

INFLUENCE OF TREE AND GROUND FRUIT SEEDS ON THE GERMINATION AND SEEDLING TRAITS OF DEWANDARU (*EUGENIA UNIFLORA* L.) FROM THE TABANAN DISTRICT, BALI ISLAND, INDONESIA

Farid Kuswantoro

Received: July 19, 2024; Revised: October 17, 2024; Accepted: November 04, 2024

Abstract

Eugenia uniflora is an exotic fruit species with significant health benefits and considerable ornamental potential. Although substantial research has been conducted on *E. uniflora* germination, there remains a need for further study on this species' generative propagation to address unexplored aspects of its reproductive processes. Thus, this study aims to describe *E. uniflora* germination and seedling biology and the impact of tree and ground fruit seeds on the germination and seedling parameters of the plant species from the Indonesian population. This study employs a completely randomised design of three replications for its germination and seedling parameters trial. Germination parameters, including final germination percentage (FGP), time for 10% (T10), 50% (T50), and 90% (T90) seed germination, and infected seed percentage, were calculated along with seedling parameters such as mean shoot length (MSL), mean root length (MRL), mean total length (MTL), vigour index, and growth index. Quantitative analysis followed by student's statistical analysis was conducted for these parameters. Descriptive analysis was also performed to study the *E. uniflora* germination process, germination type, and seedling functional type. This study shows that *E. uniflora* has hypogeal germination. Cryptocotylar, hypogeal, and reserve storage seedling functional types were observed. Seed harvested from tree and ground fruit does not exhibit significant differences in all germination and seedling parameters. However, this study found that seed infection was also present in ground fruit seeds. The results of this study fill knowledge gaps that support the sustainable use of *E. uniflora*.

Keywords: Germination; Infection; Myrtaceae; Seedling; Surinam cherry

Introduction

Fruit is an integral part of a healthy human diet. The consumption of various popular fruits is reported to offer numerous health benefits (Leelarungrayub *et al.*, 2019). However, some underutilised fruits may also provide comparable health benefits, as they contain beneficial chemical compounds (Figueira *et al.*, 2021; Surya *et al.*, 2023). *Eugenia uniflora* is an example of an underused fruit with enormous health benefits (Figueira *et al.*, 2021).

Eugenia uniflora is a plant species belonging to the myrtle (Myrtaceae) family, originating from the South American continent and cultivated worldwide (Fidelis *et al.*, 2022). *E. uniflora* is a multipurpose slender tree known by several local names, including Pitanga in Brazil and Dewandaru in Indonesia (Fidelis *et al.*, 2022; Devi *et al.*, 2023). The plant also exhibits various pharmacological activities, including antibacterial, antiviral, and antioxidant properties (Fidelis *et al.*, 2022; Ferreira *et al.*, 2023). *E. uniflora* also holds enormous landscape and environmental potential (Griebeler *et al.*, 2022).

The significant potential of *E. uniflora* suggests that identifying an appropriate propagation method is essential to support its sustainable use. Studies found that *E. uniflora* might be propagated through cutting and in-vitro methods (Cipriano *et al.*, 2022; Franco *et al.*, 2024). However, numerous other studies focus on the generative propagation of *E. uniflora* (Inocente and Barbedo, 2019; Pavithra *et al.*, 2020; Jones *et al.*, 2023). This condition is understandable, as seed propagation is a natural regeneration method for *E. uniflora*.

The generative propagation of *E. uniflora* requires further investigation, as several aspects remain unexplored. For instance, the germinability of this species in the Indonesian population has yet to be thoroughly researched. The determination of *E. uniflora*'s germination and seedling functional types also needs further study, as these traits provide vital information about the plant's ecological adaptations. Similar traits have already been studied in other exotic fruit species, such as *Inga edulis* (Kuswanto and Li'aini, 2021). In addition to these reasons, studying the effect of seed harvest sources specifically, tree and ground fruit on the germination and seedling parameters of *E. uniflora* seeds is important, as it provides essential information for determining the most effective harvest methods.

To fill those knowledge gaps, this research first aims to determine the germination biology of *E. uniflora*, especially regarding its germination and seedling functional type. Second, this study aims to

study the effect of the harvest method, tree, and ground fruit on the germination and seedling parameters of *E. uniflora*. The data provided by this study will benefit not only the scientific community but also other stakeholders, including farmers and breeders.

Material and Method

This study harvested seeds from five *E. uniflora* trees grown in the Tabanan district on Bali Island, Indonesia. Two harvesting methods were implemented: tree-fruit harvest and ground-fruit harvest. For the tree-fruit harvest, red, ripe *E. uniflora* fruits were selected. Meanwhile, unspoiled and intact fruits found beneath the trees were collected for the ground-fruit harvest. Harvested fruits were kept separate and transported to the Bali Botanic Garden laboratory.

The seeds were extracted on the same day as the fruit collection. They were manually separated from the fruit and leaned under flowing tap water five times to remove any dirt and remaining fruit pulp. After cleaning, the seeds were surface-dried with a clean cloth.

The cleaned seeds were then surface sterilized using a 10% bleach solution (5.2% sodium hypochlorite, Bayclin), rinsed three times with sterile distilled water, and sown in glass Petri dishes containing six layers of moistened straw paper with 15 ml of distilled water. The sown seeds were then incubated at ambient temperature ($24^{\circ}\text{C} \pm 1.5^{\circ}\text{C}$) in the Bali Botanic Garden laboratory for 14 days.

During incubation, the number of germinated and infected seeds was recorded daily. Cotyledon position was also observed to determine the germination type and seedling functional type. This germination trial followed a completely randomized design with three replications of twenty seeds each.

On the 14th day, eight randomly selected healthy seedlings from each replication were transferred into a germination tray with distilled water-moistened *sphagnum* moss as the planting media. The seedlings were incubated under the same conditions as the germination trial for 35 days. On the final day of incubation, the root and shoot lengths of four randomly selected seedlings from each replication were measured. A completely randomized design with three replications, each containing eight seedlings, was applied to this seedling parameters trial. Figure 1 provides a schematic diagram of the study's methods.

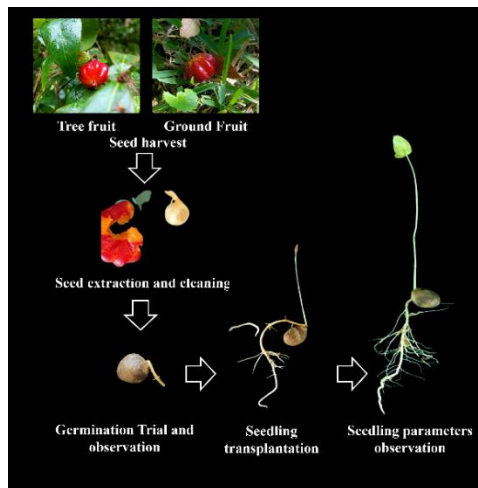


Figure 1. Schematic diagram of the study method

This study employs both descriptive and quantitative analysis. *E. uniflora* germination and seedling functional type were determined using descriptive analysis. Meanwhile, quantitative analysis was employed to understand the effect of harvest methods on the germination and seedling parameters of *E. uniflora*.

Four germination parameters, namely final germination percentage (FGP) and time for germination of 10% (T10), 50% (T50), and 90% (T90) of the seed, were calculated. Meanwhile, five seedling parameters namely, mean shoot length (MGT), mean root length (MRT), mean total length (MTL), vigour index, and growth index-were also calculated. All these parameters were computed using the SeedCalc R program (Silva *et al.*, 2019). The percentage of infected seeds was also calculated using Microsoft Excel.

This study's parametric analysis of *E. uniflora* seeds was followed by a statistical analysis. This analysis was conducted to determine the significance of the harvest method on the germination and seedling parameters. The study performed a Student's t-test using JAMOV 2.3.15 statistical software.

Result and Discussion

Eugenia uniflora Germination and Seedling Functional type.

This study found that *E. uniflora* shows hypogeal germination. The characteristic of this type of germination is that the cotyledon is not elevated during the germination process. (Ibarra-Manríquez *et al.*, 2001). *E. uniflora* cotyledon was kept inside the intact seed that stays on the media during germination.

The initially observed morphological change during *E. uniflora* germination was the emergence of a radicle. Following this emergence, the radicle elongated and transformed into a primary root. The emergence of a few secondary roots continues the development of the root system.

Shoot development was initiated after the emergence of the primary and secondary roots. This process was followed by shoot elongation and the emergence of eophylls, or the first leaves. The first leaves consisted of a pair of opposing leaves that developed terminally at the tip of the shoot. The first leaves were small, heart-shaped, and reddish in color in the early days of their emergence. However, the color of the first leaf turns green during its maturation process to enable photosynthesis. During this period, *E. uniflora* seeds have already transformed into seedlings, featuring a primary root, numerous secondary roots, and a pair of photosynthetic first leaves. The germination and seedling establishment process of *E. uniflora* is presented in Figure 2.



Figure 2. The germination process of *E. uniflora* from radicle protrusion to seedling

The observations of the germination and seedling development processes during this study also determined the functional type of the *E. uniflora* seedling. A cryptocotylar hypogeal germination with a reserve cotyledon (CHR) seedling functional type, characterized by an unelevated cotyledon that remains inside the seed and functions as a nutrient reserve (Ibarra-Manríquez *et al.*, 2001), was observed in this study.

Hypogeal germination and CHR seedling functional type in *E. uniflora* are related to the species' large and heavy seed size. The presence of a large and heavy seed implies that the seedling hypocotyl will be reduced (de Souza *et al.*, 2022) because it cannot elevate the seed. Thus, the plant adapts by growing its epicotyl instead, resulting in the seed and cotyledon remaining on the substrate during germination. This statement aligns with

previous research, which found that the CHR seedling functional type is primarily present in heavy-seeded plant species (Ibarra-Manríquez *et al.*, 2001).

The presence of heavy seed in numerous plant species, including *E. uniflora*, was highly correlated with the cotyledon function as nutrient reserve storage. Previous studies mention the presence of starch-rich cotyledon in Myrtaceae species, including *Eugenia* (de Souza *et al.*, 2022). The CHR seedling type and nutrient-rich cotyledon in *E. uniflora* provide adaptive benefits, such as protecting the plant's growth point from environmental factors by keeping it underground, while also supplying nutrients for the seedling's early development. (Undersander, 2019; Simpson *et al.*, 2021). CHR seedling functional type was also reported from other *Eugenia* species, *E. blastantha* and *E. gracillima* (de Souza *et al.*, 2022).

Eugenia uniflora Germination Parameters

This study found that *E. uniflora* has a high germinability. It indicates that seeds harvested from tree fruit produce an 83.3% germination rate, while seeds harvested from ground fruit show an 81.3% germination rate. Despite the different germinability percentages of seeds extracted from the tree and ground *E. uniflora* fruit during this study, statistical analysis shows that the differences were insignificant (Figure 3).

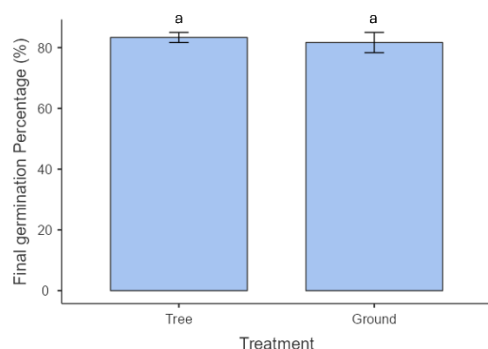


Figure 3. Final Germination Percentage (FGP) of tree and ground *E. uniflora* seeds during this study. Data are $\pm$ SE ($n = 3$). The same star number above the bars shows no significant difference ($p > 0.05$ student's test)

Despite the high germinability of *E. uniflora* seed found in this study, its germination percentage is lower than the 100% germination of fresh *E. uniflora* (Pavithra *et al.*, 2020; Rodrigues *et al.*, 2024), and its 92% germination in normal conditions (Inocente and Barbedo, 2019) previously reported. The condition might be attributed to the

difference in population and germination conditions used in the studies.

The insignificant difference in the germination percentage value of tree and ground seeds does not follow previous research that reported significantly higher germinability of fresh *E. uniflora* seeds compared to the stored seed (Pavithra *et al.*, 2020). This result also does not align with previous studies regarding the recalcitrant storage behaviour of *Eugenia* seeds (Cécel and Barbedo, 2023; Rodrigues *et al.*, 2024). Due to their desiccation sensitivity, recalcitrant seeds, such as those of *E. uniflora*, rapidly lose their viability after separating from the tree.

However, the comparable germinability of *E. uniflora* seeds observed in this study might be attributed to the fact that even ground *E. uniflora* seeds were still fresh, as the seed deterioration process requires time to reduce seed germinability. The recalcitrant behaviour of *E. uniflora* was not strong; therefore, seed deterioration in this species might require a longer time to decrease its germinability significantly. Abiotic conditions during the fruiting period were reported as other factors significantly affecting *Eugenia*'s seed desiccation tolerance (de Almeida Garcia Rodrigues *et al.*, 2022).

The results of this study also show a different daily germination pattern between *E. uniflora* seeds harvested from tree fruit and those harvested from ground fruit. We found that the seeds harvested from ground fruit initiated their germination more rapidly. In contrast, the seeds harvested from tree fruit required a longer time to trigger their germination. However, the duration of the germination period for both harvest methods was comparable (Figure 4).

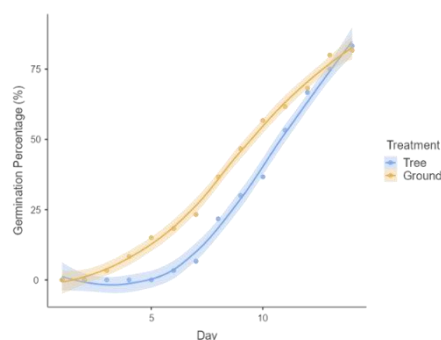


Figure 4. Daily germination pattern of tree and ground *E. uniflora* seeds during this study

This study also describes the germination speed of *E. uniflora* by calculating its T10, T50, and T90 values. Seeds harvested from tree fruit show T10, T50, and T90 values of 7.07 days, 10.13 days,

and 12.67 days, respectively. Meanwhile, seeds harvested from ground fruit show T10, T50, and T90 values of 4.70 days, 8.27 days, and 12.40 days, respectively. Figure 5 presents the T10, T50, and T90 values for *E. uniflora* obtained in this study.

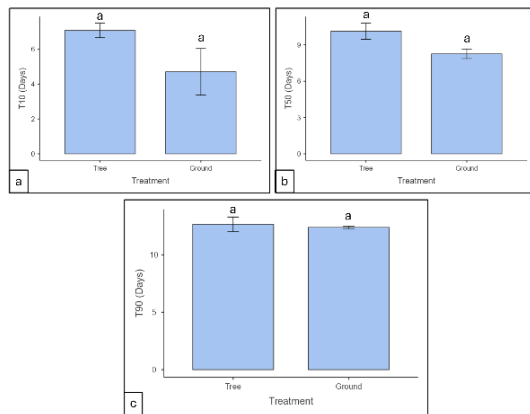


Figure 5. Germination speed parameter of tree and ground *E. uniflora* seeds. (a) T10 value, (b) T50 value, and (c) T90 value. Data are $\pm$ SE ($n = 3$). The same star number above the bars shows no significant difference ($p > 0.05$ student's test)

The T10, T50, and T90 values of *E. uniflora* seeds harvested from tree and ground fruit were not significantly different, indicating that the seed harvest method does not affect germination speed. However, the T10, T50, and T90 results suggest that the time difference needed for *E. uniflora* seeds harvested from the tree and ground fruit to germinate are most pronounced at 10% germinability, while it is closer at 50% germinability and comparable at 90% germinability. This condition supported our reading of the daily germination, which found different germination initiation times but comparable germination termination periods.

The difference in germination initiation time between tree and ground seeds in this study might be attributed to the different maturation stages of the fruit. Ground fruits contain more mature seeds compared to tree fruit. More mature seeds are more ready to germinate than less mature seeds; thus, faster germination initiation was observed in the ground seeds. This condition was not surprising as different seed maturation were reported to affect the germination parameters of several plant species, such as *Musa acuminata* and *Jatropha curcas* (Santoso *et al.*, 2012; Trimanto *et al.*, 2022).

The faster germination initiation in ground seeds might also be attributed to their earlier pre-germination process compared to tree seeds. Germination begins with the initiation of pre-

germinative metabolism triggered by water absorption (Pompelli *et al.*, 2023). Since the ground seed has already been below the trees several times, it might have already started its pre-germinative metabolism as they have already imbibed water particles from its surroundings, a condition that did not occur in the tree seeds as they were still intact in the tree until harvesting time.

Eugenia uniflora Seed Infection

This study found that seed infection occurs only in *E. uniflora* seeds collected from ground fruit. It recorded that 11.7% of seeds collected under this condition were infected. In contrast, seeds from tree fruit show a zero-infection rate (Figure 6(a)). However, despite this condition, statistical analysis indicates no significant difference in the infection rate between seeds harvested from tree and ground *E. uniflora* fruit.

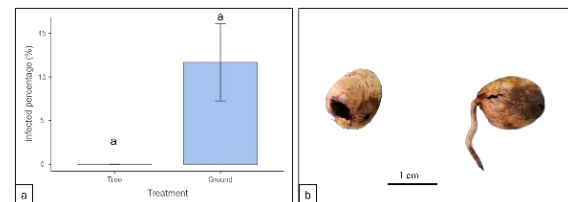


Figure 6. Infected *E. uniflora* seed. (a) Percentage of infected *E. uniflora* seed. Data are $\pm$ SE ($n = 3$). The same star number above the bars shows no significant difference ($p > 0.05$ student's test). (b) infected *E. uniflora* seed showing infection without and with germination

During this study, infected seeds were characterized by holes in the seed surface (Figure 6(b)). These holes became more prominent over time, and debris was found outside them. Infected seeds might still germinate, as indicated by the emergence of a radicle (Figure 6(b)). However, the seeds could not develop into seedlings and subsequently died. This outcome may be since, in the initial stages, the infection had not yet reached the embryo, allowing germination to occur. As the infection progresses, however, the seeds lose their ability to develop into seedlings. The ability of infected seeds to still produce radicle emergence might be another reason that made the germination percentage value of *E. uniflora* seed collected from tree and ground fruit in this study show no significant difference.

The presence of infection in seeds harvested from ground *E. uniflora* fruit is unsurprising, as a previous study notes that high seed predation was observed in *Eugenia* seeds collected from litter beneath the trees (Silva and Pinheiro, 2009).

Myrtaceae seeds, including *Eugenia*, were reported to be predated by numerous seed borer insects (Silva and Pinheiro, 2009; Araldi *et al.*, 2023). However, insect infection from only ground *E. uniflora* fruit seeds suggests insect infection happens only on the over-ripe fruit. This condition is associated with the chemical changes that occur during the over-ripening stage of the fruit, which serve as a natural cue for insect predation (Rodríguez *et al.*, 2013). Agriculturally, this result implies that selective harvest methods, such as harvesting tree fruit directly from *E. uniflora* trees, should be implemented to avoid seed infection and optimize seedling production.

Eugenia uniflora Seedling Parameters

This study found no significant difference between *E. uniflora* seed harvested from tree and ground fruit seedling size parameters. This condition is pictured by the comparable seedling mean shoot length, root length, and mean total length values. This study recorded mean root and shoot length values of 4.57 cm and 6.60 cm for seeds from tree fruit, compared to 4.13 cm and 6.97 cm for seeds from ground fruit, respectively. Meanwhile, the mean total length of seedlings from both treatments was 11.1 cm (Figure 7).

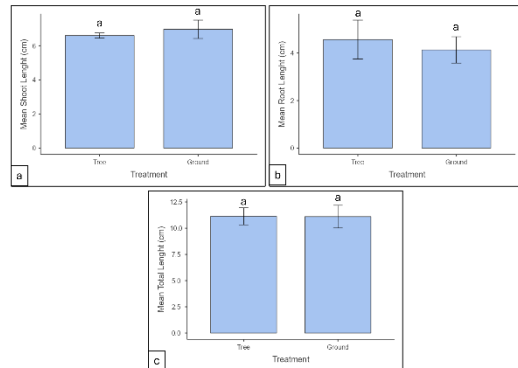


Figure 7. Seedling size parameters of *E. uniflora*. (a) Mean Shoot Length value, (b) Mean root Length value, and (c) Mean Total length value. Data are $\pm$ SE ($n = 3$). The same star number above the bars indicates no significant difference ($p > 0.05$ student's test)

This study also found that statistically insignificant higher vigor and growth index values were recorded for *E. uniflora* seeds harvested from the tree fruit. Tree-harvested seeds show vigor and growth index values of 588 and 477, respectively. Meanwhile, seeds harvested from ground *E. uniflora* fruit show vigor and growth index values of 510 and 438, respectively (Figure 8).

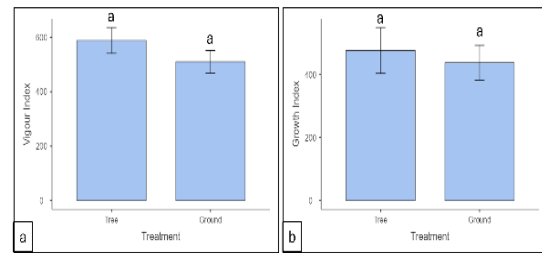


Figure 8. Seedling Vigour and Growth Index of *E. uniflora*. (a) Vigour Index and (b) Growth Index. Data are $\pm$ SE ($n = 3$). The same star number above the bars indicates no significant difference ($p > 0.05$ student's test)

The high values of seedling parameters in this study were unsurprising, as *E. uniflora* is a robust plant species. The robustness of *E. uniflora* enables the seedling to outcompete native and non-native plant species (Stricker and Stiling, 2013). This condition might be attributed to the species' ecological advantage due to its germination and seedling biology, which were previously described.

This study also indicates that the harvest method does not significantly affect the seedling parameter values of *E. uniflora*. However, despite not being affected by the seed source, several abiotic factors, such as substrate, water regime, and light intensity, are reported to affect the plant species' seedling performance (Mielke and Schaffer, 2010; Griebeler *et al.*, 2022).

This study provides valuable information regarding the generative propagation of *E. uniflora* that can be used for various purposes, including domestication through the establishment of orchards and conservation in ex-situ sites such as botanic gardens. These two efforts are essential, as *E. uniflora* is a multipurpose and multi-benefit plant species. Domestication is vital to fully harness the potential of *E. uniflora* by providing the best cultivars through selective breeding or genetic modification. At the same time, conservation efforts are crucial to safeguarding species diversity at the genetic level. Effective propagation to produce vigorous, pest-free propagules is essential in both scenarios.

Conclusions

Our study reinforces previous research that discusses *E. uniflora* hypogeal, cryptocotylar, and reserve cotyledon germination and seedling functional types. This study also found that seeds collected from the tree and those shed on the ground

do not differ significantly in germination and seedling parameters. However, we found that seed-borer infection is present only in the seeds harvested from ground fruit. The provided data enhances our understanding of *E. uniflora* germination and seedling biology, including the effect of seed sourced on its germination, infection, and seedling parameters. These are essential prerequisites for the sustainable usage of this exotic fruit species through domestication and conservation efforts.

Acknowledgement

We thank the Directorate of Research and Innovation Infrastructure - BRIN at Bali Botanic Garden for allowing the author to use the laboratory facilities for this research.

References

- Araldi, D.B., Guedes, J.V.C., Panozzo, L.E., Spinelli, V.M., Carvalho, I.R., Silva, J.A.G., Tremea, M.G., and Magano, D.A. (2023). Identification and impact of *Atractomerus pitangae*: A new pest on Rio Grande Cherry seeds (*Eugenia involucrata*). *Revista de Gestão e Secretariado*, 14(10):18778-18788. <https://doi.org/10.7769/gesec.v14i10.3074>
- Cécel, A.T., and Barbedo, C.J. (2023). Storage of recalcitrant seeds of *Eugenia brasiliensis* Lam. under control of water availability. *Journal of Seed Science*, 45:e202345009. <https://doi.org/10.1590/2317-1545v45264131>
- Cipriano, R.R., Tomazzoli, M.M., Tofanelli, M.B.D., Sant'Anna-Santos, B.F., Ribas, K.C.Z., and Deschamps, C. (2022). Rooting of *Eugenia uniflora* cuttings: Substrate, seasonality, auxine, and reinvigoration methods. *Communicata Scientiae*, 13(e3736):1-9. <https://doi.org/10.14295/CS.v13.3739>
- de Almeida Garcia Rodrigues, G., da Silva, D., Ribeiro, M.I., Loaiza-Loaiza, O.A., Alcantara, S., Komatsu, R.A., Barbedo, C.J., and Steiner, N. (2022). What affects the desiccation tolerance threshold of Brazilian *Eugenia* (Myrtaceae) seeds? *Journal of Plant Research*, 135(4):579-591. <https://doi.org/10.1007/s10265-022-01396-7>
- de Souza, L.A., Pastorini, L.H., da Silva Santos, L., and Romagnolo, M.B. (2022). Morfologia e anatomia de mudas de Myrtaceae ocorrendo em uma floresta sazonal semidecídua. *Recima21-Revista Científica Multidisciplinar*, 3(3):e331243(1-9). <https://doi.org/10.47820/recima21.v3i3.1243>
- Devi, M., Soekopitojo, S., Hidayati, L., Issutarti, I., Wahyuni, W., Hamid, M.A., and Asri, N.K.T. (2023). Proximate analysis of Dewandaru fruit (*Eugenia uniflora* L.) dried sweets. *Bulletin of Culinary Art and Hospitality*, 3(2):66-71. <https://doi.org/10.17977/um069v3i22023p66-71>
- Ferreira, M.R.A., Lima, L.B., Santos, E.C.F., Machado, J.C.B., Silva, W.A.V., Paiva, P.M.G., Napoleao, T.H., and Soares, L.A.L. (2023). *Eugenia uniflora*: A promising natural alternative against multidrug-resistant bacteria. *Brazilian Journal of Biology*, 83:e274084 (1-11). <https://doi.org/10.1590/1519-6984.274084>
- Fidelis, E.M., Savall, A.S.P., de Oliveira Pereira, F., Quines, C.B., Ávila, D.S., and Pinton, S. (2022). Pitanga (*Eugenia uniflora* L.) as a source of bioactive compounds for health benefits: A review. *Arabian Journal of Chemistry*, 15(4):103691. <https://doi.org/10.1016/j.arabjc.2022.103691>
- Figueira, J.A., Porto-Figueira, P., Berenguer, C., Pereira, J.A., and Câmara, J.S. (2021). Evaluation of the health-promoting properties of selected fruits. *Molecules*, 26(14), 4202. <https://doi.org/10.3390/molecules26144202>
- Franco, L.B., Hermann, B.R., Fritsche, Y., and Stefenon, V.M. (2024). A four-steps protocol for in vitro propagation of *Eugenia uniflora* L. (Myrtaceae). *Genetic Resources and Crop Evolution*, 71(5):1813-1823. <https://doi.org/10.1007/s10722-023-01741-2>
- Griebeler, A.M., Araujo, M.M., Turchetto, F., Mezzomo, J.C., de Andrade Cavaleiro, B., and Aimi, S.C. (2022). Water regime and substrate influence the growth of *Eugenia uniflora* seedlings. *Bosque*, 43(1):69-76. <https://doi.org/10.4067/S0717-92002022000100069>
- Ibarra-Manríquez, G., Martínez Ramos, M., and Oyama, K. (2001). Seedling functional types in a lowland rain forest in Mexico. *American Journal of Botany*, 88(10):1801-1812. <https://doi.org/10.2307/3558356>
- Inocente, M.C., and Barbedo, C.J. (2019). Germination of *Eugenia brasiliensis*, *E. involucrata*, *E. pyriformis*, and *E. uniflora* (Myrtaceae) under water-deficit conditions. *Journal of Seed Science*, 41(1):76-85. <https://doi.org/10.1590/2317-1545v41n1212109>
- Jones, L.R., Hunts, C.A., Dolan, L.A., Murphy, N.K., Ripa, G.N., Schultz, E.A., Varsha, S.S., Sklarczyk, C.A., Thornton, B.S., and Boudreau, M.R. (2023). Effects of seed size and toucan regurgitation on the germination of the tropical tree *Eugenia uniflora*. *Journal of Tropical Ecology*, 39:e5. <https://doi.org/10.1017/S026646742200044X>
- Kuswantoro, F., and Li'aini, A.S. (2021). Germination biology of the exotic ice cream bean (*Inga edulis* Mart.) seed from Bedugul, Bali. In IOP Conference Series: Earth and Environmental Science, 948(1):012008. IOP Publishing. <https://doi.org/10.1088/1755-1315/948/1/012008>
- Leelarungrayub, J., Pothasak, Y., Kuntain, R., Kaju, J., and Izhar, A.M. (2019). Potential health benefits of Thai seasonal fruits: Sapodilla and star fruit for elderly people. *American Journal of Biomedical Science Research*, 5(1):49-53. <https://doi.org/10.34297/AJBSR.2019.05.000873>
- Mielke, M.S., and Schaffer, B. (2010). Photosynthetic and growth responses of *Eugenia uniflora* L. seedlings to soil flooding and light intensity. *Environmental and Experimental Botany*, 68(2):113-121. <https://doi.org/10.1016/j.envexpbot.2009.11.007>
- Pavithra, S., Swamy, G.S.K., Suresh, G.J., and Ruchita, T. (2020). Study on viability of Surinam cherry (*Eugenia uniflora* L.) seeds on germination behaviour and vigour of the seedling. *Journal of Pharmacognosy and Phytochemistry*, 9(4):1802-1804.
- Pompelli, M.F., Jarma-Orozco, A., and Rodríguez-Páez, L.A. (2023). Imbibition and germination of seeds with economic and ecological interest: Physical and biochemical factors involved. *Sustainability*, 15(6):5394. <https://doi.org/10.3390/su15065394>
- Rodrigues, G.A.G., Mauve, C., Gakiere, B., Bailly, C., and Steiner, N. (2024). The metabolic profiles of *Eugenia astringens* and *E. uniflora* (Myrtaceae) sensitive seeds affect desiccation. *Physiologia Plantarum*, 176(1):e14220. <https://doi.org/10.1111/pp1.14220>
- Rodríguez, A., Alquézar, B., and Peña, L. (2013). Fruit aromas in mature fleshy fruits as signals of readiness for predation and seed dispersal. *New Phytologist*, 197(1):36-48. <https://doi.org/10.1111/j.1469-8137.2012.04382.x>
- Santoso, B.B., Budianto, A., and Aryana, I.G.P.M. (2012). Seed viability of *Jatropha curcas* in different fruit maturity stages after storage. *Nusantara Bioscience*, 4(3):113-117. <https://doi.org/10.13057/nusbiosci/n040305>
- Silva, A.L.G.D., and Pinheiro, M.C.B. (2009). Reproductive success of four species of *Eugenia* L. (Myrtaceae). *Acta*

- Botanica Brasilica, 23(2):526-534. <https://doi.org/10.1590/S0102-33062009000200024>
- Silva, L.J.D., Medeiros, A.D.D., and Oliveira, A.M.S. (2019). SeedCalc, a new automated R software tool for germination and seedling length data processing. *Journal of Seed Science*, 41(2):250-257. <https://doi.org/10.1590/2317-1545v42n2217267>
- Simpson, K.J., Atkinson, R.R., Mockford, E.J., Bennett, C., Osborne, C.P., and Rees, M. (2021). Large seeds provide an intrinsic growth advantage that depends on leaf traits and root allocation. *Functional Ecology*, 35(10):2168-2178. <https://doi.org/10.1111/1365-2435.13871>
- Stricker, B.K., and Stiling, P. (2013). Seedlings of the introduced invasive shrub *Eugenia uniflora* (Myrtaceae) outperform those of its native and introduced non-invasive congeners in Florida. *Biological Invasions*, 15(9):1973-1987. <https://doi.org/10.1007/s10530-013-0425-z>
- Surya, M.I., Rahmawan, H., and Semarayani, C.I.M. (2023). Changes in the profile of volatile compound in seed storage of *Rubus fraxinifolius*. *Suranaree Journal of Science and Technology*, 30(6):020025(1-8). <https://doi.org/10.55766/sujst-2023-06-e02235>
- Trimanto, T., Renjana, E., Lestari, D.A., Firdiana, E.R., Mas'udah, S., Rahadianoro, A., Ningrum, L.W., and Hapsari, L. (2022). Morphological characterization and seed germination study of wild banana *Musa acuminata* var. *flava* (Ridl.) Nasution. *Journal of Tropical Biodiversity and Biotechnology*, 7(1):66645. <https://doi.org/10.22146/jtbb.66645>
- Undersander, D.J. (2019). Forage plant structure, function, nutrition, and growth. In P. Sharpe (Ed.), *Horse pasture management* (pp. 1-10). Academic Press. <https://doi.org/10.1016/B978-0-12-812919-7.00001-9>