



# Evaluation of different substrates in the cultivation of two varieties of *Capsicum chinense* Jacq. "chile habanero" Mexican chili, in a controlled environment

## Evaluación de diferentes sustratos en el cultivo de dos variedades de *Capsicum chinense* Jacq. "chile habanero" ají mexicano, en ambiente controlado

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### Article Data

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### Abstract

In order to demonstrate the importance of nutrients, the present research work was carried out with the following objectives: to determine the production of the orange ( $V_1$ ) and red ( $V_2$ ) varieties using different organic substrates, to identify the most appropriate substrate for the cultivation of the two varieties and to compare the quantity of fruits of  $V_1$  and  $V_2$  of *Capsicum chinense* Jacq. "habanero chili" using the different substrates. The statistical results show that when observing the main effects for plant size, the effect of the variety-substrate and variety interaction were not significant, while the substrate effect is significant, with better growth and development of plants in  $S_4$  and  $S_3$ . Another effect of study is the effect of average leaf size (cm), in the  $S_4$  and  $S_3$  were recorded better average leaf size. In the number of flowers in the variety-substrate interaction and the variety effect were not significant, the best flowering occurred in  $S_4$ . In number of fruits,  $V_1$  presented a higher number of fruits compared to  $V_2$  in  $S_4$  and  $S_3$ . In the evaluation of average fruit weight (g), in the interaction and variety effects there were no significant differences, the substrate effect is significant where the best results were obtained in  $S_4$ . Finally, the average fruit size (g), in  $V_1$  is significantly greater than  $V_2$ , while in  $S_4$ ,  $S_3$  and  $S_2$  the plants presented greater average fruit size without significant differences among the three substrates

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### Resumen

Los ajíes son los principales insumos en la gastronomía, en la mayoría de los casos su producción es extensiva, sin tener en cuenta la fertilización de los suelos de cultivo, con la finalidad de demostrar la importancia de los nutrientes se realizó el presente trabajo de investigación con los siguientes objetivos: determinar la producción, de las variedades anaranjada ( $V_1$ ) y roja ( $V_2$ ) empleando diferentes sustratos orgánicos, identificar el sustrato más apropiado para el cultivo de las 2 variedades y comparar la cantidad de frutos de las  $V_1$  y  $V_2$  de *Capsicum chinense* Jacq. "chile habanero" utilizando los diferentes sustratos. Los resultados estadísticos señalan al observar efectos principales para tamaño de plantas, el efecto de la interacción variedad-sustrato y variedad no fueron significativos, mientras el efecto sustrato es significativo alcanzando mejor crecimiento y desarrollo las plantas en  $S_4$  y  $S_3$ . Otro efecto de estudio es el efecto tamaño promedio de hojas (cm), en los  $S_4$  y  $S_3$  se registraron mejor tamaño promedio de hojas. En el número de flores en la interacción variedad-sustrato y el efecto variedad resultaron no significativos, el mejor florecimiento ocurrió en el  $S_4$ . En cantidad de frutos la  $V_1$  presentó mayor cantidad de frutos en comparación con la  $V_2$  en  $S_4$  y  $S_3$ . En la evaluación de peso promedio de frutos (g), en los efectos de interacción y variedad no hubo diferencias significativas, el efecto sustrato es significativo donde los mejores resultados se obtuvieron en el  $S_4$ . Finalmente, el tamaño

**Palabras clave:**

*Capsicum chinense*-Ayacucho, adaptación de dos variedades, Huamanga, manejo orgánico.

promedio de frutos (g), en  $V_1$  es significativamente mayor a  $V_2$ , mientras en  $S_4$ ,  $S_3$  y  $S_2$  las plantas presentaron mayor tamaño promedio de frutos sin que exista diferencia significativa entre los tres sustratos.

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**Introduction**

In the highlands of Peru, there is a region rich in gastronomy, history and culture, the chili peppers characterize the cuisine of Ayacucho, with traditional dishes that are a delight for domestic and foreign tourists, being the chili bell pepper the main ingredient of this, giving it the special organoleptic characteristics of the fruits of "habanero chili" (CH) with aroma, flavor, heat, sparkle, color, texture and heat, conquering its primordial role in world cuisine<sup>1,2</sup>. This variety of resources should be added to the culinary art, such as the incorporation of CH, after studies of adaptation, acclimatization, planting substrates and fertilization under the conditions of Ayacucho.

It is necessary to introduce new varieties of chili peppers, with the intention of contributing more options to gastronomy, with a species well known in Mexico (*C. chinense*) whose importance is vital to enhance the exquisiteness of the stews, currently Peruvian gastronomy has received contributions from Japanese, African, Italian and Chinese migrants<sup>3,4</sup>. The study of new species is relevant, knowing their germination, growth and development of (*C. chinense*), which is widely used in gastronomy. There are several studies of variability, production, characterization and molecular studies of the *Capsicum* genus, none of the introduction and cultivation in other areas, as well as its adaptation to organic fertilization<sup>5</sup>. In order to achieve the desired results, cultivation materials (potting soil, black soil and sand) were requested from INIA - Ayacucho, which carries out different types of research and has material for different species or varieties of plants and guinea pig manure from a breeding farm. In *C. annuum* L variety *glabriusculum*, under experimental conditions,

germination varies according to different physico-chemical parameters (temperature, humidity, light and phytohormones). In *C. annuum* L variety *glabriusculum*, under experimental conditions, germination varies according to the different physical-chemical parameters (temperature, humidity, light and phytohormones), the phytohormone (gibberellic acid) is used to overcome seed dormancy, for which effect 2000 seeds were immersed in a solution of 400 ppm for 20 h, the seeds were dried under shade, sown and after 3 weeks germinated in 90%.

In Venezuela (Monagas), trials were carried out with transplants of *C. chinense* Jacq. at 35, 40, 45 and 50 days after seedling, in definitive soil, the highest yield (16066 t/ha) was produced when the transplant was carried out using 50-day-old seedlings. Successful transplanting was performed 40 days after germination, once the plants reached heights between 15 to 18 cm, they were transplanted into black polyethylene bags 600 caliber of 45 x 50. After 45 days, the seeds were transplanted to the definitive field<sup>6-9</sup>

Although Mexico is the country with the greatest genetic diversity of *Capsicum*, the CH is almost synonymous with Mexican nationality and its cuisine, there is little research on this species. On the contrary, in other countries there are public and private institutions that dedicate research programs on this plant in order to obtain improved varieties, adapted to the climatic conditions of the place of cultivation and organic cultivation. The use of this resource requires expanding its genetic diversity, of the varieties of chili, many are not hot, used in soft drinks and dyes, it is also used to produce many other products. A main characteristic that made it attractive is the pun-

gency that is due to capsaicin, or more precisely, to a group of substances of alkaloid nature called capsaicinoides called capsaicinoids. Because of its healing properties that CH possesses, it increases the production of endorphins, which cause a pleasant sensation, can help relieve migraines and headaches, has antibacterial properties that prevent and attack sinusitis, helps raise metabolic activity, helping the body to burn fat and calories indicates that in Yucatecan gastronomy CH is the main ingredient of one of the hottest sauces that are served<sup>10-15</sup>. The CH is not only consumed for its nutritional value but involves a persistent cultural characteristic, they consume chili because they learned from their parents, but also for its flavor and spiciness<sup>10</sup>.

Organic fertilization provides nutrients to the plants, restoring the biological properties of the soil, improving a dynamic interaction with microorganisms, making it possible to achieve good results, reducing production costs in planting, avoiding environmental pollution and soil deterioration<sup>1,16</sup>. Taking into account the importance of CH for the Ayacucho region, with the intention of carrying out genetic improvement to obtain new varieties adapted and acclimatized to our region, its biological and cultural factors and organic production with management strategies and genetic improvement, this research was carried out to allow new alternatives in the kitchen<sup>17,18</sup>. The indiscriminate use of chemical fertilization in agricultural production has caused considerable damage to the environment, which is why we are looking for organic production alternatives that have positive effects on crop yield and quality<sup>19</sup>. With the desire to enrich the Ayacucho and Peruvian gastronomy, and the purpose of carrying out genetic improvement and organic production, we proposed to carry out the research work, with the objectives were i) To determine the production of  $V_1$  and  $V_2$  of *C. chinense* Jacq. with different substrates. ii) To identify the most appropriate substrate for the cultivation of  $V_1$

and  $V_2$ . iii) To compare the amount of fruit of  $V_1$  and  $V_2$ .

## Materials and methods

The work was carried out in the city of Huamanga (Ayacucho), whose geographical coordinates are: 13°08' South latitude, 74°13' West longitude, and 2724 meters above sea level. The average annual temperature is 16.2° C, with an average annual maximum of 24.0° C, an annual minimum temperature of 8.4° C and a rainfall of 572.9 mm, with the hottest months of summer and the coldest months of June and July, with winter frosts. It is characterized by a temperate climate due to the effect of the height above sea level, with seasonal rains between the months of October and March, with rainy summer and dry winter, with an average annual humidity of 65%. An atmospheric pressure of 590 mmHg. Ecologically, according to Holdridge's world life zone classification system, it is subtropical low mountainous thorny steppe (ee-MBS)<sup>20,21</sup>, and according to Pulgar Vidal<sup>22</sup> it is located in the Quechua region.

The experiments were carried out in a nursery of 2 x 3 m, with a height of 2 m covered with rassel mesh for nursery, on the roof was placed plastic over the mesh because of the rain, located on the terrace of the house because of the pandemic. In the present research work, the methodology used in the production of potato seed<sup>23</sup> was used. In the statistical processing of the results, the Completely Randomized Design (CRD) with a factorial arrangement of 5V x 5S was used. Two varieties of CH  $V_1$  and  $V_2$  were used, 4 types of substrates, and the type of research was Basic Descriptive Experimental, taking into account the variables and indicators. *Variables and indicators*. Black soil (proportions), guinea pig manure

(proportions), cultivated soil (proportions), sand (proportions)<sup>24</sup>. In order to meet the objectives of the work, the cultivated soil, black soil and sand came from the experimental fields of INIA - Ayacucho and the guinea pig manure came from a guinea pig farm. Special care was taken in the preparation of the 4 levels of growing substrates for each experimental unit (EU), first they were prepared in the indicated proportions and then distributed in equal parts, then the seedlings were placed in a designated location.

The experiments began the first week of January 2021 with the installation of seedling beds, followed by the first and second transplanting, followed by the different phenological phases until the harvesting of the fruits and obtaining the seeds, which took place the first week of April 2022.

*Varieties of C. chinense Jacq CH.* V<sub>1</sub> and V<sub>2</sub> were considered. In the experimental production of the varieties, the following were estimated: number of emerged seedlings (NPE), plant size (TP), average leaf size (TPH), number of flowers (NF), number of fruits (CF), average fruit weight (PPF), average fruit size (TPF)<sup>9,18,25</sup>.

*Seed collection.* Two varieties of fruits of *C. chinense* Jacq. CH (V<sub>1</sub> and V<sub>2</sub>) were collected in Mexico City (2019), transferred to the city of Ayacucho. The seeds were sown obtaining fruits (2020), the seeds of the 2 varieties duly selected, were used in the present work.

*Preparation of seedbed.* The seedbed was prepared in 6 technopor buckets, using black soil and sand in a 3:1 ratio. In each of the first 3 containers 40 seeds of V<sub>1</sub> were sown and in each of the remaining 3 containers an equal amount of seeds of V<sub>2</sub><sup>26,27</sup> were grown.

*Treatment design.* It was completely randomized (DCA), the substrate factor and the variety factor<sup>28</sup> were studied. The substrate factor was examined at four levels: S<sub>1</sub> arable soil, S<sub>2</sub> arable soil + black soil + sand (3:2:1), S<sub>3</sub> arable soil + guinea pig manure (3:1), S<sub>4</sub> arable soil + black soil + sand + guinea pig manure (3:2:1:1:1). In the variety factor of *C. chinense* Jacq. CH, 2 levels were analyzed: V<sub>1</sub>, V<sub>2</sub>. The substrates were prepared in proportions (1:0, 3:2:1, 3:1, 3:2:1:1:1) that received the seedlings from the seedbed, with 3 replicates each.

*Transplanting to 7 x 10 cm polyethylene bags.* The seeds germinated in seedling beds were transplanted to polyethylene bags, the substrates were placed in equal parts in each of the 3 replications, the average height of the seedlings at the time of transplanting was 5 cm on average.

*Transplanting to 25 x 48 cm polyethylene bags.* Once the plants gained height, foliage and began to form the first flower buds, they were transplanted to larger polyethylene bags of 25 x 48 cm, to complete the growth and development in each of the experiments. *Sampling.* Sampling was carried out according to the growth and development of the plants, every 15 days for the dependent variables. Sampling began 15 days after transplanting, using a tape measure to measure plant height (PA) (from the base of the substrate to the apex of the highest branch), and a vernier to measure stem diameter (SD) (at 5 cm height of the plant stem)<sup>18,25</sup>.

*Processing and analysis of results.* These were carried out through descriptive statistical analysis; completely randomized design (CRD), analysis of variance with factorial with factorial arrangement A x B, Tukey's mean comparison test<sup>28</sup>.

**Resultados**

**Figure 1 Production process of *C. chinense* from adapted seeds to fruit harvesting and new seed production new seeds**



**Table 1 Analysis of variance and Tukey's test of plant size (cm) vs. variety\*substrate**

Source	GL	SC Adjusted	MC Adjusted	Value F	Value p
Variety	1	3.38	3.375	.32	.579
Substrate	3	2395.46	798.486	76.05	.000
Variety*Substrate	3	16.79	5.597	.53	.666
Error	16	168.00	10.500		
<b>Total</b>	<b>23</b>	<b>2583.62</b>			

**Table 2 Analysis of Variance and Tukey's test for mean leaf size (cm) vs. variety\*substrate**

Source	GL	SC Adjusted	MC Adjusted	Value F	Value p
Variety	1	2.667	2.6667	3.56	.078
Substrate	3	110.833	36.9444	49.26	.000
Variety*Substrate	3	.333	.1111	.15	.929
Error	16	12.000	.7500		
<b>Total</b>	<b>23</b>	<b>125.833</b>			

**Table 3 Analysis of variance and Tukey's test for number of flowers vs. variety\*substrate**

Source	GL	SC Adjusted	MC Adjusted	Value F	Value p
Variety	1	10.7	10.67	.22	.645
Substrate	3	12605.8	4201.94	87.01	.000
Variety*Substrate	3	19.3	6.44	.13	.939
Error	16	772.7	48.29		
<b>Total</b>	<b>23</b>	<b>13408.5</b>			

**Table 4 Analysis of variance and Tukey's test for number of fruits vs. variety\*substrate**

Source	GL	SC Adjusted	MC Adjusted	Value F	Value p
Variety	1	145.0	145.04	6.11	.025
Substrate	3	520.5	173.49	7.30	.003
Variety*Substrate	3	172.5	57.49	2.42	.104
Error	16	380.0	23.75		
<b>Total</b>	<b>23</b>	<b>1218.0</b>			

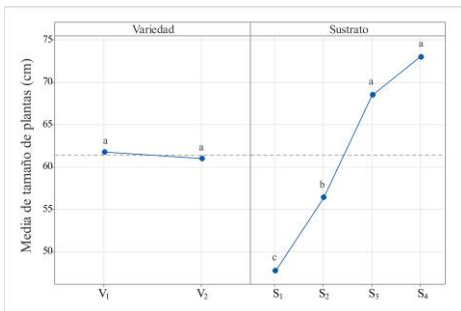
**Table 5 Analysis of variance and Tukey's test for mean fruit weight (g) vs. variety\*substrate**

Source	GL	SC Adjusted	MC Adjusted	Value F	Value p
Variety	1	.2204	.2204	.25	.623
Substrate	3	35.9346	11.9782	13.64	.000
Variety*Substrate	3	2.8379	.9460	1.08	.387
Error	16	14.0533	.8783		
<b>Total</b>	<b>23</b>	<b>53.0463</b>			

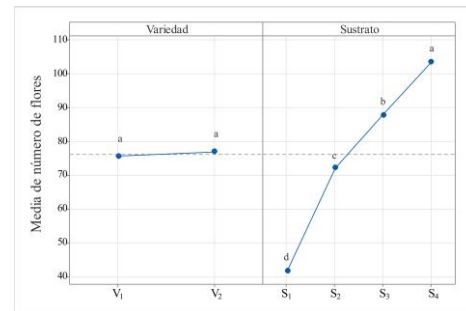
**Table 6 Analysis of variance and Tukey's test for mean fruit size (cm) vs. variety\*substrate**

Source	GL	SC Adjusted	MC Adjusted	Value F	Value p
Variety	1	1.550	1.5504	7.74	.013
Substrate	3	8.875	2.9582	14.76	.000
Variety*Substrate	3	1.468	.4893	2.44	.102
Error	16	3.207	.2004		
<b>Total</b>	<b>23</b>	<b>15.100</b>			

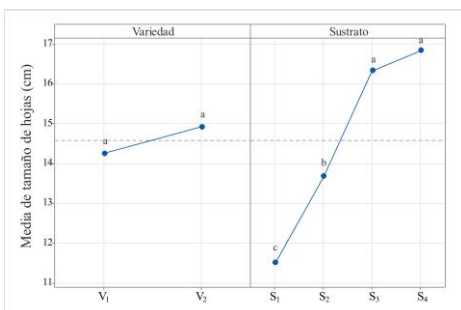
**Figure 2 Main effects for plant size (cm) with the two varieties of *C. chinense* Jacq. In 4 different substrate types**



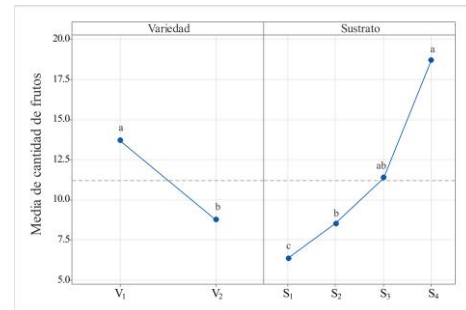
**Figure 4 Main effects for flower number with two varieties of *C. chinense* Jacq. On four types of substrates**



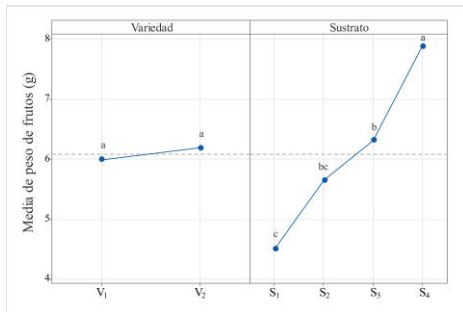
**Figure 3 Main effects for average leaf size (cm) with two cultivars of *C. chinense* Jacq. 4 types of substrates**



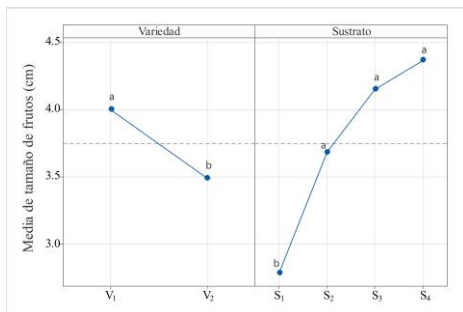
**Figure 5 Main effects for fruit quantity with two varieties of *C. chinense* Jacq. On 4 types of substrates**



**Figure 6** Main effects for average fruit weight (g) with two varieties of *C. chinense* Jacq. On 4 different types of substrates



**Figure 7** Main effects for average fruit size (cm) with two varieties of *C. chinense* Jacq. 4 types of substrates



## Discussion

The seeds of the seedlings germinated 58 V<sub>2</sub> and 54 % V<sub>1</sub> in 21 days, under the environmental conditions of the city of Huamanga. Rangel Campos<sup>29</sup> reports germination in 14 days after sowing (dds). Buenfil Ocampo<sup>30</sup>, the first seeds germinated 6 dds under greenhouse conditions using commercial substrate "Cosmopeat". Our results do not coincide, with differences of 7 and 15 days in seed germination, probably due to temperature variations during the day; our experience was in the open air.

Table 1 and Figure 2 present effects for TP (cm), the effect of the interaction between the variables is not significant, while the effect of substrate is significant, the plants reached greater size in substrates S<sub>3</sub> and S<sub>4</sub>, both not differing significantly. The figure clearly shows that as nutrient concentration increases, growth and development is upward. The interaction effects and the variety are not significant, while the

effect of the substrate is significant, the plants reached greater size in S<sub>4</sub> and S<sub>3</sub>, both do not differ significantly. López Arcos et al.<sup>31</sup>, supplied organic fertilizer, with significant differences between treatments for the PA variable. Plants treated with manure infusion (T<sub>3</sub>) reached the greatest height 52 cm, surpassing the rest. The treatment that reached the lowest height was the experimental control of 17 cm. Tucuch-Haas et al.<sup>32</sup> observed the variation in PA through statistical analysis, the differences observed in the treatments were mainly due to the effect of substrates and, to a lesser extent, of nutrient solutions. Quintal Ortiz et al.<sup>33</sup> reported that PA and leaf size were greater with T1 ( $P \leq 0.05$ ), due to greater moisture content and availability in the substrate, while growth was low in treatments with less irrigation. Rangel Campos<sup>29</sup>, a slow growth until 63 days after transplanting (ddt) this behavior may be related to the stress caused by the change from transplanting to open field and the consequent recovery, since during the first 4 weeks the plants develop their root and foliar system. Lopez Puc et al.<sup>1</sup> point out that the use of fertilizers in crops allows obtaining higher yields, reducing crop production costs and avoiding environmental contamination. Medina Gámez<sup>8</sup> observed significant differences between treatments for the PA variable. T<sub>1</sub>, T<sub>3</sub>, T<sub>7</sub> and T<sub>16</sub>, with organ mineral nutrient solution, achieved higher yields. The present work is corroborated by the aforementioned works, because greater heights were reported in treatments with higher proportions of guinea pig manure. It is known that organic matter contains NPK and other nutrients necessary for plant growth and development. It is also necessary to mention that roots absorb water and along with this vital element, nutrients are absorbed when they are dissolved in water.

Table 2 and Figure 3, show the interaction effect of the varieties are not significant, while the effect of the substrate is significant, S<sub>4</sub> and S<sub>3</sub> presented greater size (cm) of leaves, both do not present significant difference, when we observe the mean line of the TPH the 2 varieties do not differ statistically,

while when verifying the behavior of  $S_1$ ,  $S_2$  and  $S_3$  they differ statistically,  $S_3$  and  $S_4$  do not, but the TPH are statistically greater than the first 3 treatments. About TPH (cm), Quintal Ortiz et al.<sup>33</sup>, observed that leaf water potential is important in treatments, with high substrate moisture values PA and leaf area were higher with  $T_1$  ( $P \leq 0.05$ ). These results fit with those pointed out by López Arcos et al.<sup>31</sup>, when evaluating the DT, they observed vermicompost ( $T_4$ ) with 0.859 cm, surpassing the others, manure infusion ( $T_3$ ), bokashi ( $T_1$ ) and compost ( $T_2$ ) with respect to the experimental control ( $T_0$ ), they mention plants with a DT should possess leaf size. Fernando Peña & Zenner de Polanía<sup>34</sup>, affirm that high percentages of dry matter in the aerial part of *C. annuum* plants indicate a greater number of leaves, source and production of photo-assimilates for the filling of demanding organs. In addition, Peil & Gálvez<sup>35</sup>, show that, under the conditions of cultivation in artificial substrates under greenhouse, with a water and nutrient supply close to the optimum, it is possible to achieve maximum plant growth with a reduced root system that achieves foliage production. David-Santoya<sup>36</sup>, when evaluating PA, leaf area and number of leaves, the combination of vermicompost and soil (1:1) significantly increased ( $p \leq 0.05$ ) the height and leaf area of CH seedlings when compared to the control. With the results that we had in our work, they mean, when the substrate is increased the foliage increases, however, as soon as it is too much manure increased the results are similar between  $S_3$  and  $S_4$ , statistically, the leaves are important for being the places where photosynthesis takes place taking advantage of sunlight,  $CO_2$ , water and nutrients (guinea pig manure) containing the substances.

Table 3 and Figure 4, examined the interaction effect and variety effect are not significant, in the 2 varieties used, however the substrate effect is significant, the plants of the  $S_4$  substrate presented more flowers ( $p < 0.05$ ,  $\alpha=0.05$ ), the 4 substrates are statistically different, which means that  $S_1$  produces less number of flowers, while in  $S_4$  the production is higher number

of flowers. It is clearly observed that the number increases as the nutrient concentration is higher in each of the treatments. These results are corroborated by Lopez Arcos et al.<sup>31</sup>, the application of vermicompost and other organic fertilizers (bokashi, compost, manure infusion) at the beginning of flowering in vegetables, because it can present precocity in production and benefit the producer specially to calendar the harvests. Lopez Puc et al.<sup>1</sup>, in agronomic management and the factors that influence the growth and development of CH crop plants, flowers appeared 1 week after the first flower buds, flowers that formed between 27 and 47 days after transplanting (DPT) did not become fruits, while flowers that were produced at 63 DPT became fruits, considering the total quantity of flowers, significant differences in plants developed in different types of soil. Ramírez-Luna et al.<sup>37</sup>, using growth regulators on flowering and fruit setting in CH, reported an increase in NF per plant, compared to the control treatment, possibly because these products contain gibberellins, chemical substances capable of promoting flower formation under certain environmental conditions of temperature and light.

Table 3 and Figure 4, examined the interaction effect and variety effect are not significant. And variety effect is not significant, in the 2 varieties used, while the effect of substrate is significant, the plants of substrate  $S_4$  showed a greater number of flowers ( $p < 0.05$ ,  $\alpha=0.05$ ), the 4 substrates are statistically different, which means that  $S_1$  produces less flowers, while in  $S_4$  the flowers, while in  $S_4$  the production is higher quantity of flowers. Of flowers. It is clearly observed that the number increases as the nutrient concentration is higher in each of the treatments. Is higher in each of the treatments. These results are corroborated by López Arcos et al.<sup>31</sup>, the application of vermicomposting and other organic fertilizers organic fertilizers (bookish, compost, manure infusion) in early flowering at the beginning of flowering in vegetables, is based on the fact that that early production can occur and can benefit the producer benefit the



grower, especially for the timing of harvesting. The harvests. Lopez Puc et al.<sup>1</sup>, on agronomic management and the factors that influence the growth and development of CH crop plants, flowers appeared 1 week after the first flowers buds, the flowers that formed between 27 and 47 days after transplanting (DPT) did not develop into fruit, while flowers that formed between 27 and 47 days after did not develop into fruit, while flowers produced at 63 DPT developed into fruit. At 63 DPT became fruit, considering the total number of flowers, the significant the total number of flowers, the significant differences in the plants developed in different types of transplanting in the plants developed in different soil type's soil. Ramirez-Luna et al.<sup>37</sup>, using growth regulators on flowering and fruit set growth regulators on flowering and fruit setting in CH, reported an increase in NF per plant, compared to the control treatment, possibly because these products contain gibberellins, substances possibly because these products contain gibberellins, chemical substances capable of promoting flower formation under certain environmental conditions of temperature and under certain environmental conditions of temperature and light.

Table 4 and Figure 5, represent the main effects of fruits, the varieties differ in fruit production, V<sub>1</sub>, produced higher CF fruits under the conditions of the present experiment, when we observe the effects of the substrates are statistically significant, in S<sub>4</sub> and S<sub>3</sub> the plants had higher CF, both did not present significant difference, that is, the mentioned substrates produce statistically equal amount of fruits. According to Peil & Gálvez<sup>35</sup>, the number of young fruits growing on the plant depends considerably on the source/sink ratio, which can be defined as the ratio between the photosynthetic rate and the sum of the sink powers of all plant organs, a low source/sink ratio produces small fruits and abortion of young fruits. Lopez Puc et al.<sup>1</sup>, the fruits depend on NF produced by the plants, when comparing the production of CH by soil type, they observed that in the red soil they obtained better results, when performing the analysis

of variance, there was a significant difference in CF by the interaction of the factors soil type and DPT, obtaining plants developed in black soil, had few fruits 24 %, while in red and brown soils they produced 40 and 36 % respectively. Rangel Campos<sup>29</sup>, when studying the growth of CH under different spacing between rows in the Comarca Lagunera, reported fruit production per plant, there was no statistical difference between treatments. Borges-Gómez et al.<sup>38</sup>, the yield of CH was statistically similar when 120 and 240 kg N ha<sup>-1</sup> were applied, however, the yields with these doses of N were higher than the treatment where N was not applied. Haro Hernández & Valarezo Olivo<sup>9</sup>, in two harvests carried out, T<sub>2</sub> presented the highest CF with a total of 43.70 fruits per plot, followed by T<sub>1</sub> and T<sub>4</sub> with values of 36.40 and 35.70 fruits per plot respectively, while T<sub>3</sub> reached 33.00 fruits. The results of the experiments carried out were ratified by the authors cited above, as the proportion of matter increases the amount of fruit is greater, the results of which are corroborated by the results of the experiments carried out on T<sub>1</sub> and T<sub>4</sub>, the results are corroborated by the cited authors.

Table 5 and Figure 6, the interaction and variety effects for PPF are not significant, while the substrate effect is significant, the S<sub>4</sub> plants presented higher PPF ( $p < 0.05$ ,  $\alpha = 0.05$ ), the results obtained are validated by the following authors. Borges-Gómez et al.<sup>13</sup>, the yields achieved indicate the importance of applying high doses of N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O to the soil and sufficient water availability in the soil solution for this species. López Arcos et al.<sup>31</sup>, applying organic fertilizers, PPF 9.49 g per fruit using vermicompost, also observed significant differences between treatments for CH fresh fruit yield; plants treated with vermicompost (T<sub>4</sub>) and manure infusion (T<sub>3</sub>) obtained yields of 949 g/plant and 863 g/plant, respectively. With compost, bokashi and the experimental control obtained yields of 687, 679 and 325 g/plant. It is also mentioned that organic fertilizers

provide nutrients to the plants, increasing the physical, chemical and biological properties of the soil, increasing the unit production of chili, and improving the quality of the fruit. On the other hand, Tucuch-Haas et al.<sup>32</sup> reported CH yields of 302 g/plant in 3 fruit cuts, supplying the Steiner solution with a  $\text{NH}_4^+/\text{NO}_3^-$  ratio of 10/90 %, respectively, in combination with a mixture of tezontle-coconut fiber substrate (75-25 % respectively), with tezontle granulometry of 10-20 mm. Ramirez-Luna et al.<sup>37</sup>, when observing their results of the effect of regulating products in greenhouse conditions of CH, small fruit sizes, explaining this result to the fact that they received a lower intensity of light, since the type of plastic used in the greenhouse was the 600 caliber, which has 90 % transparency, reducing by 10 % the intensity of sunlight entering the greenhouse, which favored the development of larger plants, with thinner stems, but small fruits. According to Haro Hernández & Valarezo Olivo<sup>9</sup>, the fruit weights with the highest results in  $T_2$  and  $T_1$  with values of 810.00 and 753.40 g respectively per plot. The results in our work are supported by the different authors mentioned.

Table 6 and Figure 7, the interaction effect is not significant, but the effect of variety is significant, the average fruit size of  $V_1$  is significant to  $V_2$ , while the effect of substrate is significant. In substrates  $S_4$ ,  $S_3$  and  $S_2$  the plants showed higher average fruit size, and there is no significant difference between the 3 substrates. These results found in the present work are in accordance with those generated by the researchers. Haro Hernández & Valarezo Olivo<sup>9</sup> reported that  $T_2$  with 9.10 cm was outstanding in terms of fruit length, while  $T_1$ ,  $T_3$ ,  $T_4$  and the control were 8.02, 7.02, 7.30 and 6.80 cm, respectively. Huez López et al.<sup>39</sup>, when carrying out productivity studies of CH under greenhouse conditions, obtained large fruits (> 4.0 cm). Ebel et al.<sup>15</sup> reported higher fruit weights in treatments without pitahaya, whose fruits were of first quality. The length in all treatments ranged between 3.5 to 4.5 cm per chile bell pepper and the width between 2.5 and 3.5 cm. López Arcos

et al.<sup>31</sup>, using organic fertilizers on CH crops claim to have a positive and significant effect, since the nutrients are dispensed in the soil when the plants require them, since their release is slow and gradual, and there are significant differences between treatments for CH fruit yield. Tucuch-Haas et al.<sup>32</sup>, when analyzing the yield and fruit quality variables (weight, length and diameter), the effects obtained from the nutrient solution independently of the substrate showed that the best treatment was the ammonium/nitrate ratio of 20/80 %. Ugas & Mendoza<sup>27</sup> mentioned that chili peppers are demanding plants and when grown commercially require attention and nutrition, they need cattle manure or guano of 20 t/ha, in addition to foliar fertilizers and irrigation for production. Our results indicate that the more organic matter the substrates have, the larger the fruit size, which corroborates the aforementioned auto-res. In addition, we agree with López Arcos et al.<sup>31</sup>, who mention that there are few or almost no studies focused on the use of organic fertilizers in CH, being an alternative its integral use of available natural resources (manure, plant residues) of low cost for production. Its use allows obtaining higher crop yields, protecting the soil without contaminating it, and making its handling safer. The use of chemical fertilizers in crop fertilization is currently causing the soil to suffer an accelerated depletion of organic matter and a nutritional imbalance, and over time it loses its fertility and productive capacity.

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### Conflicts of interest

The authors declare that there are no conflicts of interest.

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## Ethical considerations

All procedural and experimental aspects were approved by the evaluation commission of the Research and Innovation Institute of the Faculty of Biological Sciences, Faculty and Vice-Rectorate of Research of the UNSCH with resolution acts.

## Research limitations

The authors declare that there were no limitations, in some cases we were in some cases we had restrictions in the management by COVID-19.

## Authors' contribution

*Marta Romero Viacava*, development of the research project, selection and research, selection and acquisition of seeds of *Capsicum chinense* Jacq "chile habanero"; responsible for the development for the development, execution and final report of the project. *Saturnino Martín Tenorio Bautista*, review of the literature for the project literature review for the project, sampling, preparation of the final report, discussion of results and final report, discussion of results and statistical analysis.

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