



## RESEARCH ARTICLE

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# The Effect of Shade from Two-Year-Old Oil Palms (*Elaeis guineensis* Jacq) on the Quality of Chili Pepper Seeds (*Capsicum frutescens* L.)

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## Abstract

Chili pepper (*Capsicum frutescens* L.) is a seasonal crop with high economic value and is widely cultivated in both highland and lowland areas of Indonesia. As an important horticultural commodity and a staple ingredient in Indonesian cuisine, improving chili productivity requires rapid, accurate methods for seed quality assessment. The physiological quality of chili pepper seeds plays a crucial role in germination success and seedling establishment. Therefore, information regarding seed quality variation among genotypes is essential for selecting superior seed sources. This study aimed to evaluate the seed quality of five *Capsicum frutescens* genotypes based on viability, vigor, and membrane integrity parameters. The experiment was arranged in a randomized complete block design with four replications, using genotype as the treatment factor. Observations included germination percentage (GP), maximum growth potential (MGP), radicle emergence (RE), vigor index (VI), growth rate (GR), growth synchrony (GS), normal seedling dry weight (NSDW), seedling growth rate (SGR), electrical conductivity (EC), and tetrazolium viability (TZ). Analysis of variance revealed that genotype had a highly significant effect on all observed parameters at the 1% level of significance ( $\alpha = 0.01$ ). Genotype G3 exhibited the highest performance in key viability and vigor parameters, with GP of 71.50%, MGP of 77.50%, RE of 54.50%, VI of 55.00%, GR of 54.70%  $\text{etmal}^{-1}$ , GS of 60.50%, NSDW of 0.284 g, SGR of 0.00795  $\text{g KN}^{-1}$ , and TZ viability of 88%, accompanied by the lowest EC value (17.792  $\mu\text{S cm}^{-1}$ ). In contrast, genotypes G1 and G4 showed the lowest values across most parameters, whereas G2 demonstrated moderate performance with relatively high vigor. These findings indicate that the physiological quality of cayenne pepper seeds varies among genotypes and is strongly influenced by genetic factors. This study provides valuable insights into seed quality under shaded conditions and contributes to the development of strategies for improving chili growth and adaptability in shaded environments.

**Keywords:** Genotype, Seed Quality, Seed Shape, Viability, Vigor

## 1. Introduction

Chili peppers are found in every aspect of human life. Chili peppers come in various species, but currently only five are commonly used and consumed by the public: *Capsicum annum*, *C. frutescens*, *C. baccatum*, *C. chinense*, and *C. pubescens*. Chili peppers have evolved from their initial use as a cooking spice to their widespread use as a biopharmaceutical ingredient, utilizing their capsaicin content (Sahid et al. 2020). Furthermore, chili production is also related to seed availability. Seeds, as a commercial product, must meet clear quality standards. The continuous availability of high-quality seeds is crucial

because it determines the success of production, both in terms of quality and quantity. Using high-quality seeds can minimize losses for farmers when preparing planting material. Seed quality issues, particularly germination, are thought to be due to the presence of inhibitors, including capsaicin (Barchenger and Bosland 2016).

Characterization, both conventional and using molecular markers, for various production traits has been reported by Muñoz et al. (2019). Characterization of plant morphology and cross-breeding ability between *C. annum* and *C. frutescens* (Undang et al., 2015), agronomic traits, fruit quality, and resistance to viral attacks (Nankar et al.,

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2020; Sayekti *et al.*, 2021). However, only a few studies report on seed characterization; research on chili seed aspects has been conducted by Chiou and Hastorf (2014) and Kurniawan and Azmi (2021).

Oil palm (*Elaeis guineensis* Jacq.) is a major plantation commodity in Indonesia, with extensive development (Santosa *et al.* 2011). In 2035 (Methods) In the 'business-as-usual' (BAU) scenario, projections of historical trends (2000–2018) in average actual yields and plantation areas over the next 17 years result in 9.2 million hectares of new land being converted to oil palm production without changes in average actual yields (Monzon *et al.* 2021). Oil palm plantation practices also contribute to improving household and regional economies. This is an added attraction for the community and the government (Sianturi 2017).

One effort to improve the economic viability of community oil palm plantations is to cultivate cayenne pepper. According to Junaidi (2013), a mixed cropping system (intercropping) is an alternative land-use system that combines perennial plants (trees or shrubs) with or without annual crops and livestock in a single plot. The benefits of a mixed cropping system include buffering excessive solar radiation and resisting heavy rainfall. Research by Darmawansyah *et al.* (2024) significantly affects the microclimate and the growth and yield of various cayenne pepper genotypes, with 50% shade increasing fruit weight.

Characterization of various traits related to seed quality is necessary for determining the initial identification of chili seed species to be cultivated. The success of chili production by farmers is largely determined by the quality of the seeds used and by adequate cultivation techniques. High-quality seeds with high yields and pest and disease resistance are important concerns in agriculture. Research by Darmawansyah *et al.* (2023) reported that fruit fly attacks are a potential pest that damages chili fruit, resulting in high yield losses of up to 80%. Therefore, seeds are the main input and the first link in the plant cultivation process. Seed quality can be determined by seed germination and the weight of 1,000 seeds. From these two characteristics, seed requirements per planting area can be predicted.

Seed quality is reflected in its germination performance under field conditions. However, previous studies have not extensively evaluated the effect of shading on seed quality, particularly under shaded cultivation systems, thereby necessitating further investigation. Seed quality can be estimated through laboratory germination tests, which are expected to provide reliable information on seed germination potential in the field (Soleymani). In addition, vigor testing is considered an important indicator for predicting plant growth performance across broader planting environments, Marcos-Filho. Laboratory vigor tests are also expected to show a positive correlation with

plant growth under field conditions, Nikolić. Seed vigor can be evaluated using tetrazolium staining and electrical conductivity tests, both of which are widely applied to assess seed viability and membrane integrity.

Based on the above considerations, further research is required to characterize the seeds and seedlings of cayenne pepper cultivated through intercropping with two-year-old oil palm plants. Such research is important for identifying genotypes capable of producing high-quality seeds and vigorous seedlings under shaded environmental conditions.

## 2. Material and Methods

The seed production trial will run from March 2025 to August 2025, followed by seed quality testing at the Plant Breeding Laboratory and Tropical Horticulture Study Center (PKHT) IPB University, December 2025-January 2026. The activity begins with chili seed production carried out in Usul Village located around (0°44'24.7" South Latitude (LS) and 102° East Longitude (BT)) at an altitude of 50–100 meters above sea level (MDPL), Batang Gansal District, Indragiri Hulu Regency, Riau Province. The genetic material used will be cayenne pepper plant genotypes, including shade-loving genotypes (F7.32190-5-2-2-1-4B and Bonita), shade-tolerant genotypes (Pulai Putih and Ori 212), and shade-sensitive genotypes (F10-321290-252).

The experiment will be conducted using a two-factor randomized block design (RBD), namely cayenne pepper genotype and oil palm age (two years). Research observation activities in this experiment include testing the physiological quality of chili seeds, including viability and vigor tests, conducted according to standard test methods outlined in ISTA rules (2021). 1) Standard test for chili seed viability and vigor.

1) Chili seed viability and vigor testing was conducted using the paper test (UDK) or top paper test (ISTA 2021), using 50 seeds per treatment with four replications. Seeds were germinated in closed plastic boxes using a germination medium consisting of three sheets of opaque paper moistened with distilled water. The germination was placed in a germinator at 25°C. The benchmarks observed included:

a) Weight of 100 grains (g)

Data on 100 chili seeds were collected from each lot (genotype) under each shade. A total of 100 seeds were weighed to 3 decimal places using a digital scale, with 8 replications.

b) Germination power (DB)

Germination power was calculated based on the number of normal sprouts (KN) in the first (7th day) and second (14th day) observations (ISTA 2021).

c) Maximum growth potential (PTM)

Maximum growth potential is calculated based on the total percentage of sprouts that grow both normally and abnormally until the end of the observation.

## d) Vigor index (IV)

The seed vigor index is the ratio of the number of normal sprouts in the first count (day 7) to the total number of seeds germinated.

e) Simultaneous growth ( *KST* )

Growth simultaneity is the homogeneous growth of seeds, simultaneous germination, and uniform germination performance. The observation of growth simultaneity was conducted on the day between the first and second counts (Sadjad et al. 1999), the 10th and 11th days, in the chili seed test.

## f) Normal dry weight of sprouts (BKKN)

The dry weight of normal sprouts was measured at the end of the observation (day 14). Normal sprouts were dried

in an oven at 80 °C for 24 hours, then weighed.

## g) Seedling growth rate (SGR)

The sprout growth rate is the ratio between the total dry weight of normal sprouts (BKKN) and the number of normal sprouts (KN).

## h) Radicle emergence test (RE)

The radicle emergence test used the same material as the seed viability and vigor tests. Observations were made on seeds with roots (radicles)  $\geq 2$  mm in length, according to ISTA standards (2021). Observations were made every 24 hours for 168 hours (Kusumawardana et al. 2019).

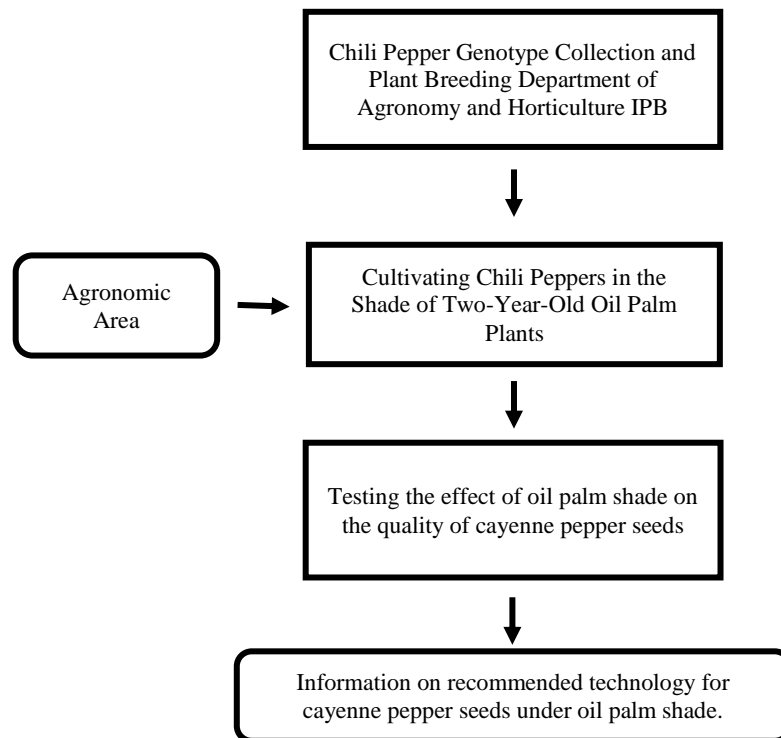


Figure 1: Research flowchart

## 2) Electrical conductivity test (DHL)

The electrical conductivity test in this experiment used 100 chili seeds per genotype and was repeated 4 times. The seeds were soaked in 75 mL of distilled water (Engreni 2016; ISTA 2021) at  $20 \pm 2$  °C for 12 hours. After soaking for 12 hours, the DHL value was measured using a conductivity meter (Appendix 6). Before measuring the electrical conductivity, the seed-soaking water was gently stirred for 10-15 seconds, then the dip-cell conductivity meter was inserted into the seed-soaking water without touching the seeds. The measurement began with the blank solution, followed by measuring the seed-soaking water for each genotype. Measurements were carried out until a stable value was obtained. The DHL value was calculated using the formula (ISTA 2021).

## 3) Tetrazolium (TTZ) staining test

The tetrazolium staining test on chili seeds began by moistening the seeds by soaking them in a container and placing them in a room at 20°C for 18 hours. Ten seeds were used for each genotype, and the experiment was repeated three times. The seeds were then wounded by cutting the testa between the radicle and the cotyledon. The wounded seeds were soaked in a 1% tetrazolium chloride solution (with phosphate buffer) for 6 hours and stored in a dark room at 30°C (Kusumawardana et al. 2018; ISTA 2021). Seed vigor assessment using the tetrazolium test on paprika chili seeds was effective at a 1% tetrazolium concentration for 24 hours (Salazar-Mercado et al. 2020).

Observations were made of coloration patterns on chili seeds, which were correlated with their anatomical structures. Observations were conducted using a stereo microscope at 4× magnification, equipped with a digital

camera and image display software on a computer. The observations were documented by photographing the monitor display using an external camera.

Germination power is calculated using the formula: This experiment tested 5 seeds from different genotypes, some of which like shade (F7.32190-5-2-2-1-4B and Bonita), then shade-tolerant genotypes (Pulai Putih and Ori 212), and shade-sensitive genotypes (F10-321290-252). Observation data were analyzed using analysis of variance (F-test). Significantly different test results were further tested using the Duncan Multiple Range Test (DMRT) at a 5% level. The software used was Microsoft Excel 2021

(SmartstatXL *add-ins*) and SAS OnDemand. Analysis of genetic variance components of morphological characters and physiological quality of chili seeds was based on the formula of Syukur *et al.* (2015).

### 3. Results and Discussion

#### 3.1. Seed Viability and Vigor Testing

The results of the analysis of variance (ANOVA) on the viability and vigor parameters of seeds from five cayenne pepper genotypes are summarized in Table 1 to assess the significance of genotype on seed physiological responses.

**Table 1.** ANOVA recapitulation of viability and vigor tests of seeds from five cayenne pepper genotypes

No	Viability and Vigor Variables	Diversity Coefficient (%)	F Count	Information
1	Germination Power	8.37	43.76	**
2	Maximum Growth Potential	7.82	35.88	**
3	Vigor Index	9.50	50.43	**
4	Growth Rate	9.08	37.62	**
5	The Simultaneity of Growth	7.46	61.15	**
6	Normal Dry Weight of Sprouts	7.11	83.77	**
7	Sprouts Growth Rate	4.44	4.46	**
8	Radicle Emergence	7.42	96.45	**
9	Electrical Conductivity	8.48	44.22	**

Description: \*= has a significant effect at  $\alpha = 0.05$ , \*\* = has a very significant effect at  $\alpha = 0.01$

The results of the analysis of variance showed that genotype factors had a very significant effect on all seed viability and vigor variables. The F-count value for germination reached 43.76, maximum growth potential 35.88, and vigor index 50.43, all significant at the  $\alpha$  level of 0.01. The highest F-count values were found for normal seedling dry weight (83.77) and radicle emergence (96.45), indicating that genotype variation strongly influenced both the initial phase of germination and seedling biomass accumulation. The relatively low coefficient of variation values for all variables (4.44–9.50%) indicated that the resulting data had good experimental accuracy and were worthy of further interpretation.

The consistent pattern of significance across all variables indicates that differences between genotypes are not random, but rather reflect inherent differences in the physiological capacities of the seeds. Parameters directly related to germination rate and synchrony showed the most sensitive response to genotype differences, a pattern commonly reported in physiological quality testing of horticultural seeds (Finch-Savage and Bassel 2016). This finding indicates that physiological seed quality is strongly influenced by genetic factors and by physiological conditions during seed filling and post-harvest processing. This pattern aligns with the basic concept of seed physiology that physiological quality is genotype-dependent and crucial for the success of early seedling establishment in the field (Bewley *et al.* 2013).

The physiological quality evaluation of five cayenne pepper genotypes is presented in Table 2, which includes information on seed viability and vigor, as measured by

general seed testing parameters such as germination rate, maximum growth potential, radicle emergence, vigor index, growth rate, synchrony, and initial seedling biomass components. The data presented provide a scientific basis for identifying variations in germination performance among genotypes and for determining which genotypes exhibit superior early growth quality.

Seed viability and vigor are key physiological quality parameters that determine a seed's ability to germinate and form normal seedlings. The results, as presented in Table 2, indicate that genotype plays a significant role in influencing most viability and vigor parameters, with significant differences between genotypes. Several genotypes demonstrated superior performance in germination, growth potential, radicle emergence, vigor index, and seedling growth rate, reflecting varying seed physiological capacities.

Germination values ranged from 31.00–71.50%, with the G3 genotype showing the highest performance (71.50%) and the G1 and G4 genotypes at the lower end (31.00% and 31.55%). A similar pattern was observed for maximum growth potential, which ranged from 36.00–77.50%, with G3 again having the highest value (77.50%) compared to G1 (36.00%) and G4 (42.00%). The absolute difference between G3 and the lowest genotype exceeded 40 percentage points, indicating a significant difference in seed physiological capacity between the genotypes. This is likely due to genetic factors, as genotype determines seed food reserves, seed physiological structure, and the seed's ability to respond to water imbibition and initiate germination. Research by Kumar *et al.* (2018) showed that

germination percentages and seed quality traits differed significantly among genotypes, suggesting that genetic factors play a role in seed viability and quality. Vasconcelos *et al.* (2018) also reported that different

genotypes of *Capsicum* spp. resulted in significant variations in germination percentage and germination speed, indicating that genetic differences between genotypes affect seed viability.

**Table 2.** Testing of seed viability and vigor on five cayenne pepper genotypes

Seed Lot	Seed Viability and Vigor Variables							
	DB (%)	PTM (%)	RE (%)	IV (%)	KCT (% etmal <sup>-1</sup> )	KST (%)	BKKN (g)	LPK (g KN <sup>-1</sup> )
G1	31.00± 2.58 d	36.00± 3.65 d	17.50± 1.91 d	19.00± 2.58 d	23.17± 2.84 d	24.00± 2.83 d	0.107± 0.01 d	0.00692± 0.0003 b
G2	55.00± 4.16 b	64.00± 5.16 b	43.50± 2.51 b	42.50± 4.43 b	43.72± 3.70 b	48.00± 4.00 b	0.209± 0.01 b	0.00762± 0.001 a
G3	71.50± 3.41 a	77.50± 3.41 a	54.50± 3.00 a	55.00± 2.58 a	54.70± 3.71 a	60.50± 3.42 a	0.284± 0.01 a	0.00795± 0.0004 a
G4	31.55± 4.43 d	42.00± 1.63 d	20.00± 3.26 d	21.00± 2.58 d	24.11± 2.24 d	26.00± 2.83 d	0.110± 0.01 d	0.00705± 0.0003 b
G5	45.00± 4.76 c	52.00± 5.65 c	29.00± 2.58 c	32.50± 4.12 c	36.28± 4.19 c	40.50± 1.91 c	0.157± 0.02 c	0.00700± 0.0002 b

Description: Numbers with the same letter in a column are not significantly different at the  $\alpha = 0.05$  level of the DMRT test. Comparisons were made only between genotypes.

Vigor parameters reinforce the same pattern as viability. The highest radicle emergence (RE) value was observed in G3 (54.50%), followed by G2 (43.50%) and G5 (29.00%), while G1 and G4 showed the lowest values (17.50% and 20.00%, respectively). The vigor index (IV), which reflects the number of seeds that germinate early (first-count germination), was also highest in G3 (55.00%), indicating that this genotype not only had a high germination proportion but also rapid, uniform initial growth. Germination rate (ERV) showed a consistent gradient, with G3 reaching 54.70% per etmal, almost double that of G1 (23.17% per etmal) and G4 (24.11% per etmal). Germination simultaneity (ER) reached a maximum value in G3 (60.50%), while the weak genotypes were below 26%. This pattern indicates that superior genotypes not only have higher germination but also better early growth synchronization ability and seed vigor, important characters in plant establishment in the field (Finch-Savage and Bassel 2016).

Biomass parameters confirmed functional differences between genotypes. Genotype G3 showed the highest normal seedling dry weight (NWW) of 0.284 g, followed by G2 (0.209 g) and G5 (0.157 g), while G1 (0.107 g) and G4 (0.110 g) had the lowest values. The almost threefold difference between G3 and G1 indicated the superior genotype's capacity to convert food reserves into new tissue more efficiently. Seedling growth rate (SGR) showed a similar pattern, with G3 (0.00795 g KN<sup>-1</sup>) and G2 (0.00762 g KN<sup>-1</sup>) superior to the other genotypes. The consistency between germination rate (DB), radicle emergence (RE), growth rate (KCT), growth simultaneity (KST), and BKKN indicates that differences in performance between genotypes reflect the actual physiological capacity of seeds during the imbibition and post-radicle emergence phases. This finding aligns with the

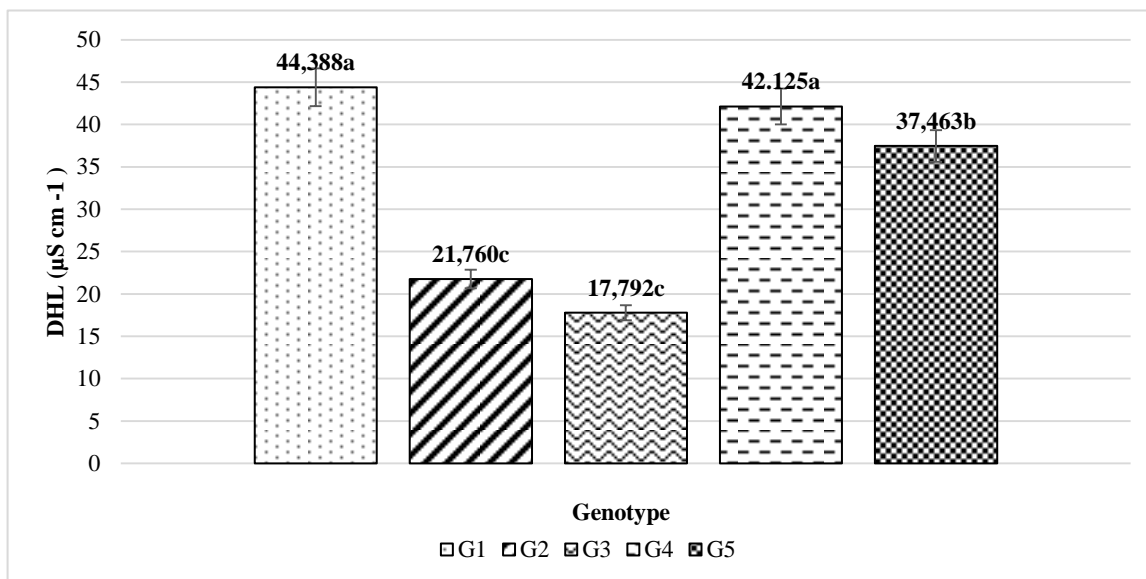
findings of Kumar *et al.* (2018), who showed that variations among *Capsicum* annum genotypes affect germination rate, vigor, and seedling biomass accumulation. Research by Vasconcelos *et al.* (2018) also confirmed that genotype plays a role in determining the germination percentage and seedling growth rate in *Capsicum* spp.

The G3 genotype performed better than other genotypes in almost all parameters of viability, vigor, and seedling biomass. The values of germination, growth potential, radicle emergence (RE), vigor index (IV), growth rate (KCT), growth simultaneity (KST), normal seedling dry weight (BKKN), and seedling growth rate (SPG) in G3 were consistently higher than those of other genotypes, indicating a more optimal physiological capacity in the imbibition phase and early seedling growth. The performance difference, for example, BKKN G3 was almost three times higher than G1, and the SPG G3 was higher than other genotypes, indicating G3's ability to convert seed food reserves into new tissue more efficiently. This pattern is consistent with the findings of Kumar *et al.* (2018) and Vasconcelos *et al.* (2018), which showed that *Capsicum* genotype influences germination, vigor, and early seedling growth.

### 3.2. Electrical Conductivity (DHL)

The electrical conductivity (ECF) test is an important indicator of electrolyte leakage from seeds during imbibition. The ECF test detects electrolyte leakage from the seed cell membrane into the immersion solution. The principle of the ECF test is to analyze the inorganic ions and organic compounds present in the seed immersion solution. The higher the organic compound content, the higher the inorganic ion concentration in seed immersion water, and the lower the seed vigor (Basu and Groot 2023). The ECF test results for five chili seed genotypes are

presented graphically in Figure 2.



**Figure 2.** Graph of electrical conductivity test values for five cayenne pepper genotypes: F7.32190-5-2-2-1-4B (G1), Bonita (G2), Pulai Putih (G3), Ori 212 (G4), and F10-321290-252 (G5).

The graph in Figure 2 shows that the cayenne pepper genotypes have significantly different electrical conductivity (EPH) values. G1 recorded the highest EPH at  $44.388 \mu\text{S cm}^{-1}$ , followed by G4 at  $42.125 \mu\text{S cm}^{-1}$ , indicating significant electrolyte leakage due to membrane damage. These high values indicate that both genotypes have experienced more severe physiological deterioration, thus losing their ability to maintain stable membrane permeability during imbibition. Conversely, G3 had the lowest EPH at  $17.792 \mu\text{S cm}^{-1}$ , followed by G2 at  $21.760 \mu\text{S cm}^{-1}$ , indicating a more intact membrane and a more controlled imbibition process. Genotype G5 was in the middle position, with an EPH of  $37.463 \mu\text{S cm}^{-1}$ . The pattern of values seen in Figure 1 is consistent with other physiological performance: G3 and G2, which have low DHL, showed the highest viability and vigor, while G1 and G4, which have high DHL, also had the lowest DB, PTM, IV, KCT, and KST. This confirms that the greater the electrolyte leakage (high DHL), the lower the ability of the seeds to restart metabolic processes and produce healthy seedlings; thus, DHL proved to be a sensitive indicator for distinguishing physiological quality between cayenne pepper genotypes in this study.

### 3.3. Tetrazolium Test

The viability identification criteria through tetrazolium staining topography are shown in Table 3. The distribution of these patterns across five cayenne pepper genotypes is summarized in Table 4 to provide a basis for evaluating differences in viability levels. The results of the tetrazolium test on the five cayenne pepper genotypes are presented in

Tables 3 and 4, which show the distribution of staining patterns and the percentage of viability by embryo topography. The data in Table 4 show a clear difference in viability between genotypes. G3 had the highest proportion of viable seeds at 88%, followed by G2 at 84% and G5 at 75%, while G1 and G4 had the lowest viability levels at 64% and 69%, respectively.

This staining pattern reflects the activity of the dehydrogenase enzyme and the integrity of the embryonic tissue, with greater intensity and wider distribution of red staining indicating higher viability. This principle aligns with Franca-Neto and Krzyzanowski (2022), who explained that the TZ topography pattern is a direct indicator of the embryo's physiological condition and is effective at accurately distinguishing live from dead tissue.

The positive relationship between TZ viability and germination across all genotypes indicates that TZ staining patterns can predict chili seed germination performance. This finding aligns with the report by Corozo-Quinonez et al. (2023), which found that TZ is an accurate indicator of viability in Solanaceae seeds. TZ values in several genotypes in this study were higher than their germination rates. This condition is consistent with the physiological concept proposed by Marcos-Filho (2015), namely that the TZ test identifies only viable embryos, whereas successful germination requires advanced metabolic activity that can be disrupted by dormancy, membrane damage, or low vigor. This is also in line with the findings of Kusumawardana et al. (2018), who reported that TZ values in chili seeds are often higher than the actual germination rate.

**Table 3.** Topographic patterns of tetrazolium

No	Topographic Patterns	Description	Information
1		The embryo and cotyledons are bright red.	Viable
2		The embryo is red with a dark red tip, while the cotyledons are dark red.	Viable
3		The embryo is bright red, with 1/2 of the cotyledons being dark red.	Viable
4		1/3 pink embryo with 1/3 bright red cotyledons	Viable
5		1/2 red embryo with 1/2 red cotyledons	Non-viable
6		Red embryo, white cotyledons	Non-viable
7		White embryo with 1/3 red cotyledons	Non-viable
8		Embryo and cotyledons are not stained.	Non-viable

**Table 4.** Percentage of each tetrazolium staining topography pattern in each genotype

Topographic Patterns	Genotype				
	G1 (%)	G2 (%)	G3 (%)	G4 (%)	G5 (%)
1	34	41	52	31	35
2	15	22	18	21	19
3	8	12	11	9	13
4	7	9	7	8	8
5	14	7	3	9	10
6	10	4	5	8	0
7	3	2	4	7	1
8	9	3	0	7	2

#### 4. Conclusion

The physiological quality of cayenne pepper seeds differed significantly among genotypes. Genotype G3 exhibited the highest performance in germination

percentage, maximum growth potential, radicle emergence, vigor index, growth rate, synchrony, normal seedling dry weight, seedling growth rate, and tetrazolium viability. In addition, G3 demonstrated better membrane integrity

during imbibition, whereas G1 and G4 showed the lowest performance across most parameters and were associated with higher DHL values. The differences in physiological seed quality among cayenne pepper genotypes were primarily attributed to genetic factors influencing physiological responses during the early stages of

germination. Therefore, selecting appropriate genotypes under suitable shade levels is essential for producing cayenne pepper seeds with high viability and vigor. Further studies are needed to evaluate the effects of different shade levels under varying oil palm plantation ages.

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