Germination of three cotton genotypes seeds (*Gossypium hirsutum* L.) with imbibition in water treatments*

Germinación de semillas de tres genotipos de algodón (*Gossypium hirsutum* L.) con tratamientos de imbibición en agua*

Germinação de três sementes de genótipos de algodão (*Gossypium hirsutum* L.) com imbibição em tratamentos de água*

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Abstract

The objective was to establish the adequate time to soak cotton seeds in water to improve the germination percentage GP, since damage can be caused by too much soaking time. An investigation was made by means of a factorial experiment, with design of complete blocks at random with the genotypes Fiber Max 1830, Fiber Max 2334, Sinuana M 137 and the imbibition times of 12h, 24h, 48h and control. With the latter, the GP was 86% for the three genotypes, while with 12h of imbibition it was 96%. With 24h of imbibition the genotypes Fiber Max 1830, Fiber Max 2334, and Sinuana M 137 reduced GP by 67%, 84% and 91%, respectively. With 48h of imbibition there was no germination.

Keywords: germination percentage, soaking of seeds in water, imbibition.

Resumen

El objetivo fue establecer el tiempo adecuado de remojo de semillas de algodón en agua para mejorar el porcentaje de germinación PG, ya que pueden ocasionarse daños por demasiado tiempo de remojo. Se hizo una investigación mediante un experimento factorial, con diseño de bloques completos al azar con los genotipos Fiber Max 1830, Fiber Max 2334, Sinuana M 137 y los tiempos de imbibición de 12h, 24h, 48h y control. Con este último, el PG fue 86% para los tres genotipos, mientras que con 12h de imbibición fue 96%. Con 24h de imbibición los genotipos Fiber Max 1830, Fiber Max 2334, y Sinuana M 137 redujeron PG en 67%, 84% y 91%, respectivamente. Con 48h de imbibición no hubo germinación.

Palabras clave: porcentaje de germinación, remojo de semillas en agua, imbibición.

Resumo

O objetivo foi estabelecer o tempo adequado para embeber sementes de algodão em água para melhorar a porcentagem de germinação PG, já que o dano pode ser causado por muito tempo de imersão. Foi realizada uma investigação por meio de um experimento fatorial, com delineamento de blocos completos ao acaso com os genótipos Fiber Max 1830, Fiber Max 2334, Sinuana M 137 e os tempos de embebição de 12h, 24h, 48h e controle. Com este último, o PG foi de 86% para os três genótipos, enquanto com 12h de embebição foi de 96%. Com 24h de embebição os genótipos Fiber Max 1830, Fiber Max 2334 e Sinuana M 137 reduziram o PG em 67%, 84% e 91%, respectivamente. Com 48h de embebição não houve germinação.

Palavras-chave: porcentagem de germinação, embebição de sementes em água, embebição.

Introduction

Cotton (*Gossypium hirsutum* L.) is the most important commercial crop in the world. It is planted for the use of its fiber in more than eighty countries with both irrigation systems and seasonal conditions. In 2016, the largest producer was India with 5748 million tons (Kamal et al., 2017; Statista, 2017).

Colombia ranks 37th in the world in seed cotton production. In 2016 it produced 9165 tons and its main producer is the department of Córdoba, which sows under seasonal conditions and contributes up to 50% of the national volume (Conalgodón, 2017).

By phytosanitary provision the Instituto Colombiano Agropecuario-ICA establishes each year in the country the dates of registration of farmers, sale of seeds, planting, destruction of crop residues and period of closure of the cotton season. For the department of Córdoba, planting dates are generally between the middle of August and the end of September. In this period most farmers are busy harvesting corn crops, which limits the time to mechanize the soil to plant cotton.

According to the above, in order to comply with the legal guidelines of planting dates, farmers establish the majority of cotton crops through the system known by the names of minimum tillage, conservation tillage, zero tillage, no tillage and direct seeding, which consists of cutting the crop residues of the corn crop with a brushcutter and then sowing the cotton seeds with a pneumatic seed drill. In agreement with what was reported by Reina et al. (2017), with this system it can maintain or exceed the yield of the crop, reduce production costs and progressively improve physical, chemical and biological properties of the soil.

Among the main problems that cotton presents, especially under seasonal conditions, are the germination of the seeds and the establishment of the crop (Santhy et al., 2014). According to reports from Asl and Taheri (2012), genotypes with larger seeds and significant genetic potential are now available, but genetic improvement has not been enough to increase the vigor of the seeds, since low vigor is a typical problem of many crops that causes low production and is the first quality component of the seed that is lost once it is harvested, because from there it begins its deterioration, which is followed by a low capacity for germination and viability.

In addition to the genetic potential and vigor, the germination of cotton seeds is modulated mainly by biotic and abiotic environmental factors. In this sense, for the seasonal conditions of sowing, as in the case of Córdoba, generally during the planting period prevail conditions of absence of rains and excesses of the same, which in both cases affect the germination making it slow, unstable and asynchronous, which has a negative impact on the establishment of the population, since the emergence and initial root development required by the crop to express the best yield and productivity and the harvest can occur over an extended period, are not uniform of time and in a staggered and unbalanced manner (Santhy et al., 2014; Lutts et al., 2016).

Taking into account that the success and improvement of seed germination in different environmental conditions is of great importance for the sustainability of the cotton industry, different treatments have been carried out on the seeds to help improve the germination and survival of the seedlings.

In general terms, the treatments used in crops to increase germination of seeds, improve the establishment and obtain healthy and uniform seedlings emerge are made through techniques that include the use of biological, physical and chemical agents, among which it is worth mentioning the use of magnetic fields, gamma radiation, electric fields, laser irradiation, healing energies, sounds, light and heat (Govindaraj et al., 2017).

In the case of cotton, seed immersion treatments have been carried out in different substances in order to evaluate their germination and obtain information on the benefit that can be obtained in the advance of the beginning of germination as well as in the increase of the germination percentage (Bange et al., 2016).

Among the main substances used for pre-germination treatments of cotton seeds to cause an increase in germination percentage are C_2H_5OH, proline, water, homeopathic preparations of both Baryta Carbonica and Abrotanum, KCl, KH_2PO_4 (Asl and Taheri, 2012), polyethylene glycol, H_2O_2 (Santhy et al., 2014; Wojtyla et al., 2016) and KNO_3 (Shafiq et al., 2015). At present, it has also been tested with the exposure of the seeds to plasma lights (Bange et al., 2016).

One of the pre-germination and invigoration treatments that constitutes a more accessible and economical option for producers and that has been used successfully in seeds of *Lycopersicon esculentum*, *Corchorus capsularis*, *Solanum melongena*, *Raphanus sativus*, *Pisum sativum*, *Oryza sativa*, *Lactuca sativa*, *Helianthus annuus* and whose research is scarce in cotton is the hydration of seeds in water, also known as soaking, priming, hydropriming or humidification, which is used to improve the physiological performance of seeds during germination, especially in various conditions of stress (Murungu et al., 2013).

In agreement with Mustafa et al. (2017) the hydration of the seeds is a process that can reduce the time of emergence and increase the vigor of the seed and the germination percentage, and brings advantages such as high efficiency in the use of water during emergence, production of deeper roots and more tolerance to diseases and environmental stress conditions.

Taking into account that cottonseed is relatively small and in general terms has a slower germination than other crops, farmers should use agronomic strategies for the establishment of the crop, including the superficial planting at a uniform depth and the increase of the sowing rates to then practice thinning and achieve optimal plant densities. The hydration of seeds has also been used successfully to improve the establishment. However, different genotypes may respond differently to this practice (Murungu et al., 2013), so the objective of the present investigation was to evaluate the hydration response of cotton seeds of three genotypes in three different times on the percentage of germination, since although this method is little known in the area of the middle Sinú Valley, some farmers practice it empirically without full knowledge of the hydration time, the correct technique and its physiological basis, in order to generate specific recommendations that can be used by a wider group of farmers and help improve the cotton production system in this important producing area of the country.

Methodology

Study area. The research was conducted between August and September 2017 at the Universidad de Córdoba, Montería, Colombia, located at 8° 45' N, 75° 53' W, altitude 16 meters above sea level, average room temperature 27.9 °C, annual average precipitation 1285 mm and average relative humidity 84% (Weatherbase, 2017).

Germination bioassay. It was done in the Plant Physiology Laboratory of the Facultad de Ciencias Agrícolas through a factorial experiment with two factors 3 x 4. The first factor had three levels corresponding to commercial seeds of cotton genotypes: Fiber Max 1830, Fiber Max 2334, supplied by the Bayer Crop Science of Colombia company, and Sinuana M 137, supplied by the Corporación Colombiana de Investigaciones Agropecuarias-Corpoica. The second factor had four levels, corresponding to imbibition times of the seeds in running tap water at room temperature 24 °C: T0 control, T1 12h, T2 24h and T3 48h. A randomized complete block design with three repetitions was used, and the possible combinations between the levels of the two factors studied are shown in Table 1.

Each block consisted of twelve experimental units, one of each treatment. Each experimental unit corresponded to a glass Petri dish, 90 mm in diameter, with a filter paper and 15 mL of sterile distilled water, where 35 cotton seeds were placed in a circular pattern (ISTA, 2017). Every third day, 5 mL of sterile distilled water was applied to each Petri dish. In total there were 36 experimental units. For each treatment, 105 cotton seeds of each genotype were used, for a total of 1260 cotton seeds for the entire bioassay.

Table 1. Possible combinations between treatments of seed imbibition in water and three cotton genotypes (*Gossypium hirsutum* L.).

Genotypes	Imbibition time of the seeds in water			
	T0	T1	T2	T3
G1	G1T0	G1T1	G1T2	G1T3
G2	G2T0	G2T1	G2T2	G2T3
G3	G3T0	G3T1	G3T2	G3T3

G1: genotype 1 Fiber Max 1830, G2: genotype 2 Fiber Max 2334, G3: genotype 3 Sinuana M 137, T0: control treatment (without imbibition), T1: treatment 1 (imbibition during 12h), T2: treatment 2 (imbibition during 24h), T3: treatment 3 (imbibition during 48h).
Source: Authors.

From sowing until ten days after sowing (das) of the seeds, germination percentage (GP) data were taken in each treatment, for which the seeds with radicle emergence were counted daily and equation 1 was applied.

$$GP = \frac{\text{Number of seeds with emerged radicle}}{\text{Number of seeds sown}} \text{x}100 \qquad (1)$$

The data obtained from the germination percentage were analyzed by applying the software Curve Expert version 1.3 and by the observed dynamics, adjustment was made by using the logistic model (equation 2) with the nonlinear regression procedure PROC NLIN of the SAS software version 9.1.3.

$$y = \frac{A}{(1+B*e^{-Cx})} \qquad (2)$$

Where:

y: adjusted data of percentage of germination
A: maximum observed value of germination percentage
B: has no biological meaning and only takes place at the initial time x = 0
x: days after emergency
C: parameter related to the value of x for the inflection point
e: base of the natural logarithm

To estimate the proportion of variability of the experimental data of the germination percentage, explained by the mathematical models obtained, the coefficient of determination R^2 was calculated by means of equation 3.

$$R^2 = \frac{SSt}{TSS} \qquad (3)$$

Where:

SSt: sum of squares of treatments
TSS: total sum of squares

From the adjusted germination percentage data, the absolute germination rate (AGR) was calculated with the procedure PROC NLIN of SAS software version 9.1.3 by means of equation 4, which represents the first derivative of the logistic model (y').

$$y' = (A * B * C * e^{-Cx})^2 \text{............}(4)$$

In addition to the above, data were taken from the following variables: number of seeds in a gram, for which the number of seeds present in 10 samples of one gram of seeds of each genotype, and weight of 100 seeds, was counted, for which were taken 10 samples of 100 seeds of each genotype and weighing said samples in Ohaus® Explorer EX1103 electronic balance.

The analysis of variance (ANOVA) and Tukey's mean comparison test (p≤0.05) were performed on the variables studied using SAS software version 9.1.3.

Results

Number of seeds in a gram and weight of 100 seeds. In Table 2 it is observed that the number of seeds in one gram and the weight of 100 seeds were equal among the three cotton genotypes evaluated. There were no statistical differences in their magnitudes, as shown in Table 3.

Table 2. Number of seeds in one gram and weight of 100 seeds (g) of three cotton genotypes (*Gossypium hirsutum* L.) in the middle Sinú Valley, Córdoba, Colombia.

Variable	Genotypes		
	Fiber Max 1830	Fiber Max 2334	Sinuana M137
Number of seeds in a gram	11,70±0,48	12,40±0,70	12,40±0,70†
100 seeds weight	8,38±0,10	8,30±0,06	8,19±0,29

†Mean ± standard deviation.
Source: Authors.

Table 3. Mean squares (MS) of the ANOVA for number of seeds in one gram and weight of 100 seeds (g) of three cotton genotypes (*Gossypium hirsutum* L.) planted in the middle Sinú Valley, Córdoba, Colombia.

SV	DF	MS	
		Number of seeds in a gram	100 seeds weight
Between genotypes	2	3,27	0,19
Experimental error	27	10,90	0,89
Significance		ns	ns
CV		0,06	0,02

SV: source of variation, DF: degree of freedom, CV: coefficient of variation, ns: not significant (Tukey; p≤0,05).
Source: Authors.

Germination percentage GP and absolute germination rate AGR. With regard to the germination percentage, it was found that this variable presented a graphical representation of sigmoid type over time, as can be seen in Figure 1.

According to Figure 1a it was found that the seeds of the genotypes FM 1830, FM 2334 and Sinuana M 137 seeded under control treatment conditions, without imbibition in water, did not present differences in their germination percentage, observing the same behavior and magnitude through time, with a maximum value of 86%.

On the other hand, with the application of treatment T1, imbibition of seeds during 12h, it was observed according to Figure 1b that the seeds of the three genotypes evaluated had positive influence of the indicated imbibition treatment on the germination percentage, since increased for all genotypes by 10% more, compared to that indicated for the control treatment.

When the seed imbibition treatment was applied during 24h, for the three genotypes evaluated, according to Figure 1c, a considerable decrease in the germination percentage was observed, since it presented values of 28, 13 and 7% for the genotypes FM 1830, FM 2334 and Sinuana M 137, respectively.

In the case of the application of treatment 3, imbibition of seeds during 48h, for the three genotypes evaluated, the germination percentage was affected in its entirety, as can be seen in Figure 1c, and foul odor was detected as a result of the decomposition of the seeds.

According to the analysis of variance, shown in Table 4, the significant interactions found between the genotypes and between the genotypes and the applied treatments, showed that the genotypes had a differential response to the seed imbibition treatments in water that were applied.

Table 4. Mean squares (MS) of the ANOVA for the germination percentage of three cotton genotypes seeds (*Gossypium hirsutum* L.) subjected to imbibition treatments in water in the middle Sinú Valley, Córdoba, Colombia.

SV	DF	MS
Blocks	2	0,18
Cotton genotypes	2	102,16*
Genotypes Fiber Max1830 and 2334 vs Sinuana M137	1	111,50*
Sinuana M137 vs Genotypes Fiber Max1830 and 2334	1	92,83*
Imbibition in water	3	19881,33*
Linear regression	1	47320,23*
Quadratic regression	1	1270,92*
Cubic regression	1	11052,83*
Interaction genotype x imbibition in water	6	81,05*
Experimental error	22	2,82

SV: source of variation, DF: degrees of freedom, CV: coefficient of variation, ns: not significant, *: significant statistical differences. (Tukey; p≤0,05).
Source: Authors.

According to the above, the graphical behavior of the interactions shown in Figure 2, confirmed that under conditions of the control treatment, without imbibition, the seeds of the three genotypes used presented an equal response in the magnitude of the germination percentage reached. When the seeds of the three genotypes were subjected to imbibition in water for a period of 12 hours, there was an increase in the germination percentage, with respect to the control treatment.

According to Figure 2, for the case of the imbibition of the seeds in water for 24 hours, the three genotypes used presented different responses in the germination percentage, with low values, lower than 50%, in which it should be noted that an equal germination percentage magnitude was obtained for FM 2334 and Sinuana M 137, surpassed by the germination percentage of the FM 1830 genotype.

a)

b)

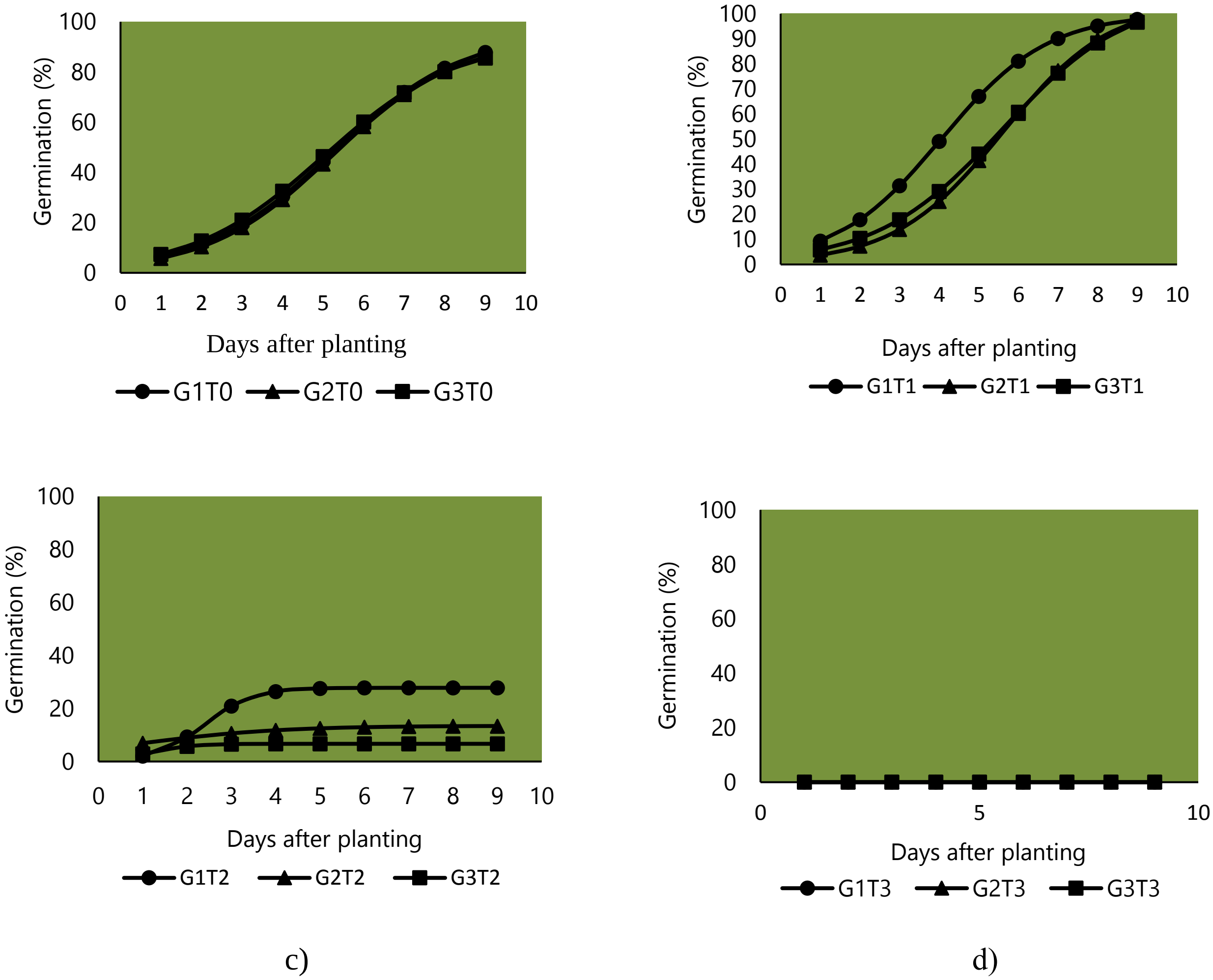


Figure 1. Germination percentage of three cotton genotypes seeds (*Gossypium hirsutum* L.) with imbibition treatments in water: a) T0, without imbibition, b) T1, imbibition for 12h, c) T2, imbibition for 24h, d) T3, imbibition for 48h. Source: Authors.

Finally, when the seeds of the three cotton genotypes were subjected to imbibition in water for 48 hours, the response in germination percentage was practically null.

In accordance with the above, it can be said that the treatments of imbibition of the seeds of the three genotypes of cotton, during 24 and 48h are harmful in regard to the germination percentage, since they reached magnitudes much lower than those obtained when the control treatment was applied, without seed imbibition.

On the other hand, by virtue of the results obtained with respect to the increase in germination percentage with imbibition of the seeds in water during 12h, consequently the dynamics of the absolute germination rate AGR that is presented in Figure 3, shows that the amount of germinated seeds per day for the control treatment, without imbibition, was lower for the three genotypes, in comparison with that observed when the seeds were soaked for 12h.

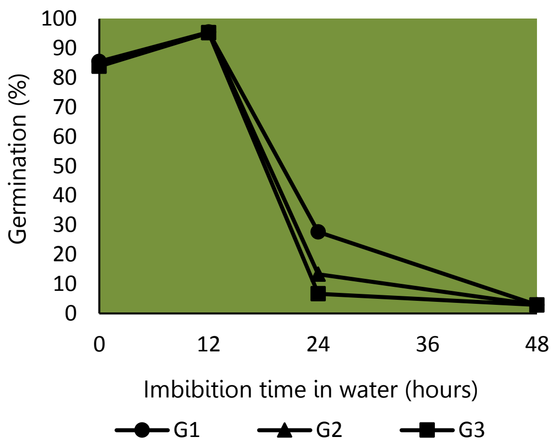


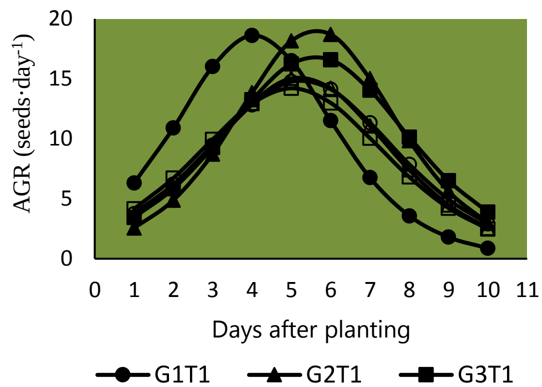
Figure 2. Interactions between three genotypes of cotton (Gossypium hirsutum L.) and four treatments of imbibition of seeds in water, in relation to the germination percentage: a) T0, without imbibition, b) T1, imbibition during 12h, c) T2, imbibition during 24h, d) T3, imbibition during 48h.
Source: Authors.

In general terms, the dynamics of the AGR showed a normal distribution with the typical bell-shaped curve, through which it can be inferred that its maximum points reached reflect the increasing effect of the germination percentage that had the treatment with imbibition of seeds for 12h.

The FM 1830 and FM 2334 genotypes reached the same maximum amount of germinated seeds per day. However, in the case of the FM 1830 genotype, this amount was reached at 4 days after planting (dap) and for the genotype FM 2334 it was reached at 6 dap.

In addition to the above, the genotype FM 1830 under conditions of treatment with seed imbibition for 12h exceeded in magnitude of the AGR during the first 4 dap to the other genotypes subjected to both control treatment and treatment with imbibition for 12h

Figure 3. Absolute germination rate AGR of three



cotton genotypes seeds (*Gossypium hirsutum* L.) with control treatments (without imbibition, treatment 0, T0) and imbibition in water for 12 h (treatment 1, T1). G1: genotype 1, FM 1830, G2: genotype 2, FM 2334, G3: genotype 3, Sinuana M 137.
Source: Authors.

Discussion

Regarding the number of seeds in a gram and weight of 100 seeds, according to what Sawan (2016) indicates, these two variables are considered fundamental components of seed cotton yield and are used by genetic breeders to group the different seeds. cotton genotypes (Clement et al., 2014), in view of the fact that they can present significant variation between different cultivars, either because of the genetic characteristics or because of the interaction with environmental conditions, which influence the growth of the crop, development and maturation of the seeds.

Regarding the number of seeds in a gram, the data presented in Table 2 are close to those indicated by Trebilcock (2015), who reports 11 seeds in one gram for the genotype Corpoica M-123 and 12 seeds in one gram for the Fiber Max FM 9162B2F genotype.

Regarding the weight of 100 seeds, the values reported in the literature are variable. According to Baloch et al. (2014) can fluctuate between 5.22 and 6.97g and according to reports from Trebilcock (2015) they are between 8.61 and 9.69g. However, this same author indicates values of 9.2, 9.3, 10.2 and 10.8g for the genotypes Coker 310, Deltapine 16, Lockett 4789A and Acala 1517-70, respectively.

Taking into account that the weight of 100 seeds directly determines the classification of cotton seeds in various sizes such as small, medium and large, whose magnitudes are between 7 and 8g, between 8 and 9g and more than 9g, respectively, it can be affirmed with this guideline that the FM 1830, FM 2334 and Sinuana M 137 genotypes have small seeds, and that this shows that not all current cotton genotypes necessarily have large seeds in response to the trend that modern breeding follows for this characteristic, without this being to the detriment of the genetic potential sought by the seed producers (Asl and Taheri, 2012). Inclusively, Baloch et al. (2014) report values that are much lower than those obtained in Table 2, among which we can highlight 6.30g for the Chandi genotype and 6.40g for the IR-1524 genotype, which may be useful in the identification and characterization of cultivars as indicated by Snider et al. (2014).

In relation to the germination percentage, the sigmoid trajectory through time observed in Figure 1, has been reported by Çokkizgin and Bölek (2015) and Chu et al. (2016), who indicate that their graphic pattern is characterized by being slow during the first days of the emergency and increases as time passes, until reaching a maximum value, which depends on each genotype and environmental conditions in where the seeds are sown.

According to the results obtained for germination percentage under conditions of the control treatment, and taking into account that according to Alvarenga and Filho (2014) this is a measure of the physiological potential of the seeds, it can be said for the three genotypes under study, that the germination did not occur at 100%, but at least it was diminished in 14%, possibly in a natural way having as main cause the deterioration and loss of vigor, which is the first quality component of the seed that is lost, shown through a decrease in the capacity of germination and viability experienced by the seeds as living organs during storage, especially when this occurs under uncontrolled conditions, as indicated by Tsaniklidis et al. (2015).

In any case, under conditions of the control treatment, the germination percentages obtained for the three genotypes are considered good, since according to what was stated by Alvarenga and Filho (2014) they exceeded 75%, a value considered as the minimum reference required for plantings commercial cotton, and according to these approaches demonstrate the high physiological potential of the seeds used in this study. In addition to the above, it is important to consider that according to Snider et al., (2014), regarding germination percentage, there are important differences between cultivars.

The increase observed in the germination percentage GP with the imbibition of seeds during 12h for the three genotypes, that shows in the Figure 1b and in the absolute germination rate AGR that shows in the Figure 3 corroborate the expositions of Çokkizgin and Bölek (2015) in the sense that the imbibition of cotton seeds in water under these particular conditions can be constituted in a treatment whose effects have been demonstrated on the increase of the vigor and the speed of germination with the additional advantage that an improvement in the uniformity of the obtained seedlings and is also an accessible, easy and economical option for the producers, and that can be an effective treatment to overcome several stress conditions, especially when seeds are sown in regions whose rainfall is widely spaced and irregular, and even in areas such as the middle Sinú Valley, where cotton is planted in seasonal conditions, taking into account the historical records of rainfall.

As the time of imbibition of the seeds in water was increased, as it was the case of 24 and 48h, it became evident the decrease in the germination percentage for the three genotypes studied, which indicates according to the approaches of Lutts et al. (2016) that the hydration of cotton seeds as a method of strengthening germination should occur in a controlled manner up to a point close, but before the appearance of the radicle.

The decrease observed for the three genotypes in the percentage of germination as the time of imbibition of seeds in water was increased, indicates that possibly the seeds were affected structurally and physiologically, mainly according to Çokkizgin and Bölek (2015) and Shafiq et al. (2015) for anatomical damages and enzymatic imbalances, oxidative stress, faults in the solubilization and transport of metabolites and nutrients and digestion of proteins, carbohydrates and lipids of tissue reserve from the seed to the embryo, which is related to the fact that cotton from sowing to harvesting is a plant that is too sensitive to oxygen deficiency that is caused by water excess, as indicated by Wang et al. (2017).

Consequently, the results obtained in the improvement of the germination percentage of the three cotton genotypes by virtue of the imbibition of seeds in water during 12h, could be basically related, according to Santhy et al. (2014) with the strengthening of the activity of antioxidant enzymes and improvement of the stability of cell membranes, which strengthens and consolidates germination, a process that according to Bange et al. (2016) is a critical and definitive condition for the healthy growth of cotton cultivation.

Taking into account that in the department of Córdoba, cotton is planted between the middle of August and the end of September, to take advantage of the rainfall in the area, climate change has brought as a consequence that, at that time of planting, alternate periods of heavy rain with periods of intense heat, coupled with low rainfall, which is precisely more intense during the month of August, which has been consolidated as a threat to the establishment of the crop. It is there where the use of strategies to solve the faults in the population density plays an important role, which harms the early plantings that are made at the beginning of the legal season, which in agreement with Çokkizgin and Bölek (2015) are important to obtain high performance and quality in cotton. In many cases due to failures in the establishment of the crop, manual reseeding of seeds with sharp wood system should be resorted to, in places where seedlings have been lost, which is the most widespread practice among farmers, among which some of them, according to reports from Trebilcok (2015) perform soaking or imbibition of cotton seeds for 12h the day before planting, from 6:00 or 7:00 PM, until 6:00 or 7:00 AM from the day of sowing, depositing them in a container with tap water.

Therefore, according to the results obtained, the imbibition of cotton seeds in water during 12h before planting, this practice is proved as valid to improve the percentage of germination and the absolute speed of germination, which increased in a way differential, depending on genotypes, and that under tropical climate conditions as indicated by Raphael et al. (2017) mitigates the negative impact that germination factors such as water deficiencies and high soil temperatures during seed sowing, emergence and establishment of seedlings can have on germination.

Conclusions

The effect that the empirical work of soaking cotton seeds in water for 12 hours before planting, carried out by some farmers in the area of the middle Sinú Valley, was validated on the percentage of germination. It was beneficial because it increased the germination percentage up to 96%, compared to 86% found for control treatment conditions, without seed soaking.

It is not recommended to soak the cotton seeds for a period of 24 hours, since the germination percentage presented a drastic drop, which varied according to the used genotypes. For Fiber Max 1830, a 67% drop in the germination percentage was found, for Fiber Max 2334 it was 84% and for Sinuana M 137 it was 91%. The soaking of seeds in water for 48 hours did not work for any of the used genotypes, showing absence of germination and decomposed seeds with foul odor in all cases.

References

Alvarenga, R., Filho, J. (2014). Vigor evaluation of stored cotton seeds, including the seed vigor imaging system (SVIS®). *Journal of Seed Science,* 36(2), 222-230. DOI: http://dx.doi.org/10.1590/2317-1545v32n2944.

Asl, M. y Taheri, G. (2012). Survey the effect of seed priming on germination and physiological indices of cotton Khordad cultivar. *Annals of Biological Research,* 3(2), 1003-1009.

Baloch, M., Khan, N., Rajput, M., Jatoi, W., Gul, S., Rind, I. y Veesar, N. (2014). Yield related morphological measures of short duration cotton genotypes. *The Journal of Animal & Plant Sciences,* 24(4), 1198-1211.

Bange, M., Groot, G. y Hundt, A. (2016). A preliminary study on the effect of cold plasma treatment on cotton seed imbibition and germination. Recuperado de: https://www.syngenta.com.au/file/10231/download?token=R6gOTiHQ

Chu, T., Chen, R., Landivar, J., Maeda, M., Yang, C. y Starek, M. (2016). Cotton growth modeling and assessment using unmanned aircraft system visual-band imagery. *Journal of Applied Remote Sensing,* 10(3), 1-19. DOI: 10.1117/1.JRS.10.036018.

Clement, J., Constable, G. y Liu, S. (2014). Increasing cotton seed fibre density as a breeding strategy to improve fibre fineness. *Field Crops Research*, 160, 81-89.

Çokkizgin, H. y Bölek, Y. (2015). Hydropriming and hot water-induced heat shock increase cotton seed germination and seedling emergence at low temperature. *Turkish Journal of Agriculture and Forestry,* 37, 300-306. DOI: 10.1515/plass-2015-0027.

Conalgodón- Confederación colombiana del algodón. (2017). Área, producción y rendimiento de algodón a abril de 2017. Recuperado de: http://conalgodon.com/estadisticas/#sc-tabs-1505317680779

Govindaraj, M., Masilamani, P., Albert, V. y Bhaskaran, M. (2017). Effect of physical seed treatment on yield and quality of crops: a review. *Agricultural Reviews,* 38(1), 1-14. DOI:10.18805/ag.v0iOF.7304.

ISTA -International Seed Testing Association. (2017). International rules for seed testing 2107. Chapter 2: Sampling. Recuperado de: https://www.seedtest.org/en/ista-rules-for-2017-_content---1--1448.html

Kamal, M., Saleem, M., Wahid, M. y Shakeel, A. (2017). Effects of ascorbic acid on membrane stability and yield of heatstressed BT cotton. *The Journal of Animal & Plant Sciences,* 27(1), 192-199.

Lutts, S., Benincasa, P., Wojtyla, L., Kubala, S., Pace, R., Lechowska, K., Quinet, M. y Garnczarska, M. (2016). Seed priming: new comprehensive approaches for an old empirical technique. pp. 1-49. In: Araujo, S. y Balestrazzi, A. (eds.). *New Challenges in Seed Biology - Basic and Translational Research Driving Seed Technology*. InTech, Croacia, Unión Europea. DOI: 10.5772/64420.

Murungu, F., Nyamugafata, P., Chiduza, C., Clark, L. y Whalley, W. (2013). Effects of seed priming and water potential on germination of cotton (*Gossypium hirsutum* L.) and maize (*Zea mays* L.) in laboratory assays. *South African Journal of Plant and Soil,* 22(1), 64-70. DOI: 10.1080/02571862.2005.10634683.

Mustafa, H., Mahmood, T., Ullah, A., Sharif, A., Bhatti, A., Nadeem, M., y Ali, R. (2017). Role of seed priming to enhance growth and development of crop plants against biotic and abiotic stresses. *Bulletin of Biological and Allied Sciences Research,* 2(2), 1-11.

Raphael, J., Gazola, B., Nunes, J., Macedo, G., y Rosolem, C. (2017). Cotton germination and emergence under high diurnal temperatures. *Crop Science,* 57, 2761-2769. DOI:10.2135/cropsci2017.03.0182.

Reina, A., Guzmán, M., Velásquez, L., Rondón, T., Vilaín, L., Anzalone, M., Araujo, D., y Pérez, J. (2017). Respuesta del cultivo de algodón (*Gossypium hirsutum* L.) a dos sistemas de labranza en un suelo inceptisol del estado Portuguesa Venezuela. *Geominas,* 45(72), 37-43.

Santhy, V., Meshram, Wakde, R., y Kumari, P. (2014). Hydrogen peroxide pre-treatment for seed enhancement in cotton (*Gossypium hirsutum* L.). *African Journal of Agricultural Research,* 9(25), 1982-1989. DOI: 10.5897/AJAR2013.7210.

Sawan, Z. (2016). Cottonseed yield and its quality as affected by mineral nutrients and plant growth retardants. *Cogent Biology*, 2, 1-29. DOI: http://dx.doi.org/10.1080/23312025.2016.1245938.

Shafiq, F., Batool, H., Raza, S., y Hameed, M. (2015). Effect of potassium nitrate seed priming on allometry of drought-stressed cotton (G*ossypium hirsutum* L.). *Journal of Crop Science and Biotechnology,* 18(3), 195-204. DOI: 10.1007/s12892-015-0035-7.

Snider, J., Collins, G., Whitaker, J., Chapman, K., Horn, P. & Grey, T. (2014). Seed size and oil content are key determinants of seedling vigor in *Gossypium hirsutum. The Journal of Cotton Science,* 18, 1–9.

Statista. (2017). ***Cotton production by country worldwide in 2015/2016.*** Recuperado de: https://www.statista.com/statistics/263055/cotton-production-worldwide-by-top-countries/

Trebilcok, A. (2015). Cultivo de algodón. Colombia: Publicaciones Universidad de Córdoba.

Tsaniklidis, G., Dermitzaki, E., Nikolopoulou, A., Darawsheh, M. y Aivalakis, G. (2015). Cotton seed storage effects on vigour and activities of NAD^+-dependent isocitrate dehydrogenase, malate dehydrogenase and *β*-amylase in seedlings. *Seed Science and Technology*, 43(1), 111-120.

Wang, X., Zhou, R., Groot, G., Bazaka, K., Murphy, A. y Ostrikov, K. (2017). Spectral characteristics of cotton seeds treated by a dielectric barrier discharge plasma. *Scientific Reports*, 7: Article 5601. DOI:10.1038/s41598-017-04963-4.

Weatherbase. (2017). Montería, Colombia. Travel weather averages. Recuperado de: http://www.weatherbase.com/weather/weather.php3?s=592500.

Wojtyla, L., Lechowska, K., Kubala, S. y Garnczarska, M. (2016). Different modes of hydrogen peroxide action during seed germination. *Frontiers in Plant Science,* 7, 1-16. DOI: 10.3389/fpls.2016.00066.