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THE EFFECT OF MATURITY LEVEL AND SIZE ON THE VIABILITY OF CINNAMON SEEDS AT DIFFERENT STORAGE TIME PERIODS (*Cinnamomum burmanii.* L)

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Abstract. *Cinnamomum burmanii* L, *a cinnamon plant developed in Indonesia, requires high-quality seeds, yet plant propagation faces challenges due to limited access to quality seeds at the appropriate time. This study aimed to determine the viability of cinnamon seeds from the level of maturity of the seeds and size. The experimental design used in this study was a randomized completed block design with a factorial pattern, with the first-factor treatment being the maturity level of the seeds, namely: 1) K1 (purple) and 2) K2 (purplish-green). The second factor was the size of the seeds, namely: 1) U1 (large size) and 2) U2 (small size) at different storage times, namely at the beginning of storage, 4,7, and 10 days after storage. The observed variables included water and carbohydrate content, germination, and seed vegetative growth (seed height, number of leaves, leaf length, leaf width, roots, and root length). The results showed that the interaction of cinnamon seeds with large size and purple maturity level had the highest viability in all storage periods. Germination reaches 70%, carbohydrate content 15.28%, and moisture content 10.51% ten days after storage.*
Keywords*:* cinnamomum burmanii; Maturity level; size; storage time; viability.

1. Introduction

Cinnamomum burmanii L is one of the cinnamon plants developed in Indonesia with production centers in West Sumatra and Jambi Provinces. Cinnamon is one of ten potential spice export products in Indonesia. The results of the study (Humaira & Rochdiani, 2021) show that the variables of cinnamon export prices, Indonesia's real exchange rate, and Indonesian cinnamon land area greatly affect the volume of Indonesian cinnamon exports, but the variable amount of cinnamon production has no significant effect on volume.. The most dominant factor influencing the volume of Indonesian cinnamon exports is the price of cinnamon exports. The total export of Indonesian cinnamon in 2005 was 37,192 tons and increased in 2009 by 38,361 tons. Indonesia's cinnamon exports have increased in the last five years, by an average of 9%, while domestic consumption grew by an average of 81.08% per year. The increase in exports and consumption is due to the increasing variety of benefits of cinnamon, especially for health.

What is produced from this plant is usually in the form of bark, which can be in the form of bars, powder or in the form of essential oils and oleoresin. The cinnamon essential oil can be obtained from bark, branches, twigs and leaves by distillation, while the oleoresin can be obtained by extracting cinnamon bark with organic solvents (Ferry, 2013). The main content of essential

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oil or oleoresin from cinnamon is cinnamaldehyde (84.82%), 1(2H)-Naphthaleneone, 3, 4, -dihydro – 1 - tetralone (2.06%), Benzenepropanal (1.43%), Terpineol (1.30%), Naphthalene, 1,2,3,5,6,8a-hexahydro-4,7-dimethyl-1- (1-methylethyl) (1.29%), Bicyclo-2,2, 1, heptan-2-ol, 1,7,7-trimethyl (1.24%) and 1,8-cineol (1.08%), eugenol, methyl ketene, furtural, nonyl aldehyde, hydrocinnamic aldehyde, cuminaldehyde, and coumarin (Ramadhani, 2017). In addition to the cosmetic and health industry, cinnamon also functions as a vegetable pesticide, including for controlling the golden snail (*Pomacea canaliculata*, Lamarck) which has been carried out by (Idris *et al.*, 2020) with 100% mortality at a dose of 156.25 ppm with a long soaking time (12 hours). Currently cinnamon is still being developed, but farmers face obstacles in obtaining quality seed sources because until now farmers have obtained it traditionally, namely by collecting seeds under trees known as swept seeds, so that production and quality are very diverse and low. The availability of quality seeds is the key to increasing cinnamon productivity, in addition to cultivation techniques, maintenance during planting and the post-harvest process. Therefore, efforts are being made to increase the production of cinnamon by providing quality cinnamon seeds. According to research (Dhalimi, 2006) that the main problems faced in cinnamon seedling to date are low productivity and quality because the success of cinnamon cultivation begins with the use of inferior seeds. The higher the quality of the seeds used, the better the productivity and quality of the cinnamon produced.

Cinnamon plant *C. burmanii*. L is classified as a plant with recalcitrant seeds that have a short life span. Recalcitrant seeds cannot be stored at low seed moisture content and cannot be stored for long. This plant can be propagated generatively (through seeds) and vegetatively (grafts, cuttings and root shoots). Until now cinnamon propagation technology is not yet available, but for other plants with recalcitrant seeds already exist such as cloves. Clove seed moisture content is at least 80%, germination is 85%, seeds must grow within 3 weeks after sowing (Hartawan & Nengsih, 2012) said that recalcitrant seeds have short viability and vigor as well as short shelf life, so distribution that requires time and long distances must be handled with special techniques. Seeds will experience a decrease in food reserves and moisture content during storage.

The maturity level of the cinnamon plant fruit has not been found, but the maturity level of other recalcitrant seeds (kemiri sunan) is 28 weeks after flowering with the characteristics of brownish green fruit color, soft fruit skin, brown seed coat with 76-80% germination (Tresniawati *et al.*, 2014). but for other plants with recalcitrant seeds already exist such as cloves. Clove seed moisture content is at least 80%, germination is 85%, seeds must grow within 3 weeks after sowing The larger the size of the seed, the higher the germination capacity because there is more food supply for large seeds, namely Melia azedarach seeds (Suita & Megawati, 2009), Senna occidentalis seeds (Saeed & Shaukat, 2000), Castanea sativa Mill seeds (Tumpa *et al*., 2021).

Large seeds have more energy than small seeds. Factors that affect seed germination are seed maturity level, seed size, dormancy, (internal factors), and external factors, namely water, temperature, oxygen and medium. The internal factor of seed maturity is influenced by the age of harvest and post-harvest methods. Seeds derived from a fruit that are too old or too young usually have low vigor. High-quality seeds have genetic, physical and physiological qualities with good handling since the plant is in the field, processing, storage and distribution. Good seed storage is an effort to maintain seed quality until the seeds are planted by farmers (Rahayu & Widajati, 2007).

Seeds harvested before physiological maturity do not have high viability, even in some plants such seeds will not germinate. For a high level of seed viability, it can be seen through the level of fruit ripeness. Seeds derived from fruit harvested before the physiological maturity level is reached, will not have high viability (Hayati *et al*, 2011).

Recalcitrant seeds are very sensitive to drought and will regress at low moisture content and temperature. Storage time has a significant to very significant effect on germination, vigor index, growth speed and sprout growth rate (Baharudin *et al.*, 2010). For Avicennia marina, which is a recalcitrant seed stored for 2 weeks, the germination rate reached 30% at a relative humidity of 83% (Halimursyadah, 2012).

Cassiavera cinnamon seeds that have been peeled (removed the flesh) will quickly lose their growth power and must be sown immediately. Seilon cinnamon seeds that have been peeled and directly sown on sand media can germinate in 15-20 days with an average germination percentage of 57-99% ((Suryani & Nurmansyah, 2009). Differences in seed size cause the difference in germination percentage. Cinnamon seeds are classified as recalcitrant seeds In this study, the viability of cinnamon seeds has been studied at the maturity level and different seed sizes. Cinnamon seeds are recalcitrant seeds. For this reason, research will be carried out to study the viability, degree of maturity and size of cinnamon seeds in several storage periods. In order to obtain optimal *C. burmanii* L seed germination technology.

2. Methods

The research was c conducted at the IP2TP Experimental Garden of Balittro Laing Solok, West Sumatra, from July to November 2019. A factorial experiment with two factors, three replications, and 30 samples (seeds) for each treatment and replicates were arranged in a Randomized Completed Block Design (RCBD)). The first factor is the level of maturity of the seeds, namely: 1) K1 (purple) and 2) K2 (purplish green).), The second factor is seed size, namely: 1) U1 (large size) and 2) U2 (small size). Seeds from each treatment and replicates of 30 seeds were put into containers, then stored at room temperature. The seeds from each treatment germinated gradually according to the storage time, namely the beginning of storage, four days after storage, seven days after storage, and ten days after storage. Seeds are sown at a distance of 5 m x 5 cm on a medium of sand + soil + manure 1:1:1.

2.1. Observation

a. Physical Quality

Cinnamon seeds were observed for their physical quality, including water content and carbohydrate content. Observations were made beginning and after storage, namely 4, 7 and 10 days. Moisture content was observed based on wet weight using the oven method. A total of 10 seeds were put into a container and then baked at a temperature of 70 ^{o}C for 3x24 hours or until the weight was constant, then weighed using an analytical. ISTA 2010 *in* Suita & Syamsuwida (2015) (1).

$$Seed\ moisture\ content = \frac{B1-B2}{B1} \times 100\% \qquad (1)$$

Information:

B1 = Initial weight of seed moisture content
B2 = Final weight of seed moisture content

The examination of carbohydrate content using the Spectrophotometer method was carried out at the Laboratory of the Solok Tropical Fruit Research Institute.

b. Germination Power Percentage

This observation was carried out by counting the number of germinated seeds against the total number of seeds sown. The characteristics of a living seed are the seeds germinate with stems and leaves that are fresh and not rotten. Observations were made at 12 WAS. Calculation using the ISTA (1972) *in* Lesilolo (2012) (2).

$$Germination(\%) = \frac{\sum plant\ life}{\sum plant\ population} \times 100\% \qquad (2)$$

c. Seed Growth

Observations of seed growth were carried out on based on experience in the field: (1) Shoot height: measured from the base of the shoot to the growing point, (2) Stem Diameter: measured at the base of the stem using a sigma (3) Number of Leaves: carried out by counting the number of leaves that appeared and had been fully open (4) Leaf Length: measured from the base of the leaf to the tip of the leaf (5) Leaf Width: measured at the center of the leaf from the right tip to the left of the leaf (6) Number of roots: done by counting the number of leaves secondary roots that grow from primary roots manually (7) Root Length: done by measuring the length of the primary root using a ruler. Observations of shoot height, number of leaves, leaf length and leaf width were carried out at 12 weeks after sowing. The number of samples observed for each treatment was 30 plants. The data obtained were analyzed using the F test at the 5% level, if the calculated F is greater than the F table then the analysis is continued with the DMRT test at the 5% level.

3. Results and Discussion

The statistical analysis showed an interaction between seed size and maturity level on the carbohydrate content of cinnamon seeds at different storage times (Table 1). The carbohydrate content of seeds decreases with the length of storage time. The seed carbohydrate content decreased from the beginning to the end of storage in all seed treatments. Cinnamon seeds began to germinate on day 21 after sowing, and after that, additional germination of seeds occurred every day until the end of the observation. The length of storage time will reduce the carbohydrate content of the seeds in all treatments. Seeds that germinate directly have a high carbohydrate content, namely 24.49%-30.01%. The highest carbohydrate content was found in the interaction treatment of seed-sized seeds with a purplish-green maturity level of 30.01% and not significantly different from the interaction of large-sized seeds with a purple maturity level of 28.40%. The carbohydrate content of large seeds was significantly different from that of small seeds, namely 25.52% in small and purple seeds and 24.49% in small and purplish green seeds. significant

The seed maturity level significantly impacts the carbohydrate content of cinnamon seeds, which in turn affects their germination ability by providing necessary food reserves. Seeds at physiological maturity contain the maximum food reserves for successful germination. Large seeds with a purple color have a higher carbohydrate content than other treatments throughout the 15.28% storage time, showing a significant difference in interaction. However, no significant difference was observed in the carbohydrate content of other treatments by the end of the observation period.

Table 1. Interaction of seed size and maturity level on carbohydrate content of cinnamon seeds at different storage times.

Size of seed	Maturity level	Carbohydrate Content/%			
		Beginning	4 DAS	7 DAS	10 DAS
Large	Purple	28.40 a	24.4 a	15.56 a	15.28 a
	Purplish green	30.01 a	18.7 b	1431 c	12.61 b
Small	Purple	25.52 c	24.25 a	14.43 b	12.55 b
	Purplish green	24.49.c	18.16 c	14.13 c	12.32 b
CV/%		2.34	0.73	1.56	2.45

Note: The numbers followed by the same letter in each column are not significantly different based on the 5% DMRT test. DAS: Day after storage.

The results of statistical analysis showed that there was an interaction between seed size and maturity level on the moisture content of cinnamon seeds at different storage times (Table 2). The moisture content of the seeds decreased with the length of storage in all interactions between seed size and maturity level. At the beginning of storage and 4 days after storage, the interaction between small seeds with a purplish green color affected the moisture content of the seeds and was significantly different from the interactions of other seed treatments. The lowest water content is 14.37% at the beginning of storage and 12.49% at 4 days after storage. Seed storage of 7 DAS and

10 DAS was not significantly different between treatments. Storage of recalcitrant *Avicennia marina* (Forsk.) Vierh seeds for 10 weeks showed a decrease in seed moisture content every 2 weeks of storage (Halimursyadah, 2012)

In accordance with what was done by (Hartawan & Nengsih, 2012), that high water content needs to be maintained for respiration rate in germination in rubber seeds which can be stored for 9 days with a moisture content of 40.25%. Where the water content is needed for the work of enzymes in the process of breaking down food reserves such as protein, fat and carbohydrates. Likewise, what is done by (Indriani & Patriyawaty, 2013) on soybean seeds with high moisture content can provide high viability for soybean seeds. Likewise with what was done by (Suita & Syamsuwida, 2015) that the germination and speed of germination of malapari seeds can be increased by lowering the moisture content of the seeds to 41.80%, and sowing in open tub conditions.

Table 2. Interaction of seed size and maturity level on moisture content of cinnamon seeds at different storage periods.

Size of seed	Maturity level	Moisture Level/%			
		Beginning	4 DAS	7 DAS	10 DAS
Large	Purple	15.41 a	13.15 a	10.97	10.51
	Purplish green	15.06 a	13.01 a	11.14	9.12
Small	Purple	15.23 a	13.26 a	10.55	9.12
	Purplish green	14.37 b	12.49 b	11.14	9.61
CV/%		1.26	1.79	9.81	12.82

Note: The numbers followed by the same letter in each column are not significantly different based on the 5% DMRT test. DAS: Day after storage.

The interaction between seed size and maturity level also affected seed germination at different storage periods (Table 3). Initial storage showed that the lowest seed germination was in large seeds with purplish green color, which was 90.0%, significantly different from the interaction between seed size and other maturity levels. Seed germination decreased with the length of time the seed was stored. Seeds with large size and purple color from the beginning of storage until 10 DAS had the highest germination rate compared to other treatments. At the end of storage (10 DAS) large and purple seeds had a germination rate of 70% and were not significantly different from small and purple seeds but significantly different from other treatments. Cinnamon seeds are recalcitrant seeds that cannot be stored for long periods of time. The seeds will regress during storage. Seed deterioration is an unfavorable process experienced by all seeds that occurs immediately after the seeds are ripe and continues when the seeds are processed, packaged, stored and also transported (Oktavia & Miftahorrachman, 2012). Storage of 10 DAS seeds reduced the germination of seeds up to 26.7%, namely the large and purplish-green seeds.

There was no interaction between maturity level and seed size on the number of leaves formed. The single factor of seed maturity level and seed size showed that the level of seed maturity and seed size did not affect the growth of the number of leaves at several storage periods of cinnamon seeds in all seed treatments (Table 4 and Table 5).

Table 3. Interaction of seed size and maturity level on germination of cinnamon seeds at different storage times at 12 weeks after sowing.

Size of seed	Maturity level	Germination (%)			
		Beginning	4 DAS	7 DAS	10 DAS
Large	Purple	96.7 a	95.8 a	76.7 a	70.0 a
	Purplish green	90.0 b	86.7 c	54.0 b	26.7 b
Small	Purple	96.7 a	90.0 b	46.7 c	46.7 ab
	Purplish green	94.4 a	76.7 d	20.0 d	29.12 b
CV		2.04	0.89	4.67	4.53

Note: The numbers followed by the same letter in each column are not significantly different based on the 5% DMRT test. DAS: Day after storage.

Table 4. Single factor effect of seed maturity level on number of leaves at 12 weeks after sowing in several storage periods.

Maturity level	Number of Leaves			
	Beginning	4 DAS	7 DAS	10 DAS
Purple	3.11	2.75	1.47 (1.28)	2.48(1.67)
Purplish green	2.87	2.64	1.73 (1.41)	3.2(1.91)
CV	9.8	5.09	35.69	21.23

Note: The numbers followed by the same letter in each column are not significantly different based on the 5% DMRT test DAS: Day after storage. The number in brackets is the result of the transformation.

This shows that the cinnamon seed storage until 10 days storage, cinnamon seeds are still able to maintain physiological quality, seen from the number of leaves formed at 12 weeks after sowing at different seed maturity levels and seed size. This happened because the water content of the seeds at 10 days after storage was still high in all treatments, both seed size and seed maturity level. The water content contained in the seeds is able to activate the germination process. According to (Cahyani *et al*., 2016) vegetative growth in the event of a water shortage will greatly affect all aspects of plant growth, including physiological, biochemical, anatomical, and morphological processes. If there is a lack of water, some of the leaf stomata will close, so CO2 will be inhibited as a result of photosynthetic activity. In addition to inhibiting photosynthetic activity, it will decrease, not only that, lack of water will also inhibit protein and cell wall synthesis. So that plants that experience a lack of water in general will be smaller in size than plants that have a normal amount of water intake.

Table 5. Single factor effect of seed size on number of leaves 12 weeks after sowing in several storage periods.

Size of seed	Number of Leaves			
	Beginning	4 DAS	7 DAS	10 DAS
Large	2.93	2.62	2.27(1.61 a)	2.66 (1.87)
Small	3.05	2.77	0.93 (1.07 b)	3.01(1.71)
CV	9.8	5.09	35.60	21.23

Note: The numbers followed by the same letter in each column are not significantly different based on the 5% DMRT test. DAS: Day after storage. The number in brackets is the result of the transformation.

There was no interaction between the treatment level of seed maturity and seed size on leaf length. The single factor of seed maturity had no effect on seed leaf length in all observed storage periods (Table 6).

The single factor level of seed size did not affect the length of the seed leaf at the beginning of storage, and did not affect the length of the seed leaf which was stored for 10 days (Table 7). This indicated that seed viability (leaf length) up to 10 days of storage was not affected by seed size.

Table 6. Single factor of seed maturity level on leaf length 12 weeks after sowing in several storage periods.

Maturity level	Leaf Length			
	Beginning	4 DAS	7 DAS	10 DAS
Purple	4.44	4.10	3.7	3.67
Purplish green	4.16	4.18	3.2	4.19
CV	5.88	10.48	30.65	36.90

Note: The numbers followed by the same letter in each column are not significantly different based on the 5% DMRT test. DAS: Day after storage.

Table 7. Single factor effect of seed size on leaf length 12 weeks after sowing in several storage periods

Size of seed	Leaf Length			
	Beginning	4 DAS	7 DAS	10 DAS
Large	4.89 a	4.38	4.31 a	3.98
Small	3.71 b	3.90	2.61 b	3.88
CV	5.88	10.48	30.65	36.90

Note: The numbers followed by the same letter in each column are not significantly different based on the 5% DMRT test. DAS: Day after storage

There was no interaction between the treatment of seed maturity level and seed size on seed height. The single factor of seed maturity level affected the seed height at the beginning of storage and 10 DAS (Table 8). Seeds with purple maturity level had seeds with a height of 8.79 cm at 12 weeks after sowing and were significantly different from purplish green seeds, which was 7.20 cm in seeds stored for 10 days.

Table 8. Single factor of seed maturity level on seed height 12 weeks after sowing in several storage periods

Maturity level	Seed Height			
	Beginning	4 DAS	7 DAS	10 DAS
Purple	10.42 a	8.38	9.24	8.79 a
Purplish green	8.00 b	9.06	9.73	7.20 b
CV	9.9	9.53	12.83	3.67

Note: The numbers followed by the same letter in each column are not significantly different based on the 5% DMRT test. DAS: Day after storage.

The single factor of seed size affected seed height at the beginning of storage and 10 DAS (Table 9). Seeds with purple maturity level had seeds with a height of 8.10 cm at 12 weeks after sowing and were significantly different from purplish green seeds, namely 7.89 cm.

The interaction of seed size and maturity level also affected root length, and number of seed roots at 12 weeks after sowing (Table 10 and Table 11). Seeds that were not stored and stored 4 days ago were sown showed that the interaction of small seeds with a purplish-green maturity level resulted in the lowest root length and was significantly different from the interactions of other treatments, namely 6.22 cm. The interaction of large seeds with purple maturity level had the best root length in seeds after 7 and 10 days of storage. This shows that large and physiologically ripe seeds shown by purple seeds can be stored longer and have the best vigor as indicated by the length of the seed roots. The best root length was found in the interaction of large seeds with purple maturity level and significantly different from other interactions in seeds that had been stored 7 and 10 days after storage.

Table 9. Single factor effect of seed size on seed height 12 weeks after sowing in several storage periods

Size of seed	Seed Height			
	Beginning	4 DAS	7 DAS	10 DAS
Large	10.26 a	8.86	9.79	8.10 a
Small	8.17 b	8.59	9.18	7.89 b
CV	5.88	10.48	30.65	36.90

Note: The numbers followed by the same letter in each column are not significantly different based on the 5% DMRT test. DAS: Day after storage.

Table 10. Interaction of seed size and maturity level on root length of cinnamon seeds at different storage times 12 weeks after sowing.

Size of seed	Maturity level	Root Length (cm)			
		Beginning	4 DAS	7 DAS	10 DAS
Large	Purple	11.20 a	8.59 a	9.63 a	9.88 a
	Purplish green	9.09 a	8.08 a	7.96 ab	5.25 c
Small	Purple	10.16 a	9.26 a	5.59 c	7.44 b
	Purplish green	6.22 b	5.56 b	7.18 bc	4.06 c
CV		16.00	18.36	18.23	13.41

Note: The numbers followed by the same letter in each column are not significantly different based on the 5% DMRT test. DAS: Day after storage.

Table 11. Interaction of seed size and maturity level on the number of roots of cinnamon seeds at different storage times 12 weeks after sowing.

Size of seed	Maturity level	Number of Roots (cm)			
		Beginning	4 DAS	7 DAS	10 DAS
Large	Purple	23.78 a	20.50	18.88	18.22 a
	Purplish green	28.40 b	17.09	14.66	12.55 ab
Small	Purple	20.15 b	18.33	18.33	15.55 ab
	Purplish green	20.44 b	17.11	17.02	9.22 b
CV		8.77	11.78	17.50	22.47

Note: The numbers followed by the same letter in each column are not significantly different based on the 5% DMRT test. DAS: Day after storage.

According to (Tustiyani *et al*., 2016; Yuniarti *et al*., 2014) seed vigor will be influenced by various factors, including starting from the seeds still in the mother plant to harvesting, processing, during transportation, to before planting. Apart from that, it is also influenced by the handling process of the seeds being dried, cleaned, sorted and packaged in the seed processing unit, as well as the method and conditions of seed storage.

This is in line with (Lesilolo *et al.*, 2012) that the speed of seed growth is a fast seed reactivation process if the surrounding conditions for optimum growth and metabolic processes are not hampered. Growth speed can be expressed as a measure of the time required to achieve germination according to the opinion (Murniati & Suminar, 2006) which states that one of the external factors (germination environment) that affects seed germination is light and temperature. Differences in early germination will also affect plant growth.

Several studies have shown that seed size will affect seed viability. Seed size is positively or negatively correlated with seed viability depending on the commodity being tested. Small seeds do not always produce plants that are not vigor. Many things affect besides seed size among other internal factors such as starch content, fat. Fiber and hormone content. Pongamia pinnata seed germination is positively correlated with seed weight (Divakara *et al.*, 2010). There is seed variation that is not influenced by seed size, there are medium-sized seeds that can produce better seed growth compared to large seed sizes as stated by (Rawat & Bakshi, 2011; Saukani & Bahri, 2017), in pine and rubber plants.

4. Conclusion

Based on this research, it can be concluded that the interaction between seed and maturity affects cinnamon seeds' viability during storage. The cinnamon seeds with large and purple sizes showed the highest viability throughout all storage periods, with a germination rate of 70%, a carbohydrate content of 15.28%, and a moisture content of 10.51% after 10 days of storage.

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