ISSN: 2594-0252

AGRO PRODUCTIVIDAD

Water supply in artificial troughs:

a strategy to mitigate the impacts of climate change in the Maya forest

pág. 69

Año 17 • Volumen 17 • Número 4 • abril, 2024

The Mexican Beekeeping Agri-food System: A descriptive analysis 3

Productive response of dual-purpose cows supplemented with chelate minerals and calcium salts 11

Materials and methods for the microencapsulation of substances of food and agricultural interest 19

Blood disorders caused by hypophosphatemia in dairy cows 27

Efficacy of chemical fungicides against the anthracnose disease caused by *Colletotrichum gloeosporioides* in *Carica papaya* fruits 35

Cardinal temperatures of populations developed from native maize (*Zea mays* L.) from central and southern, Tamaulipas, Mexico 47

y más artículos de interés...

Colegio de Postgraduados

Colegio de Postgraduados

Cardinal temperatures of populations developed from native maize (*Zea mays* L.) from central and southern, Tamaulipas, Mexico

García-Ramírez, Alejandro[1]; López-Santillán, José A.[1*]; Estrada-Drouaillet, Benigno[1]; Poot-Poot, Wilberth A.[1]; Varela-Fuentes, Sostenes E.[1]; Reséndiz-Ramírez, Zoila[2]; Mayek-Pérez, Netzahualcóyotl[3]

[1] Universidad Autónoma de Tamaulipas, Posgrado e Investigación de la Facultad de Ingeniería y Ciencias Cd. Victoria, Tamaulipas, México, C. P. 87000. Tel: 834-318-1721, Ext. 2146.

[2] Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, Campo Experimental Río Bravo, Río Bravo, Tamaulipas, México, C. P. 88900.

[3] Universidad Autónoma de Tamaulipas, Unidad Académica Multidisciplinaria Reynosa Rodhe, Reynosa, Tamaulipas, México, C. P. 88779.

* Correspondence: jalopez@docentes.uat.edu.mx

ABSTRACT

Objective: To estimate the cardinal temperatures of native maize populations from Tamaulipas.

Design/Methodology/Approach: Ten genotypes developed from native germplasms were established in Güémez, Tamaulipas, on 12 planting dates (2019 and 2020). The cardinal temperatures (T_b, T_o, and T_u) of each of the cultivars were estimated through the decomposition of a quadratic model, using the days from sowing to tasseling and the average temperature of each sowing date from that period.

Results: From sowing to tasseling, the evaluated cultivars recorded 15.7-18.1 °C base temperatures (T_b), 28.3-30.1 °C optimum temperatures (T_o), and 32.3-34.4 °C threshold temperatures (T_u). The T_b and T_o values represent the high thermal requirement of the germplasm, while T_u stands for its resistance to high temperatures. The L3, L4, L5, and VHA cultivars stood out for their broader adaptation range (16.2 to 34.4 °C), while the L3, L4, and L6 cultivars have a higher resistance to high temperatures (average T_u: 34.5 °C).

Study Limitations/Implications: The cardinal temperatures determined in this study depended on the evaluated genotypes and the environment in which they developed.

Findings/Conclusions: The maize germplasm evaluated in this study was resistant to high temperatures. As a result of its adaptation to the conditions of central and southern Tamaulipas, this germplasm is a source of variation for the characteristics that provide resistance to the stress caused by high temperatures.

Keywords: *Zea mays*, native maize, tolerance, high temperature, genetic improvement.

Citation: García-Ramírez, A., López-Santillán, J. A., Estrada-Drouaillet, B., Poot-Poot, W. A., Varela-Fuentes, S. E., Reséndiz-Ramírez, Z. & Mayek-Pérez, N. (2024). Cardinal temperatures of populations developed from native maize (*Zea mays* L.) from central and southern, Tamaulipas, Mexico. *Agro Productividad*. https://doi.org/10.32854/agrop.v17i4.2588

Academic Editors: Jorge Cadena Iñiguez and Lucero del Mar Ruiz Posadas
Guest Editor: Daniel Alejandro Cadena Zamudio

Received: May 25, 2023.
Accepted: January 16, 2024.
Published on-line: May 06, 2024.

Agro Productividad, 17(4). April. 2024. pp: 47-52.

INTRODUCTION

The wide agroecological diversity of Tamaulipas favors the genetic variability of native maize (Castro *et al.*, 2013; González-Martínez *et al.*, 2018), mainly in the center and south of the state. Many grain and forage production systems are established with these cultivars —mainly *Tuxpeño*, *Ratón*, *Olotillo*, and *Cónico* maize races (González-Martínez *et al.*, 2018). In addition, these races are known for their high adaptability to limiting agroclimatic conditions, such as high temperatures (Pecina-Martínez *et al.*, 2009). As a consequence of its geographical location, central and southern Tamaulipas reach temperatures >40 °C in summer (Castro *et al.*, 2013). Nevertheless, native maize developed under these conditions is a source of characteristics that provide resistance to this type of environmental stress (Castro-Nava *et al.*, 2011). Resistance to high temperatures is a feature with a high genotype-environment interaction (Naveed *et al.*, 2016). Consequently, determining the genetic effects that control the resistance to high temperatures in the available maize germplasm is fundamental to design effective evaluation and selection plans (Van Inghelandt *et al.*, 2019). Therefore, an accurate characterization of the cardinal temperatures (Yousaf *et al.*, 2018) of the Tamaulipas maize germplasm is required to select specific populations to be used as a base germplasm, in order to design an appropriate program for the improvement of the resistance to high temperatures (Chen *et al.*, 2012). This characterization must be based on the evaluation of germplasms with different temperature ranges —*i.e.*, the cardinal temperatures must be determined (Ruiz-Corral *et al.*, 2002; Aburto-Cansino *et al.*, 2018). In this regard, the temperature range of a given cultivar should be accurately determined. The temperature range includes a minimum or base temperature (T_b) and a maximum or threshold temperature (T_u). In addition, the optimal temperature (T_o) must be determined, based on the highest development rate (Hatfield and Prueger, 2015). When temperatures are lower or higher than the optimal temperature, they cause a decrease in the development rate of the plant; however, temperatures outside the range of the base and threshold temperatures cause a null development rate. This technique helps to determine the thermal growing periods for each cultivar, based on the thermal offer of each place (Arista-Cortes *et al.*, 2018).

MATERIALS AND METHODS

Phenological and temperature data were recorded in 12 sowing dates between 2019 and 2020 (Table 1). The data was collected in Güémez, Tamaulipas (23° 56' 28" N, 99°

Table 1. Sowing dates and thermal characteristics of Güémez, Tamaulipas.

Sowing date	Season	Year	AT
August 01		2019	29.2
August 21	-	-	27.4
August 30	-	-	25.1
September 09	-	-	24.3
January 24	FW	2019-2020	23.0
February 07	-	-	24.1
February 22	-	-	25.7
March 27	-	-	28.4
July 22	SS	2020	27.5
August 04	-	-	27.7
August 17	-	-	27.0
August 31	-	-	25.5

Sp-Su (PV): Spring-Summer; A-W (OI): Autumn-Winter; Tm: Medium daily temperature.

06' 24" W, at 193 m.a.s.l.). This region has a semi-arid warm climate (Vargas *et al.*, 2007). Each sowing date was established under irrigation conditions and included 10 maize cultivars. The furrows were established 0.08 m apart from each other and the distance between plants was 0.25 m. Two maize seeds were sown per hole and thinning was carried out 14-21 days after the sowing. The ten maize cultivars included in this study came from a germplasm from the dry subtropics and are consequently adapted to central and southern Tamaulipas (Castro *et al.*, 2013).

The following variables were evaluated: tasseling (F) days and medium daily temperature (T_m). The former is the number of days from the sowing until 50% of the plants have released pollen. The latter was calculated as the mean between the maximum daily temperature and the minimum temperature of each sowing date. The 1/F was calculated to determine the development rates of the 12 environments, during the sowing-tasseling period. The data described a curvilinear shape and, consequently, the quadratic regression model used by Ruiz-Corral *et al.* (2002) was applied to calculate base and optimal temperatures, using the following formula:

$$1/F = \beta_0 + \beta_1 T_m \times \beta_2 T_m{}^2$$

Where T_m is the medium daily temperature of the *F* period (sowing-tasseling). Based on this equation, base temperature (T_b) was estimated using the following equation: .

$$T_b = \frac{\left(-\beta_1 + \beta_1^2 - 4\beta_0\beta_2\right)^{1/2}}{2\beta_2}$$

Optimal temperature (T_o) was calculated with the following equation:

$$T_o = \frac{-\beta_1}{2\beta_2}$$

Once T_b and T_o were calculated, the maximum threshold temperature (T_u) was determined with the following identity:

$$T_u = \frac{\ln\left(2C^{T_o} - C^{T_b}\right)}{\ln C}$$

where ln is the natural logarithm and *C* is equal to 1.15 (Ruiz-Corral *et al.*, 2002).

RESULTS AND DISCUSSION

The quadratic model accurately represented the temperature-development rate relationship (R^2=0.88, Table 2). Figures 1A and 1B show the relationship between the maize development rate and the environmental temperature of the evaluated cultivars.

Table 2. Parameters of the quadratic regression and cardinal temperatures of the maize cultivars evaluated in Güémez, Tamaulipas.

Cultivar	β_0	β_1	β_2	Bt	Ot	Mtt	R^2
L1	−0.10535	0.00846	-1.46×10^{-4}	18.1	29.0	33.1	0.87
L2	−0.07200	0.00611	-1.05×10^{-4}	16.4	29.1	33.4	0.88
L3	−0.06314	0.00534	-8.86×10^{-5}	16.2	30.1	34.6	0.89
L4	−0.06614	0.00556	-9.25×10^{-5}	16.3	30.0	34.5	0.89
L5	−0.05935	0.00511	-8.48×10^{-5}	15.7	30.1	34.6	0.89
L6	−0.09536	0.00789	-1.39×10^{-4}	17.4	28.5	32.6	0.86
CAM	−0.06980	0.00598	-1.04×10^{-4}	16.3	28.8	33.1	0.87
VHA	−0.06771	0.00571	-9.63×10^{-5}	16.4	29.6	34.0	0.87
VCII	−0.10276	0.00844	-1.49×10^{-4}	17.8	28.3	32.3	0.86
CGMor18	−0.06677	0.00575	-9.98×10^{-5}	16.1	28.8	33.2	0.87

β_0, β_1, β_2: parameters of the quadratic regression; T_b: base temperature; T_o: optimal temperature; T_u: maximum threshold temperature; R^2: adjustment of the model; S-F: sowing to tasseling.

The interval of temperatures of the field experiments included the thermal levels of the suboptimal and optimal intervals for maize development (Valdez-Torres *et al.*, 2012). Based on these cardinal temperatures, the L3, L4, L5, and VHA cultivars recorded a 15.7-16.5 °C T_b, a 29.6-30.1 °C T_o, and a 34.0-34.6 °C T_u (Table 2), resulting in a 16.2-34.4 °C adaptation range (Figure 1A). Meanwhile, the L1, L6, and VCII cultivars obtained a 17.4-18.1 °C T_b, a 28.3-29.0 °C T_o, and a 32.3-33.1 °C T_u (Table 2), which results in a 17.8-32.7 °C adaptation range (Figure 1B). Finally, since the L2, CAM, and CGMor18 cultivars recorded a 16.1-16.4 °C T_b, a 28.8-29.1 °C T_o, and a 33.1-33.4 °C T_u (Table 2), a 16.3-33.2 °C adaptation range can be deduced (Figure 1B). Consequently, the L3, L4, L5, and VHA cultivars had a broader temperature adaptation range, as a result of their higher Tu (Figure 1A). These cultivars have a greater resistance to high temperatures, because they maintain the growing and development processes in temperatures >34 °C (Table 2, Figure 1A). The thermal requirements of the evaluated cultivars had a low variation, maintaining temperatures of 15.7-18.1, 28.3-30.1, and 32.3-34.6 °C, for T_b, T_o, and T_u, respectively (Table 2). The evaluated germplasm is native to a single region: central and southern Tamaulipas (Hernandez-Trejo *et al.*, 2022). These cultivars may have been developed in localities with a minimum mean temperature between 10 and 12 °C and a maximum mean temperature between 38 and 40 °C (Vargas *et al.*, 2007). The differentiation pattern of the cardinal temperatures between cultivars is the consequence of the origin or adaptation range of each cultivar (Arista-Cortes *et al.*, 2018), which explains the high values of the cardinal temperatures determined in this germplasm. Meanwhile, the levels of the cardinal temperatures were high, particularly compared with the findings of other research: 7-13°C T_b (Ruiz *et al.*, 1998; Steward *et al.*, 2018; Arista-Cortes *et al.*, 2018); 24.3-25 °C T_o (Ruiz *et al.*, 1998; Tojo *et al.*, 2005); and 28.8 °C T_u (Ruiz-Corral *et al.*, 2002).

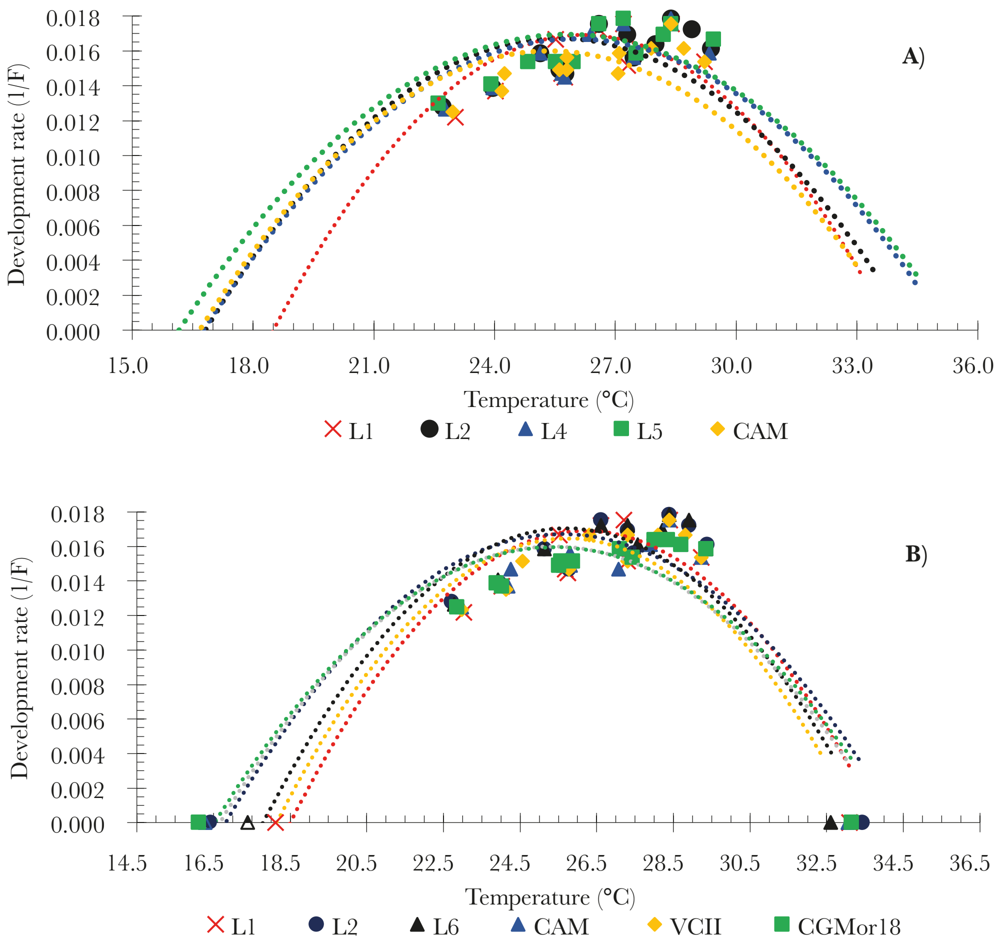

Figure 1. Relationship between temperature and development rate during the sowing-tasseling period of the following cultivars: A) L1, L2, L4, L5, and CAM and B) L3, L6, VHA, CGMor18, and VCII.

CONCLUSIONS

The variation of the cardinal temperatures between cultivars shows the need to estimate these parameters for each specific cultivar, in order to establish the adaptation range, according to the thermal offer of each place. The high threshold temperature of the cultivars proves that they are a source of variation for the selection of the characteristics that provide resistance to the stress caused by high temperatures.

REFERENCES

Aburto-Cansino, G. N., Ruiz-Corral, J. A., Sánchez, G. J. J. y González, E. D. R. (2018). Temperaturas cardinales de desarrollo del teocintle (*Zea* spp.). *Rev. Mex. de Cienc. Agríc*. 9:1269-1281.

Arista-Cortes, J., Quevedo, N. A., Zamora, M. B. P., Bauer M. R., Sonder K. y Lugo E. O. (2018). Temperaturas base y grados días desarrollo de 10 accesiones de maíz de México. *Rev. Mex. de Cienc. Agríc*. 9:1023-1033.

Castro N. S., López, S. J. A., Pecina, M. J. A., Mendoza C. M. C. y Reyes, M. C. A. (2013). Exploración de germoplasma nativo de maíz en el centro y sur de Tamaulipas, México. *Rev. Mex. de Cienc. Agríc*. 4:645-653.

Castro-Nava, S., Ramos-Ortíz, V. H., Reyes-Méndez, C. A., Briones-Encinia, F. and López-Santillán, J. A. (2011). Preliminary field screening of maize landrace germplasm from northeastern México under high temperatures. *Maydica* 56:76-82.

Chen, J., Xu, W., Velten, J. P., Xin, Z. and Stout, J. E. (2012). Characterization of maize inbred lines for drought and heat tolerance. *J. of S. and W. C. S*. 67:354-364. https://doi.org/10.2489/jswc.67.5.354

González-Martínez, J., Rocandio-Rodríguez, M., Chacón-Hernández, J. C., Vanoye-Eligio, V. y Moreno-Ramírez, Y. R. (2018). Distribución y diversidad de maíces nativos (*Zea mays* L.) En el altiplano de Tamaulipas, México. *Agro Productividad 11*(1):124-130.

Hatfield, J. L. and Prueger, J. H. (2015). Temperature extremes: Effect on plant growth and development. *Weather and Climate Extremes* 10:4-10. https://doi.org/10.1016/j.wace.2015.08.001

Hernandez-Trejo, A., López-Santillán, J. A., Estrada-Drouaillet, B., Reséndiz-Ramírez, Z., Varela-Fuentes, S. E., Coronado-Blanco, J. M. and Malvar, R. A. (2022). Maize tolerance to *Spodoptera frugiperda* (J. E. Smith) leaf damage and insecticide application. *Agro Productividad* 15:23-31.

Naveed, M., Ahsan, M., Akram, H. M., Aslam, M. and Ahmed, N. (2016). Genetic effects conferring heat tolerance in a cross of tolerant × susceptible maize (*Zea mays* L.) genotypes. *Front. in Plant Sci.* 7:1-12. https://doi.org/10.3389/fpls.2016.00729

Pecina, M. J. A., Mendoza, C. M. C., López, S. J. A., Castillo, G. F. y Mendoza R. M. (2009). Respuesta morfológica y fenológica de maíces nativos de Tamaulipas a ambientes contrastantes de México. *Agrociencia 43*(7):681-694.

Ruiz, C. J. A., Sánchez, G. J. J. and Goodman, M. M. (1998). Base temperature and heat unit requirement of 49 mexican maize races. *Maydica* 43:277-282.

Ruiz-Corral, J. A., Flores-López, H. E., Ramírez-Díaz, J. L. y González-Eguiarte, D. R. (2002). Temperaturas cardinales y duración del ciclo de madurez del híbrido de maíz H-311 en condiciones de temporal. *Agrociencia* 36:569-577.

Steward, P. R., Dougilla, A. J., Thierfelderb, C., Pittelkowc, C. M., Stringera, L. C., Kudzalad, M. and Shackelford, G. E. (2018). The adaptive capacity of maize-based conservation agriculture systems to climate stress in tropical and subtropical environments: A meta-regression of yields. *Agric., Ecosyst. and Env*. 251:194-202. https://doi.org/10.1016/j.agee.2017.09.019

Tojo, C. M., Sentelhas, P. C. and Hoogenboom, G. (2005). Thermal time for phenological development of four maize hybrids grown off-season in a subtropical environment. *The J. of Agricultural Sci.* 143:169-182.

Valdez-Torres, J. B., Soto-Landeros, F., Osuna-Enciso, T. y Báez-Sañudo, M. A. (2012). Modelos de predicción fenológica para maíz blanco (*Zea mays* L.) y gusano cogollero (*Spodoptera frugiperda* J. E. Smith). *Agrociencia* 46:399-410.

Van Inghelandt, D., Frey, P. F., Ries, D. and Stich, B. (2019). QTL mapping and genome-wide prediction of heat tolerance in multiple connected populations of temperate maize. *Scientific Reports* 9:14418. https://doi.org/10.1038/s41598-019-50853-2

Vargas T. V., Hernández, R. M. E., Gutiérrez, L. J., Plácido, D. C. J. y Jiménez, C. A. 2007. Clasificación climática del estado de Tamaulipas, México. *CienciaUAT* 2:15-19.

Yousaf, M. I., Hussain, K., Hussain, S., Ghani, A., Arshad, M., Mumtaz, A. and Hameed, R. A. 2018. Characterization of indigenous and exotic maize hybrids for grain yield and quality traits under heat stress. *Intl. J. of Agric. and Biology* 20:333-337. https://doi.org/10.1038/s41598-019-50853-2

AGRO
PRODUCTIVIDAD