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POPULATION STRUCTURE, DISPERSION PATTERN AND SEEDLING GROWTH OF GEWANG PALM (*Corypha utan* Lam.) IN TIMOR ISLAND, INDONESIA

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ABSTRACT

Food insecurity has been reported to be the top most concern in East Nusa Tenggara (Timor Island) compared to that in other provinces in Indonesia. The use of local species as food sources is one possible arm in the fight against food insecurity. Gewang (*Corypha utan* Lam.) is a palm species which produces starch similar to the true sago palm (*Metroxylon sagu*). Although it is important to promote the species as a starch crop, information on its current population and seedling growth performance is still lacking. Hence, a one-hectare plot was surveyed and an experimental plot was established for population and regeneration analyses. In the 1 ha plot there were 31 productive trees, 2 post productive trees, 63 immature trees and 2,211 seedlings. The dispersion of the species followed the clumped pattern for immature trees and seedlings, but shifted to random pattern at maturity or productive stage. The seedling survival was stable when weeded, but dropped to 50% when un-weeded. However, in spite of its stem extraction for starch consumption, the population of *C. utan* in East Nusa Tenggara was stable. This indicated that *C. utan* in East Nusa Tenggara is a potential alternative food source to help build food security in Indonesia, especially in dry lands like Timor Island and its adjacent regions.

Keywords: *Corypha utan*, East Nusa Tenggara, food, local, starch

INTRODUCTION

Global demand for food is growing rapidly. Recent estimates indicated that the demand would double in 2050 (Tilman *et al.* 2011). Furthermore, the human population was predicted to reach over 9.3 billion by the year 2050 (Dempewolf *et al.* 2014). Subsequently, the food prices have significantly increased globally since 2006 (FAOSTAT 2016). The situation clearly showed that future consumption resulting from the continuing population growth will inevitably increase the global demand for food and eventually lead to escalating prices (Godfray *et al.* 2010). However, price is not the only challenge but also the food scarcity (Khoury *et al.* 2014).

The situation needs multiple approaches, either by increasing crop yields several folds or by introducing new crops from the wild (Gregory & George 2011; Ray *et al.* 2013; Vincent *et al.* 2013; Khoury *et al.* 2014; Powell *et al.* 2015). The current circumstances present great challenges to Indonesia and other countries depending on imported foods for domestic consumption.

Confronted with these situations, the Government of the Republic of Indonesia has prioritized food security as a pivotal component of the current Government‘s Agenda in 2015-2019 (WFP 2015), focusing on some areas where food security is the main concern. Consequently, twelve districts in East Nusa Tenggara Province were identified as food and nutrition priority areas. Hence, the study was conducted in this province.

Historically and culturally, local communities in Indonesia have used and benefited from local food sources since time immemorial (Barton & Denham 2011). The locals in Borneo and Papua have traditionally extracted a variety of sago-producing palms such as *Eugeissona utilis* (Borneo

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hill sago) and *Metroxylon sagu* (Swamp sago) and have harvested sweet potatoes as a carbohydrate source (Barton & Denham 2011). Similarly, several species of ferns were predominantly used as food sources in Bali (Sujarwo *et al.* 2014). Moreover, some local crops and cereals are also a historically common food source in East Nusa Tenggara (Riptanti *et al.* 2018).

The use of local species which are related to cultivated crops (known as crop wild relatives) is believed to be a solution for food scarcity, together with the increase of crops quality through breeding (Vincent *et al.* 2013; Dempewolf *et al.* 2014). Most commonly cultivated crops worldwide actually originated from the wild but were later domesticated by humans (Khoury *et al.* 2016).

Corypha utan Lam. (locally known as *Gewang*) is a monocarphic palm species, with single stem of up to 30 m in height and 35-75 cm in diameter. This species also possess a wide 2-5 m long petiole; 1.5-3.5 m long fan-shaped leaves with 80-100 sharp-tipped segments; 3-6 m long panicle-like inflorescence at the top of stem/crown; creamy white flowers with strong scent; 2-2.5 cm wide round, green fruit and one 1-1.5 cm wide round seed (Flach & Rumawas 1996; Irawanto 2013).

Corypha utan has a wide natural distribution, mostly in the tropics from Andaman Islands to Assam and North Australia (Govaerts *et al.* 2020). In Indonesia, it can be found in Sumatra, Kalimantan, Java, Sulawesi, Nusa Tenggara and also in Papua. It commonly grows in open lowland areas, such as savanna or seasonal forests, between 1-200 m a.s.l., usually in a formation or group (Partomihardjo & Naiola 2009).

Recent reports show that local people have been extracting *Corypha utan,* among other uses, to produce starch similar to swamp sago (Naiola *et al.* 2007; Eagleton 2016). For starch production, the tree needs to be cut down prior to flowering, which does not only reduce its natural population, but also hinder its regeneration due to the lack of fruiting trees.

A study in the hilly area of Kupang, southern part of East Nusa Tenggara Province showed that the population of *C. utan* was lower than that of the more flattened areas (Partomihardjo & Naiola, 2009). Unfortunately, the population numbers in other areas, particularly northern East Nusa Tenggara was still unknown. Information on the current population, dispersion pattern and seedling performances still remain scarce, even though such information is important for its sustainability, considering the heavy exploitation of the species for starch consumption.

MATERIALS AND METHODS

Data Collection

A one-hectare plot (9°44′22.95″S, 124°44′15.61″E) was established in October 2009 at the Oele'u Village, Ayatupas District, Timor Tengah Selatan Regency, East Nusa Tenggara Province (Fig. 1). The plot was intended to estimate the population density, distribution and structure of *Corypha utan*. The plot was divided into four sub plots of 0.25 ha (50 x 50 m) each. All individuals in each subplot was enumerated and classified into four different classes following Partomihardjo & Naiola (2009), namely seedlings (<1 m height), juvenile (1-5 m height), mature/productive (>5 m height) and post-flowering.

Meanwhile, in Bogor Botanical Gardens, Indonesia ten square plots (1 m^2) were simultaneously established for monitoring the seedling performance. Two different treatments were applied i.e., weeded (all suspected weeds were totally removed) and un-weeded (no suspected weeds were removed). Thus, a total of ten plots were used at five plots per treatments. Each plot had 3 to 8 seedlings depending on its availability during experiment. Naturally grown seedlings were used and the plots were established under field condition with direct sunlight and rainfall exposure. The number of leaves, height and survival rate of the seedlings were measured.

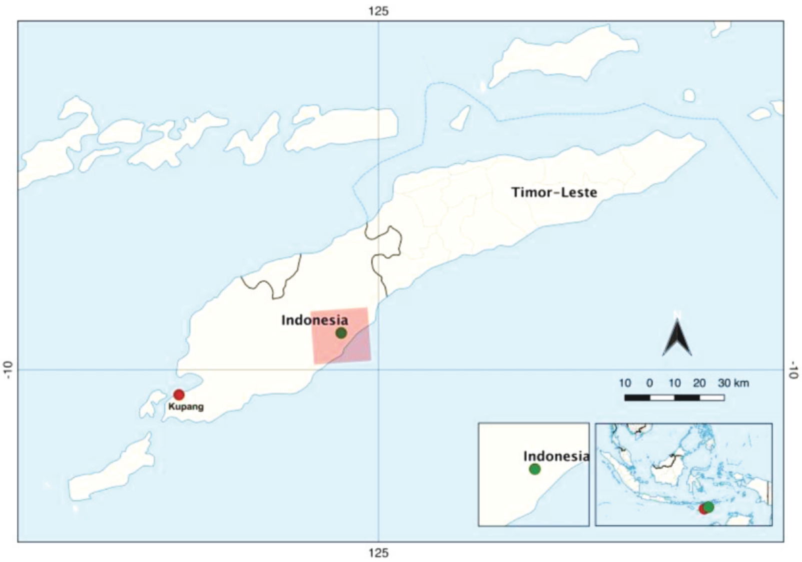

Figure 1 Study area in East Nusa Tenggara Province, Indonesia (plots were indicated with green dot)

Data Analysis

All individuals inside all the plots were enumerated and summed up to get the population size for each class. Spatial dispersion was calculated using Standardized Morisita Index [Ip] (Smith-Gill 1975), with index values ranging from -1.0 to +1.0. Generally, zero index indicates random pattern, above zero means clumped pattern and index below zero signifies regular pattern. Chi-squared test was applied to test the deviation of the index from random expectation. If p-value is > 0.05, the Morisita index [Ip] indicated random pattern, but if p-value is < 0.05, the index meant either clumped (Ip > 0) or regular (Ip < 0) (Krebs 1999). The seedling performance was analyzed for survival rates, number of leaves and height growth using the Mann-Whitney-Wilcoxon test. Computation and analyses were performed in Excel and R software using standard stats 3.4.3 package (R Core Team 2015) and vegan 2.5-1 package (Oksanen *et al.* 2018).

RESULTS AND DISCUSSION

Population Structure

The population structure of *Corypha utan* revealed that 2 post-flowering trees, 31 mature trees, 63 juveniles and 2,211 seedlings were found in the one-hectare plot. The number of mature trees was lower than those found by Partomihardjo and Naiola (2009), where within the two plots of one-hectare each 71 and 147 mature trees were present, respectively. In contrast, the number of juveniles in this study was higher than that in Plot I in the study of Partomihardjo and Naiola (2009). Similarly, the number of seedlings was fourfold higher than in the former study, indicating that early stage predation or leaf herbivory was not the problem.

However, the late stage growth experienced a bottleneck. The number of individuals at the juvenile stage dramatically decreased to 2.8% of those at seedling stage and only 1.4% of the seedlings survived until maturity or adult stage (Fig. 2). In the previous study, the pattern was better with more than 10% of seedlings in the plots becoming juvenile and mature trees. Furthermore, both studies suggested that a low survival rate was experienced during the transition from seedlings to juvenile stage.

A minor difference in the population structure pattern was also observed between this study and that of Partomihardjo and Naiola (2009). In the earlier study the number of adults/mature trees were slightly higher than those at the juvenile stage; while in the current study the number of mature trees were lower than juvenile trees, showing a reverse J-shaped (Barbour *et al.* 1987). This reversed J-shaped pattern was also observed in *Pinus torreyana* in USA (Franklin & Santos 2011), *Abies spectabilis* in Nepal (Chhetri *et al.* 2016) and in *Brahea armata* in Mexico (Wehncke *et al.* 2010). The pattern also indicated that *Corypha utan* populations show variations in survival rates.

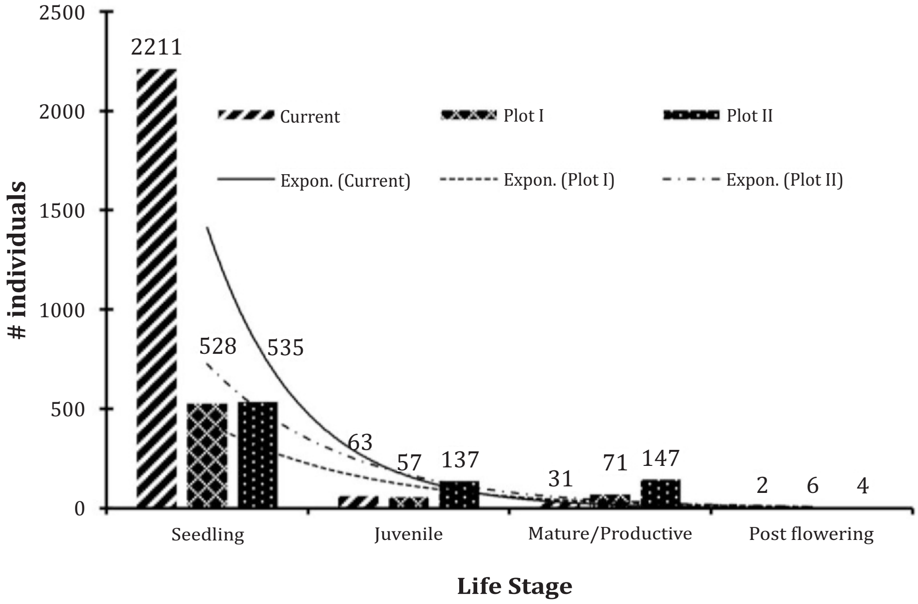

Figure 2 Population structure of *Corypha utan* in the current study and study by Partomihardjo and Naiola (2009) (Plot I and Plot II)

Historical and present use of *Corypha utan* was also likely responsible for the variation in survival rates of the populations. The study area was very close to the village where local people exploit the palm for daily needs. Utilization of their leaves and trunks resulted in the low number of mature trees. Utilization also had a severe impact on the population structure of the African palms (Blach-Overgaard *et al.* 2015). Livestock browsing also produced a similar impact on the plant population. However, this was not the case for *C. utan* as there was no report of livestock browsing in the study area.

Dispersion

The dispersion pattern of *C. utan* was considered clumped for seedlings and juveniles, but shifted to random when they reach maturity and post-flowering stage (Table 1). A similar pattern was reported by Partomihardjo and Naiola (2009), however, in the current study clumping was not only found in the seedling stage, but also among the juveniles. A clumped pattern is commonly observed among tropical and subtropical plant species (Lan *et al* 2012; Franklin & Santos 2011; Guarin *et al.* 2014; Dounavi *et al.* 2010).

The spatial patterns observed among the seedlings and adult individuals of *Corypha utan* are a result of many natural phenomena. Firstly, the suitable soil hypothesis explains that within the plots where *C. utan* are growing in clumps, the soils are relatively nutrient-rich with mid C/N ratio and high cation exchange capacity (CEC) (Partomihardjo & Naiola 2009). This condition also likely occurred in the study area, whereby many other abundant species are growing together with *C. utan*. High nutrient availability in localized spots within the plot facilitates the clustering of seedlings.

Table 1 The standardized Morisita index (Ip) of *Corypha utan* population in East Nusa Tenggara Province

Stage	Standardized Morisita Index (Ip)	p (χ^2)	Dispersion pattern
Seedlings	0.56	3.4×10^{-192}	Clumped
Juvenile	0.6	1.62×10^{-10}	Clumped
Mature/Productive	-0.06	4.4×10^{-01}	Random
Post flowering	-0.18	5.7×10^{-01}	Random

Secondly, the dispersal syndrome which suggests that plant species with a clump distribution tends to have limited dispersal (Lan *et al.* 2012; Franklin & Santos 2011). The clump size of plant populations dispersed by animals is determined by seed size (Lan *et al.* 2012). Although various animals, like mammal and birds, distribute seeds of *C. utan*, there is probably a lack of animal dispersal in East Nusa Tenggara Province. Thus, the seeds were not widely dispersed. Furthermore, the seeds of *C. utan* tend to concentrate in a radius of 10 m around the mother tree (Partomihardjo & Naiola 2009).

Thirdly, the mass fruiting event. *Corypha utan* is a hapaxanthic plant which produce flowers and fruits once in their lifetime and soon dies thereafter (Flach & Rumawas 1996). During the fruiting time, *C. utan* produces 250,000 to 350,000 fruits, yet with a very low germination percentage (Partomihardjo & Naiola 2009). The massive number of fruits in the infructescence will likely cause a great number of seed fall around the mother tree. Eventually, those seeds will germinate and become seedlings growing in clumps.

The random pattern among the mature and post flowering *C. utan* plants was also reported in another study, accordingly, due to the density-dependent factor (Franklin & Santos 2011). Intraspecific competition, which is a direct consequence of higher density in the population, must have occurred more intensively resulting in the mortality of seedlings. A self-thinning mechanism consequently occurred where only the seedlings with higher survival ability can outcompete their siblings. Lastly, another possible reason is seedling predation. However, only cattle predation was reported to have occurred in the study area (Partomihardjo & Naiola 2009). Yet, it is still unconfirmed if predation was the probable cause.

Seedling Performances

The *Corypha utan* seedlings reacted differently to the maintenance treatments (weeded and un-weeded) (Mann-Whitney-Wilcoxon $W = 24$, $p < 0.001$) (Fig. 3). Survival rate was significantly higher when the weeds inside the plots were eradicated (95%) than when the plots remained un-weeded (50%), suggesting that maintenance treatment is important in the survival of *C. utan* seedlings.

Moreover, the number of leaves and growth rates were significantly different between the maintenance treatments (Mann-Whitney-Wilcoxon $W = 25$, $p < 0.001$ and $W = 25$, $p < 0.001$, respectively). On the average, seedlings in weeded plots have more leaves than in the un-weeded plots. Similarly, seedlings in the weeded plot have higher height increments than in the un-weeded plots, an almost four-folds difference (Fig. 4).

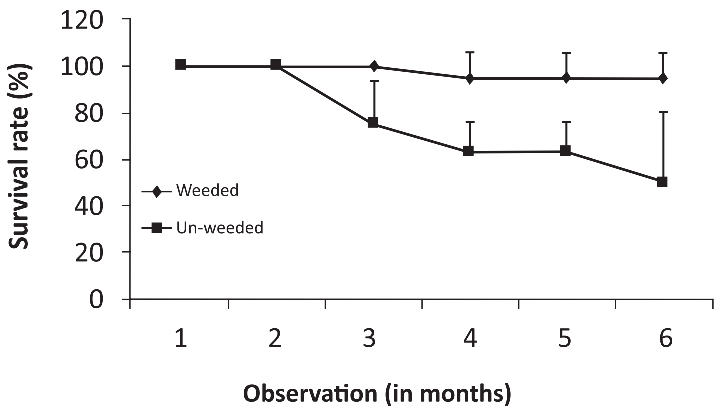

Figure 3 Survival percentage of *Corypha utan* seedlings under weeded and un-weeded conditions
Note: Error bar indicates standard deviations, n = 10.

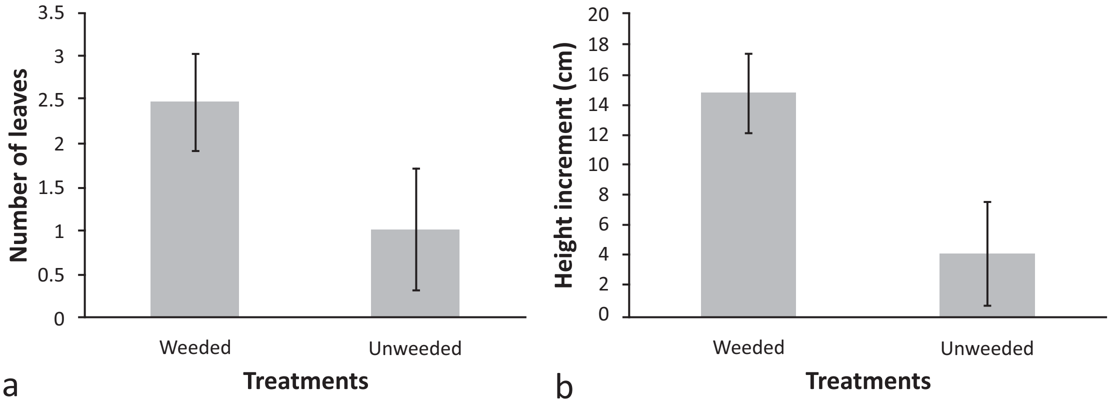

Figure 4 Number of leaves (a) and height increment (b) of *Corypha utan* seedlings under two different management treatments (error bars indicate standard deviation, n = 10)

Competition between *Corypha utan* seedlings and some grass species probably lowered the survival rates in the un-weeded plots. Some grass species, like *Paspalum* sp. were relatively abundant in the experimental plots, and even more abundant than the *C. utan* seedlings in some plots. In similar studies, grass competition affected sapling development in some savanna species (Vadigi & Ward 2013) yet, the root depth of the species also influenced the level of competition in the communities (Holdo & Brocato 2015).

The competition between grass and other species varies across time and space as well as the species themselves (Holdo & Brocato 2015). However, this study shows that grasses affected the survival rates of *C. utan*, whereas in the study of Vadigi and Ward (2013), the grasses did not affect the survival rates.

CONCLUSION

In spite of stem extraction for starch production, the population structure of *Corypha utan* in East Nusa Tenggara Province is in a stable condition. Abundant seedlings found in the study areas will ensure future regeneration. However, the shifting of dispersion pattern from clumped to random indicated some mortality of seedlings during the growing periods which also suggested high levels of competition among species, particularly with the grasses. The transition between seedlings to adult trees is an important period in the *C. utan* life cycle. Therefore, to ensure a harvestable crop, maintenance must be undertaken during this transition period to increase the survival rates and growth performance of *C. utan* seedlings, either by weeding or translocating the seedlings to other places. Finally, *C. utan* is a potential alternative food crop to help build food security in Indonesia, particularly in dry areas such as Timor Island and the adjacent regions.

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