Colegio de Postgraduados

Catiknifap, new native variety of Xcat ik pepper (*Capsicum annuum* L.)

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ABSTRACT
Objective: To describe the morphological and agronomic characteristics of Catiknifap, a native variety of the Xcat ik pepper.
Design/Methodology/Approach: Catiknifap was formed by mass selection method from a P108 accession collected in 2013 in Muna, Yucatan. Characterization and yield trails were carried out in greenhouse during three cycles from 2021 to 2022. Forty-five characteristics were evaluated based on UPOV guidelines.
Results: Catiknifap is an early-ripening variety. Its fruits ripen between 77 and 81 days after transplanting. Its main morphological characteristic is the rounded shape at the junction with the peduncle. The yield depends on the growing season and ranges from 32.3 to 42.3 t ha^{-1}.
Study Limitations/Implications: Assays were carried out in greenhouses. Pests and diseases may cause differences in open field yield.
Findings/Conclusions: Catiknifap is the first morphologically characterized variety of Xcat ik pepper. The fruits of this homogenous and stable variety have a high yield potential in Yucatan.

Keywords: *Capsicum annuum* L., vegetable, yield.

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INTRODUCTION

Xcat ik (*Capsicum annuum* L.) is a highly valued native chili pepper in the Yucatan Peninsula. The fruit has an elongated, conical, and pointed shape. Unripe fruit is greenish-yellow, gradually turning orange and red as it ripens, until it becomes fully red (Santamaría and Zavala, 2021). Consumers prefer a yellowish-green, slightly orange fruit with firm texture (Santamaría *et al.*, 2022a). The production is carried out by small-scale farmers. As a result of the limited financial resources they can allocate to cultivation, they employ low technology, particularly in mineral nutrition (Gamboa-Angulo *et al.*, 2020).

There is little variation in the vegetative characteristics of the Xcat ik chili pepper genotypes, such as the purple coloration caused by intermediate to dense anthocyanin at the nodes and stem pubescence. However, they show variation in fruit size (weight, diameter, and length-to-diameter ratio), flower size (anther and corolla length), and stem characteristics (Vera-Sánchez *et al.*, 2016). The fruit shape at the junction with the peduncle can be obtuse, truncated, or cordate, while the apex can be pointed, blunt, or sunken (Aguilar *et al.*, 2010).

The fruits of Xcat ik chili accessions from the Banco de Germoplasma of the Campo Experimental Mocochá have a narrow triangular shape with a non-enveloping calyx and an acute apex. However, the shape of its the junction can be rounded or flat or have a peduncular cavity (Santamaría *et al.*, 2022a; 2022b).

Gamboa-Angulo *et al.* (2020) and López *et al.* (2019) worked with Xcat ik chili accessions in their studies on the use of microbial biofertilizers and on genetic diversity, respectively, but both failed to describe the morphological characteristics of the said accessions. For their part, Castillo-Aguilar *et al.* (2019) used the descriptors for *Capsicum* from IPGRI, CATIE, and AVRDC (1995) for the morphological characterization of two ecotypes from the state of Campeche. As has been documented for several years, Xcat ik chili remains under-characterized and no varieties are available (González *et al.*, 2010; Santamaría *et al.*, 2022a). Therefore, open-pollinated varieties with outstanding agronomic characteristics should be developed and the seeds should be available for producers. Consequently, the objective of this study was to describe the morphological and agronomic characteristics of Catiknifap, based on the hypothesis that the morphological description of its plant, stem, leaf, flower, and fruit characteristics will establish it as a native variety of Xcat ik chili.

MATERIALS AND METHODS

Origin

Catiknifap originates from accession P108, collected in 2013 in Muna, Yucatán, and introduced into the Banco de Germoplasma of the Campo Experimental Mocochá (21° 06' 15" N, 89° 26' 15" W).

It was developed using a mass selection breeding method, which involves selecting individuals with similar phenotypic characteristics to improve a population by increasing the prevalence of desired types (López, 1995; Camarena *et al.*, 2014). The seeds from individuals with similar characteristics are mixed to form the next generation and this process is repeated as many times as necessary, until the population becomes homogeneous (Márquez, 1988; Ramírez and Méndez, 2018). Stable characteristics lead to a quick selection process (Camarena *et al.*, 2014). For example, a triple-cycle mass selection of sweet chili pepper (*Capsicum annuum* L.) led to significant improvements in the development of two agronomically outstanding varieties (Chi-Kantún *et al.*, 2017).

Growing Conditions

The yield and homogeneity evaluation trials were conducted in a greenhouse with plastic roof and anti-aphid net walls. The plants were spaced 1.5 m between rows and 0.5 m between plants on ≈15-cm tall, raised beds. Drip tape with emitters spaced every 10 cm was used for pressurized irrigation.

Characteristics Evaluation

Accession P108 was collected based on fruit characteristics; however, the varietal description also considered other characteristics. In total, 45 characteristics were evaluated: 3 related to the plant, 2 to the stem, 8 to the leaf, 5 to the flower, and 27 to the fruit. Depending on the characteristic, 10 or 20 readings were conducted based on the test

guidelines proposed by UPOV (2018, 2020) for distinctness, uniformity, and stability of *Capsicum annuum* L.

Yield

Three yield assays were conducted. The first was made on August 1, 2021 (at the beginning of the fall-winter cycle), the second on January 5, 2022 (at the end of the fall-winter cycle), and the third on November 18, 2022. Fruits were classified according to the length code established in the NMX-FF-025-SCFI-2014 Mexican standard (Secretaría de Economía, 2015): large fruits >16 cm (size 5), medium fruits from 12.1 to 16 cm (size 4), and small fruits from 8.1 to 12 cm (size 3).

Statistical Analysis

The yield data were subjected to an analysis of variance, considering the cycle (sowing date) as the treatment in a completely randomized design with three replications. The Shapiro-Wilk and Bartlett tests were used to verify the normality and homogeneity of variances, respectively. Means were compared using Tukey's test ($P \leq 0.05$) with the R statistical software version 4.2.3 (R Core Team, 2023).

RESULTS AND DISCUSSION

Morphological Characteristics

Plant. Anthocyanins can be found in the hypocotyl of seedlings during the cotyledon leaf stage. The plant is tall with a semi-erect growth habit. The height range of the Xcat ik chili plant depends on its environmental conditions: from 30 to 70 cm in open field conditions (González *et al*., 2010) and from 66 to 85 cm in greenhouse conditions (Castillo-Aguilar *et al*., 2019). The average height of the Catiknifap plant is 120 cm at 85 days after transplanting (DAT) and 160 cm at 160 DAT.

Stem. The stem show medium intensity anthocyanin pigmentation at the nodes and the pubescence is absent or very weak. Anthocyanins at the nodes are a typical characteristic of the Xcat ik chili (Aguilar *et al*., 2010; Castillo-Aguilar *et al*., 2019).

Leaves. The lanceloate-shaped leaves have a long blade (13.5 cm average) and medium width (6.5 cm average). Although their size is similar, the lanceolate shape of the leaf differs from the oval shape of the leaves in ecotypes 1 and 2 of Xcat ik chili (Castillo-Aguilar *et al*., 2019). Young leaves are greener than mature leaves. The margin undulation is weak, blistering is very weak, and the cross-sectional profile is moderately convex. The central vein of the leaf has anthocyanins.

Flowers. Each plant has 1 or 2 flowers per axil with a pendent peduncle, 5 to 6 white petals, and anthers with anthocyanin pigmentation.

Fruit. Xcat ik chili has elongated fruits (Aguilar *et al*., 2010; Castillo-Aguilar *et al*., 2019). The fruits of Catiknifap are long (14.0-18.5 cm), but have a narrow triangular shape, with a very sharp apex and medium diameter (2.5-3.5 cm at the widest point), a high length-to-diameter ratio, and an angular cross-sectional shape. They have a slight C-shaped curvature, without twisting. The fruits hang downwards. The calyx has a non-enveloping aspect, except when the fruits have not completed their development. It has no peduncular

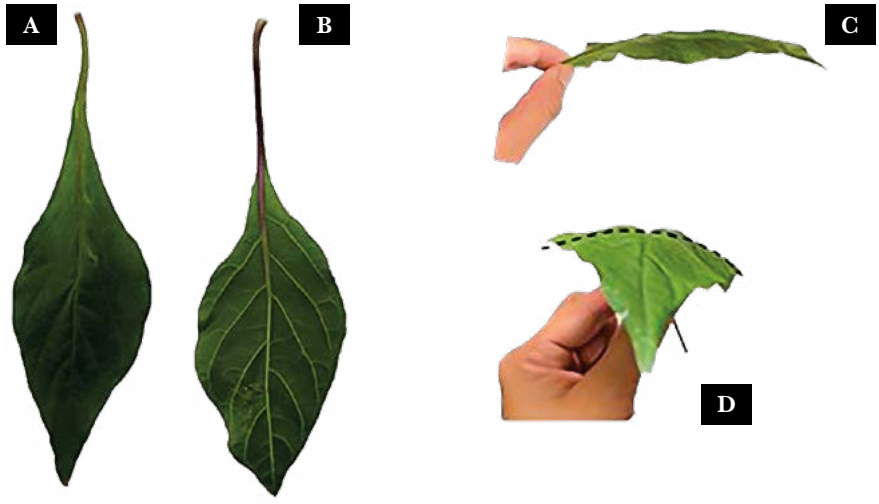

Figure 1. Leaves of Xcat ik chili var. Catiknifap. (A) Lanceolate shape with weak margin undulation. (B) Anthocyanins in the central vein. (C) Very weak blistering. (D) Moderately convex cross-sectional profile.

cavity. The main distinguishing characteristic of the Catiknifap fruit is the rounded shape at the junction with the peduncle. In other plant materials, the fruit shape at the junction with the peduncle can be obtuse, truncated, cordate (Aguilar *et al.*, 2010), rounded, or flat; they could even have a peduncular cavity (Santamaría *et al.*, 2022a; 2022b).

Unripe fruits do not have anthocyanin pigmentation; however, when plants are subjected to stress from high temperatures and/or pest attacks, the fruits may display pigmentation. Upon ripening, the yellowish-green fruit acquires a medium-intensity and very bright red hue. It has no sinuousness of the pericarp at the basal part, or it is very weak, while the non-basal pericarp is weak. The surface texture is smooth. Most of the fruits have 3 locules, although 2 and 4 locules have also been reported. It has no depth in the interlocular grooves. Capsaicin content was recorded in the fruits. The fruits have a thin pericarp (3 mm), a medium-length peduncle (3.5 cm), and a thin diameter. The cream-colored seeds are circular, slightly longer than wide. The average length, width, and weight of the seed of unripen fruits are 4.40 mm, 3.80 mm, and 6.6 g per 1,000 seeds, respectively. The seeds of ripe fruits are 4.25 mm long and 3.70 mm wide and have weight of 7.2 g per 1,000 seeds.

Some of the morphological characteristics of Catiknifap recorded in this study are the same as in other reports, such as anthocyanin pigmentation at the nodes, petal color, anthocyanin pigmentation of the anthers, fruit brightness, absence of anthocyanin pigmentation in the fruit, cream color of the seeds, and weight of 1,000 seeds. However, differences were recorded in other characteristics (plant height, leaf shape, and fruit). The Catiknifap plant is taller (up to 160 cm) than ecotypes 1 and 2 (85 cm), under similar greenhouse conditions. Catiknifap has lanceolate leaves, while ecotypes 1 and 2 have oval leaves. The fruits of Catiknifap hang like those of ecotype 1, but they are different from the erect posture of ecotype 2 fruits reported by Castillo-Aguilar *et al.* (2019).

Three characteristics distinguish Catiknifap fruits: the absence of a peduncular cavity, the rounded shape at the junction with the peduncle, and the fruit shape itself. The first two characteristics are closely related due to their location on the fruit. The third

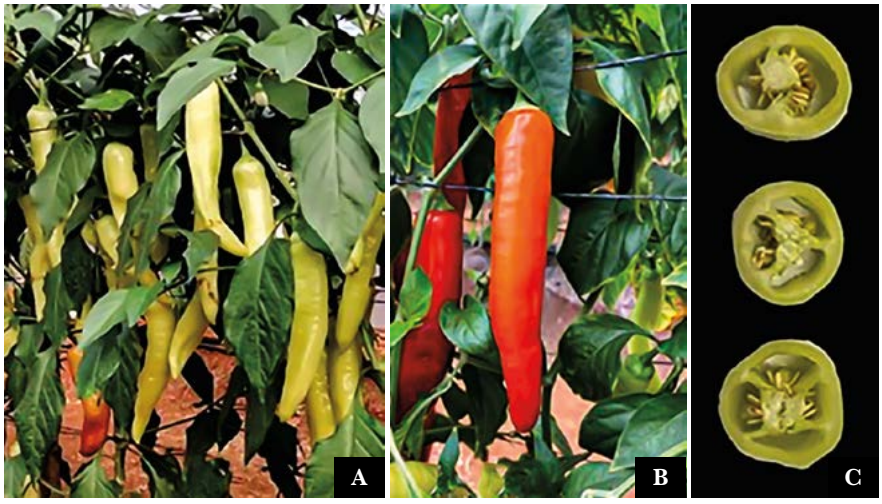

Figure 2. Fruits of Xcat ik chili var. Catiknifap. (A) Green fruits at commercial ripening. (B) Ripe fruits. (C) Angular cross-section with 2, 3, and 4 locules.

characteristic is the fruit shape; the difference between the elongated shape reported by Aguilar *et al.* (2010) and Castillo-Aguilar *et al.* (2019) and the narrow triangular shape with a very sharp apex reported in this study may be a morphological difference resulting from the choice of descriptor. Castillo-Aguilar *et al.* (2019) used the descriptors proposed by IPGRI, CATIE, and AVRDC (1995), whereas this study employed the descriptors from UPOV (2018). As has been discussed before, Xcat ik chili is poorly characterized and the lack of descriptive studies prevents comparisons between the morphology of its accessions or ecotypes. This work provides the first morphological characterization of Xcat ik chili using UPOV descriptors, which is the methodology accepted by SNICS for the registration of varieties in Mexico.

Yield

Catiknifap is an early-ripening variety, whose fruits reach maturity between 77 and 81 days after transplanting (103 to 107 days after sowing in the seedbed). The harvest lasted for 3.1 to 3.4 months (Table 1). Statistical differences were found regarding yield in the analysis of variance (Table 2). The values for the Shapiro-Wilk and Bartlett tests were 0.4198 and 0.6244, respectively. The yield of the plot established in August 2021 was 35.4 t ha^{-1}, a value that was statistically equivalent to the yield (32.3 t ha^{-1}) obtained in the plot established on November 18, 2022. In both cases, most of the production consisted of large fruits. The yield of the plot established in January 2022 was 42.3 t ha^{-1}. The productive stage of this plot took place during the hottest months, promoting faster growth and greater production. However, this situation impacted the fruit size.

The yields of the Catiknifap variety are higher (32.2 to 42.3 t ha^{-1}) than the yields reported by SIAP (2023) in protected agriculture in Yucatán (17.0 to 21.1 t ha^{-1}). Moreover, they are like the yield obtained from a local variety (37.4 t ha^{-1}), under the same greenhouse conditions during the 2020-2021 cycle (Santamaría *et al.*, 2022b). Gamboa-

Table 1. Fresh fruit production of Xcat ik chili var. Catiknifap on 3 sowing dates.

Date of planting	1 aug 2021	5 jan 2022	18 nov 2022
Planting to harvest (days)	81	79	77
Harvest (months)	3.4	3.1	3.2
Yield (t ha^{-1})	35.4 b	42.3 a	32.3 b
Small size fruits (%)	6.4	6.6	12.3
Medium size fruits (%)	29.6	52.1	31.8
Large size fruits (%)	64.0	41.3	55.9

Means with the same letter in the row are statistically equal (Tukey, $p \leq 0.05$).

Table 2. Analysis of variance for the fresh fruit production of Xcat ik chili var. Catiknifap on 3 sowing dates.

Source of variation	Degree of freedom	Sum of squares	Mean square	F	p
Date of planting	2	156.0017	78.0008	16.9409	0.0034
Error	6	27.6257	4.6043		

Angulo *et al.* (2020) reported 1.69-1.85 kg per plant yields of Xcat ik chili. Considering a density of 13,320 plants per hectare, the yields should be 22.5 to 24.6 t ha^{-1}. However, these results are lower than the yields obtained in this work.

The lack of Xcat ik chili varieties led to the development of Catiknifap; the aim was to uniformly preserve the native characteristics and to provide producers with an open-pollinated variety with outstanding agronomic characteristics.

CONCLUSIONS

Catiknifap is the first morphologically characterized variety of Xcat ik chili. Its rounded shape at the junction with the peduncle is its main distinguishing characteristic compared with other Xcat ik materials. Given its homogenous and stable fruit production, this variety has high yield potential in Yucatán.

REFERENCES

Aguilar, R. V. H., Corona, T. T., López, L. P., Latournerie, M. L., Ramírez, M. M., Villalón, M. H. & Aguilar, C. J. A. (2010). Los chiles de México y su distribución. SINAREFI; CP; INIFAP; ITConkal; UANL; UAN.

Camarena. M. F., Chura, J. C. R. H., & Blas, S. (2014). Mejoramiento genético y biotecnológico de plantas. Universidad Nacional Agraria La Molina; Agrobanco.

Castillo-Aguilar, C. C., Jiménez, A. M., Chiquini-Medina, R. A., Quej-Chí, V. H., & Lara-Reyna, J. (2019). Caracterización varietal de dos ecotipos de chile Xcat ik (*Capsicum annuum*) del estado de Campeche. In: W. Cetzal-Ix, F. Casanova-Lugo, A. J. Chay-Canul, & J. F. Martínez-Puc (Eds.). *Agroecosistemas tropicales: conservación de recursos naturales y seguridad alimentaria* (1a ed., pp. 330-337).Tecnológico Nacional de México,

Chi-Kantún, N. I., Latournerie-Moreno, L., López-Vázquez, J. S., Mijangos-Cortes, J. O., Pérez-Gutiérrez, A., Sánchez-Azcorra, P. S., & Castañón-Nájera, G. (2017). Selección masal en chile dulce criollo (*Capsicum annuum* L.) *Agroproductividad, 10*(6), 98-103.

Gamboa-Angulo, J., Ruíz-Sánchez, E., Alvarado-López, C., Gutiérrez-Miceli, F., Ruíz-Valdiviezo, V. M., & Medina-Dzul, K. (2020). Efecto de biofertilizantes microbianos en las características agronómicas de la planta y calidad del fruto del chile xcat´ik (*Capsicum annuum* L.). *Terra Latinoamericana*, 38, 817-826. https: //doi.org/10.28940/terra.v38i4.716

González, E. T., Casanova, Ch. C., Gutiérrez, P. L., Torres, T. L., Contreras, M. F., & Peraza, S. S. (2010). Chiles cultivados en Yucatán. In G. R. Durán & G. M. E. Méndez (Eds.), Biodiversidad y desarrollo humano en Yucatán (1a ed., pp. 342-344). CICY.

IPGRI; AVRDC; CATIE. (1995) Descriptores para Capsicum (Capsicum spp.). IPGRI.

López, C. L. C., Garruña, H. R., Castillo, A. C. C., Martínez-Hernández, A., Ortiz-García, M. M., & Andueza-Noh, R. H. (2019). Structure and Genetic Diversity of Nine Important Landraces of Capsicum Species Cultivated in the Yucatan Peninsula, Mexico. *Agronomy*, 9, 376. https://doi.org/10.3390/agronomy9070376

López, T. M. (1995). Fitomejoramiento. Editorial Trillas.

Márquez, S. F. (1988). Genotecnia Vegetal (1a ed., tomo II). AGT Editor.

R Core Team (2023). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/

Ramírez, M. M., & Méndez, A. R. (2018). Mejoramiento genético de los chiles comerciales en México. In A. Aguilar-Meléndez, M. A. Vásquez-Dávila, E. Katz, & C. M. R. Hernández (Coords.), Los chiles que le dan sabor al mundo (1a ed., pp. 286-300). IRD Éditions.

Santamaría, B. F., & Zavala, L. M. J. (2021). Estados de maduración de frutos de chile Xcat ik (*Capsicum annuum* L.) y su relación con el periodo de almacenamiento en la germinación de las semillas. *Brazilian Journal of Animal and Environmental Research, 4*(3), 4674-4683.

Santamaría, B. F., Díaz, P. R., & Basto, P. C. I. (2022a). Productividad y formación de variedades de chile Xcat ik. *Journal of Agricultural Science Reserch, 2*(5), 1-8. https://doi/10.22533/at.ed.973252201069

Santamaría, B. F., Díaz, P. R., & Basto, P. C. I. (2022b). Avances en la formación de variedades de los chiles criollos dulce e xcat ik. *Gaceta SIIDETEY, 10*(64), 39-41.

Secretaría de Economía. (2015). NORMA MEXICANA NMX-FF-025-SCFI-2014. Productos alimenticios no industrializados para consumo humano - chile fresco (Capsicum spp) – Especificaciones.

SIAP. Servicio de Información Agroalimentaria y Pesquera. (2023). Anuario Estadístico de la Producción Agrícola. https://nube.siap.gob.mx/cierreagricola/ [consultado el 16 de agosto de 2023].

UPOV. International Union for the Protection of New Varieties of Plants. (2020). Sweet pepper, hot pepper, paprika, chili UPOV Code(s): CAPSI_ANN. *Capsicum annuum* L. Guidelines for the conduct of tests for distinctness, uniformity and stability

UPOV. Unión Internacional para la Protección de las Obtenciones Vegetales. (2018). Ají, chile, pimiento. Código de la UPOV: CAPSI_ANN. *Capsicum annuum* L. Directrices para la ejecución del examen de la distinción, la homogeneidad y la estabilidad.

Vera-Sánchez, K. S., Cadena-Iñiguez, J., Latournerie-Moreno, L., Santiaguillo-Hernández, J. F., Rodríguez-Contreras, A., Basurto-Peña, F. A., Castro-Lara, D., Rodríguez-Guzmán, E., López-López, P., & Ríos-Santos, E. (2016). Conservación y utilización sostenible de las hortalizas nativas de México. Servicio Nacional de Inspección y Certificación de Semillas.