Original Research Article

Evaluation of Agronomic Parameters in Experimental Hybrids of Poblano Chili in Open Field in Coahuila, Mexico

ABSTRACT

Objective: To evaluate the agronomic response of sixteen experimental poblano chili hybrids in open field in Coahuila, Mexico.

Design/methodology/approach: The treatment design and statistical model, was completely randomized with 16 treatments and four replications each, analyzed with an ANVA at $p \leq 0.05$ and a Tukey means test $p \leq 0.05$.

Results: In yield (g plant^{-1}), the hybrids H-302 and H-402 were superior, the number of fruits presented very similar values, the average weight the hybrid H-402 presented better values, the fruit length stand out for their size the hybrid H-303, H-304 and H-403, The width of the base of the hybrid did not show differences, the width of the center of the fruit the hybrids H-101, H-103, H-104 and H-201 showed no differences, the thickness of the mesocarp the hybrids H-303 and H-304 stood out, the projection of the yield the hybrids H-302, H-304, H-402 and H-404 stood out. The number of fruits per plant, average fruit weight, fruit length, mesocarp thickness and projected yield are the traits that most positively influence poblano chili yield with correlations of 0.87, 0.64, 0.51, 0.55 and 1.

Findings/Conclusions: The hybrids that showed favorable agronomic response in most of the variables evaluated were H-302, H-303 H-304, H-402, H,404. The agronomic response of the experimental hybrids was variable in most of the traits, therefore, the genetic potential of each one is different and is reflected in its phenotypic response under specific environmental conditions.

Key words: Capsicum annuum, phenotype, attribute, quality, yield

1. INTRODUCTION

In Mexico, the production of poblano chili (*Capsicum annuum* L.) is an essential agricultural activity in both economic and cultural aspects, given that it is one of the most relevant crops for the nation due to its importance in gastronomy and in the domestic and foreign markets (Pérez *et al*., 2017). The poblano chili are used in a wide variety of typical dishes, one of the most internationally recognized are the peppers in nogada, this dish is in high demand in both the domestic and global markets, which has motivated the search for improved varieties that increase the production and quality of the fruit (Galván, 2022). However, there are a

large number of detrimental factors, such as climate change, which can limit the search for varieties.

Climate change is becoming an increasingly important challenge for poblano chili production, since it impacts crop performance by altering temperature and rainfall patterns, also favoring the appearance of new pests or increasing the prevalence of existing ones (Medina *et al*., 2017). In this context, the creation of hybrids capable of resisting variable environmental conditions is crucial, which would facilitate greater stability in production and a reduction in the use of pesticides and other materials (Mercado *et al*., 2019). Current research has evidenced that the use and application of improved hybrids can contribute to decrease the environmental impact of agriculture and improve resource efficiency, contributing to a more sustainable and environmentally friendly agricultural production (Ayala *et al*., 2017).

The development of experimental hybrids of poblano chili has tried to meet the ever-increasing demand, therefore, performing analysis of its agronomic parameters under open field conditions is an essential task in genetic improvement programs in Mexico, since more than 95% of its cultivation is carried out under this production system (Santiago *et al*., 2018). This research makes it possible to choose genotypes with outstanding properties in terms of yield, disease resistance and adaptability to unfavorable environmental conditions, which helps to increase the profitability and sustainability of the crop (Luna *et al*., 2018). Key agronomic factors include plant height, number of fruits per plant, average fruit weight, and fruit physical properties such as fruit length, weight, and diameter, which directly affect yield and marketable quality (Herrera *et al*., 2023). Research on experimental hybrids also encourages innovation in cultivation techniques and management of poblano peppers, promoting the adoption of more efficient and environmentally friendly agricultural practices (Hernández *et al*., 2021). Thus, the selection of variants that respond optimally to open field conditions is promoted, strengthening the competitiveness of national producers in a global context (Silva *et al*., 2013). Therefore, the objective of this research was to evaluate the agronomic performance of experimental poblano chili hybrids under open field conditions in Coahuila, Mexico.

2. MATERIAL AND METHODS

Location of the experiment

The research was carried out in an open field at the plant breeding department of the Autonomous Agrarian University Antony Narro (UAAAN), Saltillo, Coahuila, Mexico, located at 25° 21' 24" LN and 101° 02' 05" LO, at 1762 meters above sea level. The average annual precipitation is 400 mm and the average annual temperature ranges from 18 to 22 °C. Field work was carried out from May to December 2022.

Plant material

Sixteen experimental hybrids of poblano chili developed at the Training Center for Seed Technology Development of the Plant Breeding Department (Table 1), Autonomous Agrarian University Antony Narro, were used.

Table 1. Plant material of the study evaluated under shade net conditions in Coahuila, Mexico.

Identification code	Origin	Identification code	Origin

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H-101	Coahuila	H-301	Coahuila
H-102	Coahuila	H-302	Coahuila
H-103	Coahuila	H-303	Coahuila
H-104	Coahuila	H-304	Coahuila
H-201	Coahuila	H-401	Coahuila
H-202	Coahuila	H-402	Coahuila
H-203	Coahuila	H-403	Coahuila
H-204	Coahuila	H-404	Coahuila

Seedling stage

All crops for commercial production or research start with the sowing of seeds and seedling management. The seeds of the hybrids were sown in 200-cavity polystyrene trays; peat moss and perlite were used as germination substrate in a 70:30% ratio, respectively. For seedling nutrition, a commercial formulation 20-30-10 with microelements was used, 0.5 g L^{-1} at five days after emergence, 0.75 and 1 g L^{-1} at 15 and 30 days after emergence, respectively, until transplanting.

Field establishment and crop management

Transplanting was carried out 64 days after sowing the seeds, and was done in a loam type soil with the characteristics described in Table 2. It was in the autumn-winter cycle of 2022, the cultivation beds were 25 cm high, the distance between beds was 1.80 m, the distance between plants was 30 cm in double rows.

Table 2. Physical-chemical characteristics of the soil fertility analysis, in which the experimental hybrids of poblano chili were established in open field.

Physical-chimical soil characteristics							
Textural class	Bulk density ($g.cm^{-3}$)	pH (1:2 water) alkaline	Total carbonates (%)	Salinity (EC extract 1:2 water) Ds/m	PS (%)	CC (%)	PMP (%)
Franco	1.25	8.61	8.25	1.1	40	21.3	12.7
Macroelements in parts per million (ppm)							
$N\text{-}NO_3^-$	P-Olsen	S	Cl	K^+	Ca^{2+}	Mg^{2+}	Na^+
39.7	65	55.9	ND	658	3995	321	106
Microelements in parts per million (ppm)							
Fe^{3+}	Mn^{2+}	B^{3+}	Zn^{2+}	Cu^+	Mo^{2+}		
2.07	3.11	1.31	4.95	0.51	ND		

PS= Saturation point, CC= Field capacity, PMP= Permanent wilting point, pH= Hydrogen potential, ND= Not determined.

Irrigation was carried out using a drip irrigation system, which consists of an Aquatrax® 6000 caliber irrigation tape, with drippers at 20 cm and 0.75 liters per hour, the soil was irrigated

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daily until reaching field capacity, the quality of the irrigation water is described in Table 3. The total nutrition applied via fertigation during the crop cycle was 170-80-270 N-P_2O_5-K_2O.

Table 3. Characteristics of irrigation water used to supply water and nutrients to the crop.

Macroelements in miliequivalents L^{-1}								
NO_3^-	$H_2PO_4^-$	SO_4^{2-}	Cl^-	K^+	Ca^{2+}	Mg^{2+}	Na^+	HCO^{3-}
0.41	ND	1.61	2.2	0.1	5.57	2.42	3.22	7.56

Microelements in parts per million (ppm)								
Fe^{3+}	Mn^{2+}	B^{3+}	Zn^{2+}	Cu^+	Mo^{2+}	pH	CE (Ds/m)	RAS
0.0118	0.0047	0.4	0.0891	0.0122	ND	7.5	1.15	1.61

pH= Hydrogen potential, EC= Electrical conductivity, RAS= Sodium absorption ratio.

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The poblano chili plants were not pruned, so they needed support during their growth to prevent the branches from breaking under the weight of the fruit. The tutorship used to keep the plants upright was the Spanish or “fajado” type, the distance between trees was five meters, and four tutorship actions were carried out throughout the crop cycle.

For pest control (whitefly, thrips, paratrioza), weekly applications of Spirotetramat 15.3%, Spiromesifen 23.1% and Imidacloprid 17% + betacylfutrin 12% were made at a rate of 1 ml L^{-1}. Weeds were removed with hoe and manually every 15 days.

Quantification of the response variables evaluated.

One harvest was carried out during the crop cycle, 90 days after transplanting, on August 20, 2022, and was done manually when the fruit reached commercial maturity. The yield (g plant-1) resulted from adding the weight of the fruits of each plant, which were weighed on a Sartorius precision digital balance (TS 1352Q37, Gottingen, Germany), followed by multiplying this weight by the number of plants per hectare to calculate the projected yield (t ha-1). After weighing the fruits, the number of fruits on each plant (NFP) was counted, while the average fruit weight (PPF) was calculated by dividing the total fruit weight by the total number of fruits on each plant, while base width, center width, mesocarp thickness and fruit length (ABF, AMF, GM and LF) were estimated by randomly taking eight fruits per replicate, and a Truper® brand digital vernier (CALDI-6MP, Atlacomulco, Mexico) was used.

Description of treatments and statistical analysis

Sixteen experimental hybrids of poblano chili were evaluated, under a completely randomized experimental arrangement, while, the completely randomized linear statistical model was used with 16 treatments and four replications each (ANVA $p \leq 0.05$), each replication with four useful measurable and quantifiable plants, for the comparison of means the Tukey test was used (Tukey $p \leq 0.05$). Correlation analysis was by Pearson's methodology. The data obtained were analyzed in the statistical software Infostat® version 2019.

3. RESULTS AND DISCUSSION

According to Tukey's mean test $p \leq 0.05$, in the yield variable in grams per plant, it is observed that, hybrids H-301, H-304, H-402 and H-404, are statistically equal to each other, but superior to the rest of the hybrids tested, however, among them H-302 stands out, while, the hybrids that presented a lower yield were H-102, H-103, H-104, H-201, H-301 and H-

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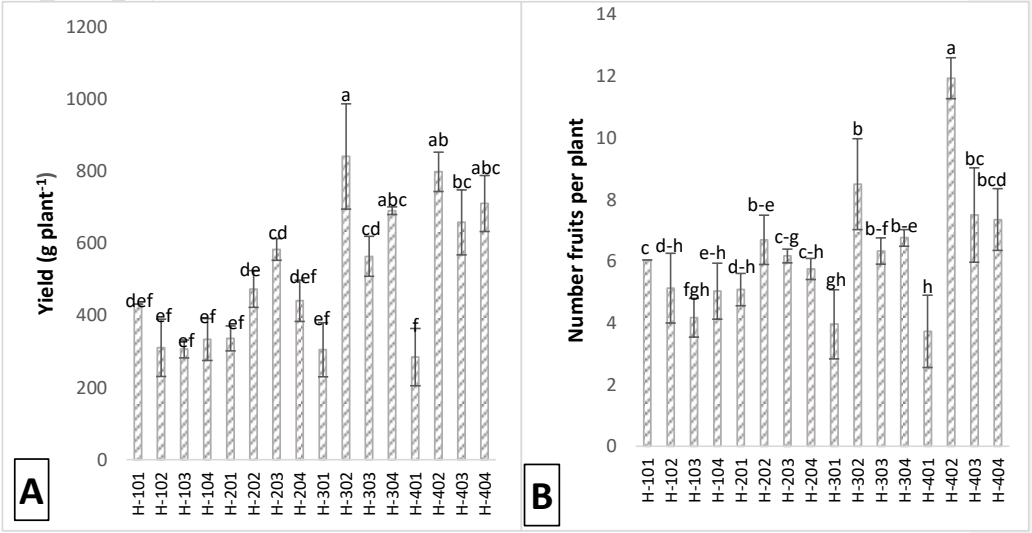
401, the rest of the hybrids maintained a yield range between 400 and 600 g plant-1 (Figure 1A). Similarly, it was observed that the hybrid H-302 outperformed the hybrid H-401 by more than 296%. The differential statistical response observed in the variable of number of fruits per plant indicates that most of the hybrids produced a very similar amount of fruits, except for the hybrid H-402, which was 319% higher than the hybrid H-401 (Figure 1B). In the mean fruit weight, significant statistical responses were observed among the hybrids tested, and the hybrids H-203, H-302, H-303, H-304 and H-404 stand out for this variable, while the other hybrids have a very similar fruit weight among them (Figure 1C), the fruits of hybrid H-304 are 63% heavier than hybrid H-102. According to the Tukey means test p≤0.05, no significant statistical differences were observed in the fruit length variable, where, the hybrid that produced the shortest fruits was hybrid H-102, while the other hybrids behaved similarly among them.

It is important to note that fruit length is of utmost importance, since this variable is a determining factor for the target market. Generally, fruit of 17-18 cm are preferred, ranges in which only hybrids H-303, H-304 and H-403 complied with this size, while the other treatments presented a smaller size at 17 cm (Figure 1D). The differential statistical response observed among the hybrids, in their yield and component variables, is attributed to the genetics of each hybrid and its response under the evaluation conditions.

Contreras *et al*. (2011), mention that yield is a quantitative trait, influenced by the interaction between alleles, this approach is essential to maximize the productive potential, since it allows taking advantage of heterosis or hybrid vigor, where hybrids show a higher yield than their parents (Hasanuzzaman *et al*., 2013).

The number of fruits per plant is another relevant aspect in the genetic improvement of poblano chili, since it is determined by genes that regulate both flowering and fruit formation, the genes that control these aspects are strongly influenced by differential expression under diverse environmental conditions (Pérez *et al.*, 2015). Since poblano chili hybrids that have a higher number of fruits per plant usually possess alleles that increase reproductive efficiency, allowing them to produce more fruits even under stress conditions, this implies genetic selection based on combinatorial ability, where parents that maximize fruit production are sought (Luna *et al*., 2021).

Fruit length and average weight are aspects of commercial interest and, from a genetic perspective, are regulated by genes that significantly influence the accumulation of reserves in the fruit, as well as its growth rate. These attributes are of great commercial importance in poblano chili, and the choice of hybrids with longer fruit length requires recognizing parents that show positive gene expression for these traits (Taco *et al*, 2024).



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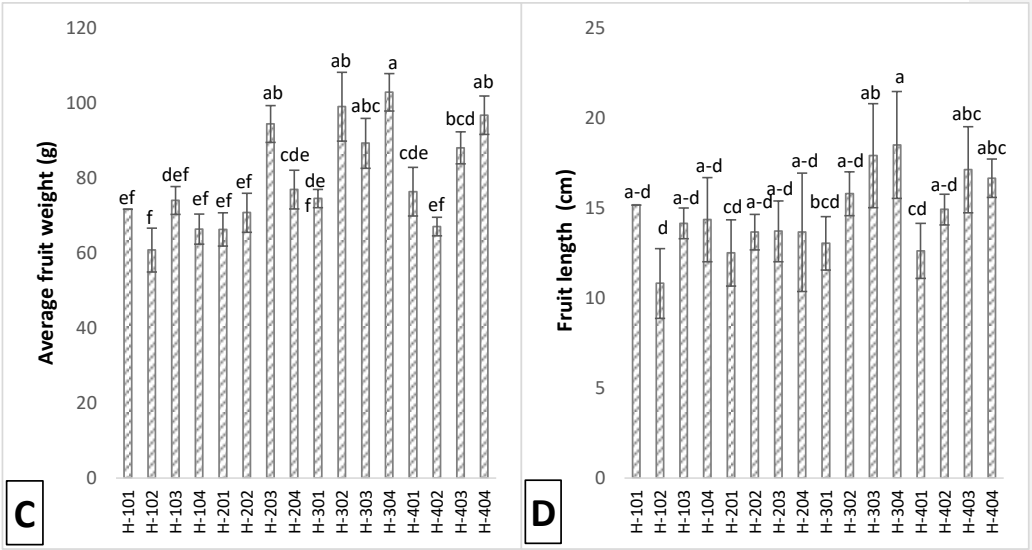

Figure 1. Response of the experimental poblano bell pepper hybrids in yield (A), number of fruits per plant (B), average fruit weight (C) and fruit length (D), ANVA $p \leq 0.05$, Tukey's mean test ($p \leq 0.05$), vertical bars correspond to standard deviation.

In the fruit base width variable, there are no statistical differences according to the Tukey means test $p \leq 0.05$, where the hybrids behaved very similarly between 50 to 58 mm, with only hybrid H-401 presenting a smaller base width compared to the others (Figure 2A). In the variable of width of the central part of the fruit, significant statistical differences were also detected according to Tukey's mean test $p \leq 0.05$, where it is observed that the hybrid with the greatest central width of the fruit is H-102, however, in the same statistical group are the hybrids H-101, H-103, H-104 and H-201, while, the fruits with the smallest width at base were deferred in another statistical group with the hybrids H-202, H-203, H-204, H-301, H-302, H-303, H-401, H-402, H-403 and H-404, the hybrid H-304 presents the smallest width of the center of the fruit (Figure 2B). In the thickness of the mesocarp, statistical differences are observed, being the hybrid H-303 and H-304 the ones that present a greater thickness, compared to the others, since they present a very similar thickness between 2 to 3 mm, but it can also be observed that the hybrid H-201, presents the smallest thickness of the pericarp (Figure 2C), which can cause a greater problem in the handling of these fruits due to its fragile structure at the moment of mobilizing fruits or packing.

According to the Tukey means test $p \leq 0.05$, in the variable yield projection in tons per hectare, it is observed that, hybrids H-302, H-304, H-402 and H-404, are statistically equal to each other, but superior to the rest of the hybrids tested, however, among them the hybrid H-

302 stands out, while the hybrids with the lowest yield projection were H-102, H-103, H-104, H-103 and H-104, However, the hybrid H-302 stands out among them, while the hybrids with the lowest yield projection were H-102, H-103, H-104, H-201, H-301 and H-401, and it is also observed that the hybrid H-401 has one of the lowest projections (Figure 2D).

The variable width of the base of the fruit is used to assess the stability and appearance of the fruit in poblano chili cultivars. Contreras *et al*. (2011) found that hybrids with a wider base demonstrated greater stability and resistance during market movement. In addition, Huerta *et al*. (2021), found that, if more extensive bases are obtained, they will react more efficiently when plants are under water stress conditions.

Fruit center width is an attribute that contributes considerably to visual quality and fruit volume. Narez *et al*. (2014), indicate that the use of hybrids would contribute an increase in fruit size compared to commercial controls that showed reduced width. Toledo *et al*. (2016) achieved similar findings by analyzing a set of experimental poblano chili hybrids, determining that fruit center width also helps to increase post-harvest quality and product longevity.

The thickness of the mesocarp is crucial for fruit quality, since it represents the portion that can be eaten and is the main indicator of the commercial quality of the fruit. Enchandi, (2005) found that fruits with a higher layer of this layer had superior nutritional value and higher disease resistance after harvest. Similarly, Diaz *et al*. (2013) found that chili bell pepper hybrids with thick mesocarp more effectively retained their freshness and appearance properties during extended storage.

Hernandez *et al*. (2021), found that yield projection in poblano chili bell pepper hybrids can be estimated by evaluating fruit morphological characteristics and plant development factors with high yield projection values presented up to 20% higher productivity compared to hybrids without directed selection. Tlelo *et al*. (2020) highlighted that yield projection is a variable highly dependent on the specific combining ability of the parents, since some hybrids showed a significant advantage in yield thanks to a favorable genetic combination, which evidences the effectiveness of evaluating the combining ability to select hybrids with superior yield potential.

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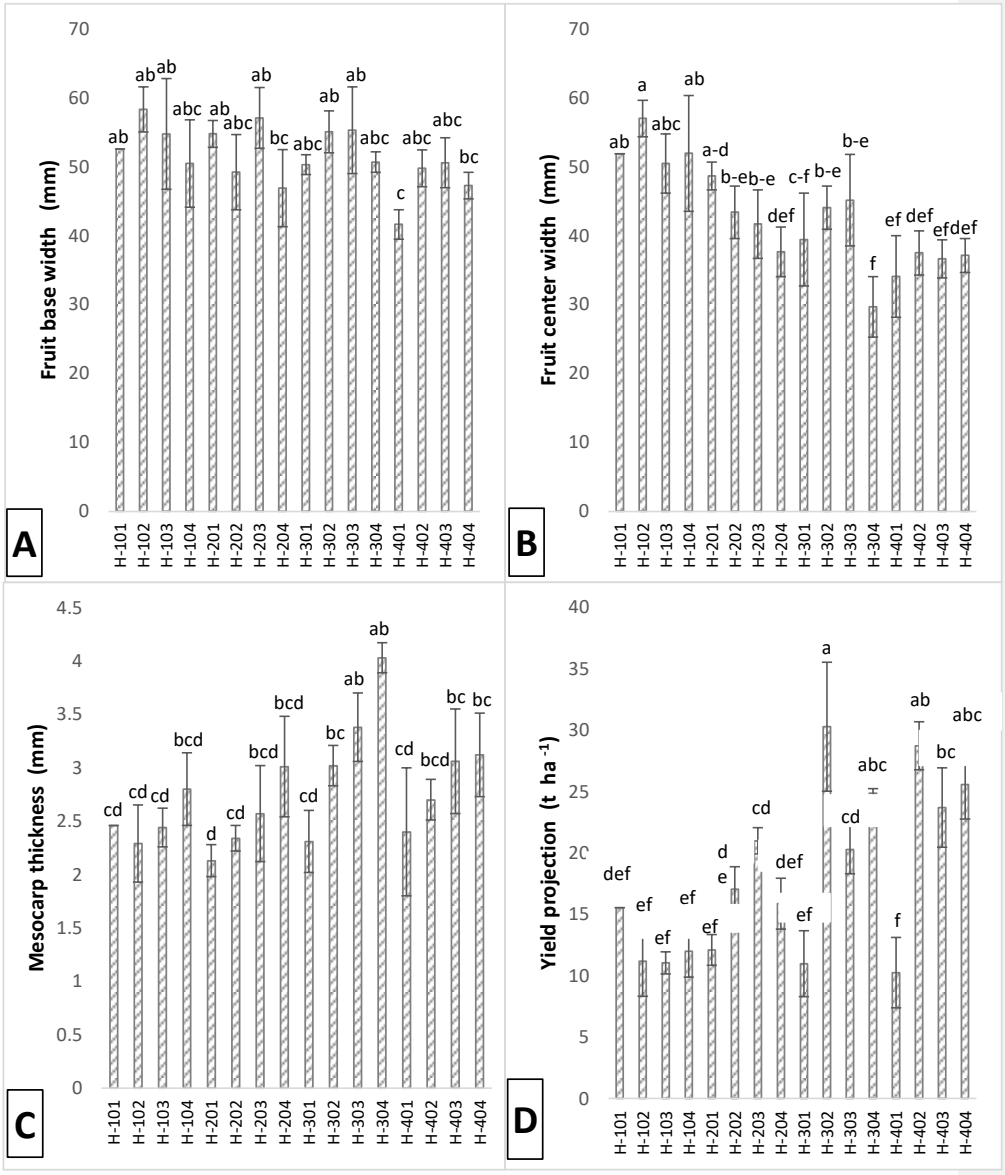

Figure 2. response of the experimental poblano chili bell pepper hybrids in fruit base width (a), fruit center width (b), mesocarp thickness (c) and yield projection (d), ANVA $p \leq 0.05$, Tukey's test of means ($p \leq 0.05$), vertical bars correspond to standard deviation.

In table 4 of Pearson's correlation coefficients, it is observed that, the number of fruits per plant, average fruit weight, fruit length and mesocarp thickness, are the characters that most positively influence the yield of poblano chili with correlations of 0.87, 0.64, 0.51 and 0.55, being very significant in comparison to that reported by Monje *et al*. (2022), finding values of

0.46, 0.44, 0.40 and 0.40. it is observed that the variable, fruit length, mesocarp thickness and projected yield, are contributing significantly to the variable average fruit weight, but negatively affect the width of the fruit center with -0.49. the variables mesocarp thickness and projected yield have a great influence in the evaluated hybrids showing a positive correlation with 0.64 and 0.51 in the fruit length variable, this is very important, because it is one of the visual and attractive characteristics for the sale of fruits in export markets. there is a significant effect between the width of the center of the fruit and the width of the base of the fruit with a positive influence of 0.60. the projected yield shows a strong relationship with the thickness of the mesocarp with 0.55, this is attributed to having a thicker and more rigid fruit wall, which will increase the weight and consequently the yield.

Table 4. Pearson's correlation coefficient of variables evaluated in poblano peppers grown under shade netting.

	REND	NFP	PPF	LF	ABF	ACF	GM
NFP	0.87**						
PPF	0.64**	0.19					
LF	0.51**	0.28	0.60**				
ABF	0.05	0.00	0.06	0.14			
ACF	-0.42*	-0.26	-0.49*	-0.29	0.60**		
GM	0.55**	0.30	0.63**	0.64**	0.03	-0.36*	
RENDP	1.00**	0.87**	0.64**	0.51**	0.05	-0.42*	0.55**

*= significant $p \leq 0.05$, **= highly significant $p \leq 0.01$. REND= yield, NFP= number of fruits per plant, PPF= average fruit weight, LF= fruit length, ABF= fruit base width, ACF= fruit center width, GM= mesocarp thickness, RENDP= projected yield.

4. CONCLUSION

The agronomic response of the experimental hybrids tested under open field conditions was variable in most of the variables evaluated, thus inferring a different genetic potential in each one of them, in response to the specific evaluation conditions under which they were developed.

The hybrids that showed a favorable agronomic response in most of the evaluated attributes were H-302, H-303, H-304, H-402, H-404.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author (s) hereby declare that nor generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image genitor's have been used during the writing or editing of this manuscript.

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