The effect of parental plant and washing materials on seed germination of F2 generation apple cactus (Cereus spp.)

I Rafiana¹, Sukaya²*, E S Muliaawi³ and E Yuniastuti³

¹Undergraduate Program of Agrotechnology, Faculty of Agriculture, Sebelas Maret University, Indonesia
²Lecturer of Faculty of Agriculture, Sebelas Maret University, Indonesia

Corresponding author: sukaya@staff.uns.ac.id

Abstract. Apple cactus (Cereus sp.) is a genus of cactus, and two species that are often crossed are long spines (Cereus jamacaru) and short spines (Cereus peruvianus). Those species have seeds with physical dormancy, that is, seed mucilage that can inhibit the germination process. This research aims to study the effect of parental plants and washing materials on the germination of F2 apple cactus seeds. This study used two-factor RCBD using 3 parental plants of the F2 generation of apple cactus (C. jamacaru open pollination, C. peruvianus × C. jamacaru, C. jamacaru × C. peruvianus) and 5 washing materials (without washing, pH 8, distilled water (pH 7), pH 5, and pH 9) which was carried out in 3 repetitions. The results showed that seeds of the cross C. jamacaru as female parent (C. jamacaru open pollination and C. jamacaru × C. peruvianus) produced better germination than seeds from the cross of C. peruvianus as female parent (C. peruvianus × C. jamacaru). Although the washing material didn't significantly affect the germination of F2 apple cactus seeds, there was an influence of using pH 9 to minimize seed mucilage so that the extraction process was easier.

1. Introduction

Cactus is one type of ornamental plant that is popular in Indonesia. Cactus refers to the systematics (taxonomy) of plants. The species can be divided into 3 subfamilies, namely Pereskieae, Opunteeae, and Cereeae [1]. One of the cactus subgenera is Cereus. The cereus belongs to the neotropical columnar cactus. Cereus is a subgenus cactus that has a diverse species and wide distribution. Some species that have been found are Cereus peruvianus, and Cereus jamacaru [2]. C. peruvianus is a cactus native to the Americas. This cactus has a close relationship with C. jamacaru, which originated in Eastern Brazil.

In general, cactus plants can be cultivated generatively and vegetatively. Generative cultivation of cacti, in the process, will be very related to seed germination. The germination process of seeds can generally be inhibited due to several factors, one of which is because there is still mucilage on the surface of the seed. Therefore, to remove the mucilage, it is necessary to first treat it by washing the seeds before germination [3].

Cereus sp. experiencing self-incompatible conditions to produce new plants need to be cross-pollinated both open pollination and artificial pollination. In previous studies, natural crosses of long spines (C. jamacaru), artificial crosses from long spines with short spines (C. jamacaru × C. peruvianus), and short spines with long spines (C. peruvianus × C. jamacaru) have been conducted.
The result of the crossing has produced F2 seeds. F2 seed is the seed produced from the cross of F1 seed. F2 seeds generally have some differences from their parents. The use of F2 seeds will show differences in yield on some growth and development parameters with F1 seeds [4]. Therefore, research needs to be done to study the influence of elders and washing materials on the germination of seeds of the plant F2 apple cactus (Cereus spp.).

2. Materials and methods
This research was conducted in February – April 2020 at the Laboratory of Plant Pests and Diseases, Faculty of Agriculture, UNS. This study used a Randomized Complete Block Design (RCBD) using 3 parental plants of the F2 generation of apple cactus (natural crosses of long spines, short spines × long spines, long spines × short spines) and 5 washing materials (without washing, pH 8 water, distilled water (pH 7), pH 5 water, and pH 9 water). This study was carried out in 3 repetitions. Seeds were germinated by the rolled paper method on opaque paper. The observed variables were seed viability (maximum growth potential, germination percentage, mean germination time), and seed vigor (germination uniformity, germination speed, and vigor index). The resulting data was then analyzed with ANOVA test 5% and continued with DMRT test 5%.

3. Results and discussion

3.1. General condition of seeds

![Figure 1](image1.png)

**Figure 1.** F2 apple cactus fruits: A (natural crosses of long spines); B (short spines × long spines); C (long spines × short spines).

![Figure 2](image2.png)

**Figure 2.** F2 apple cactus fruit cut horizontally: A (natural crosses of long spines); B (short spines × long spines); C (long spines × short spines).

The seed used is F2 seed which is the seed of F2 apple cactus fruit (Cereus spp.) or planting F1 plant seeds. Before sowing, the fruit is first stored in the refrigerator at a temperature of 3°C. Storage is carried out for 2-4 weeks after the fruit is harvested. The seeds used are derived from the ripe fruit F2 apple cactus. The fruit's skin indicates ripe fruit has been red, reddish-yellow, or reddish-green.
The fruit taken seed is also selected from the fruit with good quality and not rotten (Figure 2). Seeds are extracted with several types of water, namely pH 8, distilled water (pH 7), water pH 5, and water pH 9. The seeds to be sowed are selected with criteria such as clean and healthy seeds (intact shape, shiny seeds, and uniform size) (Figure 3).

### 3.2. Seed viability

Seed viability is the life force of seeds shown in various physiological and biochemical phenomena in seeds [5]. Determination of seed viability in this study was done using variables such as maximum growth potential, germination percentage, and mean germination time. Based on the ANOVA 5% test results, the parental plant indicates a significant effect on the germination percentage and mean germination time. The treatment of washing materials and interaction between them had no significant effect on all research variables.

| Table 1. Seed viability of three parent plants apple cactus F2 at 19 DAS (%) |
|-----------------------------|-----------------------------|-----------------------------|
| Parent plant                | Maximum growth potential (%) | Germination percentage (%)  | Mean germination time (days) |
| F2 natural crosses of long spines | 33.87<sup>a</sup> | 41.47<sup>a</sup> | 22.64<sup>a</sup> |
| F2 short spines × long spines | 16.67<sup>a</sup> | 13.87<sup>b</sup> | 23.14<sup>a</sup> |
| F2 long spines × short spines | 21.47<sup>a</sup> | 27.33<sup>ab</sup> | 16.98<sup>b</sup> |

Based on the 5% DMRT test (Table 1), it is known that the F2 seeds of natural crosses of long spines produced the highest germination percentage (41.47%) than the other two elders. Similarly, in the mean germination time variable, the F2 seed of long spines crossed with short spines produced the shortest mean germination time (16.98 days) than the other two elders. In both variables, it is known that the F2 seed of short spines crossed with long spines produced the lowest germination percentage (13.87%) and the longest mean germination time (23.14 days). Low germination percentage and long mean germination time indicate low seed quality [5]. The results related to the use of female parent plants on crosses. When used as the female parent, long spines produce better germination than short spines as the female parent. That results follow the finding of Pulungan et al. [6], which states that maternal effects affect seed germination.

Based on the results, it was shown that the F2 seed of the apple cactus has a low germination quality. This is thought to be due to the storage factor of apple cactus seeds stored in low and not constant temperatures. Therefore, the seed undergoes structural dormancy characterized by the seed testa becoming hard so that it is resistant to water and oxygen (Figure 4, Figure 5 and Figure 6). This is in line with Olvera-Carrillo et al. [7], which states that cactus seeds with storage temperature and constant germination current temperature will be better germination than cactus seeds with storage temperature and temperature when germination is not constant.
Figure 4. Number of apple cactus seeds.

Figure 5. Normal seedlings of apple cactus.

Figure 6. Abnormal seedlings of apple cactus.

3.3. Seed vigor

Vigor is the ability of seeds to grow into normal plants that normally produce in a suboptimal state. If the seed is in optimum condition, then the seed can be a quality plant above normal and durable [5]. In this study, vigor seeds can be known from variables of germination uniformity, germination speed, and vigor index. Based on the ANOVA 5% test results, the parent plants only had a significant
influence on vigor index variables (Table 2). In contrast, the treatment of washing materials and interaction between them did not significantly influence all variables.

**Table 2.** Seed vigor of three parent plants apple cactus F2 at 19 DAS (%).

| Parent plant | Germination uniformity (%) | Germination speed (%) | Vigor index (%) |
|--------------|----------------------------|-----------------------|-----------------|
| F2 natural crosses of long spines | 14.93<sup>a</sup> | 21.63<sup>a</sup> | 14.80<sup>a</sup> |
| F2 short spines × long spines | 6.27<sup>a</sup> | 6.61<sup>a</sup> | 3.87<sup>b</sup> |
| F2 long spines × short spines | 14.00<sup>a</sup> | 15.77<sup>a</sup> | 10.93<sup>a</sup> |

Vigor index is one of the variables of vigor growing strength that indicates the germination speed of seeds [8]. Based on the results of the DMRT test 5%, it was shown that the seed with the highest vigor index was indicated by the F2 seed natural crosses of long spines with an average vigor index of 14.80% and the F2 seed of long spines crossed with short spines with an average vigor index of 10.93%. The F2 seed of short spines crossed with long spines showed the lowest vigor index with an average of 3.87%.

The use of parent plants, especially female parents, indicates an influence in seed germination. Similar to the viability of these seeds, the long spines used as female parents also produce better vigor qualities than the use of short spines as female parents. The predecessor research results support this, Julindra [9], who also obtained the results that using long spines (C. jamacaru) as female parents produces seeds of better quality. C. jamacaru generally has exalbuminous seeds, wrinkled seed testa, black, not shiny, and obovate-shaped [10].

Germination uniformity indicates shelf life vigor, while the germination speed and vigor index indicate growing power vigor [5]. Based on the average results obtained, the seeds used in this study have a low vigor quality. The seeds in this study showed low germination uniformity, germination speed, and vigor index. Low seed vigor can be caused by the influence of several factors such as genetic, morphological, environmental, and seed storage [3]. In this study, the storage of fruit and seeds exerted an important influence on the condition of the seeds. Storage of seeds in conditions of low and not constant temperature causes seeds dormancy. Dormancy occurs when the seed skin becomes hard and waterproof so that the seed can not absorb water and oxygen. Hard seed skin can cause seed growth to become uniform [11].

In addition to the storage of seeds at low and not constant temperatures, the use of fruit at an unequal age causes a difference in seed quality. If the fruit has been stored for a long time, it will cause the fermentation process of glucose [12]. Mucilage that envelops the seed of the apple cactus is part of the flesh of the fruit. Therefore, if the flesh of the fruit fermented glucose, then the seed's mucilage will also be the same content, leading to a decrease in the quality of seeds and germination.

### 3.4. Washing treatment

Barrios et al. [13], states that the characteristics of cactus seeds from 40 species indicate the presence of a layer of mucilage enveloping the outer skin of the seed. The treatment of washing materials based on the 5% ANOVA test did not significantly affect all variables. Table 3 is the result of the average influence of washing materials on all variables.

**Table 3.** Average germination result influence of washing materials.

| Washing materials | Max growth potential (%) | Germination percentage (%) | Mean germination time (days) | Germination uniformity (%) | Germination speed (%) | Vigor index (%) |
|-------------------|--------------------------|----------------------------|----------------------------|----------------------------|-----------------------|-----------------|
| Without washing   | 20.89<sup>a</sup>       | 21.56<sup>a</sup>         | 22.87<sup>a</sup>         | 9.78<sup>a</sup>           | 10.72<sup>a</sup>     | 6.00<sup>a</sup>  |
| pH 8              | 24.89<sup>a</sup>       | 29.56<sup>a</sup>         | 21.51<sup>a</sup>         | 13.56<sup>a</sup>          | 15.76<sup>a</sup>    | 10.67<sup>a</sup> |
| Aquadest (pH 7)   | 23.78<sup>a</sup>       | 26.44<sup>a</sup>         | 21.55<sup>a</sup>         | 10.89<sup>a</sup>          | 12.83<sup>a</sup>    | 9.78<sup>a</sup>  |
| pH 5              | 27.33<sup>a</sup>       | 29.56<sup>a</sup>         | 20.20<sup>a</sup>         | 12.22<sup>a</sup>          | 15.18<sup>a</sup>    | 11.11<sup>a</sup> |
| pH 9              | 23.11<sup>a</sup>       | 30.67<sup>a</sup>         | 18.47<sup>a</sup>         | 12.22<sup>a</sup>          | 18.88<sup>a</sup>    | 11.78<sup>a</sup> |
Washing with pH 9 has the best germination result than washing treatment with other materials. It is related to the mucilage content that envelopes the apple cactus seed. The mucilage that envelopes the apple cactus seeds contains glucose, fructose, and organic acids [14]. The mucilage can inhibit seed germination because it can trigger the appearance of fungi and bacteria. pH 9 is considered to clear the mucilage from other washing materials (Figure 7). This is in line with Luz et al. [15], which states that immersion treatment is required in substances with alkaline pH of 10% sodium hypochlorite to remove mucilage in cactus fruit. Purwanti [16] also stated that alkaline pH washing materials could clean the seeds of dragon fruit from the mucilage that envelops it.

Figure 7. Washing treatment on each material A (pH 8), B (Aquadest pH 7), C (pH 5), and D (pH 9).

4. Conclusion
The use of long spines as female parents can increase the germination of seeds both viability and vigor. Germination percentage, mean germination time, and vigor index of F2 apple cactus seeds (Cereus spp.) are better in the long spines as female parents rather than short spines as female parents. Washing treatment using various materials has no significant effect on seed germination. Washing with pH 9 can facilitate the extraction process and minimize the risk of the seeds being infected with viruses, bacteria, and fungi.

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