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TECHNICAL PROPOSAL FOR MODIFICATION OF MAIZE SOWING DATE IN THE FUERTE-MAYO REGION, SONORA, MEXICO

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ABSTRACT

Maize is the second most important crop in southern Sonora, Mexico, so it is an asset for the economy of the region, and it is highly relevant for the fall-winter crop pattern. The Fuerte-Mayo region is conducive for maize high grain yield potential; however, farmers used to establish the crop in a period of high frost occurrence. Therefore, the objective of this work was adjust the sowing date in order to optimize grain yield per hectare and escape the frost and heat risks. Experiments were established in the Fuerte-Mayo region which is located in the southwestern part of Sonora, during the crop season 2016-2017. Five commercial fields sown on different dates and in different areas of the region were selected for a follow up of the different phenological stages. Climatic information was taken close to the crop, by placing digital sensors within three of the fields; also, temperature data was taken from the automated weather stations from Module 01 and Zapata which belong to the weather network of the National Water Commission (CONAGUA), from October to June during the years 2015 to 2017, in order to identify months with high probability of frost and heat risks. Based on the temperature recorded by the digital sensors and the development of maize in those fields, three climatic zones were detected for avoiding the possible frost and heat risks: from November 15 to December 15 for early hybrids in a cold zone (central and northwest of the region), intermediate hybrids in the intermediate zone (central and east), and late hybrids in the warm zone (southeast and west). From November 15 to 30 for intermediate hybrids in the cold zone, and late hybrids in the intermediate zone, and from November 15 to December 31 for early hybrids in the intermediate and warm zones, and intermediate hybrids in the warm zone.

Keywords: Maize, Zea mays, Fuerte-Mayo region, frost risk, heat risk.

1. INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereals worldwide for human consumption as well as for animal feed; it is the crop with the highest area sown and harvested. World production in the year 2020 was 1,162,352,997 t and Mexico produced 8,285,169.61 t with an average grain yield of 6.90 t ha^{-1}, being ranked as number 7 in world production (FAOSTAT, 2020). The states and their percentage of contribution in the country maize production are the following: Sinaloa (69.8%), Sonora (7.5%), Tamaulipas (6.5%), and Veracruz (5.7%), and the rest of the states produce 10.5 % (SIAP, 2020). In Southern Sonora, maize is an asset for the economy of the region, and it is highly relevant for the fall-winter crop pattern. In this state, maize is the second most important crop after wheat (*Triticum aestivum* L. and *T. durum* Desf.); however, the current production system requires changes or adjustments in order to mitigate the effect of climate change, and be adapted to the current needs in order to assure the integrity and profitability of the crop (Montoya Coronado and Valenzuela Borbón, 2017). The Fuerte-Mayo region (Figure 1) is conducive for high grain yield potential of maize, however, historically farmers establish this crop in October-November and therefore, plants will be exposed to frosts. Although high grain yields might be obtained under this timeframe, the risk of frost damage is even greater (Ortega Corona *et al*., 2003).

Figure 1. the Fuerte-Mayo region is located in the southwestern part of the state of Sonora, México.

This region comprises an area of almost 80,000 ha covering the counties of Huatabampo, Álamos, and Navojoa; approximately 23,000 ha are irrigated, so there are 20.5 km of main canals and 51 secondary ones, whose water is provided by the Luis Donaldo Colosio Murrieta dam, located in the neighboring state of Sinaloa (Díaz, 2018). Currently, the main crops are wheat which occupies 80% of the agricultural area, and the rest is maize, husk tomato (*Physalis ixocarpa* Brot.), jalapeno pepper (*Capsicum annuum* L.) and forage, whose yields represent 60% of the genotype x environment potential. Climate in the coastal area is dry and warm and covers most of the region with an annual average temperature of 22°C. The northern part has a semi-dry to semi-warm climate with summer rainfall, and the winter rainfall varies from 5 to 10.2 mm. Towards the Eastern part the climate is dry to semi-warm with a cool winter and the annual average temperature ranges from 18 to 22ºC (CONAGUA, 2015). However, some abnormal climatic phenomena have occurred in the region, such as the frosts during the crop seasons 2010-2011 and 2011-2012, where even the wheat producers were affected by the magnitude of the damage, and for the limitations of the crop insurance coverage (Félix Valencia *et al*., 2012). It is evident that the risk of frosts is dissipated based on the dominant impact of “El Niño” in the Pacific, so in the crop seasons 2014-2017, the persistence of the phenomenon maintained a warm ocean, and consequently, a clear decrease in the occurrence of days and hours with temperature of 3°C or lower in the agricultural areas. Therefore, the temperature is an important factor for the sowing date during the fall-winter crop season. If sowing is carried out too early, seedlings might be exposed to low temperatures which will slow down their growth and development. If it is carried out too late, plants will be exposed to high daily and nightly temperatures during grain filling, which will increase their respiration rate and reduce grain yield (Benacchio Scotton, 1982; Ojeda-Bustamante *et al.*, 2006). The objective of this work was to study and analyze different sowing dates for maize, in order to optimize the grain yield and at the same time try to avoid the risk of frost and heat.

2. MATERIALS AND METHODS

This work was carried out in the Fuerte-Mayo region, located in the southwestern part of the state of Sonora (from 26°21'12.24" N, 109°5'43.51" W to 26°35'30.47" N, 109°14'2.49" W), during the crop season fall-winter 2016-2017. Five commercial fields sown in different dates and that were located in the different climatic zones (as defined by the experience of local farmers) were selected (Table 1); phenology of the crop was followed based on the classification made by Ritchie *et al.* (1986), in which there are two main stages: the vegetative (V) and the reproductive (R) (Table 2).

Table 1. Commercial maize fields monitored in the Fuerte-Mayo region, Sonora, during the year 2017.

Commercial fields	Geographical location		Variety	Sowing date
	Latitude	Longitude		
CF1	26.391410	-109.117614	Asgrow 7573	October 22, 2016
CF2	26.407510	-109.105580	Sagitario/ Centauro/Zorro	December 9, 2016
CF3	26.406715	-109.102370	Caribu	December 15, 2016
CF4	26.405278	-109.031908	Dekalb-4050	December 25, 2016
CF5	26.410823	-109.145451	Genex 776	January 24, 2017

Table 2. Vegetative and reproductive stage of a corn plant.

Vegetative stages		Reproductive stages	
VE	Emergence	R1	silking
V1	first leaf	R2	blister
V2	second leaf	R3	milk
V3	third leaf	R4	dough
V(n)	nth leaf	R5	dent
VT	tasseling	R6	physiological maturity

The fields were monitored every 6-8 days. Temperature data were collected from the automated weather stations Module 01 and Zapata, which belong to the weather network of CONAGUA (National Water Commission). Data were filtered in hourly format from October to June during the years 2015 to 2017, in order to identify those months with the highest probability for frost and heat risk, and so to relate them with the phenological stages of the crop prone to the risk events (Table 3). Climatic data were also taken directly from the crop by placing digital sensors (datalogger LCD-520) in three of the commercial fields, with the objective to widen the data base, and have a greater coverage on this agricultural zone, considering the limited coverage by the weather network established by REMAS (automated weather station network of Sonora) and CONAGUA. Sensors were programmed for hourly temperature and relative humidity data, which were also useful to make comparisons between the automated weather station and the climate recorded by sensors. Data on rust (*Puccinia sorghi* Schwein.) (Malvick, 2022) damage as well as damage by armyworm (*Pseudaletia unipuncta* Haworth) (PU, 2022), was based on the percentage of leaf area affected (Figure 2).

Table 3. Number of days with damaging temperature to maize in the Fuerte-Mayo region, Sonora (average of 2015-2017 and two weather stations Module 01 and Zapata).

Thermic threshold	Years	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
T ≤ 5°C	2015-17	0	0	1.5	1.3	1.5	0	0	0	0
T ≥ 35°C	2015-17	20.7	4	0	0	0	1.5	5	16	26

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Figure 2. uredinia of rust (*Puccinia sorghi*) and damage by armyworm (*Pseudaletia unipuncta*) on maize plants.

3. RESULTS AND DISCUSSION

The sowing date established on October 22 had the objective of fresh cob production; tasseling and flowering initiated at the end of February. This sowing date was highly prone to frost risk during flowering and during the first developmental stage of the grain (101 to 122 days after sowing). The presence of rust in the flag leaf was 3% (Figure 3).

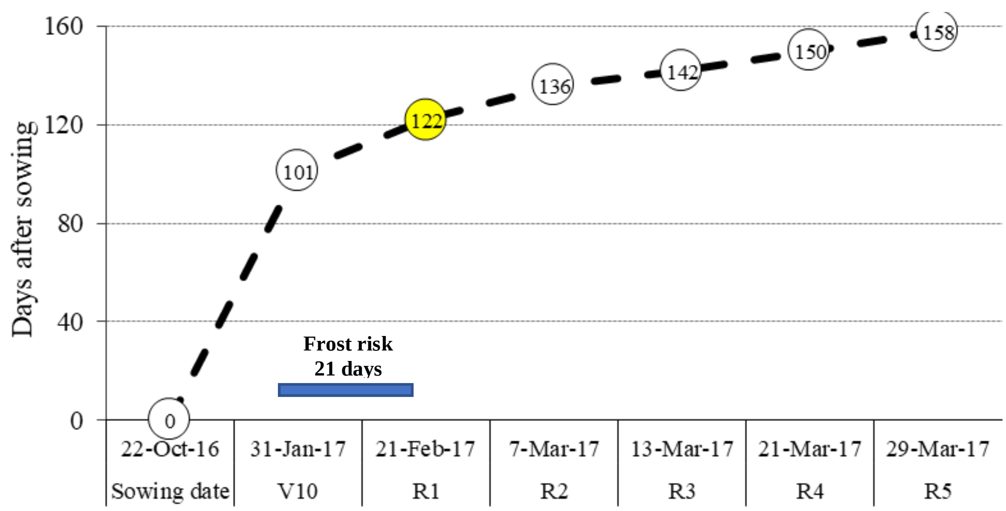

Figure 3. Phenological follow up on the commercial maize field sown on October 22, 2016.

The sowing date established on December 9, 2016, had a period of susceptibility to frost from the end of December to the middle of February.

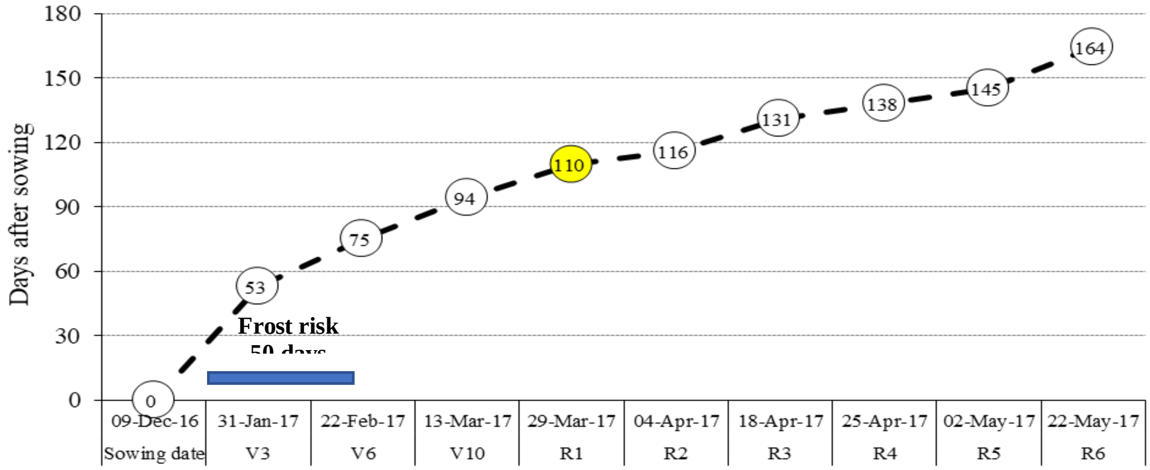

Figure 4. Phenological follow up on the commercial maize field sown on December 9, 2016.

Maize was in the germination stage to the 6th leaf appearance. Flowering initiated at the end of March; there was a 30% damage by armyworm and common rust had 5% damage in the first third of the plant. Maize plants showed a good phenotype, the stem and the cob, as well as the plant height were uniform. Grain yield obtained was 10.2 t ha^{-1} (Figure 4). For the sowing date established on December 15, 2016, the crop was between the germination stage to the 4th leaf apperance during the period of frost risk. Heat risk was also present at the end of flowering and the initiation of grain filling, with temperatures of 35°C. Despite the 3% damage to the foliage and traces of rust in the first third of plants, grain yield was 8.1 t ha^{-1} (Figure 5). Maize plants may have partial damage by frost from which they may recover, based on the phenological stage and duration of the frost (Schnell and Fromme, 2022).

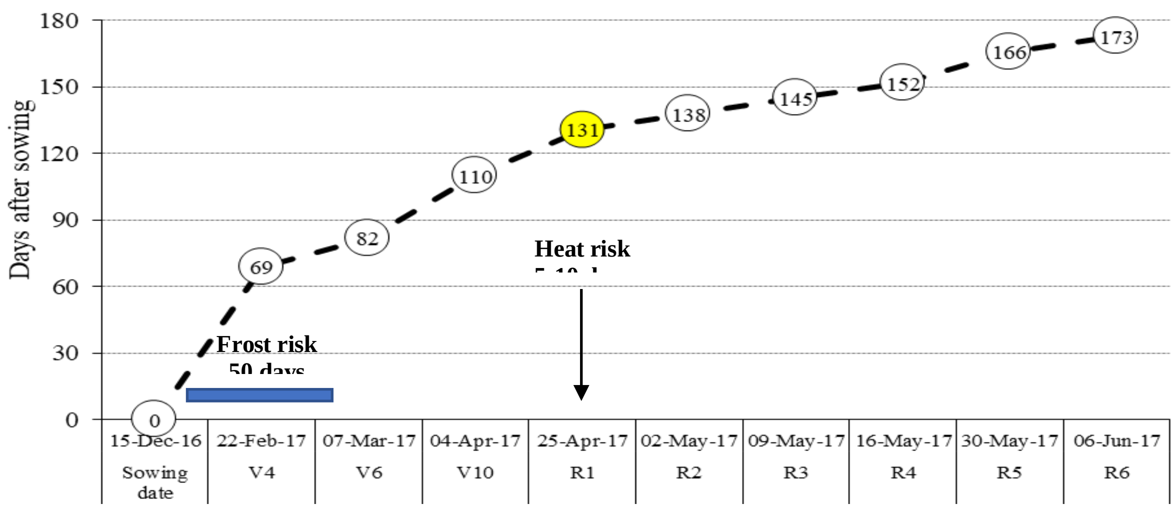

Figure 5. Phenological follow up on the commercial maize field sown on December 15, 2016.

In the sowing date established on December 25, 2016, flowering took place during the middle of April which had a heat risk of 5 to 10 days. There were traces of rust, but it did not reach the flag leaf, and the upper leaves were not damaged by armyworms. The grain yield was 8 t ha^{-1} (Figure 6). The late sowing established on January 24, 2017, produced a grain yield of 7.8 t ha^{-1}; this sowing date escaped the occurrence of frost, however, flowering coincided with the highest frequency of temperatures equal or greater to 35°C. There was a 5% of rust in the first third of the plant; in general, the cob was small and the tip empty. The sample taken to determine grain moisture content indicated damage to the number of grains, cob size, and the final yield was reduced at harvest (Figure 7).

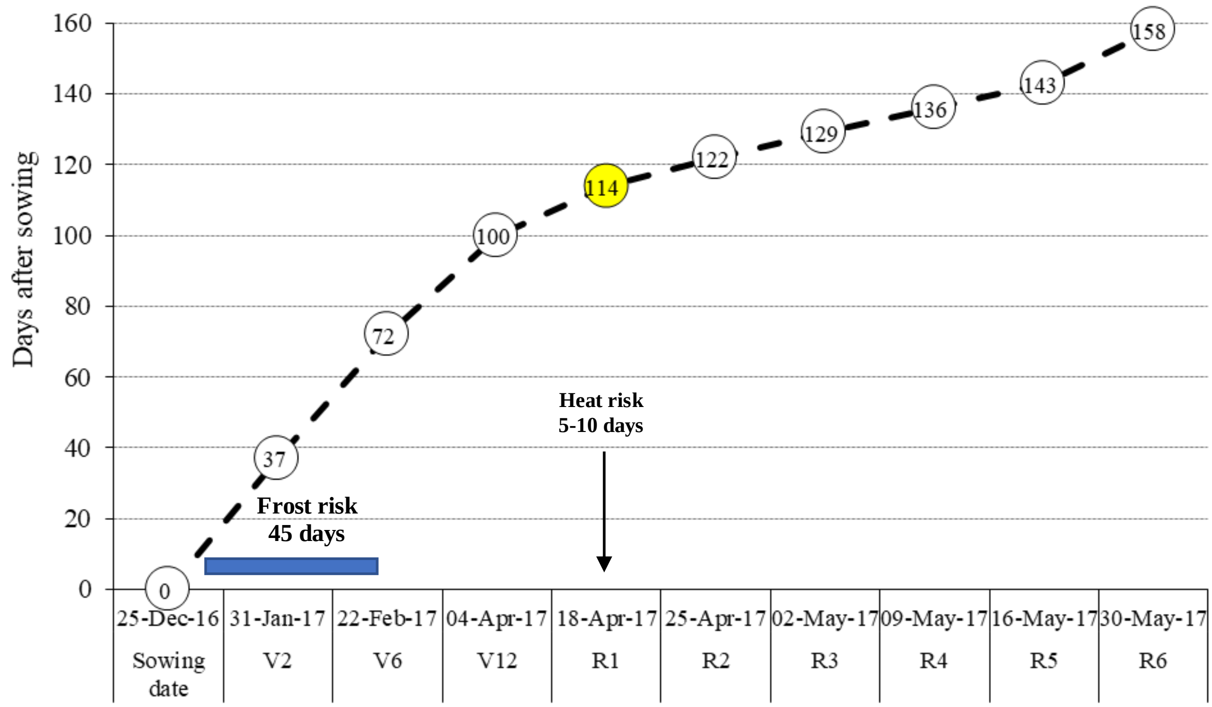

Figure 6. Phenological follow up on the commercial maize field sown on December 25, 2016.

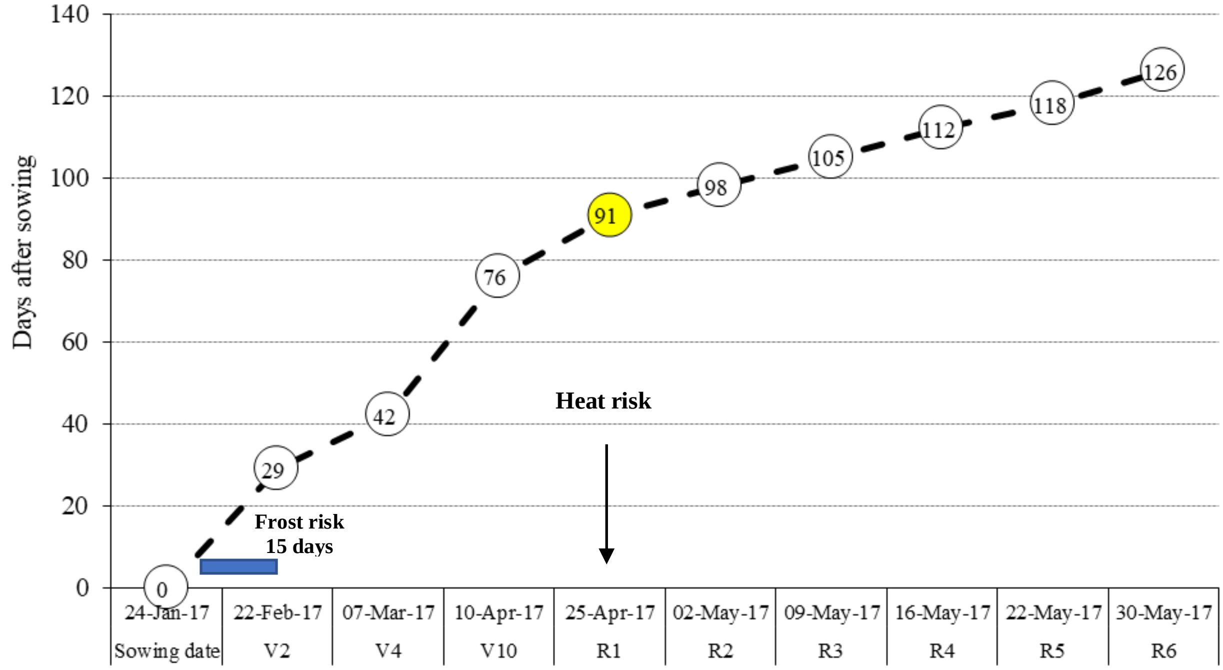

Figure 7. Phenological follow up on the commercial maize field sown on January 24, 2017.

In general, the highest grain yield was obtained from the sowing on December 9, 2016; then, it decreased according to the date, being the latest the one with the lowest yield, which agrees with Ramírez Díaz *et al*. (2010), who reported that for every 15 day delay for sowing, there is a yield reduction of 748 kg ha^{-1}. This clearly indicates that yield is subjected to climatic variation which modifies to a great extent the yield potential of the plant (Félix Valencia *et al*., 2009; Montoya Coronado and Valenzuela Borbón, 2017). The difference in the temperature recorded by the digital sensors located in three of the fields monitored which represent the climatic differential that may occur during a crop season, indicates the cold zone with 1.1°C lower than the warmest zone, calculated from March 13 to May 31. As a comparison was made between the daily temperatures recorded by the automated weather station and the three digital sensors installed within the fields, the oscillation of the average temperature of the crop was evident, which may explain clearly the effect of the minimum and maximum temperatures in some of the growth stages of the crop (Figure 8). These results agree with Torres-Cruz *et al*. (2021), who reported that the weather station in the daily hours (7:00 a 18:00) is 1.89°C in average lower than the sensor, while in the nightly hours (19:00 a 6:00), the sensor recorded colder temperatures, being -0.98°C in average lower than the weather station. Different studies confirm that the complex environment within a crop canopy leads to a high variability of the air temperature within the canopy, and therefore, the air temperature recorded by a weather station does not represent the internal energy of a crop (Neukam *et al*., 2016; Peña Quiñones *et al*., 2020).

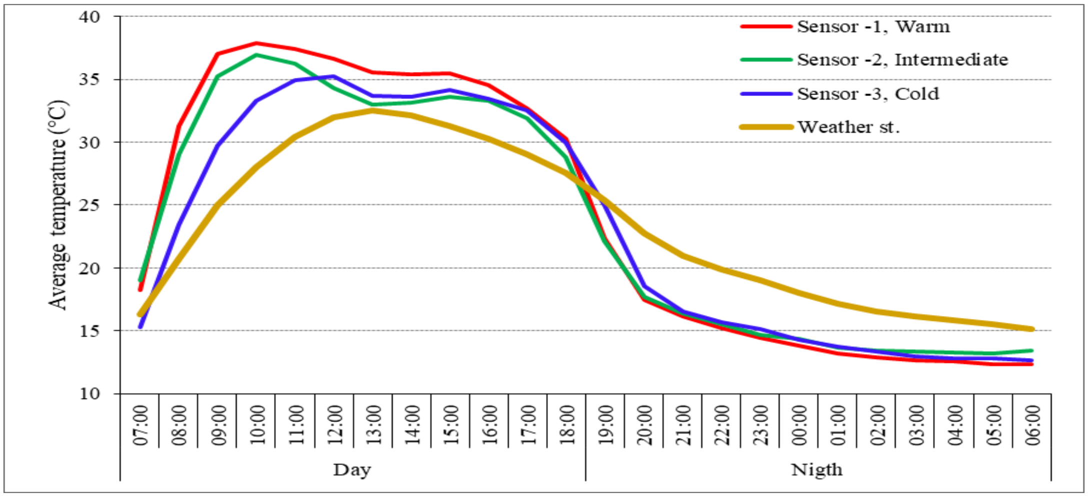

Figure 8. Differences among the average temperature between March 13 and May 31, 2017, in five commercial maize fields, in the Fuerte-Mayo region, Sonora.

The information about the phenology of the crop during different sowing dates, and the climatic frost and heat risks recorded in a crop season in the Fuerte-Mayo region, in addition to the experience of the regional maize farmer, suggest the recommendation shown in Table 4.

Table 4. Maize sowing dates suggested for the Fuerte-Mayo region in Sonora, Mexico.

Hybrid	Days to 100% flowering	Cold zone Central and northwest	Intermediate zone Central and east	Warm zone Southeast and west
Early	110	Nov 15-Dec 15	Nov 15-Dec 31	
Intermediate	115	Nov 15-30	Nov 15-Dec 15	Nov 15-Dec 31
Late	> =120	--	Nov 15-30	Nov 15-Dec 15

The recommended sowing dates for maize in the Fuerte-Mayo region in order to avoid the risk of frost, is from November 15 to December 31, depending on the hybrid used and on the zone where the field is located, in contrast to Ortega Corona *et al.* (2003), who reported that the highest grain yield is obtained by sowing in October and November, but the risk of frost is high in that region of Sonora. The experimentation carried out by Valenzuela Borbón *et al.* (2018), Valenzuela Borbón and Montoya Coronado (2019), and Armenta Cejudo *et al.* (2021), showed that intermediate-late sowing (December 15 to January 15) of maize has a technical and economical viable feasibility in this region. Based on the recommended sowing dates, the grain yield potential of commercial hybrids must be evaluated.

4. CONCLUSION

Three sowing dates for maize were detected for the Fuerte-Mayo region in Sonora, Mexico, in order to avoid frost and heat damage to the crop: a) November 15 to December 15 for early hybrids (110 days for 100% flowering) in the cold zone (central and northwest), intermediate hybrids (115 d to 100% F) in the intermediate zone (central-east), and late hybrids (> 120 d to 100% F) in the warm zone (southeast and west); b) from November 15 to 30 for intermediate hybrids in the cold zone, and late hybrids in the intermediate zone; and c) from November 15 to December 31 for early hybrids in the intermediate and warm zones, and intermediate hybrids in the warm zone. It was also detected that the phytosanitary management and irrigation regime were not properly conducted in the region.

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