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RESEARCH ARTICLE

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## TEMPERATURE INFLUENCE AND RELATIVE HUMIDITY IN CORN SEED STORAGE SYSTEMS (*Zea Mays L.*) ON THEIR GERMINATION STRENGTH

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### ABSTRACT

This study aimed to evaluate the influence of temperature and relative humidity on the germination percentage of Matuba maize variety in the fields of small-scale producers in the Maniquenique area. As maize grain production in the community increases every year, the storage capacity does not evolve at the same pace. The main issue is the storage system used, which does not ensure the safety or quality of the maize. The study was therefore carried out to demonstrate the importance of storing maize in ideal conditions (temperature and relative humidity), using a sample of 302 silos. However, due to the coinciding drought during the data collection period, only 30 silos were sampled, with 10 from each storage system containing seeds from previous agricultural seasons. After testing, it was found that temperature and relative humidity influence the germination of maize grains stored in these systems. The seeds in the drums had a low emergence rate of 72.3%, whereas the recommended rate is 85%. The emergence coefficient was 42.6%. while the seeds in bags had better results, with an emergence percentage of 90.9% and an emergence speed coefficient of 49.7%, followed by the drums with an emergence rate of 86.1% and an emergence speed coefficient of 44.1%.

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## INTRODUCTION

Maize (*Zea mays L.*) is the leading cereal crop in Mozambique as it is a basic food for everyone. It is grown in small, medium and large farms in an area of 2,286,362 hectares with an average production of 1,632,321 tonnes and an average national harvest of 803 kg/ha (Rodrigues et al. 2023). For this reason, maize is very valuable for small producers, since they have saved part of their crop production to ensure food security, commercialisation and, also, to serve as seed for the following harvest (Oliveira, 2022). However, post-harvest activities, such as storage between harvests, are essential to maintain seeds quality, ensuring their viability and strength until they reach the farmer (Capilheira et al., 2024). The quality of stored seeds is influenced by several factors, including temperature and relative humidity. When both are superior, the physiological activity of seeds intensifies, accelerating their deterioration. In contrast, conditions of low relative humidity and temperature help to reduce infestation by microorganisms (Mdalose et al., 2021).

For prolonged storage of seeds, it is essential to dry them until the moisture content is below 11%, keeping the room temperature preferably below 20° Celsius and the relative humidity up to 50% (Aqil, 2020). The shortage of technical knowhow in storage results in significant losses, which can reach 20% of the maize harvest (Da Silveira, 2023). In Maniquenique Township, Chibuto district in Gaza, corn production increases every year. However, storage capacity does not evolve at the same pace (Siteo, 2005). Therefore, a demonstrative and guiding study was carried out aiming to evaluate temperature and humidity temperature on different traditional storage systems (plastic drums, barrels and bags) of corn, observing their impact on the germination percentage.

## METHODOLOGY

This study was conducted in the province of Gaza, district of Chibuto, specifically at Maniquenique locality, located 13 km south of the city of Chibuto, bordered by Massuko-Chidunuane to the west,

Munandine to the east, the Limpopo River to the north, and to the south by the bridge over the Limpopo River that separates the town of Chibuto from the locality of Maniquenique, with a latitude of 24°47'50.00"S; longitude 33°31'42.89"E; and altitude of 10 m.

**Sample Size Calculation:** In this study, we worked with a sample size of 30 traditional silos (plastic Bottles, drums and bags) as a basic expression for a finite population (Gil, 2008), with 10 for each storage system which contained seeds, with a maximum allowed error of 5 to reduce the error margin, based on the formula:

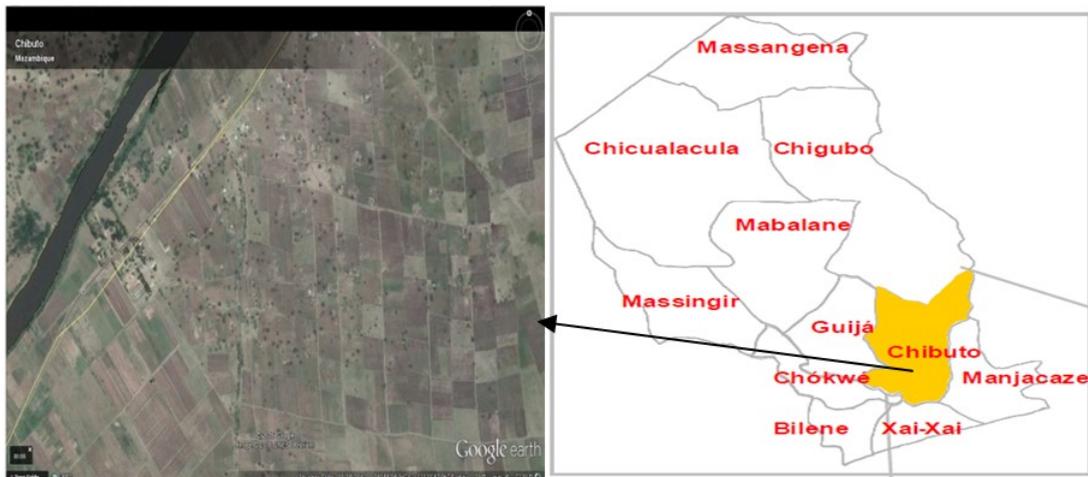
$$n = \frac{\sigma^2 p \cdot q \cdot N}{e^2(N-1) + \sigma^2 \cdot p \cdot q}, \text{ where:}$$

- $n$ = Sample size;
- $\sigma^2$ = Chosen reliability level, expressed in number of standard deviations;
- $p$ = Percentage with which the phenomenon occurs;
- $q$ = Complementary Percentage;
- $N$ = Population size and;
- $e^2$ = Maximum error allowed.

**Data Gathering:** Based on the studied population sample size, a device designated a *thermo-hygrometer* was used to measure the temperature and relative humidity of the environment inside each traditional silo containing maize grains. However, the activities were carried out over a period of five (5) days, observing the two environmental factors as an evaluation parameter in the depreciation of stores seed quality. On the last day, the seeds tested were randomly collected in each silo, using a paper cartridge package to minimize the oscillation of temperature and relative humidity.

Formula:  
 $\bar{X}_n = \frac{\sum X_i \cdot f_i}{n}$  whereas:  
 $\bar{X}_n$  – arithmetic mean;  
 $X_i$  – these are values of the variable;  
 $f_i$  – simple frequencies  
 $n$  – number of observations

**Experimental Statistics:** Experiment was conducted at Park Home greenhouse, located behind Chibuto Hotel. It was conducted in accordance with the basic principles of agricultural experimentation, employing a completely randomized block design



Fonte: (Google earth, 2025)

Figure 1. Illustrates an image of Maniquenique locality- Chibuto

Tabela 1. Interpretation made on reserve scale of temperature and humidity using the standard method (Silva et al. 1995)

Sample number	Temperature (°C) or Relative humidity (%)	Readings done on the Device					Averages	Standard
		1	2	3	4	5		
1								14.2
2	30	46.3	45.7	46.0	45.5	46.5	46	

**Experimental set up:**



Figure 2. Experimental field photo (2025)

(DBCC). The seeds collected from three (3) distinct storage systems (plastic barrels; Drums; Bags) and were sown randomly in three (3) replicates, in nine (9) trays, each comprising 77 cells.

**Data analysis:** The data was analysed on the basis of speed emergence index and emergence percentage, according to the statistical rule proposed by several authors such as (Kotowski, 1926 cited by Oliveira, 2009 & Sawant *et al.*, 2012); with the aid of Microsoft Excel 2010 to construct tables and linear regression graphs and Microsoft Word 2010 to format the work.

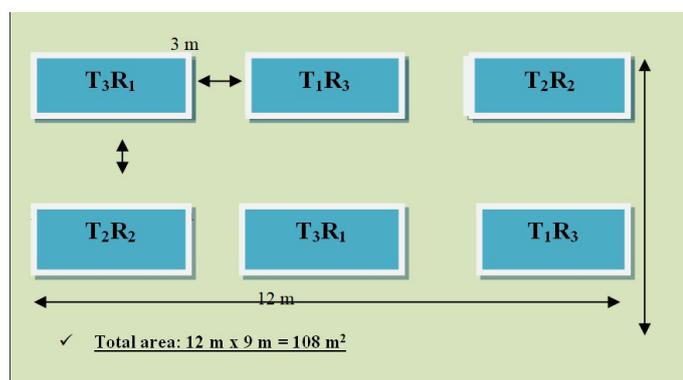
a) Germination rate index:

$$CVE (\%) = \frac{E1 + E2 + E3 + \dots + Ei}{E1T1 + E2T2 + E3T3 + \dots + EiTi} * 100$$

Where: *CVG* is the rate of emergence coefficient;

*G1* up to *Gi* is the number of seedlings which emerged each day;

*T1* up to *Ti* is the period (dias).



b) Emergence Percentage:

*Emergência (%)*

$$= \frac{\text{Número de plântulas Emergidas}}{\text{Total de sementes lançadas na cova}} * 100$$

## RESULTS AND DISCUSSION

The experimental results reveal a significant influence of environmental factors such as temperature and relative humidity on the three (3) storage systems (Bottles; Drums; Bags) for maize (*Zea mays L.*), reducing its germination power.

**Temperature and Germination:** The experimental findings, derived from the average temperatures measured within the silos and the environment temperature of the three storage systems, indicate a decline in temperature over the duration of storage. In particular, the drums and plastic barrels were found to be statistically indistinguishable from each other, with average temperatures of (35.4°C to 30.1°C and 35.2°C to 30°C), respectively. Concurrently, the seeds in the bag exhibited a mean temperature of 29.9-27.3°C, as compared to the mean temperatures of 30.2-27.2°C observed in the other treatments (Table 2). This dispersion of results may have occurred due to inadequate storage conditions and temperature fluctuations, which are arguably the most significant physical factors in the conservation of stored grains, with the majority of chemical reactions being accelerated by such fluctuations (Oliveira, 2022). In this particular context, an increase in storage temperature resulted in a decrease in the number of seeds that germinated. However, elevated temperatures, which fall outside the recommended range for maize seed storage, have been shown to cause desiccation of the cells (endocarp and embryo) of the seed, thereby reducing the speed of emergence (Heberle, 2012).

Regarding the emergence of tested seeds rate, there were no significant differences between those from the drums and the barrel (42.6% and 44.1%, respectively) (Paraginski *et al.* 2015) due to high temperatures, which caused delayed germination. Meanwhile, seeds from the bag performed well at 49.7%, taking only a few days to emerge compared to others. A similar scenario was observed in the emergence percentage, where the number of maize seedlings from seeds stored in bags was higher at 90.9%, followed by drum with 86.1%, with the two storage systems not differing statistically from each other, and lastly, from the drum with 72.3%, below the recommended 85% (Table 4). The reduction in the germination performance of maize seeds at temperatures below or above the optimum tends to slow down the germination process, exposing seeds to adverse factors for a longer period, which can lead to a reduction in total germination (Carvalho & Nakagawa, 1988) cited by Amoêdo (2006). The regression equation presented shows that, on average, a reduction of 2.2354% in the percentage of emergence are expected for each unit of temperature in the silos verified during the storage of corn seeds. The regression equation presented shows that on average, a reduction of 1.1824% in the emergence rate coefficient is expected for each unit of silo temperature verified during maize seed storage. Meanwhile, the relationship between the silo temperature and emergence rate coefficient variables is strongly negative ( $R^2 = 0.9715$ ). In other words, 97.15% of the variation in the emergence rate coefficient (Y) of corn seedlings as a function of silo temperatures (X) verified during storage is explained by the regression equation, and the remaining 2.85% is due to other factors, such as soil fertility, ventilation, etc.

**Table 2. Average temperature and relative humidity calculations for traditional silos in Maniquique**

Types of Silos	Nº of days	Environment Temperature (°C)	Silos Temperature (°C)	HR environment (%)	Silo HR (%)
Botles (A)	1	31,3	34,51	48,6	43,3
	2	30,8	36,68	46,8	50,6
	3	32,0	34,9	44,7	43,2
	4	26,26	35,51	56,6	57,2
	5	30,31	35,51	54,3	52,6
Total averages		30,1	35,4	50,0	40,0
Drums (B)	1	30,74	34,33	50,8	50,3
	2	31,92	39,28	46,9	45,5
	3	32,28	31,48	47,4	47,6
	4	29,48	34,49	49,2	47,3
	5	30,75	36,57	47,3	46,1
Total averages		31°C	35,2	48,0	47,0
Bags (C)	1	29,31	33,15	52,1	59,6
	2	25,68	28,37	42	41,8
	3	26,43	27,28	41,9	34,3
	4	27,1	29,31	47,3	46,2
	5	28,06	31,65	40,9	40,3
Total averages		27,3	29,9	45,0	44,0

Table 3. Silos temperature and emergence percentage

Types of Silos	T. Silo (°C)	P. Emergence (%)
Plastic Bottles(A)	35.4	72.3
Drums (B)	35.2	86.1
Bags (C)	29.9	90.9

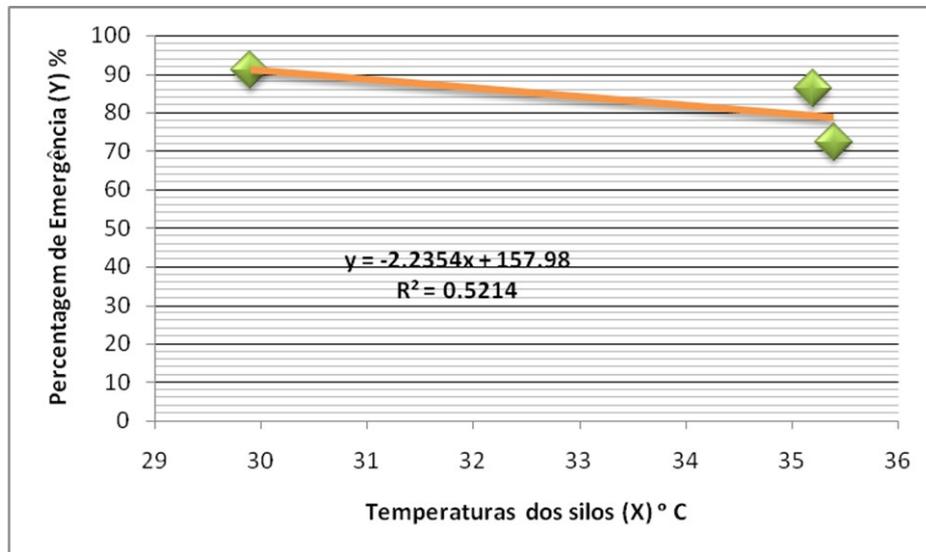


Fig. 3. Silos temperature and emergence percentage

Table 4. Silo temperature and emergence speed coefficient

Types of Silo	T. Silo (°C)	C.V. Emergence (%)
Plastic bottles (A)	35.4	42.6
Drums (B)	35.2	44.1
Bags (C)	29.9	49.7

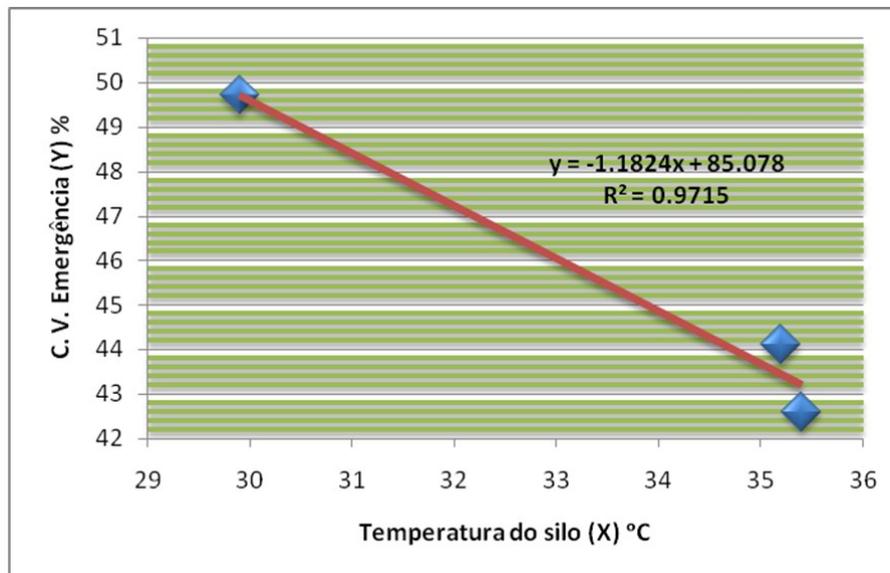


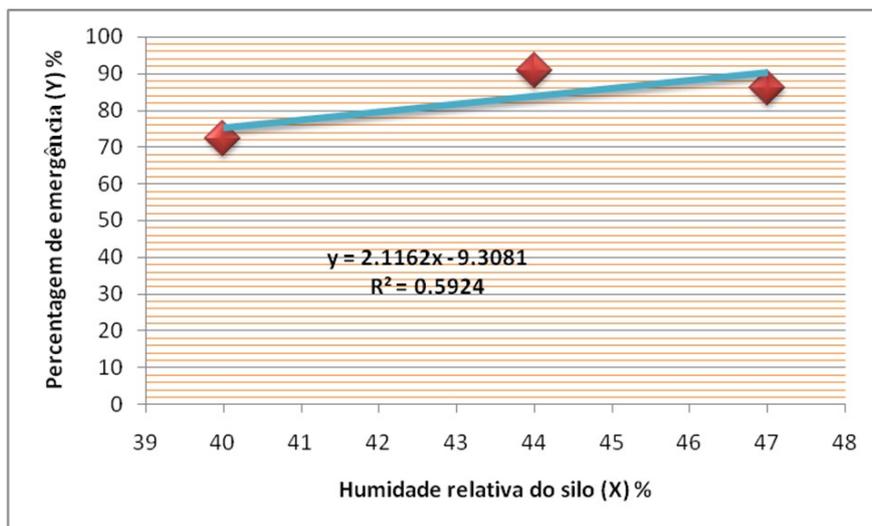
Fig. 4. Silo Temperature and emergence rate coefficient

**Relative Humidity and Emergence:** The results reveal a relationship between the moisture content inside silos and the environment, with the best storage being bagged seed at 44% to 45%, followed by drums at 47% to 48%, which did not differ statistically from each other. Meanwhile, the moisture content inside drums increased with each period of maize storage, from 40% to 50% (Table 2). This result is consistent with (Sawant *et al.*, 2012), where the deterioration of cereal in the warehouse resulted in increased moisture during respiration by insects and maize, for both released water. In terms of emergence rate of the tested maize seeds, it was observed that those stored in bags performed best with an ER of 49.9%, followed by those stored in

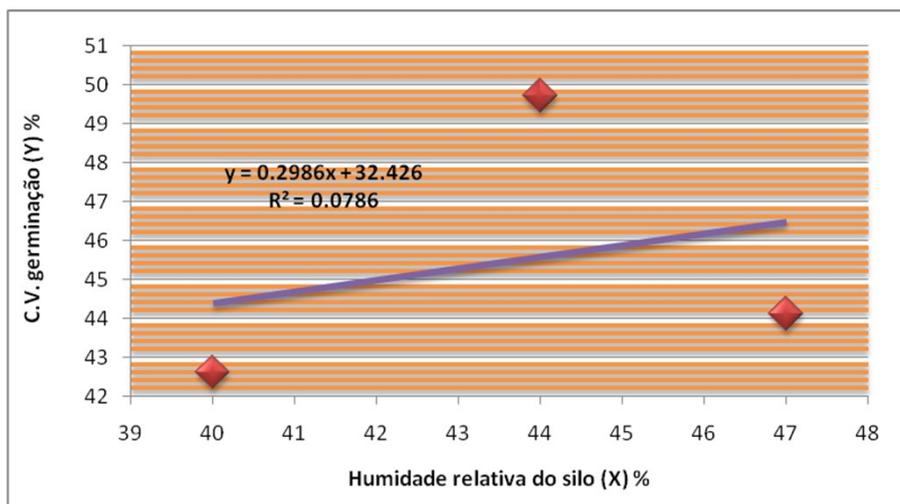
drums with an ER of 44.1% and finally those stored in plastic bottles with an ER of 42.6%. It should be noted that the last two storage systems do not differ statistically from each other in terms of moisture content and emergence rate coefficient (Table 4). With regard to the emergence percentage of maize seedlings, the scenario was repeated with seeds from bags having the best germination power of 90.9%, followed by drums with 86.1% and finally plastic bottles with the lowest number of emerged seedlings of 72.3%, below 85% (Appendix 4). This difference in results between storage systems (Antonello *et al.*, 2009) suggests that the reduction of oxygen in the bag (C) may have caused the death of insect pests, thus increasing the shelf life of the maize seed.

**Table 5. Relative humidity of silos and percentage of emergence**

Types of Silos	HR. Silo (%)	P. Emergence (%)
Plastic bottles (A)	40	72.3
Drums (B)	47	86.1
Bags (C)	44	90.9

**Fig. 5. Silos Relative humidity and emergence percentage****Table 6. Relative humidity and emergence rate coefficient**

Types of Silos	HR. Silo (%)	C.V. Emergence (%)
Plastic bottles (A)	40	42.6
Drums (B)	47	44.1
Bags (C)	44	49.7

**Fig. 6. Relative humidity and germination rate coefficient**

The regression equation presented shows that on average, an increase of 2.1162% in the percentage of emergence is expected for each unit of moisture in the silos verified during the storage of corn seeds. The regression equation presented shows that on average, an increase of 0.2986% in the emergence rate coefficient is expected as a function of silos verified humidity during maize seeds storage. In general, the different types of traditional silos used by small farmers in Maniquenique are influenced by temperature and relative humidity in the germination percentage of maize seeds.

## CONCLUSION AND RECOMMENDATION

### Conclusion

The findings of this study demonstrated that the various traditional silos employed in seed storage systems at Maniquenique locality exert a substantial influence on the physiological quality of maize seeds,

particularly with regard to the percentage and rate of seed emergence. In the course of the analysis, it was established that the temperature and relative humidity showed by storage systems in drums and bottles demonstrated a heightened propensity for the accumulation of heat and humidity. This phenomenon was found to be a contributing factor to a decline in the emergence rate and the percentage of seeds that successfully germinated. Conversely, storage in bags showed better performance, characterised by more optimal temperature and humidity conditions, which consequently resulted in enhanced germination performance, manifesting in significantly higher emergence rates (90.9%) and speed coefficients (49.7) when compared to the utilisation of plastic bottles and drums for storing maize seeds (Antonello *et al.*, 2009). Also, the findings highlight the importance of choosing the right storage system to maintain seed viability. Therefore, the use of bags as a storage method represents a viable and efficient alternative for small producers in regions with climatic conditions similar to those of Maniquenique.

## Recommendations

- Small producers are advised to pay more attention when choosing silos, ensuring they are ventilated and secure, with no water infiltration, to avoid considerable losses of stored maize.
- The results furthermore, show that seeds stored in bags performed better in terms of emergence percentage and emergence speed coefficient, taking into account storage conditions, surpassing those stored in drums and plastic bottles.
- If it is intended to use silos made of drums and plastic bottles, they should be smaller in size because they do not accumulate oxygen. Burning newspapers (combustion) is also a good alternative for eliminating oxygen in larger silos which harbour warehouse pests.

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