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Seed yield and fruit quality of habanero pepper with chemical and organic fertilization

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Abstract

The objective of the present investigation consisted in evaluating populations of habanero pepper, with chemical and organic fertilization, for seed and fruit yield. In 2017, at the National Technology of Mexico campus Roque, three genotypes of habanero pepper were established with five different types of fertilization. A group of agronomic variables were evaluated with the SNICS norms. The variables were subjected to an analysis of variance and principal components. The best collection was the Rojo Campeche 12 genotype with an average fruit weight of 4.8 g, 27.5 seeds per fruit and a germination at 16 days of 39.2%. Regarding fertilization, it was determined that the best fruit weight was reached with 50+50% of chemical and organic fertilization. For seeds per fruit and germination, chemical fertilization was better, although statistically similar to the value of combined fertilization (50+50). The above allows to explore genotypes, doses and application opportunities of organic fertilizers that improve seed production and quality, with sustainable and environmentally friendly management.

Keywords: *Capsicum chinense* Jacq., germination, organic production.

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Introduction

The production of habanero pepper has been limited by factors such as the incidence of pests and diseases, poor irrigation and nutrition programming, which is serious under greenhouse conditions, where with proper management, the probability of disease infestations is reduced and pests; in addition to not limiting crop production and fruit quality, it has been observed that the habanero pepper responds appropriately to the application of nitrogen, increasing yield and its nutritional quality (Huez, 2013).

Among the great diversity of the *Capsicum* genus, the habanero pepper (*C. chinense* Jacq.) has become a symbol and example of pungency, due to its high content of capsaicin in the fruit. The importance of capsaicinoids is due to the fact that in addition to providing the spicy flavor, they are used by the pharmaceutical, arms, tobacco, cosmetic and paint industries, among others, giving rise to various products (Borges *et al*., 2014). It is estimated that, of the total production, 75% is destined for consumption in fresh state, 22% is used by the industry in the production of sauces and 3% is destined to obtain seed (Tucuch *et al*., 2012).

Regarding the commercialization of fresh habanero pepper, SIAP (2015) reported that the highest price to the producer was located in Nayarit with $29.41, the lowest price was in Campeche with $9.61, while the highest consumer price was It was located in Durango, with $99.90 and the lowest price was detected in Veracruz, with $29.75. The sauce industry gives preference to certain varieties and color, these being red and yellow (Huez, 2013).

In the southeast of Mexico, the habanero pepper has increased its planted area, in 2014 951.52 ha were established, with a production of 9 977 t (SIAP, 2015). Currently the habanero pepper is cultivated in various regions of Mexico, mainly in the states of Yucatan, Tabasco, Campeche and Quintana Roo, with yields that range from 10 to 30 t ha^{-1}, depending on the level of technification used in cultivation (Latournerie *et al*., 2015). In 2010, the denomination of origin was published as ‘Chile habanero de la Península de Yucatán’ (DOF, 2010), which resulted in the resolution of the ‘Project Official Mexican Standard PROY-NOM189-SCFI-2012 Chile habanero de la Península de Yucatan (*Capsicum chinense* Jacq.) - specifications and test methods’ (DOF, 2012).

The cultivation of horticultural species faces limitations that minimize its potential for yield and utility. Plant nutrition is preponderant because the misuse of chemical fertilizers can have a high economic cost, in addition to causing adverse effects on the soil and water. An ecologically acceptable alternative to increase crop yield is the inoculation of growth-promoting microorganisms, called biostimulants or biofertilizers (Reyes *et al*., 2014).

Organic fertilizers are of great importance in the fertilization of the soil, this depending on the nature of the fertilizer, characteristics of the soil, type of crop, periodicity of application and applied amount of the fertilizer. Organic fertilizers provide nutrients, correct deficiencies because they contain slow-release nutrients and improve the physical-chemical and biological conditions of the soil, thus helping the development and growth of plants (López *et al*., 2012). Furthermore, the application of agrochemicals in modern agriculture has caused the degradation of natural resources and the technological erosion of traditional production systems, putting at risk the sustainable productivity of agroecosystems (Nieves *et al*., 2013).

In commercial seed production, quality is determined by a set of attributes, where genetic, physical, sanitary and physiological quality play an important role. The physiological quality implies the integrity of the physiological structures and processes, the main indicators being: viability, germination and vigor, which depend on the genotype. Among the factors that may have an effect on the quality of the seed are the degree of maturity and the maturation time of the seed after harvest (Tamayo *et al*., 2014).

One of the greatest challenges in the production of the habanero pepper is to have healthy, vigorous seedlings of excellent quality at the time of transplantation. The mineral fertilizations to the soil could be potentiated with the use of compost, since the frequent use and application of these improves the soil structure. For the habanero pepper production system to be sustainable, the applications of chemical fertilizers that make the production chain of this crop more expensive must be reduced.

For this reason, it is convenient to carry out compost applications that balance the nutrition of the crop and make it feasible for producers to make it. One strategy to improve organic nutrition is crop rotation with legumes. Although some organic fertilizers present high concentrations of macronutrients, the analysis of total contents is a reference to define their real value as organic fertilizer (Ertani, 2015). Therefore, the objective of this research was to evaluate the effect of chemical and organic fertilizers on the seed yield of habanero pepper, and its fruit quality.

Materials and methods

The study was carried out in the experimental field of the National Technology of Mexico campus Roque, located in Celaya, Guanajuato, with geographic coordinates of 20° 34’ 54.24” north latitude and 100° 49’ 35.34” west longitude, at an altitude of 1 767 m. The predominant climate is semi-warm, subhumid BS and C (Wo) with an average temperature ranging from 14 to 22 °C and rainfall varies from 600 to 1 000 mm per year. The soils of the region are clayey in texture, slightly alkaline reaction planes, extremely fertile and suitable for a great variety of crops.

For the establishment of the habanero pepper seeds, the sowing was carried out in germinating trays, sterilized with 20% sodium hypochlorite for 12 h. The substrate was a mixture of Sunshine® Brand number 3 and vermiculite. 200 seeds were used per genotype from three collections, one with red fruit and the other two, orange.

Previously, the substrate mixture where the seedlings were placed was prepared, the ratio was 1:1:1 of tezontle-soil-vermicompost. They were mixed and placed in greenhouse bags of 25 x 25 cm and in a ratio of 4 k of substrate mixture per bag. A pre-transplant treatment was given with a radical development promoter made from N (7%), P_2O_5 (47%), K_2O (6%), L-amino acids (3%), humic acids (15.5%), auxins (0.03%) and inert matter (21.47%) (20 g), a biological growth promoter with *Pseudomonas fluorescens* (1 x 10^5 cfu ml^{-1}), *Azotobacter* spp. (1 x 10^5 cfu ml^{-1}), *Bacillus* spp. (1 x 10^5 cfu ml^{-1}) conditioners and 16.8% organic diluents (40 ml), (40 ml) a complex of chelated nutrients based on Mg (1.5%), carbohydrates (1.5%) Mn (1.5%) Fe (3%) fulvic acids (1%) soluble fish extract (5%) and 86.5% of conditioners and diluents (40 ml) and water (10 l). Submerging each root ball for five seconds. The transplant was carried out on March 24, 2017, 105 days after sowing.

The chemical fertilization and organic fertilization program were carried out in accordance with the postulated by Soria (2002); Lopez (2012), respectively: chemical fertilization: 125-100-150, first fertilization (vegetative development): 63% N - 33% P - 33% K. Second fertilization (flowering and mooring): 25% N- 50% P - 22% K and the third fertilization (fruiting): 12% N-17% P-45% K. As organic fertilization: vermicompost (2-2-4), 200 g plant^{-1} every 20 days, throughout the cycle from 18 days established.

The complementary percentage fertilization of chemical nutrients and organic fertilizers used in the production of habanero pepper, were five fertilization combinations: chemical 100%, chemical 75% + organic 25%, chemical 50% + organic 50%, chemical 25% + organic 75 % and 100% organic.

Fertilizers, both chemical and organic, were applied to the substrate in the form of solids. Complementary to this fertilization, in all the experimental units three foliar applications of microelements were made with commercial products whose content is: a) Fe 4%, Zn 1.5%, Mg 0.5%, B 0.02%, Mn 0.1%, Cu 0.05%, Mo 0.03%, Co 0.01%, S 12%, chelating agents 45%, diluents and conditioners 36.6% (10 ml); and b) N 8%, P_2O_5 4%, K_2O 3%, CaO 0.49%, Zn 0.44%, Mn 0.4%, S 0.27%, Co 0.16%, MgO 0.09%, B 0.034%, Cu 0.01%, Fe 0.01%, Mo 0.004%, humic acids 0.005%, fulvic acids 0.2% and AIA 0.003% (10 ml), in addition to the previously described complex of chelated nutrients.

The presence of whitefly (*Bemisia tabaci*) and two-point spider (*Tetranicus urticae*) was detected in the vegetative development and flowering stages. For its preventive control, weekly applications of organic repellants were made, consisting of garlic extract (25%), hot pepper (25%) and cinnamon (10%), as well as a biological caress based on cinnamon extract.

Variables evaluated

At harvest, the fruit weight (fruit weight), number of locules per fruit (loc fruit^{-1}) individually, pericarp thickness (per fruit^{-1}) was evaluated when measuring the external wall of the fruit (mm) transversely and the number of seeds per fruit (sem fruit^{-1}), according to SNICS (2019). Previously, the selected fruits were left at rest for 15 days, in order to achieve their physiological maturity.

For the analysis of seeds, they were evaluated with the methodology of ISTA (2004); that is, with four repetitions of 25 seeds each, to evaluate the percentage of seeds that produced normal seedlings on the eighth day (PorGerm8D) and on the sixteenth day (PorGerm16D), (ISTA, 2004).

In the greenhouse, a randomized complete block factorial design was used with three genotypes, five types of fertilizations and two repetitions. The experimental unit consisted of two blocks of 7 m long by 6.4 m wide, in an area of 89.6 m^2, 30 plants per genotype, a 0.6 m arrangement between plants and a separation of 0.5 m between blocks. The fruit, seed and germination variables were subjected to an Anava, the Tukey's mean test (p= 0.05) and a principal component analysis, in the SAS ver. 9.3. (SAS, 2003).

Results and discussion

In the analysis of variance in the fruit production and harvest stage, significant statistical differences ($p \leq 0.01$) were detected for fruit weight, number of locules per fruit, pericarp thickness per fruit, number of seeds per fruit, and thickness pericarp, due to genotypes, fertilization treatments and their interaction. Similarly, in the analysis of variance for the germination percentage at 8 and 16 days there were also significant differences ($p \leq 0.01$) between treatments, genotypes and the interaction of both. In all Anova, the highest variability detected was due to genotypes, followed by fertilization treatments and finally by interaction.

Mixed fertilization with 50% chemical fertilization and 50% organic, shows the highest values in fruit weight (4.78 g), number of locules per fruit (3), pericarp thickness per fruit (0.21 cm) and number of seeds per fruit (16.78); treatment that registered a response superior to that of totally chemical fertilization in fruit weight and number of locules per fruit. The 25% -75% treatment presented a similar response in all the variables evaluated, in comparison with the totally chemical fertilization (0% - 100%).

In the opposite case, treatment 5 (0-100), yields the lowest magnitude indices: fruit weight (1.4 g), number of locules per fruit (2), pericarp thickness per fruit (0.11 cm) and number of seeds per fruit (2.56), so that the levels of exploration of quantity and opportunity in fertilization did not cover the demands of the crop. Being statistically different from the rest of the treatments, positioning itself in the last scale.

In seed yield per fruit, three treatments are grouped in a first group, the values range from 16.78 to 27.67 seeds per fruit, two treatments with organic fertilization participate (Table 1). These results indicate that the incorporation of organic fertilizers is very important in the production of habanero pepper seeds, in contrast, if you want to produce fruits, because in this case, the yields in weight of fruits are lower than chemical treatments.

Table 1. Comparison of means for characteristics of fruits and seeds of habanero pepper with chemical and organic fertilization, Roque, 2018.

Fertilization	Description		Mean value			
	Chemical (%)	Organic (%)	Fruit weight (g)	Loc fruit^{-1}	Per fruit^{-1} (mm)	Sem fruit^{-1}
1	100	0	4.61 b	2.72 b	0.2 ab	27.67 a
2	75	25	3.08 bc	1.67 c	0.12 b	9.67 b
3	50	50	4.78 a	3 a	0.21 a	16.78 a
4	25	75	4.08 b	2.67 bc	0.18 b	17.94 a
5	0	100	1.4 c	2 bc	0.11b	2.56 c

Equal letters mean that there are no statistical differences. fruit weight= weight per fruit; loc fruit^{-1}= number of locules per fruit; per fruit^{-1}= pericarp thickness per fruit; sem fruit^{-1}= number of seeds per fruit.

For genotypes, the comparison of means shows significant statistical differences between each genetic material. Showing independence in individual grouping in all variables, with the exception of the pericarp thickness per fruit, where the variation is very narrow and the materials G19

(Naranja Yucatan-14) and G20 (Naranja Yucatan-15) are similar with values of 0.15 and 0.14 cm, respectively. Regarding the other variables, fruit weight, locules per fruit and seeds per fruit, genotype 19 exceeds 20.

The Rojo Campeche-12 (G4) genotype shows the highest values in fruit weight was 4.8 g, number of locules per fruit is 2.97, pericarp thickness per fruit of 0.17 cm and 27.5 for the number of seeds per fruit, that is, it surpassed on average with 54.4% in yield per future the rest of the collections (Table 2). The effect of the type of chemical versus organic fertilization and added to the genetic makeup of each evaluated population of habanero pepper, it turns out that the two factors of importance in this research show statistical differences for fruit and seed.

Table 2. Comparison of means for fruits between genotypes of habanero pepper. Roque, 2018.

Genotype	Description	Mean value			
		Fruit weight (g)	Loc fruit^{-1}	Per fruit^{-1} (mm)	Sem fruit^{-1}
G4	Rojo-Campeche-12	4.80 a	2.97 a	0.17 a	27.5 a
G19	Naranja-Yucatan-14	3.27 b	2.27 b	0.15 b	13.17 b
G20	Naranja-Yucatan-15	1.1 c	1.67 c	0.14 b	4.1 c

Equal letters means that there are no statistical differences. Fruit weight= weight per fruit; Loc fruit^{-1}= number of locules per fruit; per fruit^{-1}= pericarp thickness per fruit; sem fruit^{-1}= number of seeds per fruit.

In this regard, López *et al*. (2017) mention that the best response in the size and weight of the fruit was obtained with the regime 14 (NO3-), 12:1:7 (NO_3: H_2PO_4: SO_4) and 14: 5 (NO_3 : K^+) me L^{-1}, achieving, on average, fruits of 3.48 cm in length, 2.29 cm in diameter and a weight of 3.45 g fruit^{-1}. Data that differ below those presented in this work, where in the specific case of the Rojo Campeche-12 (G4) genotype and fertilization 3 (50% organic and 50% chemical), the average weights of the fruits oscillate in the 4.8 g fruit^{-1}.

According to Ramírez *et al*. (2012), the length of the habanero pepper fruit, variety ‘Jaguar’ is 3.8 to 5.5 cm, the diameter of 2.5 to 3 cm and 6.5 to 10 g fruit^{-1}; however, they do not indicate whether this fruit size is obtained under greenhouse conditions. In another work, Tucuch (2012), mentions that for the variables yield and quality of the fruit (weight, length and diameter) the effects of the nutrient solution independently of the substrate, are observed with treatment whose ammonium/nitrate ratio was 20/80%.

This allows to affirm in principle and in a general way that the proportions of ammonia in the nutrient solution of the order of 10 to 30% of the total N and the granule size of the tezontle of the order of 5 to 20 mm are associated with higher fruit yields. These values coincide with what is reported here, where the best quality of fruits was obtained with fertilization 3 (50-50), whose contribution of nitrate in chemical form decreases 50% and the grain size of tezontle is similar.

Also López *et al*. (2012) observed significant differences between the treatments for the yield of fresh fruit of habanero pepper, the plants treated with vermicompost and the infusion of manure, obtained yields of 949 g plant^{-1} and 863 g plant^{-1}, respectively. The plants treated with compost, bokashi and the experimental control obtained yields of 687, 679 and 325 g plant^{-1}. The parameters cannot be equitably compared, since in this project a thinning of 20 fruits plant^{-1} was carried out, obtaining a weight per fruit that ranges from 1.4 to 4.78 g fruit^{-1}.

For their part, Quintal *et al*. (2012) mention that the treatment with the highest level of humidity (T1, 60% of the usable humidity (HA) had a higher yield and weight of fruits with respect to the other treatments. The lowest yield and smallest fruit size were recorded in T4 and T5, which correspond to 30 and 20% HA. The water productivity index (IPA) was higher ($p \leq 0.05$) with 60% HA, than in T4 and T5, with 30 and 20% HA, a response that is directly proportional to the yield.

The response of the three genotypes was associated with their adaptation to the ambient temperature conditions in which they were evaluated, which in this case were not ideal for the development and expression of the G20 genotype (Naranja Yucatan 15), as argued by Latournerie *et al*. (2015).

In the comparison of means with respect to the type of fertilization, two groups are observed in the percentage of germination at 8 days. The first group is made up of fertilization 1 (100-0), 3 (50-50) and 4 (25-75), these data range, from 19.3 to 25, the highest germination rates, showing with it, that the application of compost provides a high vigor of the seed in the different genotypes. In the evaluation of the germination percentage at 16 days, the disparity and statistical differentiation between treatments became more noticeable when regrouped into 4 groups.

The highest germination values were in fertilization 1 (100-0) and 3 (50-50) with 40 and 37%, respectively. Followed by treatment 4 (25-75) whose intermediate values represent an acceptable germination percentage, not being the case for treatments 2 (75-25) and 5 (0-100) that show a low and very low percentage in germination, respectively (Table 3). Therefore, the best treatment (50-50), gives rise to the production of sustainable and healthy seed, since in addition to resulting in the best fruit quality (weight, number of locules and pericarp thickness), it also presented the greater number of seeds and their physiological quality (germination). To the extent that the 50:50 ratio was modified, germination was reduced, so the assimilation and translocation of dry matter to the seed was probably altered.

Table 3. Comparison of means for germination percentages at 8 and 16 days between treatments in habanero pepper seeds. Roque, 2018.

Treatment	Description		Mean value	
	Chemical (%)	Organic (%)	PorGerm8D	PorGerm16D
1	100	0	25 a	40 a
2	75	25	3 b	13 c
3	50	50	20.67 a	37 a
4	25	75	19.33 a	30.67 b
5	0	100	6 b	8 d

Equal letters means that there are no statistical differences. PorGerm8D= germination percentage at 8 days; PorGerm16D= germination percentage at 16 days.

In the case of genotypes, a strong genetic effect is observed, being statistically different between them, the Rojo Campeche-12 genotype with the highest germination percentages at 8 and 16 days (26 and 39.2, respectively) was higher than the rest. The genotype with the lowest germination values was the Naranja Yucatan-15 (Table 4). Both genotypes were exceeded by G4 with 31.63 and 71.42% at 16 days after sowing. The most important variable to measure the physiological quality of a seed is germination in all crops. In the case of the habanero pepper seed, its conservation and quality are still a problem, while the effect of its nutrition and storage, mainly, should be studied to a greater degree. The result obtained reached 39.2% germination at 16 days after sowing.

Table 4. Comparison of means for germination percentages at 8 and 16 days between habanero pepper genotypes. Roque, 2018.

Genotype	Description	Mean value	
		PorGerm8D	PorGerm16D
G4	Rojo-Campeche-12	26 a	39.2 a
G19	Naranja-Yucatan-14	14.2 b	26.8 b
G20	Naranja-Yucatan-15	4.2 c	11.2 c

PorGerm8D= germination percentage at 8 days; PorGerm16D= germination percentage at 16 days.

Herrera *et al*. (2018) in a study of piquin pepper collections found the highest germination rate at 21 after sowing, values ranging from 30 to 40%. Ayala *et al*. (2014) show that the best physiological quality of the seed in peppers is obtained when the seed is extracted from ripe fruits and stored for 15 days. However, from the beginning stage of fruit color change with subsequent extraction, it is possible to obtain vigorous seeds with uniform germination, which could be used in genetic improvement programs with shorter selection cycles, which would also serve for production. commercial seed as they are of sufficient germination quality and would be harvested in less time. The seeds extracted immediately germinated an average of 4 days after a 15-day rest inside the fruit and with lower values of total accumulated germination.

In the Arbol, Ancho and Guajillo peppers, the subsequent seed extract produced a faster germination, with values of 93, 99 and 98%, respectively. In the three types of pepper the maximum germination speed occurred between 6 and 11 d, regardless of the combination of treatments. These data coincide with what was done in this project, where the fruits were harvested when they presented 50% physiological maturity and later, they were stored for a period of 12 to 15 days until they reached their optimum point of maturity and thus, the seed was extracted and stored for a period of four months.

For their part, Andueza *et al*. (2017) mention that the seed germination of the varieties H-228, H-259 and H-244 was significantly the same with values of 93%, 91% and 81%, respectively, when subjected to three months of storage; while at six months the germination of the H-259 variety rose to 93%. Six months of storage of H-259 pepper is enough to reach maximum germination. The bioassay developed by Garruña *et al*. (2014) showed that storing the habanero pepper seed for 4 and 8 months at 22 °C reduces germination to 70% and 0%, when initially it was 95%.

The results also emphasize the close relationship between germination and vigor of the outstanding local varieties, since they formed a greater number of normal seedlings of habanero pepper. ABA accelerates germination and emergence. The osmotic solutions of KNO_3 and polyethylene glycol

(PEG) prevent germination during conditioning and cause increased emergence. KNO_3, PEG and ABA conditioning solutions are the most suitable for obtaining habanero pepper seedlings ready for transplantation.

In the evaluation of the variables evaluated in through the analysis of principal components (PC), for the case of fertilization, the first two principal components referred to 87.07% of the data dispersion. PC1 explains 66.98% of the total variability of the experiment, represented on the abscissa axis and made up of the germination percentages at 8 and 16 days. The PC2 (ordinate axis) observed 20% and where the weight of the fruit and the thickness of the pericarp stand out. Thus, in the first quadrant there are chemical fertilization (0 - 100) and 25% organic with 75% chemical, which stood out for improving their germination (at 8 and 16 days) but also presented low weights and number of locules per fruit.

Next, in quadrants II and III, the totally organic fertilization treatments (0-100) and 75% organic with 25% chemical were located, which presented the lowest germination percentages (at 8 and 16 days), with the difference is that the latter presented a higher fruit weight and number of locules. Finally, in quadrant IV the 50-50 treatment was located, which allowed the highest germination at 8 and 16 days, in addition to the higher fruit weight and number of locules (Figure 1).

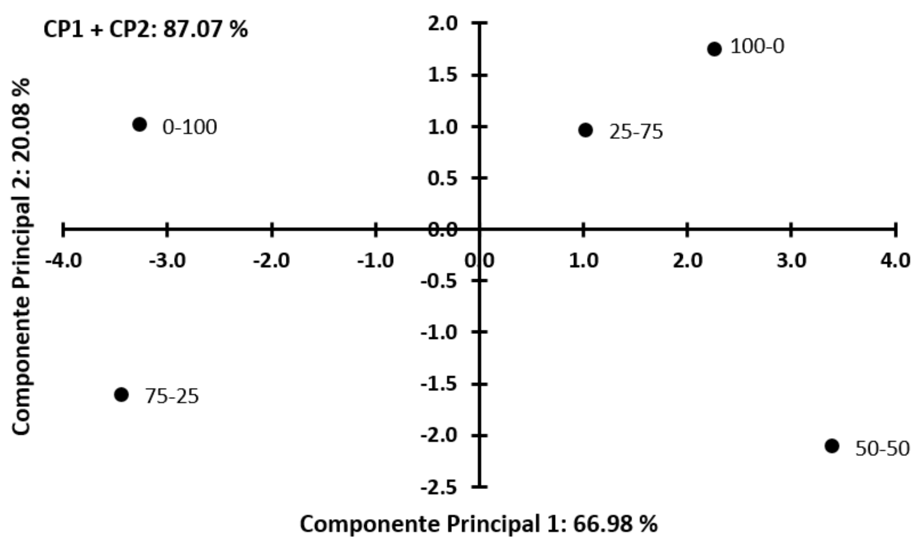

Figure 1. Main components for chemical and organic fertilization treatments in the production of habanero pepper seeds. Roque, 2018.

In the case of genotypes (Figure 2), no clustering was observed, so the response was contrasting between them. In this case, the two main components of greatest importance explain 100% of the variability generated in the experiment. In the main component 1 on the X axis, which explains 94.2% of the entire dispersion, the variables number of locules per fruit, germination percentage at 8 days and fruit weight. Through this component, there are genotypes Rojo Campeche-12 (G4) and Naranja Yucatan-14 (G19) and finally G20, in the same order, they presented from highest to lowest number of locules, vigor (germination at 8 days) and fruit weight.

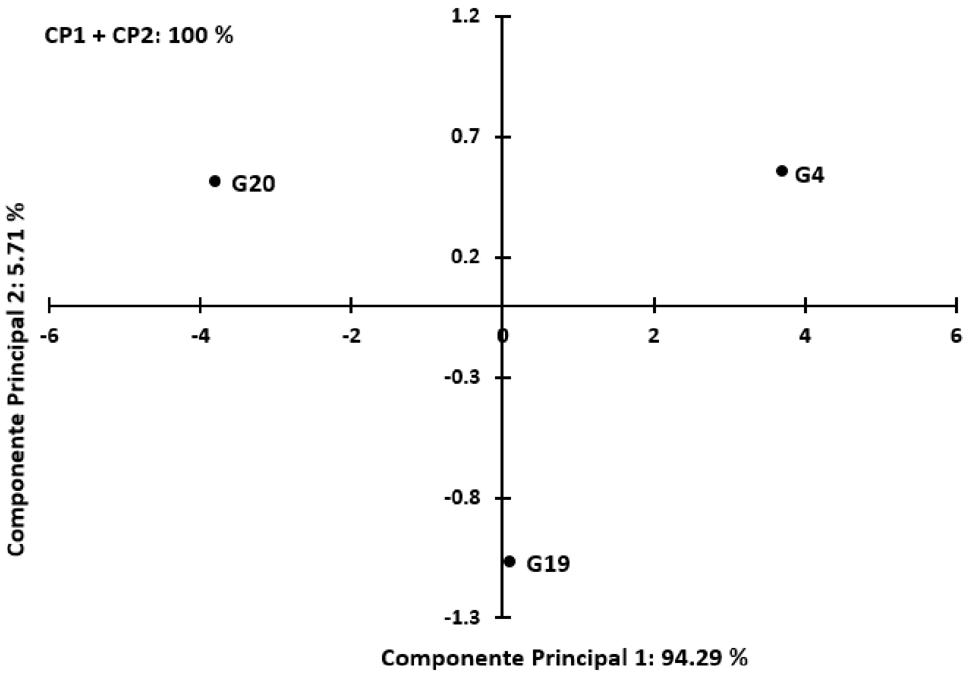

Figure 2. Main components for habanero pepper genotypes. Roque, 2018.

While the main component 2, represented on the Y axis, which explains 5.7% of the differences, is the pericarp thickness setting the tone, with G4 and G20 being the ones that presented the highest value, where G19 presented the lowest value. As the genotypes are contrasting among themselves, the statistic of the main components indicates that G4 is the only genotype that is different and stands out from the rest of the genetic materials. Mexico is considered the center of origin of the genus *Capcicum annuum* and the habanero pepper (*Capcicum chinense*) is currently recognized as a denomination of origin of the Yucatan peninsula, this indicates the great genetic variation of these species in the country.

Within the main components where all the evaluated characteristics are grouped, dispersion was found among them for the evaluated genotypes and fertilizations; that is, the qualitative and quantitative characteristics differ between populations of habanero pepper. In this regard, López *et al*. (2018) in a study of genetic diversity in habanero pepper indicate that genetic diversity in habanero pepper populations is high, where 95.5% of the observed variation is within the populations and only 4.5% between them. High gene flow was detected between populations.

For their part, Pacheco *et al*. (2016) measured 13 phenotypic characteristics in 27 collections belonging to seven morphotypes of native pepper peppers in Sinaloa and Nayarit. The characters measured were: plant height, branch length, stem diameter, leaf length, leaf width, peduncle length, fruit length, fruit width, fruit weight, thickness of the wall of the fruit, weight of seeds per fruit, number of seeds per fruit and weight of the seed. Morphological data were examined using univariate analysis, nested analysis of variance, and principal component analysis. Wide variability was found in all the measured characteristics.

The nested and principal component analyzes of variance differentiated the morphotypes, indicating a high variation between them. These results indicate that each morphotype is a phenotypic and genetic entity. The data shown are similar to those obtained in the present work, matching variants such as stem length (plant height), fruit weight and number of seeds per fruit, which in the main component 1, explain 94.2% of the total variations, for the case of genotypes. Latournerie *et al*. (2015) evaluated twelve creole populations of habanero pepper in three localities of Yucatan, Mexico and concluded that the populations were influenced by the environment (locality), but still found stable materials for yield and other very specific ones.

Similarly, Ramírez *et al*. (2016) of the 11 evaluated populations of piquin pepper, found that the main component 1 explained 25.6% of the total variability, it was better correlated with the characteristics of the fruit (weight, width, length, days to fruiting and fruiting period). PC2, which explained 16.7% of the total variability, was better correlated with plant characteristics (leaf width, leaf pubescence, stem pubescence, growth habit and tillering) and together they explain 42.3% of the total variability.

For their part, Guillen *et al*. (2016) found significant statistical differences ($p \leq 0.01$) in nine variables from Peron pepper. The characters with the highest variation between collections were fruit color, spots or stripes present, fruit shape, apex, base, fruit length and diameter, wall thickness, and number of seeds. The analysis of PC performed indicated that the first three components explained 62.95% of the total variation. Additionally, the cluster analysis performed for the 13 variables generated three groups of accessions at a Euclidean distance of 5.44. Some of these variables, such as the pericarp thickness (wall thickness) and the number of seeds, coincide with the main component analysis of this project, where PC1 explained 66.98% of the total variability of the treatments.

Conclusions

Variability was found between the three populations of habanero pepper and a differential response to chemical and organic fertilization for the variables under study. With the 50-50 treatment, the best fruit quality was obtained (weight, number of locules and pericarp thickness), the highest number of seeds and their physiological quality (germination); treatment that equaled 100% inorganic fertility in the number of seeds, pericarp thickness, germination at 8 and 16 days, but statistically exceeded it in fruit weight (3.6%), number of fruit^{-1} locules (10.3%) and germination (3%).

The best collection was the Rojo Campeche 12 genotype, as it stood out in all the variables evaluated, with an average behavior of the fruit weight of 4.80 g, 27.5 seeds per fruit, 2.97 locules per fruit, a thickness of the pericarp of the fruit of 0.17 mm, 27.5 seeds per fruit and a germination at 16 days of 39.20%, with 50-50 fertilization.

The above allows to explore doses and opportunities for applying organic fertilizers that improve seed production with sustainable and environmentally friendly management, as well as a greater number of collections that express their genetic potential in different environments in terms of quantity and opportunity in the application of organic fertilizers, regardless of a greater range of atmospheric conditions.

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