Physiological changes of *Capsicum baccatum* var. pendulum during ontogenesis and rest after harvest

Alterações fisiológicas de *Capsicum baccatum* var. pêndulo durante a ontogênese e repouso após a colheita

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ABSTRACT
The objective of this study was to evaluate the physiological quality of seeds of young finger pepper during ontogenesis and rest after harvest. The experiment was conducted in a completely randomized design with five replications. The treatments consisted of the harvest of the fruit at 30, 45, 60, 75, and 90 days after anthesis (DAA), and two rest conditions: no rest and post-harvest resting for 10 days. The seeds were evaluated for water content, dry mass of the seeds, germination, first germination count (germination energy) and germination speed index. The harvesting period and the post-harvest resting period of the fruits affect the physiological quality of the “Dedo-de-moça” pepper seeds. Seeds with maximum physiological quality (germination and strength) and dry matter are obtained with fruits harvested between 70 and 80 days after anthesis. The post-harvest resting period of fruits allows the anticipation of the harvest to 57 days after the anthesis, without compromising the physiological quality of the seeds.

Keywords: anthesis, anticipation of the harvest, germination, seed vigor.

RESUMO
O objetivo deste trabalho foi avaliar a qualidade fisiológica de sementes de pimenta dedo-de-moça durante a ontogênese e repouso após a colheita. O experimento foi conduzido em delineamento inteiramente casualizado com cinco repetições. Os tratamentos consistiram na colheita dos frutos aos 30, 45, 60, 75 e 90 dias após a antese (DAA), e duas condições de descanso: sem descanso e descanso pós-colheita por 10 dias. As sementes foram avaliadas quanto ao teor de água, massa seca das sementes, germinação, primeira contagem de germinação (energia de germinação) e índice de velocidade de germinação. O período de colheita e o período de repouso pós-colheita dos frutos afetam a qualidade fisiológica das sementes de pimenta dedo-de-moça. Sementes com máxima qualidade fisiológica (germinação e força) e matéria seca são obtidas com frutos colhidos entre 70 e 80 dias após a antese. O período de repouso pós-colheita dos frutos permite a antecipação da colheita para 57 dias após a antese, sem comprometer a qualidade fisiológica das sementes.

Palavras-chave: antese, antecipação da colheita, germinação, vigor de sementes.
1 INTRODUCTION

The pepper is widely cultivated in tropical regions, being mainly consumed in the States of Rio Grande do Sul, São Paulo and Goiás (CARVALHO; NAKAGAWA, 2009). Currently, the pepper production is a very profitable agricultural activity, both for small and large producers, which generates jobs and income for families.

Large companies have vast areas for cultivation, employing plenty of employees, especially at the time of harvest, justifying the need to use higher quality seeds, so that gains in productivity can be achieved.

The quality of the seeds is defined as the sum of the characteristics that affect its capability to generate high productivity plants (PEDROSO et al., 2008). The high quality of the seeds is obtained through the correct field production management and, especially, of the appropriate moment of harvesting, which prevents the seeds to be exposed to the adverse conditions and the attack of plagues and diseases. Thus, knowing the process of development and maturation of the seeds is important to establish the ideal period of harvest, in which the seeds have maximum germination and vigor (MELO et al., 2014).

The peppers, in general, present a continuous production. This allows the fruits to be harvested at different stages of development and maturation, hence, playing an important role on the physiological quality of the seeds, because the ones that are harvested at the immature state present lower strength and lower germinative power (PEDROSO et al., 2014). In species that exhibit uneven maturity, such as pepper, fruit harvesting followed by a postharvest storage period represent an advantage for the producer, since the rest period would allow immature fruits to complete the ripening process.

Researches carried out in postharvest rest period of fruits have provided important information for seed producers. Adequate rest may allow early harvesting, which reduces the time the fruit stays in the mother plant and in the field, avoiding a greater wastage of these plants and reducing the risk of losses due to possible unfavorable conditions in the field of production (SILVA et al., 2015).

However, studies that evaluate the possible effects of postharvest rest of fruits associated with different harvesting times should be performed, since the duration of resting period depends on several factors inherent to the species and to the climatic conditions related to the postharvest environment.
The objective of this study was to evaluate the physiological quality of seeds of young finger pepper during ontogenesis and rest after harvest. Materials and

2 METHODS

The experiment in the field and laboratory was conducted at the Department of Agricultural Sciences (DCA), of the Universidade Estadual de Montes Claros (UNIMONTES) in Janaúba, Minas Gerais. The municipality of Janaúba is located in the northern region of Minas Gerais, whose geographic coordinates are: 15°47’50”S and 43°18’31”W, with 516m altitude. According to the Climatic classification of Koppen, the climate is from “AW” type (tropical rainy with dry winter), with annual average rainfall of 900 mm, annual temperature of 25 °C and mean relative air humidity of 65%.

The experimental design was the completely randomized, in a factorial scheme 5x2, composed of five stages of maturation of the fruits, 30; 45; 60; 75 e 90 after anthesis (DAA) and two resting conditions: without rest and post-harvesting rest for 10 days, with five replications for each treatment.

It was used seeds from the pepper variety “Dedo-de-moça”. At the beginning, it was made the production of seedlings in expanded polystyrene trays with 128 cells, which contained a commercial substrate (Bioplant®) and 3 seeds per cell. After the emergence, when the seedlings presented the first definitive leaf stage, pruning was done, leaving only one seedling in each cell. At 45 days after sowing, when the seedlings had 10-15 cm in height and 4-5 definitive leaves, the transplanting was performed.

In the field, soil preparation consisted of pit openings with the aid of a hoe and the plants were arranged in an area of 72 m² (9 m x 8 m) with spacing of 1.0 x 1.0 m between plants. The fertilization was based on the chemical characteristics of the soil in the layer of 0 to 20 cm of depth, and according to the recommendations for pepper culture, and consisted in the application of 500 kg ha⁻¹ of P₂O₅, 60 kg ha⁻¹ of K₂O, and 67 kg ha⁻¹ of N, applied in the pit at the time of seedlings transplanting, and six cover fertilizations with 39 kg ha⁻¹ of K₂O and 43 kg ha⁻¹ of N, applied within 15 days between each fertilization.

In the flowering phase of the crop, the flowers were labeled on the day of their anthesis with cotton twine of different colors, and in order to obtain enough fruits for the proposed tests, this operation was carried out for five consecutive days. The fruits were harvested manually at
30, 45, 60, 75 and 90 days after anthesis (DAA). For each maturation stage, 200 fruits were randomly collected, placed in plastic bags and transported to the seed laboratory. From the collected fruits, one hundred fruits of each stage had their seeds extracted soon after the harvest, and the remaining fruits remained with the seeds, in laboratory ambient conditions at 26 °C, for a period of 10 days. After removal of the fruits, the seeds were washed in running water and set to dry under ambient conditions for 48 hours. Then, physical and physiological analyses were performed.

The water content of the seeds was determined according to the methodology prescribed in the Rules for Seed Analysis - RAS (BRAZIL, 2009), using the oven method at 105 ± 3 °C for 24 hours, with five replicates of 50 seeds per treatment, with the results being expressed as % water content. Simultaneously, the weight of the dry matter of the seeds was determined and the results expressed in %.

For the germination test, the seeds were sown on two sheets of germitest paper, moistened with distilled water in volume equivalent to 2.5 times their dry weight and arranged in gerbox type plastic boxes. After this procedure, the boxes containing the seeds were kept in a digital germinator pre-set at a temperature of 30 ºC and with constant light. The evaluations were done in the fourth (first count after germination) and fourteenth day after sowing, and the results expressed as percentage of normal seedlings, according to the criteria established by the RAS (BRAZIL, 2009).

The germination speed index (GSI) was conducted along with the germination test, and the number of seedlings with a visible cotyledonary arm was recorded daily until the 14th day after sowing (MAGUIRE, 1962).

3 RESULTS AND DISCUSSION

Studying the effect of the resting period of the fruits within each harvesting time, revealed that the water content of the seeds varied according to the time of harvest (Figure 1).
It can be verified that the rest of the fruits promoted a reduction in the water content of the seeds when the fruits were harvested at 30 and 45 DAA.

These results can be explained because the fruits enter into a hygroscopic equilibrium with the environment, thus reducing the water content of the fruit wall and, consequently, of the seeds. Similar results were found by Ricci et al. (2013) with Jalapeño pepper (Capsicum annuum L.).

Seeds extracted from fruits harvested at 60 and 90 DAA did not present statistical differences in water contents immediately after harvest and after 10 days of rest in fruits (Figure 1). For the seeds of the fruits harvested at 75 DAA the rest promoted an increase in the water content, possibly due to a rotting of the fruits, since they had a water content of 36% at harvest time.

The unfolding of the interaction between FR and TH, evaluating the effect of the resting period of the fruits within each time of harvesting, revealed significant differences for the two assessed periods. Results of the water content of the seeds at zero and ten days of rest were fitted into a linear behavior regression equation (Figure 1).

It is observed that in the absence of the rest of the fruits, the water content of the seeds ranged from 66% at 30 DAA to 19% at 90 DAA. The high-water content in the initial stages of seed development may be justified because there is an osmotic equilibrium between the fruit pericarp and the seeds, hence allowing an aqueous medium that provides synthesis and the translocation of fruit metabolites to the seeds Justino et al. (2015). With the rest of the fruits,
there was a reduction in the water content of the seeds at all times of harvest (Figure 1). At 30 days after anthesis, the seeds had a water content of 51%, reducing to 19% at 90 DAA.

In this way, it can be noticed that with the separation of the seeds of the mother-plant carried out by the harvest associated with the rest of the fruits, occurred a reduction in the water content of the seeds at the different harvesting times, which indicates the preparation of the seed metabolism towards the physiological maturity Ricci et al. (2013). Although the water content decreased during the rest period, the final value observed at 90 DAA can be considered relatively high, in agreement with the results obtained for seeds of other fleshy fruits, such as “malagueta chili” pepper (Capsicum v frutescens L.) “bode” pepper (Capsicum chinense Jacq.) Abud et al. (2013), and “Dedo-de-moça vermelha” pepper (Capsicum baccatum) Pereira et al. (2014).

Monitoring the water content of seeds in the production systems has great importance, since the humidity exerts a remarkable and direct influence on the quality and longevity of them, since it stimulates the metabolic activity of the embryo (MARCOS FILHO, 2015). It is also mentioned that as the seeds lose water, the metabolic reactions are reduced until the respiratory activity becomes quite reduced. In this condition, the seeds can be stored for long periods. Thus, it is important that the harvest be performed as soon as possible, after the physiological maturity.

Evaluating the effect of the resting period of the fruits within each harvesting time, revealed that the dry mass of the seeds varied according with the time of harvest (Figure 2).

Figure 2. Accumulation of dry matter of seeds (mg/seed) of pepper, from “Dedo-de-moça” variety, according to the harvesting times and the rest period of the fruits.

<table>
<thead>
<tr>
<th>Days after anthesis (D.A.A.)</th>
<th>Dry matter (mg/seed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>1</td>
</tr>
<tr>
<td>45</td>
<td>2</td>
</tr>
<tr>
<td>60</td>
<td>3</td>
</tr>
<tr>
<td>75</td>
<td>4</td>
</tr>
<tr>
<td>90</td>
<td>5</td>
</tr>
</tbody>
</table>

Source: The authors.
It is verified that seeds extracted from fruits submitted to postharvest rest (10 days) presented a higher weight of dry matter in the harvests at 30, 45 and 60 DAA. On the other hand, seeds harvested immediately after fruit harvest (0 days) presented a higher accumulation of dry matter in relation to those harvested at 10 days of rest in the fruit, when it was harvested at 75 and 90 DAA.

It is important to highlight that, in general, the monitoring of seed development is carried out based on the changes that occur in some physical and physiological characteristics of the seeds, such as the water content, the content of accumulated dry matter, germination and strength, and such alterations start after fertilization, culminating with the physiological maturity, when the translocation of assimilates from the plant to the seed ceases (DIAS; NASCIMENTO, 2009). From this point, the seed is bound to the plant only physically, so that the climatic conditions prevailing at this stage will be decisive for the final quality of the seed.

The dry matter of the seeds for both periods of rest evaluation was framed in a quadratic behavior regression equation (Figure 2). It can be verified that, for seeds extracted from fruits not submitted to postharvest rest, as the harvesting times elongated, there was accumulation of dry matter in the seeds, reaching the maximum content of dry matter (4.21 mg/seed) at 74 DAA. From this time on, there was a small reduction in the observed values. This reduction is possibly associated to the losses caused by the respiration of the seeds (CARVALHO; NAKAGAWA, 2012).

According with Dias and Nascimento (2009), the dry mass of seeds is represented by proteins, carbohydrates, lipids and other substances. Immediately after fertilization, the accumulation of dry mass occurs slowly, since in this phase the cell divisions predominate, with an expressive increase in the number of cells. Thereafter, a continuous and rapid increase in the content of the dry mass is verified until reaching the maximum value, which is maintained for a certain time.

For seeds harvested from fruits subjected to rest for 10 days, it was observed that the dry matter of the seeds at 30 DAA was 2.79 mg/seed, reaching the maximum content (4.92 mg/seed) at 60 DAA (Figure 2). From the results, it can be observed that for harvests up to approximately 60 DAA, the maintenance of the fruits at rest for 10 days allowed a greater accumulation of dry matter in the seeds compared to those extracted from fruits not submitted to rest.
Silva, (2009) point out that some research results indicate that the fruits of some species harvested prematurely, when stored for some time before the extraction of seeds, also produce good quality seeds, once they complete the maturation process with the rest.

The germination of the seeds, due to the postharvest rest period of the fruits, within each harvesting season, varied according to the harvest times (Figure 3).

Figure 3. Seed germination (%) of “Dedo-de-moça” pepper, in accordance with harvesting times and resting period of the fruits

The germination of the seeds obtained from fruits harvested at 30, 45 and 60 DAA and submitted to rest for 10 days was higher in relation to the fruits without rest.

It can be seen that fruit rest was beneficial for immature harvested seeds (30 DAA), which initially presented null germination and, after rest, reached 47% germination. Seeds extracted from fruits not submitted to rest had a higher percentage of germination than those extracted at 10 days, only when they were harvested at 75 and 90 DAA (Figure 3). According to Castro et al. (2008), the resting period of the fruits favors the germination only when the harvested fruits present seeds in development, that is, before the physiological maturation.

The seeds germination, for the two periods of resting of the fruits, showed quadratic effect (Figure 3). It is verified that seeds from fruits harvested at 30 DAA, not submitted to rest, presented null germination, indicating that at this stage the seeds are still immature. Additionally, Justino et al. (2015) demonstrated that at this initial stage of the maturation process there is a possibility of seed dormancy, which directly affects its real germination potential.
From the 30 DAA, there was an increase in seed germination, reaching the maximum percentage (88.93%) approximately at 72 DAA, before the seeds reached the maximum dry matter accumulation at 74 DAA (Figure 2), which is defined by Ellis and Pieta Filho (1992) as mass maturity point.

Theoretically, the ideal seed harvesting point would be at the physiological maturity, characterized by some authors as the maximum dry mass content (TEKRONY et al., 1980; DEMIR; ELLIS, 1992), which may or may not coincide with the maximum seed quality.

Initially, the percentage of germination of seeds collected from fruits harvested at 30 DAA was approximately 47% (Figure 3), reaching the maximum percentage (87.61%) at approximately 57 DAA. From this point, there were reductions in the values, with 21% germination at 90 DAA, indicating a negative effect on seed quality when late harvesting was associated with the postharvest rest of the fruits.

Dias and Nascimento (2009) reported that, from the physiological maturity, a period of storage of the seeds in the field begins, which can compromise their quality. These facts were verified in the present study, once the seeds were exposed to the natural weather, which is especially severe in regions where the end of maturation coincides with rainy periods.

The timing of the harvest is one of the most important factors that affect seed quality. In the case of early harvests, immature seeds may be harvested, while in the late harvests there is the risk to harvest seeds that are already in the process of deterioration, with detrimental effects on the quality of the harvested material. Vidigal et al. (2009) reported that early harvesting of pepper fruits, cultivar Long Yellow, was not beneficial to the physiological quality of seeds, even when associated with 15 days post-harvest storage.

Studying the effect of the resting period of the fruits within each harvesting time, revealed that the seed vigor evaluated by the first count tests and germination speed index varied according to the time of harvest (Figure 4 e 5). It is verified that the rest promoted increases in the strength of the seeds harvested at 30, 45 and 60 DAA, when compared to seeds extracted from the fruits immediately after harvest.

In contrast, as occurred in germination, it was observed a reduction in the strength of seeds harvested at 75 and 90 DAA and submitted to rest. This negative effect can be explained by the deterioration of the seeds due to the deterioration of the fruits.
Through the results it is possible to note that the increase in vigor of the seeds, with the advancement of harvesting times, indicates that the seeds obtained from the pepper fruits at 75 and 90 DAA (without rest) have higher longevity and the ability to generate perfect and vigorous plants. However, immature harvested fruits and fruits in the initial stages of maturation can be submitted to a rest period after the harvest for 10 days, in order to the seeds complete their maturation.

The results First germination count (FGC) e germination speed index (GSI) for the two resting periods were framed in a quadratic behavior equation, following the same trend of the results obtained in the germination test for seeds obtained from fruits with rest. This demonstrates, once again, the improvement in the strength of the seeds along with the resting period of the fruits.

The first germination count is a simple strength test, performed simultaneously to the germination test, and it assumes that the most vigorous seeds germinate faster. In this sense, the maximum germination points at the first count in the equations were estimated at 90 and 57 DAA, with and without rest, respectively (Figure 4).

Figure 4. First germination count (FGC) of “Dedo-de-moça” pepper seeds, in accordance with harvesting times and the rest period of fruits.

Seeds from fruits not submitted to rest and harvested at 30 DAA presented zero GSI, and as the harvesting times continued, there was an increase in germination speed until at 76 DAA, considered the best GSI result (8.81) (Figure 5). After 76 DAA the GSI decreased, with an index of 7.93 at 90 DAA.
As harvest times increased, there was an increase in the values observed until the 57 DAA, reaching the maximum value of GSI (7.84), with a decrease in the values observed from this harvest time until reaching the index of 1.23 at 90 DAA (Figure 5).

It can be noticed that the rest of the seed in the fruit seems to have favored the seed performance, since even after a reduction in the values after 58 DAA, the results were superior to those verified by the seeds without rest harvested until that time.

The emergency speed index was efficient in indicating significant differences among the evaluated treatments, as already reported. Satisfactory results in the germination speed index and the first germination count are important, since they evaluate seed vigor by providing additional information on seed germination performance, potential germination, speed and uniformity in the seedling growth.

4 CONCLUSIONS

Harvest times and postharvest rest of fruits affect the physiological quality of “Dedo-de-moça” pepper seeds;

Seeds with maximum physiological quality (germination and vigor) and dry matter are obtained with fruits harvested between 70 and 80 days after anthesis;

The postharvest rest of fruits allows the anticipation of the harvest to 57 days after the anthesis, without damages to the physiological quality of “Dedo-de-moça” pepper seeds.
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