ab	123.2ab	19ab
R7	14	10:0.75:9.25	12:7	42.94ab	33.63a	15.48a	2.44a	11.8a	184.4a	28.8a
R8	14	10:0.75:9.25	14:9	41.59abc	35.67a	14.48a	2.43a	5b	72.4ab	11.5ab
LSD	-	-	-	11.69	6.91	4.32	0.39	1.23	116.74	17.65
CV (%)	-	-	-	23.12	15.57	21.84	12.88	36.4	79.16	75.93

Means with the same literal in columns are statistically equal according to the LSD test ($p\leq 0.05$). FL= fruit length; FD= fruit base diameter; WFMF= weight of the fresh matter of the fruit; WDMF= weight of the dry matter of the fruit; NFP= number of fruits per plant; YFMF= yield of the fresh matter of fruits per plant; YDMF= yield of the dry matter of fruits per plant; LSD= least significant difference; CV= coefficient of variation; *= control.

In habanero pepper *var* Big Brother, the optimal requirements of P were with 1.5 mEq L^{-1}, however, the accumulation of P is concentrated in greater proportion in roots, mainly affecting the production of fruits (Nieves-González *et al*., 2015). The number of fruits increased 156.52%, the yield of fresh matter of fruits 176.87% and the yield of dry matter of fruits 200% with the regime (R7) 14 (NO_3^-), 10:0.75:9.25 (NO_3^-:$H_2PO_4^-$:SO_4^{2-}) and 12:7 (NO_3^-: K^+) mEq L^{-1} in relation to the plants that received (R4) 12, 10:0.75:9.25, 14:9 mEq L^{-1}. Vázquez-Vázquez *et al*. (2011) reported a similar percentage of first and second quality fruits, regardless of fertilization.

In chilhuacle, the addition of ammonium in 3 mEq L^{-1} in the NS, the yield increased by 54.1% in the black cultivar (434.34 g $plant^{-1}$) than in the red cultivar (274.14 g $plant^{-1}$) (Urbina-Sánchez *et al*., 2020). Chile de agua requires high amounts of K (until 90 days), then of N (next 150 days) and to a lesser extent of P (Valentín-Miguel *et al*., 2013). In this sense, *Capsicum* require more N and K in the early stages of the crop, while P, K and Mg increase as flowering and fruiting begin.

The different response of the plant to nutrition may be related to the regime, species and environmental variables of the production region, such as temperature as it can increase or decrease the quality and yield of a crop. In pepper, a daytime temperature <18 ºC produces parthenocarpic fruits, while <10 ºC reduces their growth, causing an excess of small, poorly set, poor quality, pointed, seedless and deformed as type 'cookies or balls' fruits (Mármol, 2010). In the present experiment, the average temperature during the fruiting stage (116 d) was 18.27 ºC, it is possible that this environmental condition is part of the explanation for the presence of small fruits (< 2 g of dry matter) deformed in the form of 'wings'.

In relation to the percentage production of large fruits (> 4 g) and medium fruits (2 to 3.9 g), the regimes with 12, 10:0.75:9.25, 14:9 (R4); 14, 12:1:7, 12:7 (R5); 14, 10:0.75:9.25, 12:7 (R7) and 14, 10:0.75:9.25, 14:9 (R8) (mEq L^{-1}) made the plants have on average 71.6% of large fruits and 28.4% of medium fruits. The opposite happened in the plants nourished with 14, 12:1:7, 14:9 mEq L^{-1} (R6), which had 35.8% of large fruits and 64.11% of medium fruits (Table 6). The above data indicate that the concentration of phosphorus in the reproductive stage and that of potassium in the fruiting stage are important; however, the relationship with other anions affects the final response, in this case, the weight of the dry matter of the fruits.

Table 6. Effect of nutrition in the different phenological stages of chilhuacle (*Capsicum annuum* L.) on the percentage of large and medium fruits.

	Nutritional regime (mEq L^{-1})			Large fruits (%)	Medium fruits (%)
	Vegetative stage NO_3^-	Reproductive stage NO_3^-:$H_2PO_4^-$:SO_4^{2-}	Fruiting stage NO_3^-:K^+		
R1	12*	12:1:7*	12:7*	59.88 ab	40.12 ab
R2	12	12:1:7	14:9	53.23 ab	43.77 ab
R3	12	10:0.75:9.25	12:7	53.69 ab	46.31 ab
R4	12	10:0.75:9.25	14:9	77.7 a	22.3 b
R5	14	12:1:7	12:7	68.66 a	31.34 ab

	Nutritional regime (mEq L^{-1})			Large fruits (%)	Medium fruits (%)
	Vegetative stage NO_3^-	Reproductive stage $NO_3^-:H_2PO_4^-:SO_4^{2-}$	Fruiting stage $NO_3^-:K^+$		
R6	14	12:1:7	14:9	35.89 b	64.11 a
R7	14	10:0.75:9.25	12:7	63.64 a	36.36 ab
R8	14	10:0.75:9.25	14:9	76.4 a	23.6 b
LSD	-	-	-	1.81	0.39
CV (%)	-	-	-	10.57	20.63

Means with the same literal in columns are statistically equal according to the LSD test ($p \leq 0.05$). LSD= least significant difference; CV= coefficient of variation; large fruits= weight of dry matter greater than 4 g; medium fruits= weight of dry matter 2 to 3.9 g; *=control.

In the regional markets of Oaxaca, chilhuacle is marketed as large and medium fruits. Large fruits are considered of first quality, while medium fruits, of second quality. Chilhuacle is not considered in the Official Mexican Standard NMX-FF-107/1-SCFI-2014 (SEGOB, 2014) for the production of dried chilis, such as cascabel, ancho, mulato and pasilla chilis, where in the quality standards, size (length), color, appearance, spiciness, weight and health predominate, so it represents an opportunity to generate quality parameters for chilhuacle.

Conclusions

The nutrition of chilhuacle through a regime based on a specific solution for the vegetative, reproductive and fruiting stages benefited growth variables and yield components such as fresh and dry matter of the fruit. In the autumn-winter cycle, the nutrition of chilhuacle with the regime 14 mEq L^{-1} of NO_3^- in the vegetative stage, 10:0.75:9.25 mEq L^{-1} of $NO_3^-:H_2PO_4^-:SO_4^{2-}$ in the reproductive stage and 12:7 mEq L^{-1} of $NO_3^-:K^+$ in the fruiting stage significantly increased the leaf area, dry matter of stem, of leaf, of fruit, of the whole plant, the number of fruits per plant and the yield of fresh and dry matter of fruits per plant, while the percentage of large fruits (> 4 g) was 63.64% and of medium fruits (2 to 3.9 g) was 36.36%.

Recommendations

It is proposed to continue carrying out studies to determine the factors that influence the quality of chilhuacle fruits in relation to size, appearance, physical and organoleptic characteristics as determined by the Official Mexican Standard NMX-FF-107/1-SCFI-2014 for the production of commercial dried chilis in our country.

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