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Domestication of *Aframomum giganteum* K. Schum and *Aframomum melegueta* K.Schum in Yangambi pedoclimatic conditions, Democratic Republic of the Congo (DRC)

[Domestication of *Aframomum giganteum* K. Schum and *Aframomum melegueta* K. Schum in Yangambi pedoclimatic conditions, Democratic Republic of the Congo (DRC)]

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Abstract

This study focused on domestication of two species of Zingiberaceae, *Aframomum giganteum* K. Schum and *Aframomum melegueta* K.Schum in Yangambi pedoclimatic conditions, Democratic Republic of the Congo (DRC). The fruits of these two species are edible and widely consumed by local populations. The biological material used in this study consisted of the vegetative and generative seeds of these two species. The soil was amended with ow dung. Plant growth was evaluated and ethnobotanical study was conducted. Ethnobotanical results show that both species are used by local populations for food and the treatment of diseases. The results obtained show that the two species have similar germination rates, 40.25% and 42.67% for A. *gigateum* and A. *melegueta,* respectively. Significantly higher survival rates were observed in *Aframomum gigantism* (83.78%) compared to *Aframomum melegueta* (10.34%). The average monthly diameter growth is 20.32 cm for the two species and the stem diameters at the base range from 2.02 to 6.92 cm. The integration of *Zingiberaceae* into permaculture systems can improve yields of food crops, as suggested by the results of the study. The sucess of in situ and ex situ cultivation of these two species is a promising solution for the sustainable of biodiverty.

Keywords : Domestication, *Aframomum*, germination, *Zingibéracées*, semence

Résumé

Cette étude porte sur la domestication de deux espèces de *Zingibéracées*, *Aframomum giganteum* K. Schum et *Aframomum melegueta* K. Schum, dans les conditions pédoclimatiques de Yangambi, en République démocratique du Congo (RDC). Les fruits de ces deux espèces sont comestibles et largement consommés par les populations locales. Le matériel biologique utilisé dans cette étude était constitué des semences végétatives et génératives de ces deux espèces. Le sol a d'abord été enrichi avec de la bouse de vache, puis la croissance des plantes a été évaluée. Une étude ethnobotanique a également été réalisée. Les résultats obtenus indiquent que les communautés locales recourent à ces deux espèces tant pour se nourrir que pour lutter contre plusieurs maladies. Les deux espèces présentent des taux de germination similaires, soit 40,25 % et 42,6 % pour *Aframomum giganteum* et *Aframomum melegueta*, respectivement. Des taux de survie significativement plus élevés ont été observés chez *Aframomum giganteum* (83,78 %) par rapport à *Aframomum melegueta* (10,34 %). La croissance moyenne mensuelle en diamètre est de 20,32 cm pour les deux espèces, et les diamètres des tiges à la base varient de 2,02 à 6,92 cm. L'intégration des Zingibéracées dans les systèmes de permaculture peut améliorer les rendements des cultures vivrières, comme le suggèrent les résultats de cette étude. Le succès de la culture in situ et ex situ de ces deux espèces constitue une solution prometteuse pour la durabilité de la biodiversité.

Mots-clés : Domestication, *Aframomum*, germination, *Zingibéracées*, semence

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1. Introduction

The forests of the Democratic Republic of Congo (DRC) are home to several plant species that are exploited by local populations to meet their basic needs, including food and treatment of certain diseases. These plant resources are extracted from their habitats without any effort to implement domestication policies, which could have allowed for sustainable management of these multi-purpose resources (Ntalakwa et al (2022), Dhetchuvi et al (1990); Belesi (2009), Lubini (2022). This way of considering natural resources as inexhaustible poses a risk of biodiversity loss. Among the exploited species are *Zingiberaceae*, which are used for their edible fruits and other organs used in traditional medicine. Among the *Zingiberaceae* are *Aframomum* species Ivan et al (2015), Doucet et al. (2021). This mode of exploitation cannot guarantee any form of regularity, quality, and quantity of production. The resources are therefore unable to keep up with the growing demand FAO (2009). As a result, the most sought-after and endemic resources are becoming scarce. This research aims to valorize *Aframomum giganteum* and *Aframomum melegueta* species by domesticating them in the pedoclimatic conditions of Yangambi, in the Democratic Republic of the Congo. Domesticating these wild species and integrating them into traditionally cultivated species will contribute to increasing the number of varieties of cultivated species in the DRC and will improve access to fruits from these species.

2. Material and methods

2.1. Study area: Yangambi Biosphere Reserve (YBR)

2.1.1 Geographic location

This study was conducted in biosphere reserve is located in the Congo River basin, in the northeast of the Cuvette centrale, and is bathed by the Congo River, about 100 km west of the city of Kisangani, in the Tshopo province, Democratic Republic of the Congo. The total area of the Yangambi forest reserve is approximately 245,000 ha, including indigenous enclaves (4,300 ha).

The geographic boundaries of the YBR are between 24°18' and 25°08' East longitude and 00°43' and 01°08' North latitude, thus situating the reserve near the Equator Toirambe (2011), Tulonde (2013), Tulonde (2015). The altitudes range from 400 to 550 meters. The location and boundaries of the reserve are shown in figure 1.

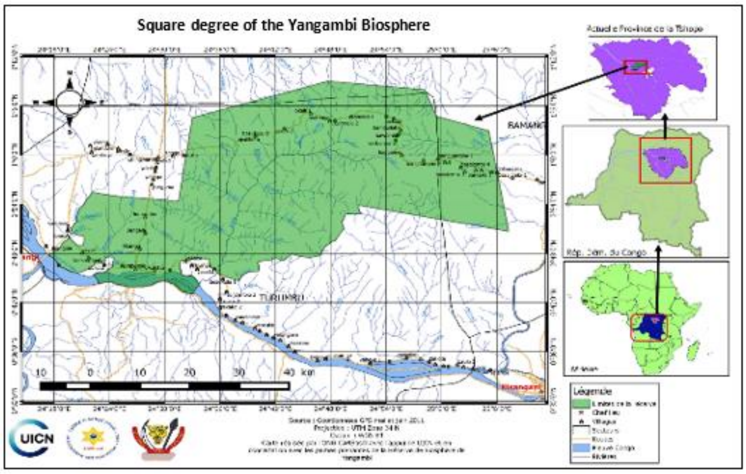
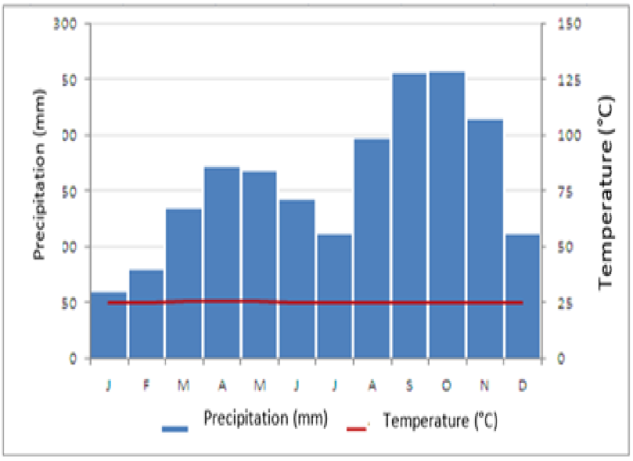


Figure 1. Geographic location of Yangambi Biosphere Reserve (Tulonde, 2013)

2.1. Climate

The Yangambi region has an equatorial climate of type Af, according to the Köppen classification. This area is characterized by average annual rainfall of around 1500 mm to 2000 mm, with an average temperature of 25.3°C. Figure 2 shows the annual evolution of temperature and rainfall in the Yangambi Reserve.



2.2. Geological and pedological conditions

The deep geological substrate in the Yangambi region consists of the Loya stage attributed to the upper jurassic and composed of a mixture of sandstone and red clay, marl, and limestone. The soils of Yangambi are mainly formed from aeolian sediments, composed of quartz sand, kaolinitic clay, and free iron oxides more or less hydrated. They are classified according to WRB (World Reference Base for soil resources) as Haplic Ferralsol (Dystric, Xanthic) and Hygroferralsol, yellow, according to the INEAC classification (Lubini, 1982). The vast majority of the biosphere reserve is formed from old ferralitic soils, favored by advanced weathering of all primary minerals, due to the climatic conditions of the humid tropics (hot and rainy climate). The recent, hydromorphic, weakly evolved soils are the most fertile and occupy only the low-lying part of the area, poorly drained and corresponding to the valleys and tributaries of the Congo River.

2.3. Ethnobotanical survey

The ethnobotanical survey made it possible to evaluate the endogenous knowledge of the populations of Yangambi on the uses of products from these two species of *Aframomum giganteum* and *Aframomum melegueta*. We thus identified and selected farmers and phytotherapists meeting our requirements to participate in the activities of our study. In this approach, the main criteria for selecting participants in this study were availability and level of education (6 years post-primary). The selected participants were trained in all aspects of the study and then assigned to appropriate tasks including the required tools, according to the organizational structure of the project. Survey questionnaires were developed for conducting the surveys

2.4. Biological material

The biological material used for this study was vegetative and generative seeds of *Aframomum giganteum* and *Aframomum melegueta*. These seeds were used for domestication trials and botanical description of the latter. The seeds and rhizomes used for domestication were from local sources (Yangambi) for *Aframomum giganteum* or came from the Bateke plateau (Kinshasa Province) for *Aframonium melegueta*.

2.5. Experimental design

The experimental design (D), representing the cultural space, was rectangular in shape with 100 m in length and 30 m in width. This design was subdivided into sub-designs (SD), each sub-design into three blocks (B1, B2, and B3), and each block into 12 plots of 2 m x 2 m, separated from each other by 1 m. The SDs are separated from each other by 4 m and the blocks are separated by 2 m. The nursery for these two species was installed about 70 m from the Congo River for water availability for irrigation. The soil of the site was clay-loamy and hosted a grassy fallow dominated by Poaceae, *Cyperaceae* and *Fabaceae.*

2.6. Pre-cultural work and plantation

For the transplantation or cultivation of the plants of the species under study, preliminary land preparation work was carried out. This involved weeding and tilling of the land, making up the experimental setup. The soil was fertilized with cow dung. The seedlings were transported to the experimental setup in poly bags. The planting consisted of setting up plants from the nursery and rhizomes, with spacings of 1 m x 1 m. The *Aframomum* were planted with associated food crops of the region, namely cassava, soybeans, and beans.

2.7. Phenology and measurement

The phenological phenomena taken into account are the dates of sowing, germination, germination rate, and the appearance of plant organs. Periodic measurements were carried out in relation to plant growth. Thus, height, collar diameter, and leaf area were measured. Measuring equipment was used, including an analytical balance, caliper, GPS, tape measure, and some agricultural equipment.

3. Résults

3.1. Ethnobotanical survey on Aframomum giganteum and Aframomum melegueta

The results of the ethnobotanical survey on the medical use of two *Aframomum* species are presented in table I.

Table I. Results of the ethnobotanical survey on the medical use of two Aframomum species

Tribe and vernacular name	Disease	Organs used	Preparation mode
Basoko (Tondolo)	Hemorrhoids and cough	Leaf and rhizome	Ground leaves and rhizome
Turumbu (lososo, or Soso),	Hemorrhoids	Rhizome	Grind and made into a suppository
Mbole (soso, tondo),	Sore throat and cough	Leaf and rhizome	Dried, ground into a powder, and mixed with coffee
Topoke (Soso)	Hemorrhoids and the flu	Leaf, rhizome, fruit	Ground and made into a suppository
Ngando (Soso, Tondo)	Intestinal worms and measles	Leaf, rhizome	Dried, ground into a powder, and mixed with coffee or tea
Lokele (Soso)	Asthma and chickenpox	Leaf and rhizome	Consumed raw Preparation Method

It appears from this table that the leaves, rhizomes, and fruits are used for medicinal purposes by local populations for the treatment of certain diseases. The list of diseases concerned includes hemorrhoids, cough, flu, asthma, and angina.

3.2 Germination and recovery rates

Table II. Statistical analyses of the germination rate of Zingiberaceae

Statistical parameter	Value	Interpretation
Germination rate *A. giganteum*	40.25%	Moderate germination performance
Germination rate *A. melegueta*	42.67%	Slightly higher
Absolute difference	2.42 %	Small inter-species gap
Relative difference	6.01%	Species comparable in germination
Inter-species mean	41.46%	Global reference
Non-germinated seeds (*A. gig.*)	59.75%	Significant germination loss
Non-germinated seeds (*A. mel.*)	57.33%	Significant germination loss

Table III. Statistical analyses of the recovery rate of Zingiberaceae

Statistical parameter	Value	Interpretation
Reestablishment rate *A. giganteum*	83.78%	Excellent vegetative ability
Reestablishment rate *A. melegueta*	10.34%	Very low biological viability
Absolute difference	73.44%	Very large inter-species gap
Ratio *A. gig.* / *A. mel.*	8.10×	*A. giganteum* ~8× more performant
Cuttings *A. giganteum*	3 700	Very representative sample
Cuttings re-established	3 100	83.78% success
Cuttings *A. melegueta*	58	Limited sample

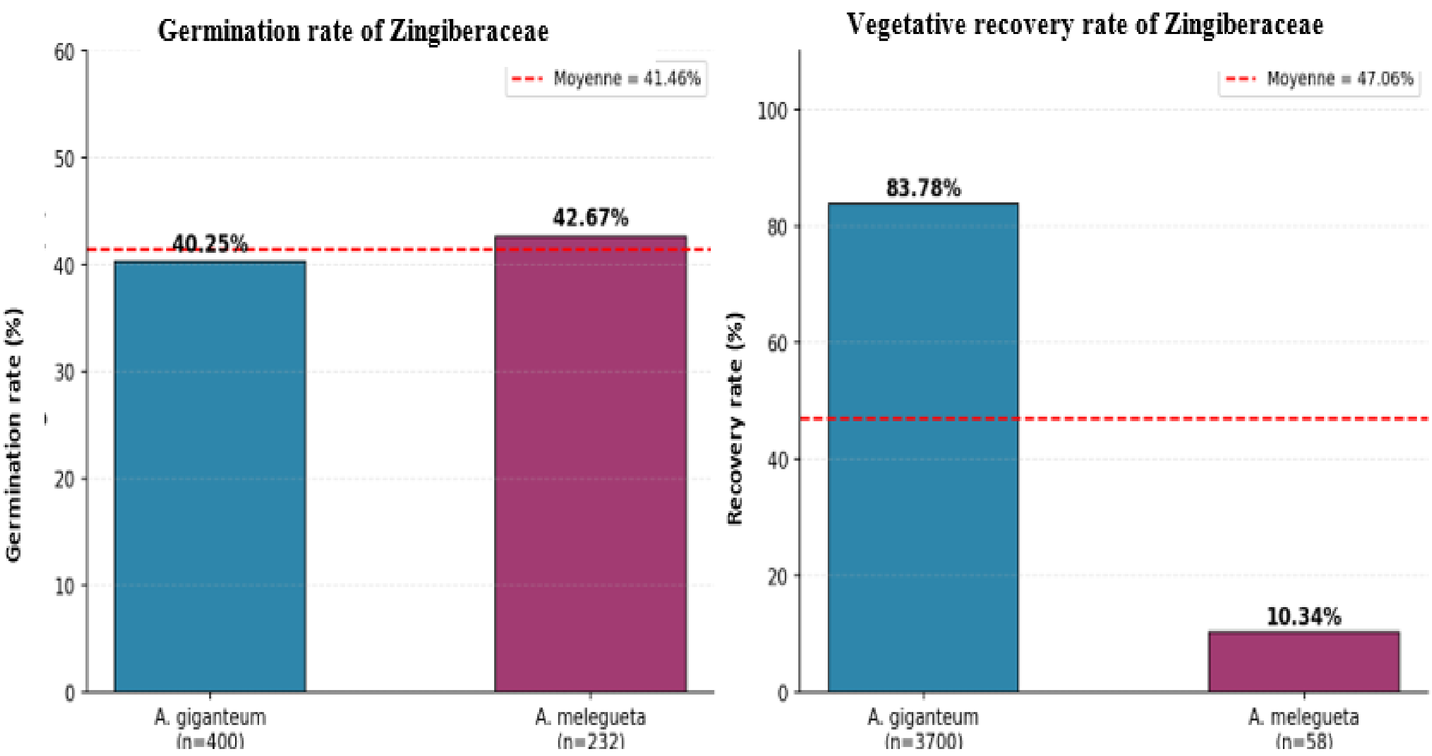


Figure 3. Germination and recovery rates of Zingiberaceae

The germination and recovery rates are given in figure 3. Tables II and III give the statistical analyses of the germination and recovery rates of the two species. The results obtained show that the germination rates are 40.25% and 42.67% for A. *giganteum* and A. melegueta, respectively. The inter-species germination average is 41.46%. The recovery rate is 83.78% for A. giganteum and 10.34% for A. melegueta.

3.3. Evolution of emergence as a function of time

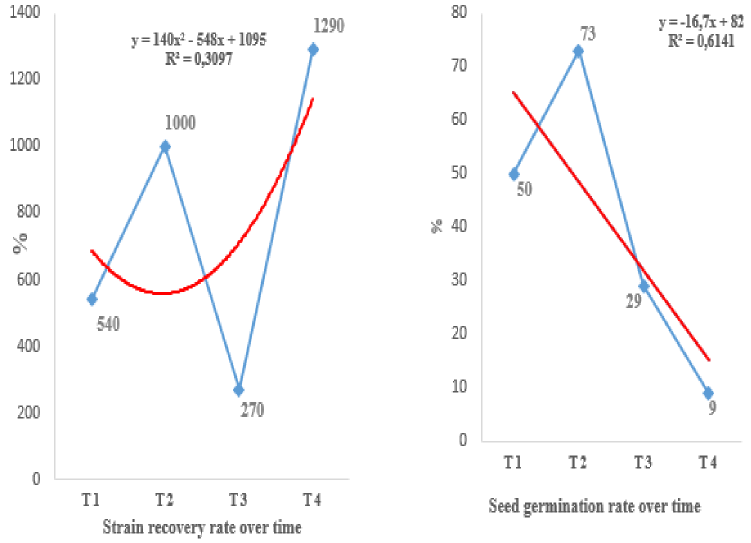


Figure 4. Evolution of the germination and emergence rate of cuttings as a function of time

Figure 4 shows the evolution of the germination and emergence rate of cuttings as a function of time: T1 (period of 6 to 11 days, T2 (12 to 17 days), T3 (18 to 23 days), and T4 (18 to 30 days).

3.3. Height growth of Zingiberaceae in the nursery.

Table IV. Statistical analyses of evolution of average height growth of Zinziberaceae

Statistical parameter	Value	Interpretation
Initial height (15/07	17.09 cm	Starting value in the nursery
Final height (30/10)	37.41 cm	Observed terminal value
Average total increase (ΔH)	20.32 cm	Net gain over 3.5 months
Overall growth rate	118.90%	Height approximately doubled
Average monthly growth	~5.81cm/ month	Consistent growth rate
Maximum growth phase	30/8 → 30/9	Consistent growth rate
Coefficient of variation (ΔH)	46.00%	High inter-individual variability

Table V. Statistical analysis of individual increements in height

Statistical parameter	Value	Interpretation
Sample size (n)	50 individuals	Representative sample
Mean (ΔH)	20.32 cm	Average gain per individual
Standard deviation (σ)	9.35 cm	Large dispersion
Median	18.65 cm	Actual central value
Minimum	5,0 cm (sample no. 40)	Low-growth individual
Maximum	41,3 cm (sample no. 22)	High-growth individual
Range	36.3 cm	High amplitude of variation
Skewness	0.555	Slight positive skew
Kurtosis	-0.418	Flattened distribution (platykurtic)
95% CI of the mean	[17.66 ; 22.98] cm	Confidence interval

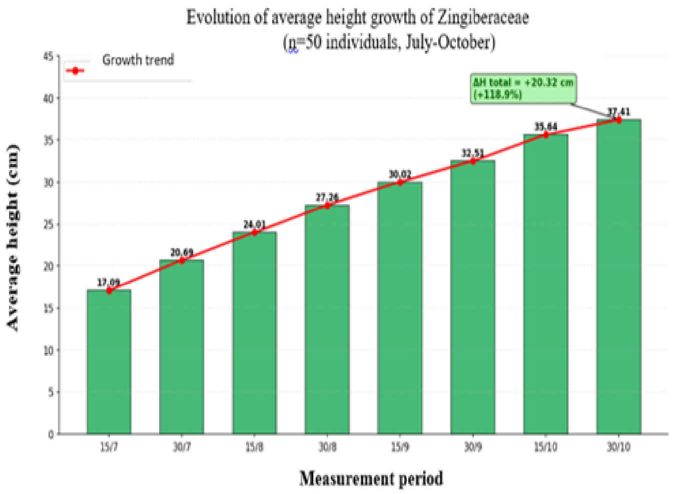


Figure 5. ***Evolution of average height growth of*** *Zingiberaceae (n=50)*

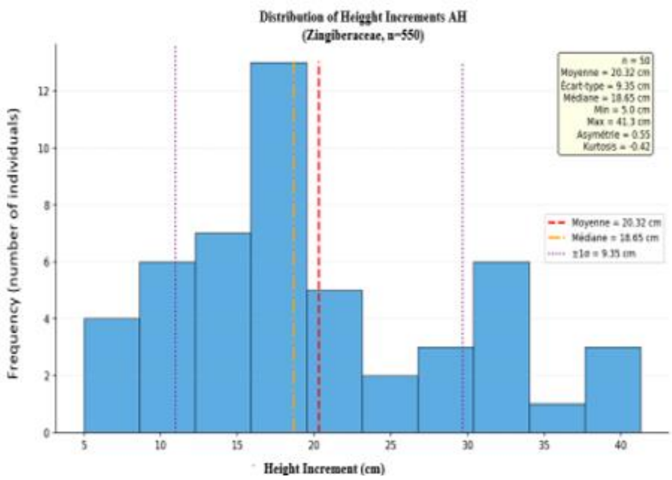


Figure 6. Distribution of individual increements in height (n=50)

Height growth was monitored on 50 individuals, from July to October, with eight bi-monthly measurements. Figures 5 and 6 show the determined height growth and individual increements in height, respectively. The statistical analyses of these two parameters are given in tables IV and V.

3.4 Growth in collar diameter

Table VI. Statistical analyses of evolution of the average diameter growth

Statistical parameter	Value	Interpretation
Initial diameter (15/07)	4.90 mm	Starting value in the nursery
Final diameter (30/08)	6.92 mm	Observed terminal value
Total increase (ΔD)	+2.02 mm	Net gain over 1.5 months
Overall growth rate	+41.2 %	Sustained diameter growth
Average bi-monthly growth	~0.67 mm / 15 days	Fastest growth phase
Acceleration phase 15/7→30/7	+1,02 mm	Very high individual
Coefficient of variation (ΔD)	60.20%	Variability

Table VII. Statistical analyses of increements in the average diameter growth

Statistical parameter	Value	Interpretation
Sample size (n)	50 individuals	Complete sample
Mean ΔD	2.02 mm	Average gain at the collar
Standard deviation (σ)	1.21 mm	High dispersion
Median	1.75 mm	Median
Minimum	0.13 mm (sample no. 28)	Near-zero growth
Maximum	6.08 mm (sample no. 38)	Individual with strong radial expansion
Coefficient of variation	60.20%	Marked heterogeneity
Max/Min ratio	46.8×	Extremely high dispersion

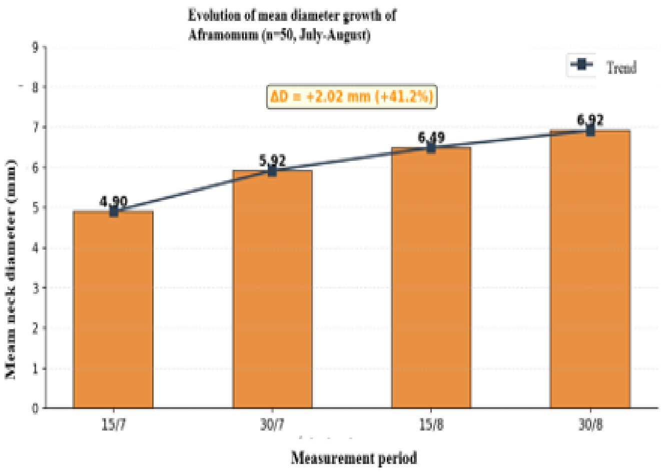


Figure 7. Evolution of the average diameter growth during the study period from July to August (n=50; twice a month)

The growth in collar diameter was measured on 50 individuals during the four aforementioned periods. Figure 7 shows the evolution of the average diameter growth during the study period from July to August. The statistical analyses of the temporal evolution of the diameter as well as the descriptive statistics of the increments are presented in tables VI and VII. The results obtained show that the collar diameter increases from 4.90 cm to 6.92 cm in 45 days, i.e. an increase of 41.2 %.):

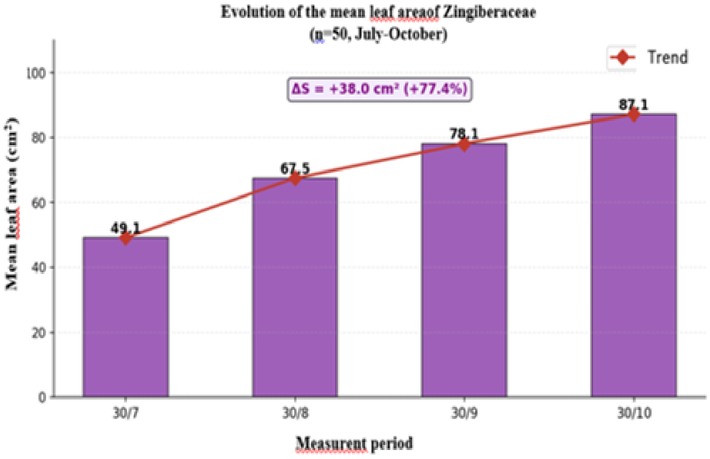


Figure 8. Evolution of the mean leaf area of Zingiberaceae (n=50; juillet-octobre)

The leaf area (S = L x l x 0.72) was measured at 4 key dates. Figure 8 shows the evolution of the leaf area of the species under study during the observation period. It is observed that the leaf area follows an almost linear progression over the three months of observation (+77.4% in total). The inter-individual variation remains significant (ΔS varies from 0.2 to 100.5 cm^2), reflecting the differential development capacities within the species. Figures 9 to 11 show photographs of the cultivated species.

Figure 9. Aframomum seedlings in the nursery

Figure 10. Growth of Aframomum plants in the field

Figure 11. Aframomum fruit production in the field

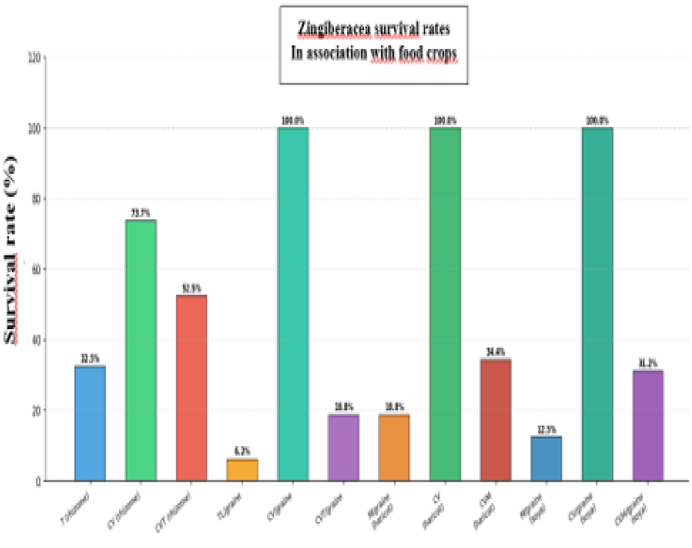


Figure 12. Recovery rates of Aframonium giganteum and Aframonium melegueta in association with food croops

The recovery rates obtained for the two species under study are given in figure 12. In light of the results obtained, it appears that food crops (cassava and soybean) have a facilitating effect on the recovery of A. giganteum. The FC (food crops) modality by rhizome reaches 73.7% against 32.5% for A. giganteum monoculture (+41.2%) (figure 12). The FC modality by seed reaches 100% recovery for cassava. The treatment by seed in isolated condition (6.25%) is extremely low.

3.6. Yields in food crops in isolated culture or in association with Zingiberaceae

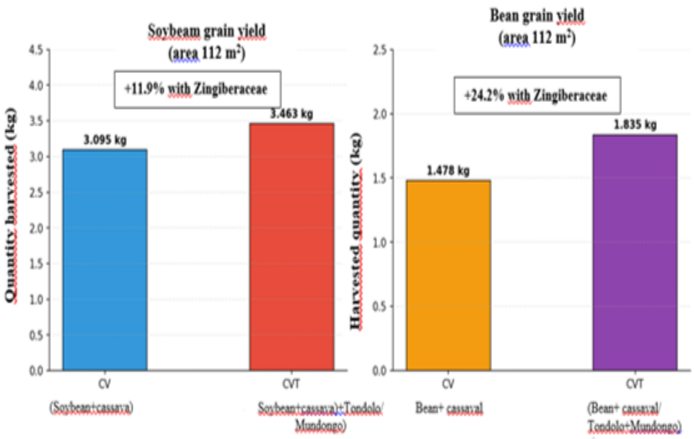


Figure 13. Yields of food crops in isolated culture or in association with Zingiberaceae.

The yields of food crops were evaluated in isolated culture or in association with Zingiberaceae. The results obtained are shown in figure 13. The results show that food crops generate a beneficial effect as measured by the yields obtained. The improvement in yield is 11.89% for soybean and 24.15% for bean.

4. Discussion

The leaves of Zingiberaceae are the most use by the local communities of Yangambi for the treatment of many afflictions (table I). Karmelie et al. (2016); Kambale (2021), also reported that the leaves and rizhomes of Aframomum are often used in traditional medecine for the treatment of certain diseases.

Observations made in nurseries show that the seeds of *Aframomum giganteum* and *Aframomum melegueta* have hypogeal germination. The two species have a similar germinative capacity (tables II and III; figures 3 and 4). The germination rates lower than 50% obtained indicate that the majority of seeds do not reach the germination stage, which is consistent with biological characteristics.

The results obtained show that the germination rate varies depending on the species and the method of propagation (seeds or rhizomes). In Aframomum giganteum, the germination rate is significantly lower than the vegetative recovery rate. Conversely, in *Aframomum melegueta*, the germination rate is relatively close to that of A. giganteum, but the vegetative recovery is very low. These observations confirm that vegetative propagation by rhizome is more effective in certain *Aframomum* species, particularly A. giganteum. Similar results were reported by Tchoundjeu et al (2002), Chen (2022) and Yaradua (2025), who showed that several species of tropical rhizome plants have better vegetative regeneration than germinative regeneration, due to seed dormancy and physiological constraints.

Regarding the germination rate, the rates obtained remain relatively moderate. This could be explained by the presence of hard seed coats and dormancy phenomena, as reported by Oni (2005), who indicates that Zingiberaceae seeds often require pre-treatments to improve their germination. Futhermore, the low vegetative recovery observed in A. melegueta (table III and figure 3) could be linked to increased sensitivity to environmental conditions or the quality of the rhizomes used (Ana et al,2010; Anjah, 2020). The success of multiplication depends heavily according on factors such as soil humidity, rhizome maturity, and agro-ecological conditions. Addionally, work on *Zingiberaceae*, particularly that of Heller (1996), shows that species of the genus *Aframomum* exhibit great interspecific variability in their regeneration capacity, which could explain the differences observed between the two species. These results may be explained by species-specific differences in root architecture and physiological tolerance, conferring *Aframomum giganteum* advantage under the tested climatic and soil conditions (Ngakegni, 2013).

The asymmetric distribution of height increments of plants indicates that the majority of individuals are concentrated in size values below the average. The high standard deviation observed reflects intra-population variability, reflecting genetic differences or differential responses to nursery conditions (figures 5). The high rate of increase in diameter reflects active root and culinary development (tables VI and VII).

The continuous growth of leaf area indicates increasing photosynthetic activity and regular vegetative expansion. The remarkable progression during the first period of growth corresponds to a phase of intense foliar development (figures VII and VIII). The results obtained show the superiority of the vegetative propagation compared to the germinative propagation of Zingiberaceae studies.

The increase in the recovery of A. giganteum and A. melegueta obtained in association with food crops indicates that food crops have a gowth-facitating effect on *Aframomum* recovery (figure 12). This may be due to the improvement of soil quality by these food crops species.

The improved yields in food crops obtained by associating the cultivation of Zingiberaceae suggest that permaculture integrating these species represents an advantageous agronomic strategy (figure 13). These gains can be explained by an improvement in soil properties, a limitation of water erosion or a positive allelopathic effect of *Zingiberaceae* on associated crops. It emerges from this study that the domestication of local species contributes to the enhancement of resources, as reported by other authors (Nkongmeneck et al., 2017; Abondo et al. , 1995 ; Mialundama et al., 2006 ; FAO, 2010 ; Zakaria, 2012 ; Mbandu, 2021 ; Ntalakwa et al., 2022).

5. Conclusion

The results of the study on the domestication of Zingiberaceae show that vegetative propagation is more effective than germination for the cultivation of these plants. Indeed, the germination rates lower than 50% obtained for *Aframomum giganteum* and *Aframomum melegueta* indicate that the majority of seeds do not reach the germination stage. In contrast, vegetative propagation allows for continuous growth of leaf area, indicating increasing photosynthetic activity and regular vegetative expansion. The integration of *Zingiberaceae* into permaculture systems can improve yields of food crops, as suggested by the results of the study. The gains obtained can be attributed to an improvement in soil properties, a limitation of water erosion or a positive allelopathic effect of Zingiberaceae on associated food crops.

These results highlight the importance of domestication of *Zingiberaceae* for sustainable agriculture and biodiversity conservation. However, further research is needed to optimize domestication protocols, evaluate the environmental and social impacts of this practice, and develop strategies to improve productivity and quality of products derived from these plants. Additionally, the domestication of *Zingiberaceae* could also contribute to the valorization of traditional knowledge and the improvement of living conditions of local communities that use these plants for their medicinal and culinary properties. The cultivation and commercialization of these plants could generate additional income for these communities and promote biodiversity conservation.

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Conflict of interest

The authors declare that they have no competing interests.

Ethical Considerations

This article was prepared in accordance with ethical research principles, ensuring compliance with current standards

Authors' Contributions

M.Z.T. and H.K.B. actively participated in the fieldwork and data collection.

J.M. L, O. K, T.M. N, E.N. K, F.L. L, B.W.T and A.K.M.K contributed to data analysis and discussion of results.

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