Response of *Ficus variegata* seedling size on their early growth in *imperata* grassland

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Abstract. *Ficus variegata* is pioneer species that provides pulp raw materials, soil water protection, beehives tree, animal fodder, and medicinal plants. Introduction of *F. variegata* seedling at *imperata* grassland constrained with low plant survival which caused by stressed plants and stagnant growth. The objective of this research was to determine the effect of five *F. variegata* seedlings size on the initial growth at *imperata* grassland. The research was used Randomized Complete Block Design, with 5 seedling sizes for the treatment, there are size A (seedling height 15-50 cm), size B (51-75 cm), size C (76-100 cm), size D (101-125 cm), and size E (126-150 cm). In this research, we observe some parameters like height and stem diameter increment, canopy width, and plant survival at 1, 6, and 12 months old. Different seedling size has a very significant effect at six months old and very significant effect at 12 months old on the height, diameter and crown width increment. Seedling size 15-50 cm has shown faster height growth but has lower survival than another size in the dry season. For rehabilitation *imperata* grassland, it is recommended using seedling size 50-125 cm because more adaptive and shown better growth in all parameters.

1. Introduction

*Imperata cylindrica* grassland rehabilitation is often constrained with low plants survival. Meanwhile, the acceleration of natural succession by depending on natural regeneration is less sufficient, because *imperata* grassland inhibits seedling recruitment [1]. Introduced seedlings in *imperata* grassland are often faced with the slow growth of new plants because the seedlings must be able to adapt to new environmental conditions, experience stress, lack of water availability, and many disturbances from predators.

Plants rarely grow in ideal environments, many stresses affected slow plant growth and development [2]. The initial mortality that occurs during the early (seedling or sapling) stages of development are high and caused by microsite effects [3]. Planting of tree seedlings at *imperata* grassland will encounter a similar problem, especially when the morphology of a seedling has a vigor less adaptive, such over high or over short seedling size. Different case with revegetation on peat swamps and flooded area, where seedlings with higher size have the advantage and are not submerged during the rainy season, revegetation at *imperata* grassland encounter with the high competition. Moreover, the plants were grown at *imperata* grassland must be adaptable with open environmental conditions, high temperatures, limited groundwater in the dry season, and other disturbances [4].

*Ficus variegata* Blume. (Urticales: Moraceae) is a pioneer native species. Its natural regeneration is found growing under fast-growing trees (*Paraserianthes moluccana* and *Acacia mangium* stands) in former *imperata* grassland at Riam Kiwa [1]. *Imperata* grassland is less productive and has a high risk
of fire in the dry season. Therefore, *Imperata* revegetation areas are becoming increasingly important, not only to create a new secondary forest but also to restore original biodiversity [5].

*F. variegata* is categorized as fast-growing tree species and has been developed as a forest plantation at East Kalimantan since 2003 [6]. With various utilities, this species recently also developed on degraded lands to accelerate natural succession, increase land coverage, supporting wildlife, reduce soil erosion, and increase groundwater availability [7] and [8]. Information of effect *F. variegata* seedling size with their success at *Imperata* grasslands is very scarce. Although more than 100 species have been tested in *Imperata* grassland at Riam Kiwa, including exotic plant species and native species, but *F. variegata* has never been evaluated [9].

Revegetation of *F. variegata* at *Imperata* grassland must be regarded with appropriate seedling size. Seedling size affects the growing root conditions and their ability to grow faster and suppress weeds. Short or small seedlings are frequently assumed to have a little root and are less adapted to the new growing site. However, small seedlings are easier for distributed into far planting locations with poor road access. Seedlings with large size easy to fracture risk during transportation, otherwise, they can grow immediately to suppress *Imperata* grass because their roots are fully developed since at nursery. Therefore, the objective of this study was to observe the growth response of several sizes of *F. variegata* seedlings at the early growth at *I. cylindrica* grassland in Riam Kiwa, South Kalimantan.

2. Research Methods

2.1. Study site

The study area, Riam Kiwa research forest area is situated south-east from Kalimantan Island, about 19 km from Riam Kanan Dam (321'40"- 3' 30' 23" S, 115' 40'03"-115' 0'06" E). Riam Kiwa is located at Lubang Baru Village, Pengaron Subdistrict, Banjar District, and South Kalimantan Province at altitude 50 m asl. Soil type at Riam Kiwa research forest dominated by red yellow podzol which spread out in a mosaic and alluvial soils are found in relatively flat areas along streams and rivers. The soil type in the trial area is poor in nutrients, especially nitrogen, potassium, and phosphorus, and has a low pH value (4.8 – 5.4) [10]. The local climate is wet tropical and including type B (Schmidt & Ferguson), with an average rainfall of 2,299 mm.year\(^{-1}\) falling mostly in the period October-April. May to September is the dry period, with just 20% of average rainfall per year. The average air temperature is 25°C with an annual maximum air temperature of 33°C and a minimum of 22°C [11].

![Figure 1](source: perkim.id)

**Figure 1.** Location of Riam Kiwa research forest (source: perkim.id)

2.2. Research methods

The research was used Randomized Complete Block Design, with 5 seedling sizes for the treatment i.e: (1) size A (seedling height 15-50 cm), (2) size B (seedling height 51-75 cm), (3) size C (seedling height 76-100 cm), (4) size D (seedling height 101-150 cm) and (5) size E (seedling height 126-150 cm). Five replicated blocks were established to compare the field performance of the five *F. variegata* seedling sizes at *I. cylindrica* grassland, and each block consists of 10 plants (10 tree plots). The dimension of seed sizes was tested in this research are shown in table 1.
Table 1. Dimension of seedlings was tested

| Treatment (Seedling sizes) | Average Height (cm) | Average Stem diameter (mm) | Seedlings age |
|---------------------------|--------------------|---------------------------|---------------|
| 15-50 cm (A)              | 38.21              | 3.84                      | More than 5 months |
| 50-75 cm (B)              | 62.76              | 4.69                      |               |
| 75-100 cm (C)             | 81.27              | 5.84                      |               |
| 100-125 cm (D)            | 105.62             | 7.69                      |               |
| 125-150 cm (E)            | 134.35             | 8.25                      |               |

Note: All seedlings fulfilled quality requirements and were ready to plant [6].

The previous vegetation on the trial site was alang-alang (I. cylindrica) land. Land preparation was done by mechanically (using a tractor) with three stages of tillage: disc plough I, disc plough II, and harrow with an interval of one month for each stage. Seedlings were planted with a spacing of 3 x 3 m, in December (in peak rainy season). After the plants are 1 month old, fifty grams of fertilizer (NPK 15-15-15) was applied in a ring around each tree. After planting out, plots were weeded by slashing and an additional dose of fertilizer was applied at 6-week intervals, during the rainy season.

The observation included height and stem diameter increment, canopy width, and plant survival was collected at 1 month, 6 months, and 12 months old after planting. The total height was measured with a measuring stick from the ground level to the tip of the shoot. The crown diameter was measured with the same tool, where measurement twice from each tree, once parallel to the passing side road and the other time at 90° angle from the first measurement. The recorded result was the average of these values. And the diameter was measured with a caliper at 5 cm above ground level.

2.3. Data analysis

The data were analyzed in this study are growth data ($\Delta$ growth), which obtained from subtracting the value of the last observation with the value of the previous observation. The total height, stem diameter, and canopy width increment were calculated using a growth rate formula (equation 1), and plant survival was calculated using a plant survival formula (equation 2).

\[
\text{Growth rate} = \frac{\text{size change}}{\text{time interval}} \quad (1)
\]

\[
\text{Plant survival} (\%) = \frac{\text{number of plants live}}{\text{number of planted plants}} \quad (2)
\]

Calculated data was then analyzed with analysis of variance (ANOVA) and continued with Tukey (Tukey-Kramer Multiple Comparison Test) to find out the difference from some treatments that tested.

3. Result

3.1. Height increment

The height increment of F. variegata during observation is shown in figure 2. Analysis of variance (ANOVA) results was showed that at 6 months old seedlings size had a very significant effect (p>0.01) on the height increment, while at 12 months old seedlings size had a significant effect (p>0.05).

At age of 6 months, seedlings with size A was showed the highest height increment, followed by seedling sizes C, B, D, and E respectively. Furthermore, after 12 months old, a seedling from sizes E, D, B, C showed better height increment than seedling size A. In the early months after planting, the majority of seedlings size A (15-50 cm) has shown spontaneous height growth. Otherwise, most of the seedlings > 100 cm tall (size D and E) experienced permanent wilting and necrosis. Both damages cause slower growth in height, as the plant needs to form new shoots before continuing to grow taller.
4

**Figure 2.** Height increment of *F. variegata* seedling from five different seedling size

### 3.2. Diameter increment

The diameter increment of *F. variegata* during observation is shown in figure 3. Results of analysis variance were showed that at 6 months old, seedlings size had a very significant effect (p>0.01) on the stem diameter increment, while at 12 months old seedlings size had a significant effect (p>0.05).

![Diameter increment of F. variegata](image)

**Figure 3.** Stem diameter increment of *F. variegata* seedling from five different seedling size

As a reason of very significant growth of stem diameter in seedlings at the age of 6 months, because plants with a height of > 75 cm (size C, D, and E), showed faster stem growth due to the emergence of new shoots, after experiencing shoot death a few months after planting. Meanwhile, seedlings with sizes A (15-50 cm) and B (50-75 cm) which did not experience shoot death, rarely saw the appearance of new shoots on their main stem. Therefore seedlings with sizes A and B showed faster growth in their height rather than growth in stem diameter.

After 12 months old, the trend of stem diameter growth also did not change. Seedlings with sizes C, D, and E still showed faster stem growth than seedlings A and B (figure 2). The difference between the age of 6 and 12 months is, at the age of 12 months the plant has passed the dry season, so that the speed of stem growth decreases by 25%-50% compared to stem growth in the rainy season.

### 3.3. Crown width increment

The crown width increment of *F. variegata* during observation is shown in figure 4. Analysis of variance results was showed that at 6 months seedlings size had a very significant effect (p>0.01) on the crown width increment, while at 12 months seedlings size had a significant effect (p>0.05).
Plants crown diameter is influenced by the arrangement of branches and the position of leaves on the stem. Morphologically *F. variegata* has a heart shape, and dioecious strain which will drop the leaves under certain conditions [12].

Plants adaptation mechanism into drought conditions also through with the low ratio of the external leaf surface to its volume [13]. In unfavorable conditions, leaves move into a vertical orientation as a result of high temperatures, independent of the direction of light [14] [3]. A wider crown diameter indicates that the plant has good adaptation to the new environment and grows horizontally. A narrow crown usually happens when plants reduced leaf area by reducing the evaporative level and the amount of water lost through transpiration [15], especially during the early stages of growth [2]. Especially for plantations in *Imperata* grassland, crown diameter development is an important characteristic. A wide crown will shade out the *Imperata* grass faster [4], and can reduce the risk of fire in the stands during the dry season.

At age of 6 months, the best crown width increment found at seedling size D (100-125 cm), followed by size E (125-150 cm), C (75-100 cm), and the lowest is in size B (50-75 cm). This indicated that seedlings size 15-75 cm showed slower crown growth diameter as a result of plants that tended to grow upwards rather than lateral growth.

This trend also did not change after the plants reached the age of 12 months. The growth of the plant crown tends to increase with increasing seedling size. The best crown diameter was in seed size E, followed by D, C, B, and A (figure 4.).

### 3.4. Plant survival

The survival rate of *F. variegata* did not decrease until 1 month. But 0.4-67% mortality took place during the first six months, and 1.6-15.3% during the first twelve months. Seedling size with the best survivorship at 12 months old is size E (98%), followed by seedling size D (97%), size B (95%), size C (93%), and the lowest survival at size A (85%) (Figure 5).

The highest mortality level (15.3%) at seedling size A, was occurred after drought season in June-September (when the seedling reaches age 6-9 months after being planted). During the dry season, small seedlings are more severely affected than larger seedlings and caused the plants to fail to regrow during the rainy season in October-April. Even though *F. variegata* is a type that is easy to sprouting [16], but small seedlings are supposed unable to hold water reserves in their stems and experience permanent wilting.

Furthermore, [17] stated that *F. variegata* is a non-hemiepiphytic tree species that usually have large pith in their stem. Lack of water condition for several months supposes has caused plant stem tissue difficult to regrowth because the cells experience permanent death. Drought can induce damage by negative stress on the plant, and the damage may be recoverable or irrecoverable depend on plant adaptation ability [15].
3.5. Discussion

*F. variegata* is categorized as intolerant species and required full light. This species is often found in burnt natural forests in East Kalimantan and is distributed along with other pioneer species such as jabon (*Anthocephalus cadamba*), mahang (*Macaranga* spp.), binuang bini (*Octomeles sumatrana*), and nuklea (*Nauclea* sp.) [6]. Pioneer tree species also generally grow faster than climax species [16]. *F. variegata* is included in the group of non-hemiepiphytes, which are an important plant component of tropical vegetation. However, non-hemiepiphyte *Ficus* species are less adaptable to drier conditions during seedling survival than hemiepiphytes species [18]. Because non-hemiepiphytes species have a lower ability to maintain the availability of water in their body than hemiepiphytes species, which could be adapted to limitations of water and nutrient availability by controlling water loss from their leaf surface [17].

After planting at *Imperata* grassland, most of the *F. variegata* seedlings experience stress with a new environmental condition. The stress condition is caused when any environmental factor is not ideal for plant growth and development, which can be caused by numerous factors i.e: temperature, water deficit, solar radiation, nutrient deficiency, and pests [2].

Not different from commonly *Imperata* grassland, the climatic condition at the trial site is also less comfortable for young seedlings mainly in the dry season (Mei-September). The daily maximum temperature is within the range 32-36 °C, and the relative humidity varying between 70-90 % depending on the time of day. This is similar to [5], where the microclimate ecosystem at *Imperata* grassland tends to have lower humidity and high day temperature. The research of [19] has shown that seedling injury and mortality were more intense during the dry season. This impact is exacerbated by the condition of the former *Imperata* grassland which is similar to the case above bare soil bare land, where temperature distribution is different during the night and day [3].

Growth performance, which can be described as total height, stem diameter, crown diameter, and *F. variegata* survival rate, is an important aspect and can be the indicator for plant species evaluation in adapting to a new environment [20]. This study indicates that without water shortage conditions (during the rainy season), small seedlings size (15-50 cm) showed spontaneous height growth early after planting. However, small seedlings are less able to adapt to dry conditions in the dry season. In this study, it was found that the most stable plant survival was found in seeds with a size of 100 cm up because they had a well-developed root system in the soil. This is similar to [13], which explained that higher seedling survival is often linked to larger biomass at roots so makes plants allowed a better water and nutrient uptake due to the possibility to explore larger volumes and deeper layers of soil.

Roots that have developed well in the soil are very helpful for plant survival in the dry season because plants can still access water in the soil compared to seeds with smaller sizes. Higher probability survival from a larger seedling (taller and have greater above biomass) at the initiation of the drought period was

![Figure 5](image.png)

**Figure 5.** Plant survival from five different seedling size.
also reported at *Chrysotamnus nauseusus* due to greater rooting deep and hence increasing access to moisture in a deeper soil layer [21].

After being planted in a new environment, seedlings can survive after going through a seedling emergency [22]. The viability of new plant seeds is strongly influenced by the ability to regrow after defoliation. Damage to newly planted seedlings generally occurs during the dry season, due to increased drought stress. When transpiration exceeds water uptake by roots, water deficit increases in plants, and stress can occur. During a soil water deficit, plants can avoid physiological stress through osmotic adjustment and storage of water in organs or isolation of roots (stress avoidance) [15]. Water deficits cause stomatal closure, reduce transpiration rates, and elevate foliage temperatures. Leaf loss is one of the plant mechanisms to reduce evaporation [2].

Except for defoliation, disturbances of *F. variegata* young plants are come from pests and diseases attack such as leaf caterpillar (*Glyphodes militaris*) and stem borer (*Apriona* sp.), but the damage does not impact yet for causing death plant [20]. Another disturbance which quite influential is strong wind especially in May and August, which causes some thin young plants to becomes crooked.

Survival of plants indicates the adaptability to the environment at the trial site [23]. Plants survival in this study which ranges between 85-98%, has shown that *F. variegata* is quite adaptive to be developed and categorized as possible species on former *Imperata* grassland at Riam Kiwa. *Ficus variegata* is quite adaptive to be planted in an open area, and this has been shown from the [16] research that their survival in Cikampek at 24 months old is more than 83% and even reaches 100%.

### 4. Conclusion

In the early months after planting, the majority of seedlings size 15-50 cm has shown faster height growth. Unfortunately, they are unable to survive in the dry season and suffered a mortality of 15% in the first year. While seedlings size > 100 cm (D and E) experienced necrosis and appearance many sprouting on their stem. A large number of sprouting made the crown growth and stem diameter are faster. Seedlings with a size of 50 up – 125 cm seem to be more resistant to dry conditions during the dry season on *Imperata* grassland, and their viability ranges from 93-98% at the age of 12 after planting. For rehabilitation *Imperata* grassland, it is recommended using *F. variegata* seedling size 50-125 cm because more adaptive and shows better crown growth for suppressing *I. cylindrica*.

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