Chapter

# Analysis of the Effect of Scarification Process on Papaya (*Carica papaya* Lin.) Seeds Germination

*Sergio Rodríguez, Iramis Vargas, Asterio Hijuelo, Frederique Loumeto, Juan J. Silva, Jorge Pérez, Quirino Arias, Yanexis Fonseca, Yarisbel Gómez, Michel Baldoquín and Daliannis Oliva*

## Abstract

The presence of the aril (sarcotesta) in the papaya causes a slow and low germination, being necessary to break the state of dormancy. Calcium hydroxide that was applied in order to evaluate its scarifying effect was the objective. The sample consisted of 60 randomly selected fruits of hermaphrodite plants in a commercial production batch of approximately 1 ha (2222 plants) showing commercial maturity, of homogeneous size (±2 kg). The treatments were calcium hydroxide $Ca(OH)_2$ at three doses, dipping the seed for a period of 24 h; the standardized sodium hydroxide (NaOH) at 25% with a 15 min immersion time. The highest germination and vigor seeds were obtained applied $Ca(OH)_2$ with highly significant differences respect to the rest treatment, especially for the dose of 60 g $l^{-1}$ of water for reasons of diminishing expenses. Significant correlations were found, with direct relations (aril and mechanical damage) and inverse relations (abnormal seeds) between the variables evaluated related to the vigor and germination of the seeds. It can be an ecological and not expensive methodology to improve the germination and vigor of papaya seeds in relation to other chemical compounds to scarify.

**Keywords:** papaya, dormancy, seed germination, scarification, vigor, aril

## 1. Introduction

Fruit trees play an important role in human nutrition; and among these highlights, the papaya, this is a crop of tropical climate, widely appreciated for being one of the few fruit that provide continuous production throughout the year after the start of fruiting, to possess fruits with a high nutritional value, and to achieve high yields; generating good income to the families dedicated to their cultivation, due to the high prices that reaches in the market [1].

*Carica papaya* Linn belonging to family Caricaceae is known as papaya in France, United Kingdom, Mexico, Cuba, etc., papita in India, tree melon in Holland, paw paw in Australia and United Kingdom, and mamao in Brazil. The plant is native of tropical America. The properties of papaya fruit and other parts of the plant are also well known in traditional system of medicine. During the last few decades, considerable progress has been achieved regarding the biological activity and medicinal application of papaya and now it is considered as valuable nutraceutical fruit plant [2].

The world production of papaya occurs in more than 60 countries, according to FAO, for the year 2010, a production of 11,568,346 tons of the fruit was registered, with the main producing countries of the highest to lowest volume: India, Brazil, Indonesia, Nigeria, Mexico, Ethiopia, Colombia, Thailand, and Guatemala [3].

As a crop is an important source of employment, has a good yield, earliness to enter into production, and guarantees staggered crops throughout the year. Despite all these advantages, it does not reach the maximum productive potential, this is due in large measure to the problematic that it manifests in terms of the quality of seed [4]. Is consider one of the tropical fruits more appreciated for fresh consumption and for industrialization [5]. In Mexico like in Cuba, Maradol variety is the more cultivated, is a Cuban variety.

Different varieties of papaya are commercially propagated through seed an easy management and low cost, without taking into account the heterogeneity caused by crossed polinization [5].

In the sowing of papaya, it is best to use freshly harvested seeds, because while increasing the storage time of the seed, the germination rate decreases [6]. The majority part of the papaya sowing is done with stored dry seeds, and in this condition, the seed germination is erratic, asynchronous, slow, and incomplete [7], which diminishes the germination percent [5]. The desiccation produces stress in the papaya seeds when the moisture content lowers to 8.0% [8], being the cause of the seed dormancy or metabolic quiescence [9, 10]. In Taiwan, the papaya industry is limited by seed germination rates [11]. This is attributed to the presence of inhibitors as the phenolic compounds in the sarcotesta and seed coat [12, 13], and in some cases, the seeds lack embryos [6].

The seed is enclosed in a gelatinous sarcotesta (aril or seed coat), which is formed from the outer integument [14]. The sarcotesta can delay germination, and also dormancy is observed in seeds from which the aril has been removed [15].

Papaya, like many plants, presents as one of its main problems in its reproduction, the dormancy of the seed which influences the quality of it; because by reaching its maximum point of maturity, it initiates a period of latency produced by internal and external factors. It is normally interrupted when the natural conditions suitable for germination are present or when treatments are used that help to propitiate these ideal conditions and increase the percentages of germination [16], but in vitro conditions favored germination of papaya more than in vivo environment [17].

The seed of papaya is characterized by being bitegumented, since the internal tegument originates the tegumen and the external one to the testa, which is multiplicative up to 60 layers and 3 distinctive strata: endotesta, mesotesta, and exotesta (sarcotesta). This last one of semipermeable consistency, high humidity and concentrate phenolic compounds that, as a whole, induce latency. This causes the inhibition of fluid and gas exchange, delayed dehydration and colonization of pathogenic microorganisms. In [18] are mentioned others researchers who investigated this problem [19, 20].

One of the ways to break the latency of the seeds and make them have a good quality overall, increasing the percentages of germination is using the different methods of scarification.

The methods of scarification include physical, mechanical, and biological treatments such as dry heat, the rupture of the testa, the soaking in water, and chemical

solutions that promote the germination of the seeds, where any treatment that destroys or reduces the impermeability is called scarification, so in some cases, it is only enough to destroy a single point of the cover to produce the imbibitions and exchange of gases and thus initiate the germination [21].

Apparently, latency is a survival mechanism in the presence of certain climatic conditions: very low temperatures, alternations of dry and humid times, and desert climates. The exact causes of the latency phenomenon are unknown, and on the other hand, when the latency is due to testa conditions, the lethargy ends at the moment that it cracks or weakens by mechanical or chemical actions or by effect of the environment [22, 23].

Different seed treatments to promote germination and to reduce germination time are mentioned in [24], sowing seeds and at warm temperatures, exposing dry seeds to 10°C prior to sowing, drying seeds and soaking seeds in distilled water, potassium nitrate, thiourea, sodium thiosulfate, tannic acid or ferulic acid. The same authors described contradictory results using gibberellins on papaya seed germination. But in your research, they demonstrated that dehydration to 5.3% or 6.9% and 6.8% moisture content, followed by exposure to subzero temperatures and treatment with GA3, were the most favorable combined treatments to enhance papaya seed germination.

The used of smoke water on seed germination and seedling growth of papaya, cultivar Tainung No. 2 consistently and significantly increased the percentage of nitrogen in roots and shoots and significantly increased the percentage of magnesium in shoots. In these experiments, smoke-water showed potent germination promotion at low concentrations and promoted multiple growth attributes such as chlorophyll content and seedling vigor index at all concentrations in papaya seedling production [11].

Pregerminative treatments are used to break the latency status of the seeds. In [25] are mentioned stratification and scarification. Scarification is any process that breaks, scratches, mechanically alters or softens the covers of the seeds to make them permeable to water and gases.

Seed scarification methods have been developed and modified over time to make these more practical and effective. Important methods of seed scarification include heat, freeze–thaw, mechanical, and acid scarification [16].

In the scientific literature, some types of scarification are described, such as mechanical [26–28], physical [29–31], chemical [32, 33], and biological. Mechanical, physical, and biological scarification have disadvantages in relation to chemical scarification, because they require more time, are laborious and inadequate to condition large quantities of seed; while chemical scarification still requires more research [18], especially with calcium hydroxide.

There are chemical substances used to scarify seeds, among the most used are the sulfuric acid [34], sodium hydroxide, and hydrochloric acid [7, 18, 20, 31]. The positive effect of the use of NaOH in the benefit of papaya seed is that simulates natural degradation of sarcotesta and improves the conditions of the seed, so it is a viable alternative for use in conditioning seed [18]. Other results have been demonstrated that the combination of NaOH treatment and stratification is an effective practice to break *Iris lactea* var. chinensis seeds dormancy and improve germination percentage [35].

Chemistry scarification is considered as one of the most effective scarification methods used for seed scarification. Sulfur acid is the most popular and effective chemical product for acid scarification. The effectiveness of acid scarification depends on concentration of acid duration of scarification and species and cultivars used [16, 36].

Traditionally, it has been used to separate the mucilage from the papaya ferment the seeds in water at different time intervals and the sunny one for 2 or 3 h [37].

The objective of the research was to evaluate the scarifying effect of calcium hydroxide on the germination and vigor quality of papaya seeds, Maradol variety.

## 2. Experiment location

The experiment was carried out in the Laboratory of Seed Test of the plant of Benefit Manuel Espinosa Ramírez of the business unit of seeds base Granma, belonging to the company producer and marketer of seeds, using seed of papaya 'Red Maradol', collected in areas of the Experimental Station Jucaibama of the Agricultural Research Institute Jorge Dimitrov, Bayamo, Granma province.

### 2.1 Development of the experiment

The sample consisted of 60 randomly selected fruits of hermaphroditic plants in a commercial production lot of approximately 1 ha (2222 plants), showing commercial maturity (two strips), of homogeneous size (±2 kg). The seeds were extracted, and the batch was homogenized; 200 g of fresh dough were deposited with 500 ml plastic flasks representing each experimental unit.

### 2.2 Treatments

The treatments were composed of the solution of calcium hydroxide ($CaOH_2$) at three doses (60, 80, and 120 g $l^{-1}$ of water) by dipping the seed for a period of 24 h, the standardized sodium hydroxide (NaOH) at 25% with a 15-min immersion time, for a total of four treatments plus the control and six replicates. The control consisted in fermenting in running water the seed for 24 h.

To eliminate the sarcotesta (aril), the seeds were rubbed between two jute cloths where the time needed to remove all the aril of the material was evaluated, being the optimal time to use of 15 s for each treatment given the amount of material to process. Immediately, they were rinsed three times with running water, spread over a sieve in the shade and at room temperature (28 ± 1°C) for drying for 48 h.

The physical quality of the seed was determined by the effectiveness of the product, physical appearance, and mechanical damage within 3 days of the treatment, compared to the control; the physiological quality was determined by the germination percentage 7 days after sowing (vigor), being valued by the germination rate [38], and 28 days for final germination (as indicated in the germination standard, with the method in sand). The seed was soaked for a term of 24 h and placed in previously disinfested aluminum trays at a temperature of 100°C.

The incubation was carried out in the germinating chamber Paul Polikeit, Model HALLE S. A, with 80% of relative humidity, 40 ± 2°C of temperature and natural light; for the sanitary quality, it was determined by assembling all the treatments with the method between paper (BP), evaluating by observing the evidences of the development of microflora on the seed, during the germination test.

To carry out this test, three repetitions of 25 seeds were used by extraction, it was put to incubated in water the seeds for a time of 24 h, after the time elapsed, each seed was sectioned in longitudinal form leaving the cotyledons visible placed in culture tubes wrapped with aluminum foil adding a solution of 2, 3.5-triphenyl chloride tetrazolium to 1%, and the tubes were placed in an incubator at 35 ± 1°C for a time of 2 h.

### 2.3 Experimental design and evaluated variables

The experimental design used was completely randomized with bifactorial arrangement and six replicates. The variables assessed were vigor (vigor, 120, 240, and 360 days of conservation at 4–8°C, in percent); germination (germination, 120, 240, and 360 days of conservation at 4–8°C, in percent); the time needed to eliminate aril (s), mechanical damage, MD (%), and abnormal plants, AP (%), according to ISTA Methodology [38].

The data for each measured variable were statistically processed to check compliance with the normal distribution of the data (Kolmogorov-Smirnov test) and the homogeneity of the variances (Bartlett test). These two premises of the analysis of variance were not met, even after testing several data transformation equations, so we proceeded to the application of nonparametric variance analysis through Kruskal-Wallis, to demonstrate the existence or not of variability between treatments with a probability level of 0.05. The averages (aver.) of the treatments, the standard deviation (sd) of the mean, and the significance are shown. The multiple comparisons between treatments were made through the differences between the averages of the ranges [39].

We also performed analysis of partial correlations between variables with the use of Spearman correlating coefficient, with the aim of determining the existence of linear relationship between selected variables. Those variables that could have a direct or inverse relationship were selected in relation to the vigor and germination in their different times used as the aril, the mechanical damages, and the percentage of abnormal seeds.

Statistical processing was carried out with the use of statistical packages MINITAB 13 [40] for the test of homogeneity of variances and Infostat 2017 [41] for the rest of the statistical analyses.

## 3. Results and discussion

Significant differences were found between the different treatments in the vigor of the seeds (**Table 1**). The highest level of vigor of the seed was due to the use of calcium hydroxide, more than sodium hydroxide and fermentation. This tendency was maintained during the different storage times of the seeds at a constant temperature. Significant although not shown statistically, there is evidence of a decrease in

| **Vigor (%)** | | | | | |
|---|---|---|---|---|---|
| **Compound** | **Dose** | **0 days** | **120 days** | **240 days** | **360 days** |
| | | **Aver. ± SD** | **Aver. ± SD** | **Aver. ± SD** | **Aver. ± SD** |
| $Ca(OH)_2$ | 60 g $l^{-1}$ | $80.7^{ab}$ ± 2.8 | $83.7^{a}$ ± 2.7 | $77.3^{b}$ ± 2.3 | $71.7^{ab}$ ± 5.7 |
| $Ca(OH)_2$ | 80 g $l^{-1}$ | $81.7^{ab}$ ± 1.6 | $81.2^{ab}$ ± 1.2 | $79.3^{ab}$ ± 2.3 | $60.0^{bc}$ ± 6.8 |
| $Ca(OH)_2$ | 100 g $l^{-1}$ | $89.3^{a}$ ± 1.2 | $82.3^{a}$ ± 2.2 | $82.3^{a}$ ± 1.7 | $75.7^{a}$ ± 3.6 |
| NaOH | 25 g $l^{-1}$ | $50.3^{c}$ ± 4.2 | $42.7^{c}$ ± 3.7 | $26.5^{c}$ ± 3.4 | $6.7^{c}$ ± 0.5 |
| Fermentation | | $75.3^{bc}$ ± 1.9 | $75.8^{bc}$ ± 3.4 | $73.5^{bc}$ ± 3.5 | $71.7^{ab}$ ± 4.8 |

*Different letters indicate significant differences to $p \leq 0.05$ through the differences between the average of the ranges.*

**Table 1.**
*Effect of calcium hydroxide and sodium hydroxide with different doses on the vigor of the seeds in different storage times.*

| Germination (%) | | | | | |
|---|---|---|---|---|---|
| **Compound** | **Dose** | **0 days** | **120 days** | **240 days** | **360 days** |
| | | **Aver. ± SD** | **Aver. ± SD** | **Aver. ± SD** | **Aver. ± SD** |
| $Ca(OH)_2$ | 60 g $l^{-1}$ | $88.0^{ab}$ ± 2.18 | $87.3^{b}$ ± 1.6 | $80.2^{bc}$ ± 1.73 | $89.3^{ab}$ ± 6.6 |
| $Ca(OH)_2$ | 80 g $l^{-1}$ | $89.0^{ab}$ ± 1.9 | $89.0^{ab}$ ± 1.6 | $81.8^{ab}$ ± 1.2 | $70.5^{bc}$ ± 8.2 |
| $Ca(OH)_2$ | 100 g $l^{-1}$ | $94.0^{a}$ ± 2.9 | $92.3^{a}$ ± 2.0 | $85.3^{a}$ ± 1.8 | $88.8^{a}$ ± 4.3 |
| NaOH | 25 g $l^{-1}$ | $65.3^{c}$ ± 4.2 | $56.0^{c}$ ± 3.2 | $42.0^{d}$ ± 3.0 | $15.5^{c}$ ± 3.1 |
| Fermentation | | $83.7^{bc}$ ± 2.3 | $83.7^{bc}$ ± 2.7 | $76.3^{cd}$ ± 2.9 | $84.3^{ab}$ ± 6.08 |

*Different letters indicate significant differences to $p \leq 0.05$ through the differences between the average of the ranges.*

**Table 2.**
*Effect of calcium hydroxide and sodium hydroxide with different doses in germination percentage of seeds.*

the seeds vigor for all the evaluated treatments by increasing the conservation time of papaya seeds, which suggests that it is more efficient to apply calcium hydroxide in order to improve the response of papaya seeds with a minimum storage time.

The variability in the response of calcium hydroxide could be a consequence of the fact that some seeds within the same batch have a more persistent dormancy than others and that small and large seeds can be found in the same batch [42].

Sodium hydroxide reached lower percentages, even less than 60%, which is the minimum value established for Cuba for this crop [43, 44].

The physiological quality of the papaya seed is characterized by a high sensitivity to several factors with respect to germination and vigor, considering that there are integrating elements of great importance at the plantation level [45].

For the germination (**Table 2**), the application of calcium hydroxide obtained the best results, with percentages over the 80% in comparison with the rest of the treatments. Germination was more affected when the seeds were treated with sodium hydroxide and to the extent that the storage time of the seed was increased. Like the vigor, the germination percentage decreases in the treatments when the conservation time increased.

Physiologically, these results could be interpreted as a sequence of events of deterioration that begins with problems of functionality in the seminal membranes, which causes an excessive flow of cellular constituents, evidenced this by the high absorbance values and consequent loss of metabolites, the magnitude of which can restrict the germinative process [46].

Cold stored papaya seeds maintained significantly higher germination and better seedling vigor than the room stored seeds. With the increase in the duration of storage seed germination decreased after 20 mo. at room temperature, it declined marginally during the same period when kept in cold storage. Irrespective of the storage conditions, seeds kept in sealed polythene bags or plastic bottles had better germination and seedling vigor than those on paper and cloth bags. Shoot length and dry weight decreased significantly with the increase in the duration of storage. Viability of papaya seeds can be maintained considerably at room temperature up to 8 mo. by storing the seed in sealed, preferably airtight, polythene bags or plastic bottles. Cold storage using polythene bags or plastic bottle is recommended [47].

The storage conditions are very important. According to the classification of seed storage behavior, the papaya seed is classified as recalcitrant seed [48], others in intermediate seed [49]. In storage behavior ambient conditions, the papaya seeds survive for a short period of time [50] and are considered intermediate between

recalcitrant and orthodox attribute and deteriorate rapidly at higher storage temperatures and relative humidity. Fresh seeds give higher germination rate and seedling vigor that will decline with increasing the storage time [51] and consider that the best conditions for papaya seed storage is when containing 6.0% moisture and stored at 0°C gave higher percentage of germination, lower dormancy, and seed death.

In [18], the treatment that most affected the germination was the application of sodium hydroxide and the higher incidence of microorganisms, with high percentages of plants affected by fungi, which remained even below the germination approved for marketing, which requires, more than 60% [43].

In [52], described some pre-sowing treatments with the finality of increase the germination, like preconditioned papaya seed at 24°C before transfer to 32°C, soaked in $KNO_3$ for 30 min, soaking in gibberellic acid ($GA_3$; 200 ppm) for 24 h resulted in highest germination percentage in soil compared to α-naphthalene acetic acid (NAA) and $KNO_3$ treatment, and using a protocol of sterilization and germination of papaya seeds in response to light emitting diodes and got 100% of sterilization and 100% of germination.

The efficiency of the different scarification methods has been demonstrated in several investigations to favor the germinative process. In [53] were evaluated several methods of scarification of pacain seeds (*Chamaedorea* sp.), where the germination results indicated that the highest percentage was 77.8% and that corresponded to cold water treatment for 15 days (physical scarification), followed by treatment with mechanical scarification by hammer blow with 77.17% compared to the absolute control that obtained a 5.67% of germination.

With chemical scarification methods also obtained positive results [54], and verified germination percentages of 97 and 94%, respectively, in seeds of *Centrosema macrocarpum* for 10 min immersion.

The treatments used release the aril at different time intervals and there are differences between them in relation to the mechanical damage and the quantity of abnormal seeds of the Maradol variety (**Table 3**). The best results were obtained when calcium hydroxide was applied at the 100 $l^{-1}$ dose and with sodium hydroxide. Those compounds only needed an average time of 12 s to achieve an efficiency in the detachment of the aril, while with the application of the control dose, the worst results were obtained, with an average of 38 s that in some cases reached reaching more than 420 s to achieve the release of the aril, so that with this result, it is inferred that to work 25 kg of wet seeds, it would take approximately 38 min if treated with sodium hydroxide or calcium hydroxide in 100 l dose and approximately 106 min for the case fermented only with water.

| Compound | Dose | Aril (s) | MD (%) | AP (%) |
|---|---|---|---|---|
| | | Aver. ± SD | Aver. ± SD | Aver. ± SD |
| $Ca(OH)_2$ | 60 g $l^{-1}$ | $21.2^{cd}$ ± 1.3 | $1.0^{a}$ ± 0.9 | $1.5^{ab}$ ± 1.5 |
| $Ca(OH)_2$ | 80 g $l^{-1}$ | $17.7^{cd}$ ± 2.5 | $1.0^{a}$ ± 0.9 | 0.7a ± 1.0 |
| $Ca(OH)_2$ | 100 g $l^{-1}$ | $13.3^{ab}$ ± 1.4 | $0.5^{a}$ ± 0.6 | $0.4^{a}$ ± 0.7 |
| NaOH | 25 g $l^{-1}$ | $12.0^{a}$ ± 0.9 | $0.5^{a}$ ± 0.2 | $3.3^{b}$ ± 1.0 |
| Fermentation | | $37.7^{d}$ ± 6.3 | $9.2^{b}$ ± 1.2 | $0.8^{a}$ ± 0.9 |

*Different letters indicate significant differences to $p \leq 0.05$ through the differences between the average of the ranges.*

**Table 3.**
*Effect of calcium hydroxide and sodium hydroxide with different doses in the time (s) of detachment of the seed's aril.*

When carrying out an essay [55], with different methods to improve the germination of four forage shrubs legumes [Tagasaste (*Cytisus proliferus*) and three species of Teline (Genista)], obtained the most encouraging results for the elimination of the aril in the treatment with concentrated sulfuric acid for 30 min, demonstrating the effectiveness of chemical compounds in the scarification of seeds.

Refs. [7, 20] observed a negative effect on the papaya germination due to the presence in the aril or sarcotesta of inhibitory substances. It is also said that the marked decrease in germination, in the presence of sarcotesta is due to the low oxygenation of the seeds, which is why it is recommended to remove it. Likewise, in a study carried out in Honduras with seeds of the papaya, Maradol variety, higher percentages of germination were obtained with freshly harvested and oared seeds (83%), while fresh seeds with burned arils showed a lower percentage of germination, with 75% [56].

Similar results presented by [18, 20] which treated seeds with very corrosive products not only the germination is affected, but that several plants emerged with problems fundamentally in the radicle and hypocotyl, assuming the influence of other factors such as fluctuation in the moisture of the seed in the time of conservation.

The variables that were selected for the multiple correlation analyses (**Table 4**) showed that the release of aril seed correlated significantly with germination and vigor 360 days, positively and in a mean size. No correlations were found between this variable and the rest of the values of germination and vigor evaluated. Candiani et al. [57] concluded that the germination of *Michelia champaca* L. seeds is hindered probably due to the presence of inhibiting substances in the aril, is considered as endogenous causes of seed dormancy which include factors such as phytohormones, or by interference with water uptake [58]. Abscisic acid (ABA) is the key inhibitor of germination in *Taxus yunnanensis* seeds during wet sand storage [59].

The mechanical damage caused to the seeds during this process in this experiment did not correlate with the different levels of germination and vigor that were studied; however, the percentages of abnormal plants in the different time intervals evaluated showed a significant correlation, with medium to high values, but inverse and indicates that as the percentage of abnormal plants increases in a seed lot, the number of seeds germinates decreases and the vigor. Germination vigor is driven by the ability of the plant embryo, embedded within the seed, to resume its metabolic activity in a coordinated and sequential manner.

| **Correlations analysis** | | | |
|---|---|---|---|
| | **Aril** | **MD** | **Adnor** |
| Ger 0 | 0.13 ns | 0.07 ns | −0.74* |
| Ger120 | 0.24 ns | 0.15 ns | −0.71* |
| Ger240 | 0.25 ns | 0.18 ns | −0.72* |
| Ger360 | 0.46* | 0.34 ns | −0.70* |
| Vigor | 0.13 ns | 0.08 ns | −0.73* |
| Vigor120 | 0.28 ns | 0.19 ns | −0.70* |
| Vigor240 | 0.30 ns | 0.22 ns | −0.69* |
| Vigor360 | 0.46* | 0.34 ns | −0.70* |

*Ger is germination, MD is mechanical damage, and adnor is adnormal plants.*
**Indicate significant differences to $p \leq 0.005$.*

**Table 4.**
*Spearman correlations coefficient between variables.*

Was analyzed the vigor tests on lettuce (*Lactuca sativa* L.) seeds and their correlation with emergence [60], demonstrated that saturated salt accelerated aging and digital image analysis were the best laboratory tests for lettuce seed vigor evaluation, especially for seed lots to be used for plug seedling production. In some case, the use of seed vigor tests is used to predict field emergence in plants, like lucerne (*Medicago sativa*) [61].

In studies [62] about studied the correlations of seed germination percent of two sweet corn hybrids (*Zea mays* L.) with field emergence and some measured traits related to yield, the results of correlation analysis indicated that there was a high positive correlation between seed germination ability and vigor with seedling field emergence and most of the measured traits, as the percent of the radicle emergence.

The germination vigor depends on multiple biochemical and molecular variables. Their characterization is expected to deliver new markers of seed quality that can be used in breeding programs and/or in biotechnological approaches to improve crop yields [63].

Calcium hydroxide has great potential to be used as biocide in agriculture, because it has the advantage of not being phytotoxic, is economic and easy to use and is harmless to the environment and to humans. Decreased Ca levels in the nutrient medium reduced soybean leaf dry matter during seed fill, seed production, seed Ca concentration, and seed germination and increased the incidence of seedling disorders such as watery hypocotyl and epicotyl necrosis [64].

In [65] performed standard germination tests, germination and growth rate, accelerated aging, electrical conductivity, respiration rate and ATP content, to evaluate the vigor of the seeds of *Bromus biebersteinii* Roem & Schult and determined that the correlations with the behavior in the field of that forage were accelerated aging, respiration rate, and ATP content. The cited authors conclude that a vigor test alone is not adequate to measure the quality of seed lots. A combination of tests which measure both physiological and biochemical aspects should be used.

Some researches [66] showed that seed size is an important factor for germination and seedling vigor, establishing that larger seeds produce more vigorous seedlings but with slower emergence. So it can be argued that by using the largest scarified seeds that we have, we can help considerably to decrease the percent of abnormal plants and at the same time increase the vigor and the percentage of germination, variables evaluated in the present investigation.

To correlate characters related to seed germination, is important to investigate the effects of environmental factors prevailing during seed maturation under controlled conditions to understand exact reasons for unusual seed dormancy and germination requirements, for example, the germination of *Citrullus colocynthis* (*Cucurbitaceae*) is very sensitive to light and incubation temperature as well as to the environmental conditions associated with the time of seed maturation [67] and seed dormancy is a temporary failure of a viable seed to complete germination under normally favorable physical environmental conditions [33].

Seed germination tests assess the ability of the seed to produce a healthy plant when placed under favorable environmental conditions. Germination tests are conducted for a prescribed time period under laboratory conditions that assure optimum moisture, temperature, and light. Unfortunately, these conditions are seldom encountered in the field, and field emergence may be overestimated by standard germination tests. Seed lots that have low germination also are less vigorous due to seed deterioration. As seeds deteriorate, loss of vigor precedes loss of viability, so seeds with low germination usually will be less vigorous. Hence, in seed lots with poor germination, those seeds that do germinate often produce weaker seedlings with reduced yield potential. However, some species (such as many native

grasses) have inherently low germination potential and cannot be assumed to have poor vigor due to low germination. Seed vigor usually cannot be assessed by the consumer. Germination is a good indicator of seed vigor [63, 68].

Using efficient methods to scarify papaya seeds can increase the germination percentages of seeds, only if there is good control of environmental factors, because papaya seed germination is affected by light, temperature, oxygen, pH, and the moisture of the substrate [7].

It is necessary to conduct researches about the biometric and morphological characteristics of fruit and seeds, aiming at the maximum germination capacity and seed vigor [69], because biometric studies of seeds and their phenotypical correlations allow the quantitative evaluation of a character's relevance in relation to another [70]. It continues to investigate the correlations between the different indicators that can characterize the quality of the seeds. In adaptive correlations between seed size and germination time [71], present a model for the coevolution of seed size and germination time within a season when both affect the ability of the seedlings to compete for space and show that even in the absence of a morphological or physiological constraint between the two traits, a correlation between seed size and germination time is nevertheless likely to evolve.

Seed germination is a complex process and we need to understand the underlying molecular, hormonal, and mechanical aspects [72]. The environment during seed production has major impacts on the behavior of progeny seeds [73]. For that reason, the seed biology is considered the principal research topic for food security take into consideration the climate change [72].

Nowadays, there are advances in the propagation of papaya by biotechnological methods. Efficient micropropagation of papaya has become crucial for the multiplication of specific sex types of papaya and in the application of genetic transformation technologies. Significant progress has been achieved using organogenesis and somatic embryogenesis as the shoot tip, axillary bud and single node culture, organogenesis, anther and ovule culture, and regeneration from protoplasts, callus induction and somatic embryogenesis and the mass propagation by ex vitro rooting and acclimatation [74].

## 4. Conclusions

In natural conditions, the germination of papaya seeds has difficult by the presence of aril (sarcotesta) that become in a physical barrier which limits the diffusion of water and gases into the seeds and by the effect of phytohormones which preventing germination of seeds, causing dormancy, limiting the development of the embryos and causes a low and variable germination affecting the final percentage. This problem can be solved with the scarification of papaya seed. The results of this research showed that the dormancy by the presence of aril is produced in the papaya seed can be broken with the use of NaOH; but higher results were achieved with the use of calcium hydroxide, $Ca(OH)_2$. The results suggested that chemical scarification with calcium hydroxide can improve germination percentage and vigor of the papaya seeds, take into account that the seed is considered the major essential input in crop production. If the seed quality parameters (vigor, germination rate) decrease, the yields are affected. The scarification of papaya seeds with the use of calcium hydroxide for its proven effect in this research on the benefit of papaya seeds and easy acquisition and will reduce the costs of seed. But a good germination of the papaya seedlings depends on the many environmental factors and excellent agronomy practice. Finally, the effectiveness of scarification methods could change among cultivars within the papaya specie.

## Author details

Sergio Rodríguez[1*], Iramis Vargas[2], Asterio Hijuelo[3], Frederique Loumeto[4], Juan J. Silva[1], Jorge Pérez[1], Quirino Arias[5], Yanexis Fonseca[1], Yarisbel Gómez[3], Michel Baldoquín[3], Daliannis Oliva[3]

1 Plant Biotechnology Study Center, Faculty of Agricultural Science, University of Granma, Cuba

2 Seed Production and Marketer Enterprise, Ministry of Agriculture, Bayamo, Granma, Cuba

3 Faculty of Agricultural Science, University of Granma, Cuba

4 Educagri, Ministry of Agriculture and Food, French, Guiana

5 Applied Chemistry Study Center, Faculty of Engineering, University of Granma, Cuba

*Address all correspondence to: srodriguezr@udg.co.cu

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