Article

Osmoconditioning of creole maize: effects on phenology and growth

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Abstract

Given the importance of creole maize for small farmers in Mexico and the need to take advantage of moisture in temporary crops, the objective of this work was to study the effects of osmoaconditioning treatments on maize seeds on the emergence, growth and phenology of the resulting plants. The treatments were water and a solution of AG_3 at 0.3 g L^{-1} with two exposure times (12 and 18 h) in creole maize (Mején, Chalqueño and Negrito) and a commercial variety (VS-536). The variables observed were percentage and speed of emergency, growth, dry matter, days to flowering and NPK concentration. The experimental design in randomized complete blocks with factorial arrangement (4 x 2 x 2) had four repetitions and four control. The results showed that the variety factor was highly significant ($p\leq 0.001$) for the emergency percentage, where the Negrito creole with 12 h showed the highest value (76.8%) 3 days after sowing (dds), although the Mején showed higher emergency speed (4.6 seeds day^{-1}) and higher growth rate (4.32 cm day^{-1} $plant^{-1}$) at 11 dds. On the other hand, the Chalqueño creole reached the highest gain of dry matter (0.71 g day^{-1} $plant^{-1}$) at 25 dds, while the Mején showed a smaller number of days to male and female flowering (48 and 55, respectively). The highest concentration of NPK in the plant was found in the VS-536 variety. It is concluded that osmoaconditioning treatments induce positive effects on the emergence, growth and phenology of the maize studied.

Keywords: emergency, flowering, height, imbibition.

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Introduction

Maize (*Zea mays* L.) is the most important agricultural crop in Mexico where 82% of the sowings are carried out under temporary conditions. For this crop 75% of the producers use seeds of native races and each producer grows from one to three different races (Espinosa-Calderón *et al*., 2017). The native maize has adaptability to local agroecological conditions, which manifests itself in different levels of precocity and resistance to adverse factors (Ángeles-Gaspar *et al*., 2010), in addition that the native races require less quantity of inputs for their cultivation.

However, in temporary conditions these seeds would present low germination and a greater number of days to the emergency, which causes little uniformity and low water use, which makes it necessary to look for options that contribute to overcome these limitations. An alternative is the osmoaconditioning of the seeds which is a proven method that improves the physiological quality of the seed to achieve emergency uniformity and higher germination percentage. The objective of this work was to evaluate the effect of different treatments of osmoaconditioning of seeds on the emergence, growth, phenology and NPK concentration of creole maize, under greenhouse conditions.

Materials and methods

The work was carried out in the greenhouse of the Experimental Field of the Campus Tabasco Graduate College, located at the geographical coordinates 17° 59' 10" north latitude and 93° 35' 02" west longitude, at an altitude of 18 m. For osmoaconditioning, 80 maize seeds for each variety were subjected to treatment (Water, or AG_3 solution in conc. of 0.3 g L^{-1}) for two times (12 and 18 h), plus one control for each treatment, with four repetitions (20 treatments in total). Three creole races of maize (Negrito and Chalqueño from the state of Hidalgo and Mején from the state of Tabasco) and the synthetic variety VS-536 were used. The seeds of each variety were osmoaconditioned in the established solution and times; upon completion, the seeds were removed for aeration for 48 h at room temperature.

The sowing was carried out after the treatments in plastic containers with a capacity of 7.5 L filled with the soil substrate: sugarcane cachaza (1:1 v/v). The experimental design was completely random with a 4 x 2 x 2 factorial arrangement (four types of maize, two osmotic solutions and two imbibition times) with four repetitions. Each treatment consisted of 80 plants in total.

Emergency percentage

The number of seedlings emerged was counted daily, considering the moment when the seedling was visible as an emergency. The counts were made from one to five days after sowing (dds), time in which 100% emergency was reached in the varieties of maize evaluated. The calculations were made with the formula (Ahammad *et al*., 2014).

$$\% \text{ of seedlings emerged} = \frac{\text{Number of seedlings emerged}}{\text{Number of seeds sown}} \times 100 \qquad 1)$$

Emergency speed (seeds day^{-1})

From the emergency data and days, the emergency speed (seeds per day) for each variety was calculated, with the following formula (Maguire, 1962):

$$VE=\sum ni/t \quad (2)$$

Where: VE= emergency speed, ni= number of seeds emerged, t= emergency time (days).

Absolute growth rate

From the data of plant height and biomass gain, the absolute growth rate (TAC) expressed as height (cm day^{-1} plant^{-1}) and dry matter (g day^{-1} plant^{-1}) was calculated, using the formula (Barrera *et al*., 2010).

$$TAC=\frac{P2-P1}{T2-T1} \quad (3)$$

Where: TAC= absolute growth rate; P1= height or initial dry matter; P2= height or final dry matter; T 1= initial time; T2= final time.

Days to male and female flowering

The number of days elapsed since planting and until 50% of the plants presented their flowering, both male and female, was recorded.

NPK concentration

To determine the possible effect of osmoaconditioning on the concentration of nitrogen, phosphorus and potassium in the plant, whole plants were sampled at 59 dds. These were dried at 60 °C for 48 h. Composite samples (repetitions) were ground and sent to the laboratory for NPK elemental analysis.

Statistical analysis

To obtain a normalized distribution of the data, the logarithmic transformation [T= log (y)] was performed. Subsequently, the analysis of variance was performed under a factorial design, as well as the means tests (Tukey $p\leq 0.05$). For the statistical analyzes, the SAS program (version 9.4) was used.

Results and discussion

Emergency percentage

The analysis of variance for the evaluated variables shows a highly significant effect ($p\leq 0.001$) of the variety factor on the percentage of emergency, emergency speed, height and accumulation of dry matter of the plant, while for the days of female flowering ($p\leq 0.01$) and male ($p\leq 0.05$) the

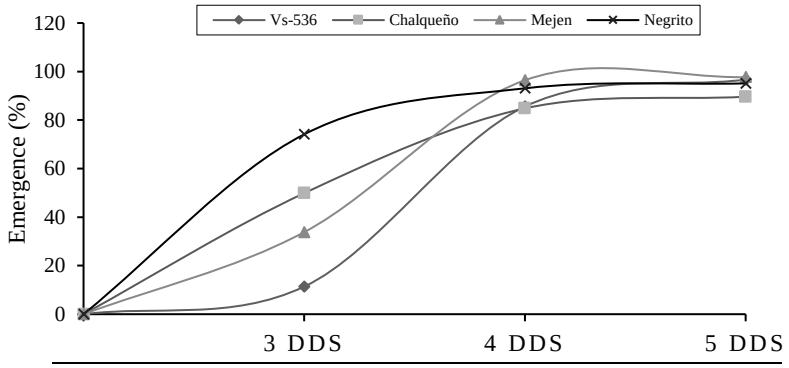
effect was significant. On the other hand, the effect of the solution factor was only significant for female flowering days ($p \leq 0.05$). The race∗time interaction was highly significant for plant height ($p \leq 0.001$) and significant for emergency percentage ($p \leq 0.01$) while the triple interaction was only significant ($p \leq 0.01$) for days of male flowering (Table 1).

Table 1. Analysis of variance of the variables under study, for maize under osmoaconditioning treatments.

Variation factor	PE	VE (seeds day^{-1})	Flowering (days)		Dry material (g day^{-1} plant^{-1})	Growth (cm^{-1} day^{-1} plant^{-1})
			♂	♀		
Race (R)	1.3***	1.2**	53.1*	60.5**	0.56**	7.26*
Time (T)	0.07	0.04	25	3.5	0.01	0.06
Solution (S)	0.01	0.03	18	50.7*	0.22	0.02
R∗T	0.14**	0.29	26.3	8.5	0.52	1.74
R∗S	0.01	0.03	9.7	4.6	0.11	1.13
T∗S	0.07	0.12	4	15	0.57*	6
R∗T∗S	0.02	0.35	65.1**	18.6	0.02	0.98
Error	5.80	13.44	779.75	667.75	20.71	654.75
CV	9.94	11.18	11	5.7	30.29	29.81

*; **; ***= significant difference with $p \leq 0.05$, $p \leq 0.01$, $p \leq 0.001$, respectively; PE= emergency percentage; VE= emergency speed.

The creole Negrito and Chalqueño presented a faster emergency compared to Mején and the VS-536, obtaining Negrito 74% emergency at 3 dds and Chalqueño 50% (Figure 1). As time progressed, the emergence of these maize changed and at 7 dds Mején, Negrito and VS-536 reached higher emergency rates than Chalqueño (89.6%). These varieties with a higher percentage of emergency in a shorter time, have a favorable characteristic, since when the seedlings emerge faster, they achieve an aerial and radical growth for the establishment of the crop (Imran *et al*., 2013). These authors, when trying several treatments, found that osmoaconditioned maize had a greater number of roots.



Maíz	3 dds	4 dds	5 dds
VS-536	11.4 d	85.6 b	96.7 a
Chalqueño	49.9 b	84.8 b	89.6 b
Mején	33.8 c	96.4 a	97.7 a
Negrito	74.1 a	93.1 a	95.1 a

Figure 1. Effect of osmoaconditioning treatments on the emergency percentage in creole maize and a synthetic variety.

After 5 dds, Mején creole maize obtained 97.7% emergency, which favors a greater number of plants per hectare and potentially better crop yield (Tonaka and Yamaguchi, 2014). In Tabasco it has been reported that the best maize yields are obtained in densities of 60 000 and 70 000 plants ha^{-1} (De la Cruz-Lazaro *et al*., 2009), which is why it is important to avoid the low emergency rates for that maize yields are not diminished (Barrón-Freyre, 2008).

Variety∗time interaction

At 3 dds, significant differences were observed between the creole Negrito, Chalqueño and Mején with 18 h of osmoaconditioning, which presented values superior to the rest of treatments. The creole Negrito showed the highest emergency percentage (>70%) during this observation period (Table 2).

Table 2. Effect of the race∗osmoaconditioning interaction on the emergence percentage of maize seeds.

Maize∗time	3 dds	4 dds	5 dds
Negrito 12 h	76.8 ±10.4 a	93.7 ±4.4 ab	96.2 ±3.5 abc
Negrito control	76.8 ±12.58 a	94.9 ±5.7 ab	97.5 ±2.8 abc
Negrito 18 h	70.3 ±7.3 a	91.6 ±7 ab	92.9 ±6.5 abc
Chalqueño control	57 ±8.6 a	89.5 ±10.8 ab	94.8 ±7 abc
Chalqueño 12 h	55.6 ±13.1 a	86.1 ±5.2 ab	88.5 ±6.4 bc
Mején 18 h	44.1 ±12.7 a	98.1 ±3.7 a	98.1 ±3.7 abc
Chalqueño 18 h	41.9 ±13.7 a	81.4 ±10 b	88.2 ±10.3 c
Mején 12 h	36.5 ±19 ab	96.8 ±2.6 a	99.4 ±1.8 ab
VS 536 18 h	18.6 ±8.5 bc	84.6 ±8.5 ab	95.5 ±4.2 abc
Mején control	17 ±18.8 bc	92.5 ±2.8 ab	93.7 ±4.7 abc
VS 536 12 h	8.8 ±8.8 cd	81.7 ±12 b	96.2 ±4.4 abc
VS-536 control	7.1 ±5.77 d	96.2 ±4.79 ab	100 ±0 a

Different letters within columns indicate significant statistical difference (Tukey $p \leq 0.05$); dds= days after sowing.

At 5 dds the control VS-536 obtained 100% emergency, followed by the Mején 12 h treatment (99.4%), while the Chalqueño 18 h presented the lowest emergency (88%); however, this emergency percentage is higher than reported by Nicasio-Arzeta *et al*. (2011) in Chamoque osmoaconditioned maize for 24 h. In previous works Afzal *et al*. (2002) report a higher percentage of germination in osmoaconditioned maize seeds for 24 h, while Moradi *et al*. (2008) indicate a better percentage of germination in a time of 36 h. On the other hand, Rangel-Fajardo *et al*. (2014) indicate that, after a given point, the longer the osmoaconditioning the emergency percentage tends to decrease.

Emergency speed

The emergency speed was statistically higher in the Mején creole since it had a rate of 4.6 seeds day^{-1} at 5 dds while the Chalqueño had a speed of 4 seeds day^{-1} (Figure 2). The greater emergency speed favors the establishment of the crop avoiding losses and allowing greater uniformity, as well as greater plant height, in less time (Imran *et al*., 2013; Karmore and Tomar, 2015).

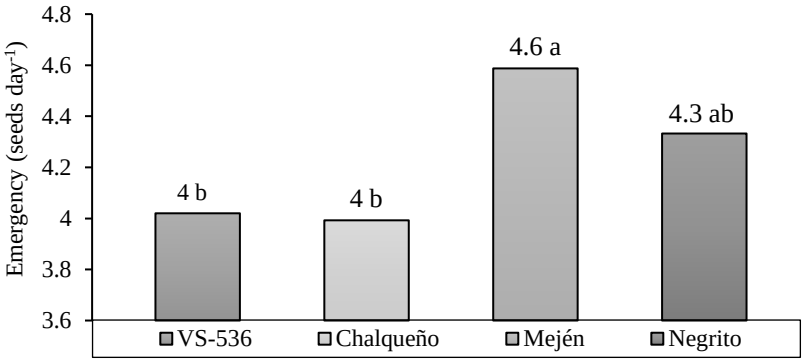


Figure 2. Emergency speed of maize seeds under osmoaconditioning treatments, five days after planting.

Absolute growth rate in height

Although initially the creole Mején showed a higher growth rate than the other varieties (4.32 cm day^{-1} plant^{-1}), towards the end of the observation period (46 dds) it was below the Negrito and Chalqueño varieties that reached up to 5.7 and 5.5 cm day^{-1} plant^{-1}, respectively (Figure 3). Creole Mején initially presenting a higher seedling height (11 dds) could have environmental advantages at times when water availability is limited (Karmore and Tomar, 2015).

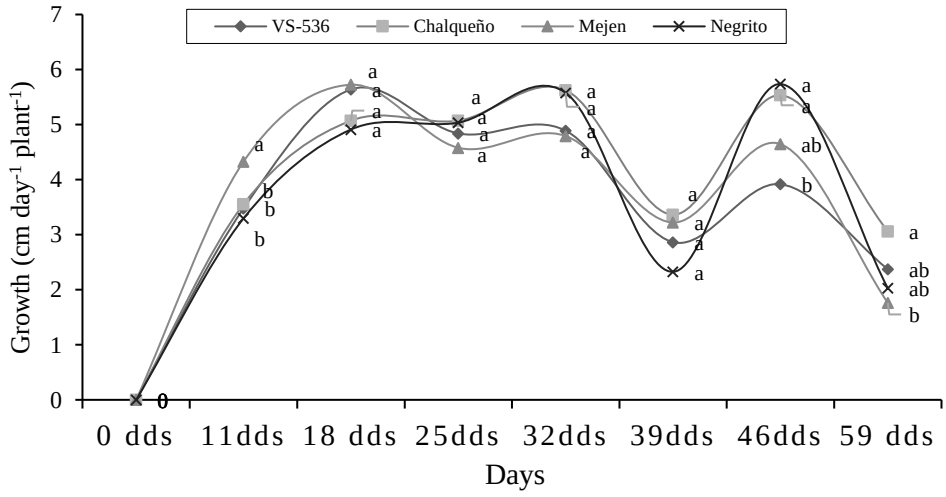


Figure 3. Absolute growth rate (cm day^{-1} plant^{-1}) of three creole maize and a synthetic variety under osmoaconditioning treatments (dds= days after sowing).

The reduction of the growth rate in the Mején maize towards the end of the cycle (59 dds) could be due to its precocity of flowering, since at that time the flowering stage in this variety began. All the maize studied presented variations of the TAC throughout their phenological cycle, but from 46 dds the creole Negrito stood out with the highest growth rate (5.7 cm day^{-1} plant^{-1}) that is characterized by its high bearing and rapid growth (CONABIO, 2010). Towards the middle of the cycle, creoles had a higher growth rate than the VS-536 variety, which indicates that they responded better to environmental conditions (Figure 3).

Absolute rate of growth in dry matter

The creole Chalqueño at 25 dds was the one that obtained a greater gain of dry matter with 0.71 g day^{-1} plant^{-1} (Figure 4), which indicates a rapid initial growth. However, at 39 dds the creole that presented the highest gain of dry matter was Mején (1.11 g day^{-1} plant^{-1}). At 59 dds, the four maize showed a similar gain in dry matter. At this stage the plants were already in bloom, even so, the daily weight gain continued in the four varieties of maize.

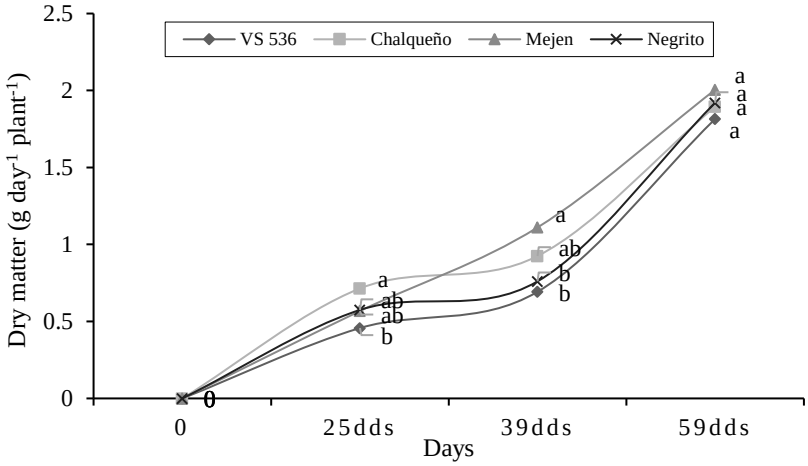


Figure 4. Gain of dry matter (g day^{-1} plant^{-1}) in three creole maize and a synthetic variety under osmoaconditioning treatments.

Interaction time∗solution

The water treatments 12h, 18h and AG_3 18h induced greater dry matter gain (0.64 g day^{-1} plant^{-1}) at 25 dds, compared to the control (0.42 g day^{-1} plant^{-1}). Subsequently (59 dds) the plants resulting from the 18 h water treatment showed considerably greater gain (2.2 g day^{-1} plant^{-1}) than the control (1.7 g day^{-1} plant^{-1}). Throughout the experiment, it was found that the control produced the lowest rate of dry matter gain, so it is concluded that osmoaconditioning treatments induce greater production of dry matter than those of untreated seeds (Figure 5).

The application of osmoaconditioning treatments favors a greater gain of dry matter per day, which would favor greater production and crop yield. What was found in this work coincides with what is reported by Haider *et al*. (2016) in wheat, who report higher performance with osmoaconditioning treatments. In the scientific literature no papers were found that report values of the absolute growth rate for maize cultivation.

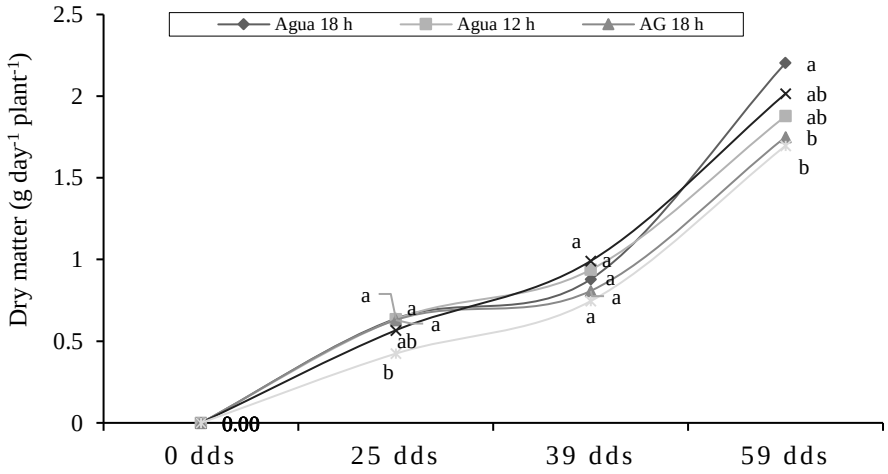


Figure 5. Effect of the solution∗time interaction on the gain of dry matter (g day^{-1} plant^{-1}) in maize undergoing osmoaconditioning treatments.

Days to male and female flowering

The flowering showed significant differences between varieties, being Mején the one that reached the male and female flowering in less time (48 days and 55 days respectively). In contrast, the Negrito and Chalqueño races took longer to reach the flowering stage (Figure 6). Similar results were published by De la Cruz-Lázaro *et al*. (2009) for variety VS-536 at 55 days after sowing.

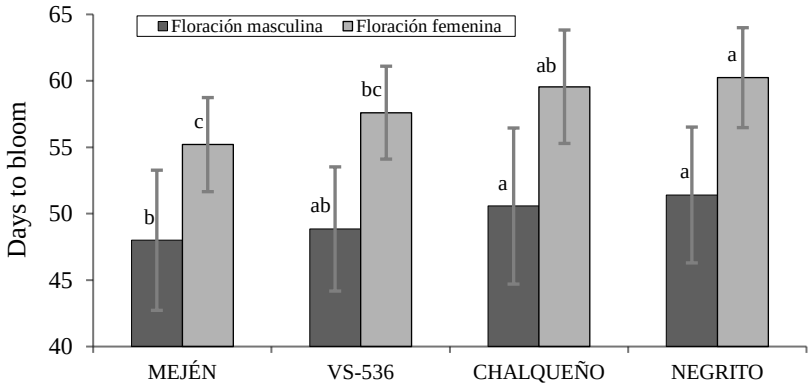


Figure 6. Effect of osmoaconditioning treatments on flowering days in three creole maize and a synthetic variety.

The water and AG_3 osmoaconditioning treatments managed to shorten the days to male and female flowering compared to the control. This precocity was up to five days for the first and four days for female flowering (Figure 7). Osmoaconditioning treatments of maize seeds before sowing are favorable since an earlier harvest could be obtained compared to sowing without osmoaconditioning. In previous works Mahboob *et al*. (2015) report that plants resulting from osmoaconditioned seeds have fewer days at maturity than untreated seeds.

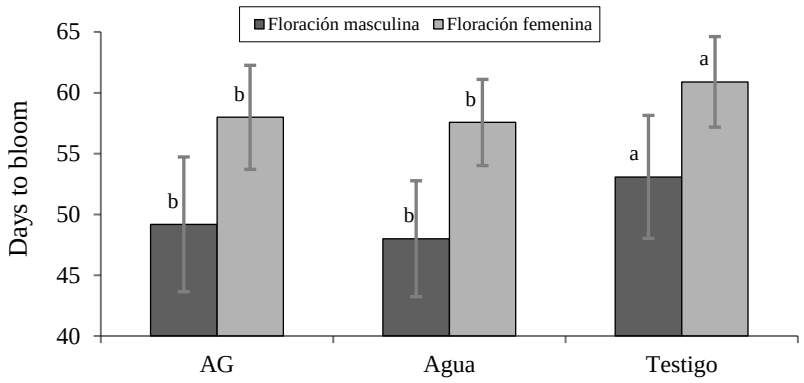


Figure 7. Days to male and female flowering of maize plants resulting from seeds under different osmoaconditioning treatments.

Interaction variety∗time∗solution

In the analysis of the variety∗time∗solution interaction, it was found that the treatments showed significant statistical differences between themselves and with respect to the control. The Chalqueño with water treatments for 18 h and Mején with AG_3 for 18 h, are those that presented the least number of days to male flowering (43 dds) while the Chalqueño control took more days to reach male flowering (57 dds). Therefore, the use of these varieties in combination with time and osmotic solution shortened the crop cycle, all treatments were better than controls without osmoaconditioning (Figure 8).

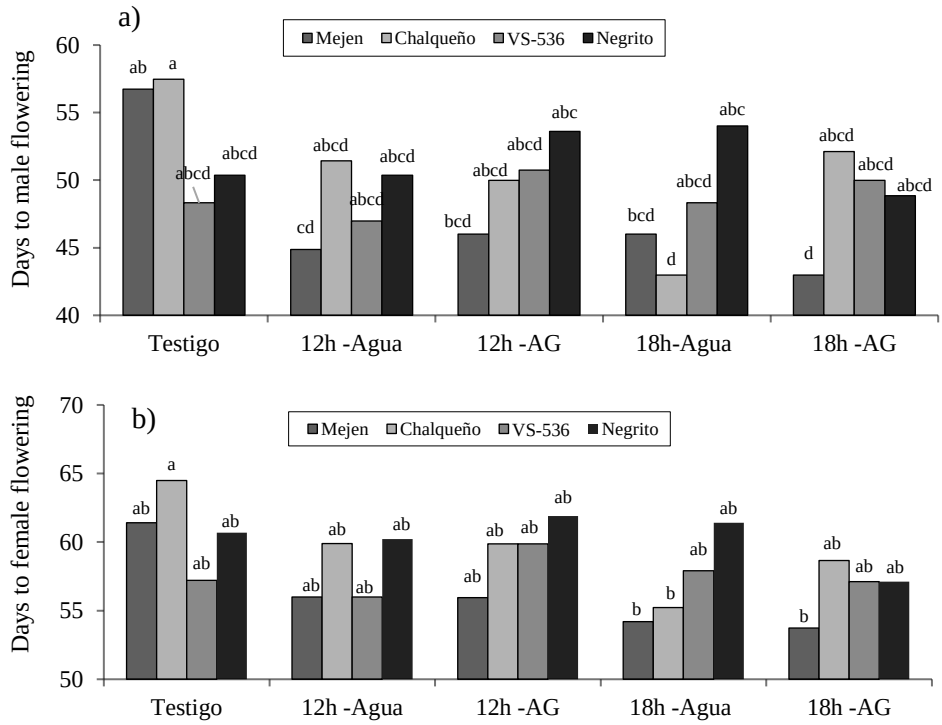


Figure 8. Days to flowering male (a) and female (b) of maize plants resulting from seeds subjected to osmoaconditioning treatments. Different literals within the graph indicate significant statistical difference.

As for the female flowering, the Mején 18 h variety, it was done in 54 days while the control Chalqueño took 64 days to reach this flowering. It was observed that the osmoaconditioning of creole maize seeds shortens the number of days to female flowering. Arif *et al*. (2014) indicate that in soybeans osmoaconditioning treatments increased precocity to flowering compared to the control. In this sense, the present work is new to include this response variable to osmoaconditioning treatments since no previous reports were found in the literature.

Nitrogen, phosphorus and potassium concentration in plant

The results of this work show that the VS-536 variety had the highest concentrations of nitrogen (1.62%), phosphorus (0.32%) and potassium (0.57%), while the Negrito variety had the lowest values of these elements (1.07 , 0.2 and 0.37, respectively), these comparisons being statistically different (Figure 9). These values correspond to the behavior of other variables such as height and dry matter production.

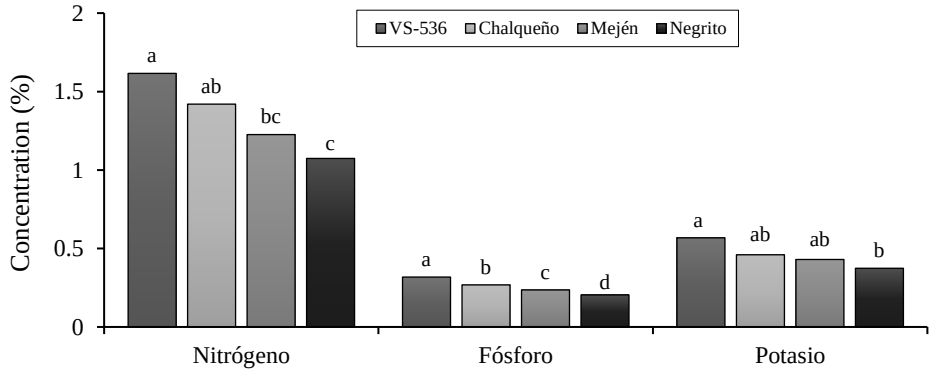


Figure 9. Concentration of nitrogen, phosphorus and potassium in four varieties of maize under osmoaconditioning treatments.

In contrast to the above, the osmoaconditioning times and solution did not influence the concentration of NPK in the plant. Similar results were reported by Bismillah *et al*. (2014) who found no significant statistical difference in wheat cultivation when using water compared to the control, on the concentration of phosphorus and potassium in the plant. In the case of maize under osmoaconditioning, no reports were found in the literature.

Conclusions

Maize varieties presented high percentage and emergency speed in response to time and solution factors; the creoles Chalqueño and Negrito, in both times of imbibition presented a greater percentage of emergency in less time, while Mején presented greater height in the first days of sowing. The factors time and solution of osmoaconditioning favored greater production of dry matter when the seeds were osmoaconditioned with water for 18 h. The interaction with the variety did not show significant differences.

Regarding days to flowering, the plants coming from the seeds of Mején osmoaconditioned with AG_3 for 18 h and those of Chalqueño osmoaconditioned with water for 18 h, were earlier when presenting the least number of days to the male flowering. The NPK concentration in the plant only showed a significant difference for the variety factor, while the type of solution and osmoaconditioning time factors showed no effect on this variable.

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