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Characteristics of Seed Germination and Growth of Wood Apple Seedlings (Feronia limonia (L.) Swingle) from Five Districts in Rembang Regency

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Abstract: Rembang Regency is a central area for wood apples, but the population is decreasing, so the plant population must be increased to ensure it does not become extinct. To propagate wood apple plants, information on high-quality seed sources is necessary to produce healthy seedlings. The research aimed to determine the germination and growth characteristics of wood apple seeds from five districts in Rembang, where there are still many wood apple plants. The research consisted of two experiments: germination and growth of wood apple seedlings. The research was a single-factor experiment using a completely randomized design, consisting of 5 seed source districts, namely Kaliori, Lasem, Sulang, Rembang, and Pamotan districts. The results showed that there were differences in the germination characteristics of wood apples from five seed sources in Rembang; however, no differences were observed in seedling growth. Seeds from Pamotan and Sulang, which have a heavier seed weight, provide a higher percentage of germination and seedling emergence than seeds with a lower weight. Seeds from Kaliori, which had the lowest seed weight, showed a lower percentage of germination and seedling emergence. Even though there was no difference in seed growth, the seeds from Pamotan and Sulang, which had seeds with a higher weight, showed better seed growth. On the other hand, seeds with a lower weight give lower seedling growth.

Keywords: *Feronia limonia*, germination, seed, seedling, wood apple

1. Introduction

Wood apple (*Feronia limonia* (L.) Swingle) is a fruit plant in the Rutaceae family. Wood apple naturally grows in dry areas in India, Sri Lanka, Myanmar, and Indo-China, and then spreads to other countries, including Indonesia. In Indonesia, wood apple is found on the islands of Sumatra, Java, Bali, and Nusa Tenggara (Widiati 2010; Jones 1992). Almost all parts of the wood apple plant are useful, including roots, stems, leaves, young fruit, and ripe fruit, used for medicine, food, and drink (Jones, 1992; Apriyantono & Kumara 2004; Orwa et al., 2009; Ilango & Chitra, 2009; Intekhab & Aslam, 2009; Parial et al., 2009; Upadhyay et al., 2010; Qureshi et al., 2010; Mutmainah, 2011; Yulianti et al., 2019; Kusuma and Jastian, 2021; Lamani et al., 2022; Afifah et al., 2023;). Wood apple seedlings are used as rootstock for the propagation of citrus plants because they are based on their adaptation to large areas of land and resistance to drought and disease (Sirisena, 1998; Yulianti et al., 2019). The wood apple plant is also recommended as one of 10 rare fruit plants for dry land conservation by the Purwodadi Botanical Gardens because it is tolerant of drought, and its fruit has economic value, as well as efforts to protect it from extinction. Currently, wood apple plants in Indonesia are included in the status of rare plants in the endangered category (Yulistyarini et al., 2000).

One of the areas producing wood apple fruit is Rembang Regency; in fact, wood apple has become the identity plant of Rembang Regency (Rahayu et al., 2017). However, the population of wood apple plants is currently decreasing. Data from the Rembang Agriculture and Forestry Service in 2011 recorded that only 1042 wood apple trees more than 20 years old still existed in Rembang. This number decreased to 1202 in 2015 because there were no efforts to regenerate plants. The wood apple fruit syrup industry, which has high economic potential and has become an icon in Rembang, only relies on fruit from the yard. Therefore, it is necessary to increase the plant population to prevent extinction.

In order to increase the population of wood apple plants in Rembang, information is needed about the quality of wood apple seeds, which includes the characteristics of seed germination and seedling growth from several districts in Rembang. This information is useful for selecting good seeds and seedlings. Wood apple plants are spread across 14 districts in Rembang, with different environmental conditions so it is thought that there are differences in the morphological and physiological characteristics of seeds and seedlings from each district. Allard (1960) stated that

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differences in morphological characters are thought to be caused by differences in environmental conditions. Morphological characteristics are also influenced by genetic factors, which will influence the differences between seeds and seedlings (Hartuti, 2008). Research by Nugroho (2012) shows that the diversity of wood apples in Rembang is quite large due to differences in location and environment.

Currently, there has been no research on the characteristics of seed germination and growth of wood apple seedlings in Rembang. Research was carried out to determine the characteristics of seed germination and growth of wood apple seedlings from five districts in Rembang. The research was carried out in five districts in Rembang, namely Kaliori, Lasem, Rembang, Sulang, and Pamotan, based on the consideration of districts that still have many wood apple plants (Rembang Agriculture and Forestry Service, 2015). Information about the characteristics of seed germination and growth of wood apple seedlings is expected to improve seed studies and wood apple conservation programs (Nurhayani et al., 2019).

2. Material and Methods

The research was conducted at the Agronomy Laboratory and Experimental Field, Faculty of Agriculture, Muria Kudus University. Wood apple seeds were collected from five districts in Rembang, which currently have a lot of wood apple plants, namely Kaliori, Lasem, Rembang, Sulang, and Pamotan. The number of fruits used as a seed source was 75, from which physiologically ripe fruit was marked by being ripe and falling from the tree (Murrinie, 2017). The fruit is aged until ripe for 6 days, then the seeds are extracted by separating the seeds from the fruit flesh using water (Murrinie et al., 2017). The research consisted of two experiments, namely (1) the seed germination experiment and (2) the seedling growth experiment.

2.1 The Seed Germination Experiment

The seed germination experiment was carried out at the Agronomy Laboratory, Faculty of Agriculture, Universitas Muria Kudus, using a completely randomized design, consisting of five seed source district treatments, namely Kaliori, Lasem, Sulang, Rembang, and Pamotan. The research was carried out by germinating 25 seeds in a Petri dish covered with Whatmann filter paper, which was repeated four times from each district, so that there were 20 experimental units. Observations were made for 21 days on the percentage of germination (1), germination rate (2), radicle length, hypocotyl length, and dry weight of the sprouts. Observation of the weight of 100 seeds from each seed source was carried out by weighing 100 seeds randomly and repeated eight times for each seed source. Germination percentage and germination rate were calculated using the formula according to Sutopo (1985).

$$\mathrm{PG} = \frac{\mathrm{NGS}}{\mathrm{NSS}} \times 100\% \qquad (1)$$

PG: Percentage of Germination
NGS: Number of Germinated Seeds
NSS: Number of Sown Seeds

$$\mathrm{GR} = \frac{\mathrm{N1T1+N2T2+\cdots+NxTx}}{\text{Total number of seeds that germinate}} \qquad (2)$$

GR: Germination rate
N: Number of seeds that germinate at a certain time
T: the total amount of time between the beginning of the test and the end of a certain interval of observation.

2.2 The Seedling Growth Experiment

The experiment was arranged using a Randomized Complete Block Research on the growth of wood apple seedlings was carried out at the Experimental Field of the Faculty of Agriculture, Universitas Muria Kudus, which has a height of 36 m above sea level using a completely randomized design, consisting of five treatments in the districts where the wood apple seeds came from as in the first study, each treatment was repeated 3 times, and each replication consisted of 10 polybags. Wood apple seeds were sown in germination trays containing sand three times for each seed source. Observations when sowing seeds are the percentage of seedling emergence and the rate of seedling growth. The percentage of seed emergence and seed growth rate is calculated using the same formula as the percentage of germination and germination rate (Sutopo, 1985). After one month, the seedlings were transferred to polybags filled with soil, sand, and manure (1:1:1). Observations were made until the seedlings were eight weeks old, including seedling height, stem diameter, number of leaves, root length, and dry weight of the seedlings.

2.3 Data Analysis

Data were analyzed using analysis of variance and followed by Duncan's Multiple Range Test (DMRT) 5% using R Software version 3.1.1.

3. Results and Discussion

3.1 Characteristics of Wood Apple Seed Germination from Five Subdistrict in Rembang

Seed germination characteristics observed consisted of germination percentage, germination rate, and sprout growth as indicated by radicle length, hypocotyl length, and sprout dry weight. The results showed that different seed sources had different germination percentages, germination rates, and sprout growth. Seeds from Lasem, Rembang, Sulang, and Pamotan gave a higher germination percentage than seeds from Kaliori; however, the germination percentage from all seed sources showed a high germination percentage, namely 85-100%. This is in line with the statement of Wawo et al. (2020) that a germination percentage of greater than 80% is included in the high criteria. Seeds from different sources also show different germination rates. Seeds from Sulang had the fastest germination rate, namely 7.09 days, and this was significantly different from other seed sources, which had a germination rate of 13-17 days (Table 1).

Table 1: Weight of 100 seeds, germination percentage, and germination rate of wood apple seeds from five districts in Rembang

Seed source (district)	Weight of 100 seeds (g)	Germination percentage (%)	Germination rate (day)
Kaliori	2.83 d	85.00 b	16.06 c
Lasem	2.90 cd	100.00 a	13.05 b
Sulang	2.95 bc	98.33 a	7.09 a
Rembang	3.02 b	98.33 a	17.12 c
Pamotan	3.25 a	100.00 a	12.83 b

Note: Numbers followed by the same letter in one column indicate no significant difference with DMRT 5%

The seed source also influences the growth of sprouts as indicated by radicle length, hypocotyl length, and dry weight of sprouts. Seeds from Rembang and Pamotan gave the highest dry weight of sprouts and were significantly different from other seed sources (Table 2).

Table 2: Radicle length, hypocotyl length, and dry weight of wood apple sprouts from five districts in Rembang

Seed source (district)	Radicle length (cm)	Hypocotyl length (cm)	Dry weight of sprouts (mg)
Kaliori	2.81 a	3.31 a	18.08 b
Lasem	1.57 c	3.26 a	17.35 b
Sulang	2.42 b	3.32 a	18.12 b
Rembang	2.21 b	2.27 b	20.03 a
Pamotan	2.14 bc	3.30 a	19.71 a

Note: Numbers followed by the same letter in one column indicate no significant difference with DMRT 5%

According to Schmidt (2000), seed germination is influenced by various factors such as seed quality, pre-germination treatment (breaking dormancy), and germination environmental conditions (water, temperature, media, light). In other words, germination is influenced by several factors, which can be divided into internal factors and external factors. Internal factors that influence seed germination include seed size. Smaller seeds show a lower germination percentage compared to larger seeds. Seeds from Kaliori, which had the lowest 100-seed weight, gave the lowest germination percentage and longer germination rate (Table 1), as well as low seed dry weight (Table 2). Seed weight is related to the food reserves in the seed. Seeds that have a larger weight have more food reserves than seeds with a smaller weight.

Seed size is positively correlated with seed vigor; heavier seeds tend to have better vigor. Schmidt (2000) explains that large and heavier seeds are thought to contain more food reserves than small seeds, and it is thought that the embryo size is also larger. Food reserves stored in seeds are carbohydrates, proteins, fats, and minerals. These food reserves are needed as raw materials and a source of energy for the embryo during the germination process (Sutopo, 1985). This is in line with research on the seeds of *Intsia palembanica*, *Melia azedarach*, *Mimusops elengi*, *Manilkara kauki*, and *Zea mays,* which shows that seed size influences the percentage and rate of germination. Seeds with higher weights provide significantly higher germination percentages and germination rates (Suita, 2008; Suita and Megawati, 2009; Sudrajat and Megawati, 2010; Pratama et al., 2014). The results of the research showed that seeds from Pamotan and Sulang, which had a high weight, gave a high percentage of germination and dry weight of the sprouts. Ginwan et al. (2005) added that differences in viability that occur between seed sources are influenced by differences in seed morphology from each source.

3.2 Characteristics of the Growth of Wood Apple Seedlings from Five Districts in Rembang

In line with the germination characteristics of seeds, there is an influence of seed source on the percentage of emergence and growth rate of wood apple seedlings. Seeds from Sulang and Pamotan, which had high seed weights, also showed a higher percentage of seedling emergence (Table 3). This is in line with observations of seed germination characteristics, which show that seeds from Sulang and Pamotan provide higher seed germination characteristics than other seed sources.

Table 3: Percentage of emergence and growth rate of wood apple seedlings from five districts in Rembang

Seed source (district)	Percentage of seed emergence (%)	Seedling growth rate (days)
Kaliori	60.00 bc	34.82 a
Lasem	68.67 abc	33.12 a
Sulang	86.67 a	33.05 a
Rembang	52.67 c	41.49 b
Pamotan	78.67 ab	35.55 a

Note: Numbers followed by the same letter in one column indicate no significant difference with DMRT 5%

Sutopo (1985) and Setiawan et al. (2021) stated that larger seeds contain a greater amount of food reserves and larger embryos compared to smaller seeds. If the food reserves available in the seeds are less, the germination of the seeds is weaker, so the percentage of seedlings that emerge to the surface is less. Food reserves stored in the seed's food reserve tissue are used as an energy source for the embryo during germination. Heavier seeds have more food reserves as a source of energy for the germination process. The main function of food reserves in seeds is as a source of energy for embryos and sprouts before plants produce assimilates, hormones, and proteins (Ashari, 2006). Seed weight correlates with seed vigor and viability. Large seeds have higher vigor than small seeds (Schmidt, 2000). Research by Yuniarti et al. (2013) showed that large and heavier seeds of *Acacia crassicarpa* had a higher germination percentage compared to medium-sized and light seeds. Although the seed source has a significant effect on seed germination characteristics and the percentage of seedling emergence, the seed source does not affect seedling growth as indicated by seedling height, number of leaves, root length, stem diameter, and seedling dry weight.

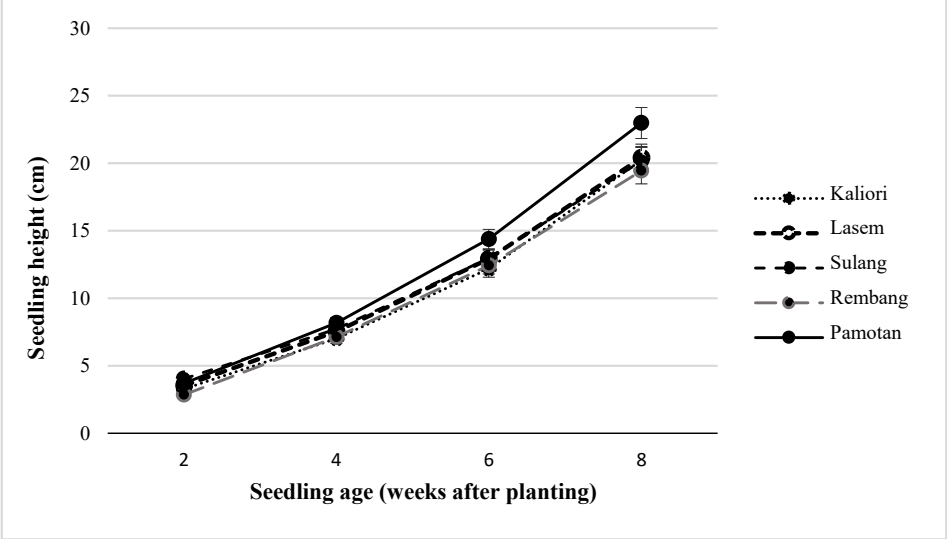

Fig. 1: Seedling height of wood apple from five districts in Rembang

Fig. 1 shows that there is no difference in seedling height from Kaliori, Lasem, Sulang, Rembang, and Pamotan. Such as seedling height, the number of leaves of wood apple seedlings from Kaliori, Lasem, Sulang, Rembang, and Pamotan aged 2-8 weeks after planting also showed no significant difference (Fig. 2). These findings indicate that the origin of seeds from the five districts did not significantly influence early vegetative growth of wood apple seedlings. The similarity in seedling height and leaf number across all locations suggests that the seedlings exhibited comparable growth performance during the early establishment phase (2–8 weeks after planting). This uniformity may be attributed to similar genetic characteristics among seed sources or to homogeneous environmental conditions during nursery cultivation, such as growing media, watering regimes, and light exposure. Consequently, variations in geographical origin within Rembang Regency appear to have minimal impact on the initial growth traits of wood apple seedlings under controlled nursery conditions.

The absence of significant differences in seedling height and leaf number among wood apple seedlings from Kaliori, Lasem, Sulang, Rembang, and Pamotan indicates a consistent growth response during the early developmental stage. This suggests that seed provenance within the same regency may not create substantial variation in early morphological

traits. At the seedling phase, growth is primarily driven by seed reserves and basic physiological processes, which may override minor environmental or geographical differences among seed sources. Therefore, early growth parameters such as height and leaf production are likely more influenced by nursery management practices than by district-level origin.

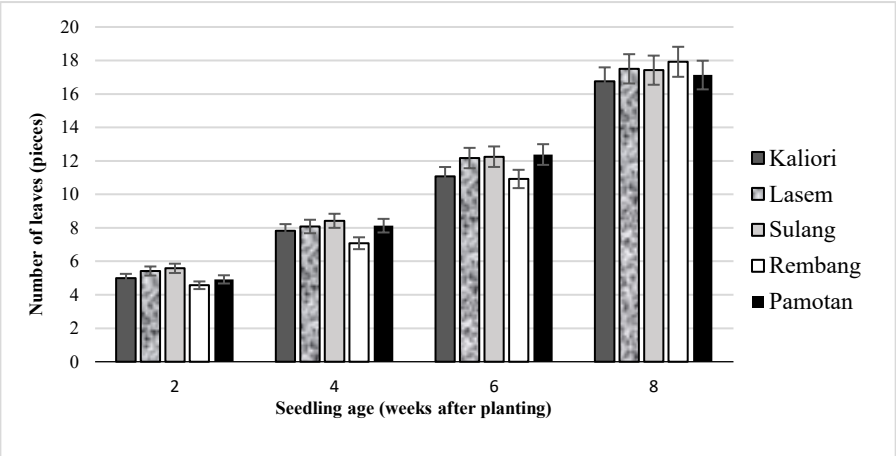

Fig. 2: Number of seedlings of wood apples from five districts in Rembang

Observations of root length, seedling diameter, and seedling dry weight at 8 weeks after planting also showed no significant differences (Table 4).

Table 4: Root length, stem diameter, and dry weight of wood apple seedlings from five districts in Rembang

Seed source (district)	Seedling root length (cm)	Seedling stem diameter (cm)	Seedling dry weight (g)
Kaliori	11.80 a	0.32 a	1.10 a
Lasem	14.05 a	0.31 a	1.17 a
Sulang	13.03 a	0.33 a	1.21 a
Rembang	15.95 a	0.33 a	1.15 a
Pamotan	15.86 a	0.37 a	1.39 a

Note: Numbers followed by the same letter in one column indicate no significant difference with DMRT 5%

According to Sutopo (1985), seed weight influences growth speed and production because seed weight determines germination at the start of growth and plant weight at harvest. Seeds that are larger in size tend to have better growth, but further growth is greatly influenced by environmental factors. The results of the research show that different sources of wood apple seeds provide different germination characteristics, but after the germination phase ends and the seedlings do not depend on food reserves, the subsequent growth of wood apple seedlings is very dependent on the environment in which they grow. Wood apple seedling growth experiments were carried out in the same environment, resulting in the same seedling growth.

Even though there was no effect of seed source on seedling growth until eight weeks after planting, seedlings from seeds with a lower weight (Kaliori) gave the lowest seedling growth, whereas seedlings from seeds with a larger weight gave higher seedling growth (Figure 3).

Figure 3: Wood apple seedlings from five districts in Rembang, eight weeks after planting

Owoh et al. (2011) found that seed size had a significant effect on the growth of *Gmelina arborea* seedlings. Large and medium seed sizes provide better seed growth than small ones.

4. Conclusion

The results of the research showed that there were differences in the germination characteristics of kawista from five districts in Rembang, but there were no differences in seedling growth. Seeds from Pamotan and Sulang, which have a higher seed weight, provide a higher germination percentage and seedling emergence percentage than seeds with a lower weight. Seeds from Kaliori, which had the lowest seed weight, showed a lower percentage of germination and seedling emergence.

Even though there was no difference in seedling growth, the seeds from Pamotan and Sulang, which had seeds with a higher weight, showed better seedling growth. On the other hand, seeds with a lower weight give lower seedling growth. Thus, because the research results show that the germination characteristics and percentage of seedling emergence from Sulang and Pamotan are higher than those of other seed sources, seeds from Sulang and Pamotan can be considered for use as a source of wood apple seeds in Rembang.

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Conflict of Interest

The authors declare no conflicts of interest.

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