Seed health and germination of nyamplung and kenari on various media

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Abstract. Nyamplung (*Calophyllum inophyllum* L.) and kenari (*Canarium indicum* L.) offer a variety of benefits and potential across historical, economic, energy, ecological, and social dimensions, making their propagation essential for enhancing productivity. This study aimed to assess the physical characteristics of the seeds, examine seed health regarding pests and diseases, and identify the optimal germination media for nyamplung and kenari seeds. The treatments included soil (control), zeolite, cocopeat, and a soil-sand mixture (1:1 v/v). Nyamplung seeds exhibit good physical characteristics: they are thick and hard, round in shape, ivory yellow in color, and maintain firmness when pressed. On average, these seeds weigh 3 grams, have a height of 2.6 cm, and a diameter of 1.7 cm. In contrast, kenari seeds are characterized by a tapered oval shape with a tough shell, a light brown color, an average weight of 6.9 grams, and average measurements of 3.7 cm in height and 1.9 cm in diameter. Fungi pathogens associated with nyamplung seeds include Rhizoctonia sp. and Pythium sp., while kenari seeds are known to carry Colletotrichum sp. The findings indicate that zeolite serves as the most effective germination medium for nyamplung seeds, whereas a soil-sand mixture (1:1 v/v) is optimal for kenari seeds.

1 Introduction

Nyamplung (*Calophyllum inophyllum* L.) is a hardwood plant that thrives in sandy and humus-rich coastal regions. It can reach a height of up to 20 meters with a trunk diameter of 0.8 meters. The productivity of nyamplung seeds ranges from 40 to 150 kg per tree per year, translating to about 20 tons per hectare annually. This yield surpasses that of many other plants, including those used for fencing. Approximately 2 to 2.25 kg of nyamplung seeds are required to produce one liter of nyamplung oil. In marginal coastal areas, this plant is often cultivated as a windbreak. The benefits of nyamplung include as commercial wood as a raw material for light construction, the sap helps make oil, the leaves are helpful as a burn medicine and cosmetics, the flowers are a mixture of hair oil, and the waste of nyamplung also has the potential to be used as charcoal briquettes and liquid smoke which is helpful in wood preservation [1]. Nyamplung is a priority NTFP (non-timber forest product) along with

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bamboo, agarwood, honey bees, silk, and rattan, determined by the Directorate General of Watershed Management and Forest Rehabilitation, Ministry of Environment and Forestry.

Kenari (*Canarium indicum* L.) is one of the tropical plants cultivated as a superior non-timber forest product (NTFP) for the people of Maluku and Papua. Kenari are classified as a multi-purpose tree species [2]. Kenari seeds can be utilized as a food ingredient due to their content of carbohydrates, fats, and proteins. The sap of the kenari tree serves as a varnish, while the oil can be used as an alternative to coconut oil in various cosmetics. Additionally, the leaves have medicinal properties, and the bark provides raw materials for items such as paddles and firewood. Kenari trees are commonly found as roadside plantings throughout Bogor City and are designated as heritage trees under the Mayor's Regulation No. 17 of 2015, which aims to solidify Bogor City's status as a Heritage City.

Given the significant potential of both nyamplung and kenari, employing effective plant propagation techniques is essential to enhance their productivity. Propagation of these species can occur either generatively, using seeds, or vegetatively, utilizing parts from the parent plant. Generative propagation involves scarifying the seeds. Nyamplung seeds are classified as recalcitrant, possessing high moisture content that limits their storage to temporary periods. In contrast, kenari seeds are classified as orthodox seeds, featuring relatively low moisture levels that allow for extended storage. To reactivate dormant seed cells, must fracture the dormancy in kenari seeds before germination [3].

Research on dormancy fracture techniques, particularly regarding the dormancy of kenari seed shells, remains limited. The physical condition of seeds is crucial as it significantly influences plant growth and health, which in turn affects the quality of production. Additionally, selecting the appropriate planting medium for seed germinationa is essential because it's fundamental stage in plant development. Different plants require distinct media for optimal germination. There is also a scarcity of studies exploring the use of soil media, zeolite, cocopeat, and a soil-sand mixture (1:1 v/v) in the germination of nyamplung and kenari seeds. This study aims to assess the physical condition of the seeds, examine any health issues related to pests and diseases, and identify the optimal medium for the germination of nyamplung and kenari seeds.

2 Methods

2.1 Time and places

The study was conducted over a period from November 2023 to January 2024. It took place within the Forest Ecology Greenhouse and the Forest Entomology Laboratory, part of the Department of Silviculture at the Faculty of Forestry and Environment. Additionally, research activities were held at the Forest Biotechnology and Bioremediation Laboratory located within the BIOTECH CENTER at IPB University.

2.2 Material and methods

The tools used in this research include 24 cm mica container, a petri dish, a microscope, an optilab, a laptop, blotter paper, tweezers, glass prepared, Microsoft Excel software, IBM SPSS 23 software, solder, grinder, hammer, spear, shovel, digital scale, tape meter, mobile phone, bucket, and stationery. The materials used in this study are nyamplung seeds from trees in front of the Old IPB University Sport Hall, kenari seeds from trees on the side of the road around Doctor Semeru and Jenderal Ahmad Yani Street, Bogor City, soil, sand, zeolite, cocopeat, water, alcohol 70%, and a tally sheet.

2.2.1 Seed collection

The nyamplung and kenari were collected under the trees using the collection method. Nyamplung fruits that have reached physiological ripeness have a brown skin color. Meanwhile, kenari that have reached physiological ripeness have a bluish-black skin color.

2.2.2 seed extraction

Extracting nyamplung seeds was carried out by hitting the seeds with a hammer until the shells peeled off. The obtained seeds were dried at room temperature (28ºC). Nyamplung seeds are recalcitrant seeds, so the seed seeding process must be done the same day after the seeds are extracted [1].

The extraction of kenari seeds is first done by soaking for 24 hours. This process makes seeds soft, so that they are easy to clean. Then, dry the seeds at room temperature (28ºC). Kenari seeds are orthodox, so they require dormancy fracture treatment. After that, soaking the seeds with water for 48 hours as a preliminary treatment to reactivate dormant seed cells. This soaking aims to soften the seeds, remove inhibitory substances, and accelerate germination [3]. Following the initial preparation, it is important to dry the seeds under sunlight. The process of scarification applied to kenari seeds involves removing the tip of the seed using a grinding tool. This treatment enhances the permeability of the seed coat, thereby facilitating improved absorption of water, which is critical for successful germination.

2.2.3 Physical condition of seeds

Observation of the physical condition of the seeds was carried out by observing the physical characteristics of the seeds and measuring the average height and diameter using a tape measure. The weight of the seeds was measured using a digital scale. Seeds that will be planted are selected first, with the criterion of good physical condition.

2.2.4 Identification of seed-borne fungi

Fungi that affect seeds during germination can be identified using the seed blotter test method. In this procedure, affected seeds are placed on a petri dish lined with blotter paper, which is then moistened with distilled water. Seeds that show fungi overgrowth are sterilized by washing them with 70% alcohol. Following this, the seeds are incubated for 8 days. The identification of seed-borne fungi is carried out using a microscope. Fungi were identified by comparing macroscopic and microscopic appearances with the key book "Pictorial Atlas of Soil and Seed Fungi" [4]. The number of seeds infested with the fungus is calculated using the formula as follows [5] :

$$\text{Infection rate} = \frac{\textit{Infected seeds}}{\textit{Tested seeds}} \times 100\%$$

2.2.5 Germination media treatment test

The media used in germination consists of several treatments. The first treatment (K1) is in the form of soil medium (control), the second treatment (K2) is in the form of zeolite media, the third treatment (K3) is in the form of cocopeate media, and the fourth treatment (K4) consists of a mixture of soil and sand (1:1 v/v). Clean the media to be used first. Planting seeds was carried out in mica containers that already contain media. Maintenance was carried out by daily watering using padlocks and weeding if there were weeds.

2.2.5 Data observation and acquisition

Germination observation is carried out daily by recording the number of normal sprouts that grow. Observations were carried out for 50 days until the number of germinations stagnated.

2.2.5.1 Germination power (%)

Germination power indicates the ability of seeds to grow under normal conditions. The calculation of germination power uses the following formula [6]:

$$\text{Germination Power} = \frac{\textbf{Number of normal germinated seeds}}{\textbf{Number of germinated seeds}} \text{ x } 100\%$$

2.2.5.2 Growth rate (%/day)

Growth rate shows the accumulation of seed growth rate each day in a unique percentage per day (etmal or 24 hours) benchmark. This calculation of growth rate is based on the formula of Thronebery and Smith [7] :

$$\text{Growth Rate} = \sum_{\mathbf{0}}^{\boldsymbol{tn}} \frac{\boldsymbol{N}}{\boldsymbol{t}} \text{S}$$

Information:

N = Normal Germination Percentage (%)
T = Observation time (days)
0 - tn = Observation time from day 0 to day nth

2.2.5.3 Germination value (%/day)²

The germination value is an index that shows the speed and perfection of the seed's germination process. The calculation of the germination value uses the formula as follows [7] :

$$\text{Germination value} = \textit{Peak Value (PV)} \text{ x } \textit{Mean Daily Germination (MDG)}$$

$$\text{PV} = \frac{\textbf{\%highest germination}}{\textbf{\Sigma days required to achieve}} \text{ x } 100\%$$

$$\text{MDG} = \frac{\textbf{\%end of period germination}}{\textbf{\Sigma total test days}} \text{ x } 100\%$$

2.3 Data analysis

The experimental design used in the study was a complete randomized design with one factor and four treatments. Each treatment consists of 3 replicates, so each type of seed contains 300 seeds. The research data was analyzed using fingerprint analysis with the help of Microsoft Excel software and IBM SPSS Statistics 23 software. If there is a fundamental difference between the treatments, further tests are carried out using the Duncan Multiple Range Test (DMRT).

Also, a weighting is carried out to determine the best media treatment for the germination of nyamplung and kenari. The weighting is divided into 10 classes with a value interval of 1-10 (smallest to largest). The determination of class width is calculated using the following formula [8]:

$$\text{Class width} = \frac{\textbf{\textit{The most considerable mean value of a treatment}}}{\textbf{\textit{Class}}}$$

3 Results and discussion

3.1 Physical condition of nyamplung and kenari Seeds

Seeds were physically tested by visually inspecting the seeds and checking for damage. Based on Figure 1a, the characteristics of the physical condition of nyamplung seeds are round, thick, and hard, ivory yellow in color, and not soft when pressed, with an average weight of 3 grams, an average height of 2.6 cm, and an average diameter of 1.7 cm. Ethnobotanical research on nyamplung [9] states that the height of nyamplung seeds ranges from 2.5 to 5 cm. Based on Figure 1b, the characteristics of physical condition kenari seeds include an elongated, pointed shape with a tough shell, light brown color, and coarse texture, with an average seed weight of 6.9 grams, an average height of 3.7 cm, and an average diameter of 1.9 cm. Research on the physical characteristics of kenari genotypes from North Maluku [10] showed that the diameter ranges from 3.26 cm to 4.68 cm.

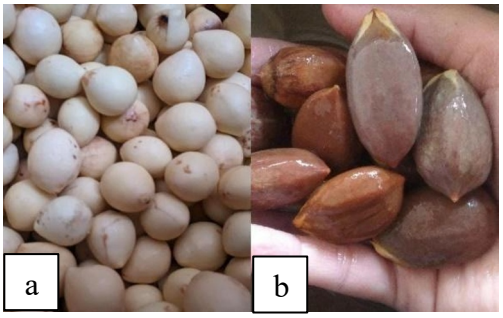
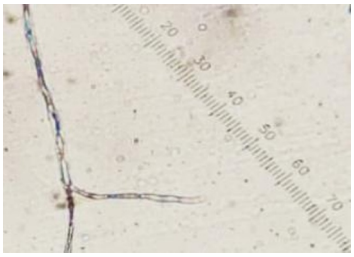
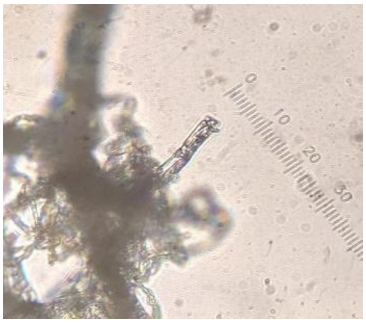


Fig. 1. Physical condition of seeds (a) Nyamplung seeds (b) Kenari seeds.

3.2 Seed-borne fungi

Germination of nyamplung seeds in soil media and a mixture of soil and sand (1:1 v/v) affects the appearance of fungi on some seeds. Fungi also appear on kenari seeds that are germinated on soil media. This is suspected to be due to the compaction of the media, which causes puddles to form. Conditions like this make the media damp. A sufficiently humid environment allows the growth of fungi mycelium. Another thing that affects the appearance of mushrooms on seeds is how seeds that come from under the stand are deposited. The condition of the seeds in the soil for an unknown period until the seeds are downloaded allows for contamination of the seeds. Seeds carried by nyamplung and kenari are presented in Table 1.

Table 1. Macroscopic and microscopic appearance of nyamplung and kenari seed-borne fungi.

No	Macroscopic	Microscopic	Type
1			*Rhizoctonia* sp.
2			*Pythium* sp.
3			*Colletotrichum* sp.

Fungi carried by nyamplung seeds are *Rhizoctonia* sp. and *Pythium* sp. The characteristic hyphae of *Rhizoctonia* sp. appear to form a branching angle of 90° and blocked hyphae [11]. *Pythium* sp. is a fungus that infects seeds and causes seed rot due to enzyme activity. The characteristics are thickening of hyphae, irregular hyphae with a cylindrical shape, and a round sporangium [4]. Kenari seeds carried the type of fungi of *Colletotrichum* sp. The characteristic of this fungus is that it forms a yellowish-white colony, has cylindrical conidia with a rounded tip, produces transparent conidia, and has an acerbus. The acerbulus is a fruiting body that contains fertile hyphae and produces conidia [12]. The rate of fungi infection in nyamplung seeds and Kenari seeds (Table 2) is relatively low. The low infection

rate can be affected by checking the physical condition and selecting seeds before planting. Seeds in good physical condition can determine the growth and health of plants to provide quality production. The application of fungicides can be a countermeasure against the presence of fungi carried by seeds. Fungicides are compounds that can prevent and eradicate the development of fungi.

Table 2. Rate of fungi infection carried by nyamplung seeds and kenari.

No	Types of fungi	Number of seeds	Infection rate
1	*Rhizoctonia* sp.	4	1.33%
2	*Pythium* sp.	2	0.67%
3	*Colletotrichum* sp.	2	0.67%

3.3 Growth of nyamplung seeds

3.3.1 Germination of nyamplung seeds

The germination process of nyamplung seeds is marked by the appearance of red color on the emergence site of the root (radicle) and stem (plumule). Over time, the seed's original yellow color changes to green, indicating that the root has emerged. The stem growth process will continue once the seed has produced a root. Nyamplung germinated seeds have 2 or 3 pairs of young leaves [1]. The type of nyamplung seed germination is hypogeal, characterized by the epicotyl growing elongated, followed by the plumule growing to the soil surface, penetrating the seed coat. At the same time, the cotyledons remain in their original position. Observations indicate that germination in zeolite media achieves the highest germination rate compared to other media. Germination on this medium increased on the 26th and continued on the 29th day with an average germination rate of 96%. The results of observations of nyamplung seed germination in various germination media are presented in Figure 2.

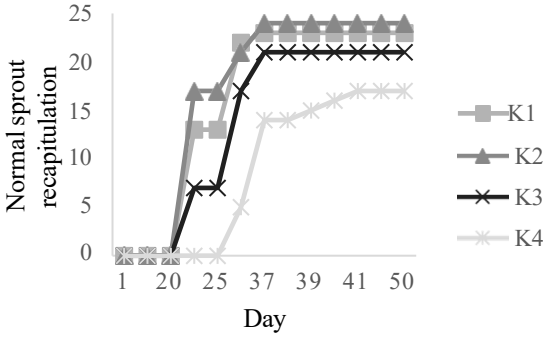


Fig. 2. Summary of nyamplung seed germination in the four media. Description: K1 = soil medium (control), K2 = zeolite medium, K3 = cocopeat medium, K4 = soil and sand medium (1:1 v/v).

3.3.1 Nyamplung seed growth test

3.3.1.1 Germination power

Germination power is the ability of seeds to germinate, usually under optimal conditions. Internal and external factors influence the seed germination process. Internal factors include dormancy and seed maturity level, while external factors include water, light, gas, and germination medium. A summary of the results of Duncan's test on the germination capacity of nyamplung seeds is presented in Table 3.

Table 3. Germination power of nyamplung seeds in the four media.

No	Treatment	Germination Power (%)
1	K1	93.33[b]
2	K2	96.00[b]
3	K3	84.00[b]
4	K4	65.33[a]

Description: Numbers followed by the same letter are not significantly different at the 5% test level. Note: K1 = soil medium (control), K2 = zeolite medium, K3 = cocopeat medium, K4 = soil and sand medium (1:1 v/v).

The germination medium for nyamplung seeds that provided the highest germination rate was obtained from the zeolite medium treatment (K2), which was 96%. The natural habitat of nyamplung is in coastal areas with soil conditions dominated by sand and humidity levels of 75%-97% [13]. Zeolite has characteristics similar to sand. Sandy-textured media have good drainage and air pore availability (aeration) and have a tiny cumulative surface area.

3.3.1.2 Growth rate (%/day)

The growth rate is the number of seeds that germinate normally each day. A summary of the growth rate of nyamplung seeds is presented in Table 4.

Table 4. Growth rate of nyamplung seeds in the four media.

No	Treatment	Growth rate (%/day)
1	K1	4.04[c]
2	K2	4.22[c]
3	K3	3.33[b]
4	K4	2.12[a]

Description: Numbers followed by the same letter are not significantly different at 5% test level. Note: K1 = soil medium (control), K2 = zeolite medium, K3 = cocopeat medium, K4 = soil and sand medium (1:1 v/v).

The best growth rate of nyamplung was observed in zeolite medium with a value of 4.22%/day. Growth rate is one of the indicators of seed vigor. Seeds with good vigor have a high growth rate. Zeolite can supply water and has good aeration for germination. Seeds will germinate faster in moist conditions (watering every day).

3.3.1.3 Germination value (%/day)^2

Germination value is an index of the speed and perfection of seed germination. The higher the germination value, the more perfect the seed germination process. A summary of the germination values of nyamplung seeds is presented in Table 5.

Table 5. Germination value of nyamplung seeds in the four media.

No	Treatment	Germination value (%/day)^2
1	K1	4.27^b
2	K2	5.10^b
3	K3	2.23^a
4	K4	0.88^a

Description: Numbers followed by the same letter are not significantly different at the 5% test level. Note: K1 = soil medium (control), K2 = zeolite medium, K3 = cocopeat medium, K4 = soil and sand medium (1:1 v/v).

Germination rates were obtained from periodic observations of the emergence of radicles and plumules. Germination rates on zeolite media (K2) showed relatively higher results, namely 5.10 (%/day)^2. High germination rates indicate good seed germination capacity. Zeolite medium is the most optimal medium for nyamplung seed germination. The advantages of this medium include its porous nature, which facilitates better oxygen exchange [14]. The rapid exchange of ions also accelerates seed metabolism.

3.4 Growth of kenari seeds

3.4.1 Germination of kenari seeds

Seed germination begins with water absorption, which causes the seed to swell (imbibition). This is caused by the enlargement of embryo cells and the softening of the seed. The imbibition process occurs due to the activity of the enzyme amylase in converting starch into sugar. The root tip begins to grow toward the ground (geotropism), followed by the activation of cells and increased seed respiration. The hypocotyl and cotyledon leaves also start to develop at this stage. After the seed germinates, the first young leaf (plumule) emerges, followed by the formation of new leaves through cell division, enlargement, and division. Kenari seed germination has a fanerocotyl type, meaning the cotyledons emerge above the soil surface (epigeal). A summary of kenari seed germination is presented in Figure 3.

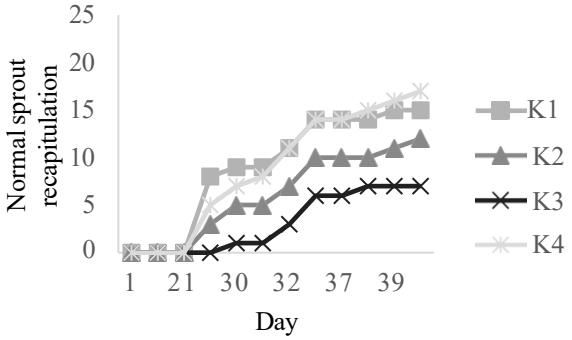


Fig. 3. Summary of kenari seed germination on the four media. Note: K1 = soil medium (control), K2 = zeolite medium, K3 = cocopeat medium, K4 = soil and sand medium (1:1 v/v).

A significant increase in the number of normal seedlings on the soil and sand mixture medium (1:1 v/v) (K4) occurred on the 28th day after planting. By the end of the observation period, the average number of normal seedlings on the soil and sand medium (1:1 v/v) was 73.33%.

3.4.2 Kenari seed growth test

3.4.2.1 Germination power (%)

This parameter is the most widely used measure of seed viability in seed quality testing. Seed viability is defined as the ability of seeds to germinate. Seeds with good viability have active metabolism and enzymes that can catalyze metabolic reactions.

The average germination rate in soil and sand medium (1:1 v/v) was 73.33%, which was better than other media (Table 6). Soil and sand medium (1:1 v/v) can accelerate germination because it has good moisture and light mass. Soil contains mineral components, organic matter, water, and air that plants require. Combining these two media makes it suitable because the plant germination requires a moist environment with appropriate watering.

Table 6. Germination power of kenari seeds in the four media.

No	Treatment	Germination Power (%)
1	K1	56.00[b]
2	K2	46.67[b]
3	K3	33.33[a]
4	K4	73.33[c]

Description: Numbers followed by the same letter are not significantly different at 5% test level. Note: K1 = soil medium (control), K2 = zeolite medium, K3 = cocopeat medium, K4 = soil and sand medium (1:1 v/v).

3.4.2.2 Growth rate (%/day)

Seed vigor is measured based on growth rate. The higher the growth rate, the higher the seed vigor, and vice versa. Seeds with high vigor react quickly when growing conditions are optimal and metabolism is not inhibited [7]. Based on the observations presented in Table 7, the highest growth rate in kenari seeds was observed in the soil and sand medium (1:1 v/v) treatment, at 2.30%/day. The soil and zeolite media had growth rates of 1.81%/day and 1.50%/day, respectively. The treatment with the lowest growth rate was the cocopeat medium at 1.01%/day. The soil and sand medium (1:1 v/v) was optimal for the kenari seed growth rate. This medium has sufficient water content and good aeration. High porosity and mineral content are other advantages that help accelerate the rooting process.

Table 7. Growth rate of kenari seeds in the four media.

No	Treatment	Growth Rate (%/day)
1	K1	1.81[a]
2	K2	1.50[b]
3	K3	1.01[a]
4	K4	2.30[d]

Description: Numbers followed by the same letter are not significantly different at the 5% test level. Note: K1 = soil medium (control), K2 = zeolite medium, K3 = cocopeat medium, K4 = soil and sand medium (1:1 v/v).

3.4.2.3 Germination value (%/day)²

The germination rate indicates the percentage of seeds germinating per day until the end of the test. A summary of the germination rates of kenari seeds can be seen in Table 8.

Table 8. Germination value of kenari seeds in the four media.

No	Treatment	Germination value (%/day)²
1	K1	0.45[a]
2	K2	0.32[a]
3	K3	0.19[a]
4	K4	0.90[b]

Description: Numbers followed by the same letter are not significantly different at the 5% test level. Note: K1 = soil medium (control), K2 = zeolite medium, K3 = cocopeat medium, K4 = soil and sand medium (1:1 v/v).

The highest germination rate of kenari seeds was observed in the soil and sand medium treatment (1:1 v/v) (K4) at 0.90 (%/day)². Seeds with good vigor indicate a high germination rate. These seeds can grow into normal seedlings when cultivated under optimal conditions. The preliminary treatment previously

conducted (seed soaking) was considered sufficiently helpful for germination. The soil and sand mixture (1:1 v/v) was the best medium for kenari seed germination due to adequate water availability, optimizing soil moisture. This aligns with the research conducted by Yunirti *et al.* [3], which found that the best medium for kenari germination is a mixture of soil and sand (1:1 v/v).

3.5 Weighting value

The best medium for nyamplung seed germination is zeolite, while the best medium for kenari germination is soil and sand (1:1 v/v). The germination rates of nyamplung and kenari seeds in the four media are presented in Tables 9 and 10.

Table 9. Weighting values for nyamplung seeds germination in the four media.

Parameters	K1	K2	K3	K4
Germination Power	9.72	10.00	8.75	6.81
Growth Rate	9.57	10.00	7.88	5.02
Germination Value	8.38	10.00	4.38	1.73
Total	27.67	30.00	21.01	13.56

Description: K1 = soil medium (control), K2 = zeolite medium, K3 = cocopeat medium, K4 = soil and sand medium (1:1 v/v).

Table 10. Weighting values for kenari seeds germination in the four media.

Parameters	K1	K2	K3	K4
Germination Power	7.64	6.36	4.55	10.00
Growth Rate	7.87	6.52	4.39	10.00
Germination Value	5.00	3.56	2.11	10.00
Total	20.51	16.44	11.05	10.00

Description: K1 = soil medium (control), K2 = zeolite medium, K3 = cocopeat medium, K4 = soil and sand medium (1:1 v/v).

4 Conclusion

Good physical conditions of nyamplung seeds include being round, thick, and hard, with an ivory yellow color. When pressed, they should not be soft. The average weight is 3 g, height is 2.6 cm, and diameter is 1.7 cm. Good physical conditions of kenari seeds include an elongated, pointed shape with a tough shell, light brown, with an average weight of 6.9 g, an average height of 3.7 cm, and an average diameter of 1.9 cm. Fungi carried by nyamplung seeds originate from *Rhizoctonia* sp. and *Pythium* sp., while those in kenari seeds are *Colletotrichum* sp. The most optimal germination medium for nyamplung is zeolite medium,

while the most optimal germination medium for kenari seeds is a mixture of soil and sand (1:1 v/v).

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