

Original Article

Floral Morphometry and Sexual System Determination in Pink Pepper (*Schinus terebinthifolia* - Anacardiaceae)

Morfometria Floral e Determinação do Sistema Sexual em Pimenta Rosa (*Schinus terebinthifolia* - Anacardiaceae)

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Abstract

The increasing global importance of pink peppertree (*Schinus terebinthifolia*, Anacardiaceae) as a high-value commercial crop and its potential for expansion in production demand appropriate management due to uncertainties regarding its sexual system. This study focused on evaluating the morphology of sterile and fertile floral whorls, as well as analyzing the sexual system of pink pepper in two populations in northeastern Brazil. The results revealed no significant differences in the morphological characteristics of the flowers between the studied areas, suggesting that the species possesses notable adaptability to environmental conditions. However, a significant difference in the proportion of staminate individuals was observed in both areas, representing over 88% and 72%, respectively. A correlation was observed between the size of the stamens and the presence of apparently atrophied pistils ($r=0.275$; $df=178$; $p<0.001$), along with the occurrence of fruits in these hermaphroditic plants. In this context, the species should be considered gynodioecious due to the presence of plants with hermaphroditic flowers and plants with pistillate flowers. However, further research is essential to elucidate the role of pollinators, especially bees and wasps, and to better understand the fruiting process in hermaphroditic flowers. These insights have the potential to significantly enhance management aiming for efficient fruit production, promoting its economic and ecological relevance.

Keywords: gynodioecy, floral morphology, pink pepper, floral reproduction, *Schinus terebinthifolia*

Resumo

A crescente importância global da Pimenta rosa (*Schinus terebinthifolia*, Anacardiaceae) como uma cultura de alto valor comercial e seu potencial de expansão na produção demandam um manejo apropriado devido às incertezas quanto ao seu sistema sexual. Este estudo se concentrou na avaliação da morfologia dos verticilos florais estéreis e férteis, bem como no análise do sistema sexual da Pimenta rosa em duas populações no nordeste do Brasil. Os resultados revelaram que não houve diferenças significativas nas características morfológicas das flores entre as áreas estudadas, sugerindo que a espécie possui uma notável adaptabilidade às condições ambientais. No entanto, observou-se uma marcante diferença na proporção de indivíduos estaminados em ambas as áreas, representando mais de 88% e 72%, respectivamente. Observou-se correlação entre o tamanho dos estames e a presença de pistilos aparentemente atrofiados ($r=0,275$; $gl=178$; $p<0,001$), juntamente com a ocorrência de frutos nessas plantas hermafroditas. Neste contexto, deve-se considerar a espécie como ginodióica devido à presença de plantas com flores hermafroditas e plantas com flores pistiladas. No entanto, é fundamental conduzir pesquisas adicionais para elucidar o papel dos polinizadores, especialmente abelhas e vespas, e entender melhor o processo de frutificação em flores hermafroditas. Esses insights têm o potencial de aprimorar significativamente o manejo visando a uma produção eficiente de frutos, promovendo sua relevância econômica e ecológica.

Palavras-chave: ginodioicia, morfologia floral, pimenta-rosa, reprodução floral, *Schinus terebinthifolia*

1. Introduction

Many of the major crops worldwide rely on pollination services to ensure significant yields in terms of quantity and quality (Roubik, 2018; Lopes et al., 2020). The process of pollen transfer by pollinators plays a crucial role in

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Received: September 23, 2023 – Accepted: April 15, 2024



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the global economy, estimated at around US\$ 577 billion (Potts et al., 2017). However, these services face threats due to environmental degradation and biodiversity loss resulting from agricultural expansion to meet the growing world population (Potts et al., 2010; Rosa et al., 2019). The economic benefits of ecosystem pollination services exceed half a billion dollars globally (Lautenbach et al., 2012; Potts et al., 2017; Aizen et al., 2019).

In Brazil, pollination services are estimated at approximately US\$ 12 billion per year (BPBES/REBIPP – Wolowski et al., 2019). Among the 191 plants related to food production in Brazil, *Schinus terebinthifolia* Raddi, known as Brazilian peppertree or pink pepper, stands out due to its culinary use, wide distribution, and high performance in annual flowering, which contributes to its production (Neves et al., 2016). Despite its wide distribution in the southeast and northeast regions of Brazil, research on the reproductive biology, reproductive strategies, and floral variations in Brazilian pink pepper crops is still limited. So far, studies have mainly focused on investigating the species' potential in the recovery of degraded areas (José et al., 2005; Brancalion et al., 2015) in reforestation programs (Brancalion et al., 2015; Jesus et al., 2016), as well as assigning its medicinal potential (Nocchi et al., 2022).

Floral hermaphroditism plays a crucial role in optimizing pollination, enabling efficient pollen collection and deposition by pollinators, including self-pollination (Teixeira et al., 2014). It is worth noting that self-pollination is a complex process that encompasses a wide diversity of mechanisms, such as both early and late self-pollination enabling fruit formation in self-compatible plants (Domingos-Melo et al., 2018). However, plants develop strategies such as herkogamy, floral polymorphism, and genetic mechanisms of self-incompatibility to prevent self-fertilization, establishing spatial and physiological barriers (Oliveira and Maruyama, 2014; Renner, 2014; Ferreira et al., 2022). On the other hand, dioecy, found in about 6% of angiosperms (Renner, 2014), involves clearly differentiated male and female individuals, with separate plants producing flowers of only one sex. This characteristic contrasts with monoecious species, where each individual possesses flowers containing both male and female reproductive organs (Nunes et al., 2016; Coelho et al., 2017). Furthermore, dioecious flowers exhibit distinct secondary characteristics that promote efficient pollen transfer to conspecific stigmas, as evidenced in previous studies (Barrett and Hough, 2013; Moquet et al., 2020; Gouker et al., 2021; Ferreira et al., 2022).

The Anacardiaceae family is known for its flowers, which often exhibit bisexual or unisexual characteristics in dioecious plants. However, some species show a remarkable diversity of floral morphs, resulting in a wide variety of sexual systems. This context includes species ranging from monoecious, polygamous, or hermaphroditic flowers to variations such as dioecy and andromonoecy, which confer different morphologies and functions to the flowers (Silva-Luz et al., 2023). *S. terebinthifolia* is a striking example of this sexual segregation and stands out for presenting a gradual transition in the size of sexual organs in both morphological types, which may have a direct impact on fruit production.

Previous field observations with *S. terebinthifolia* highlighted the absence of a functional gynoceium in staminate flowers (Lenzi and Orth, 2004). However, Cesário and Gaglianone (2008) identified a minimal proportion (about 2%) of staminate flowers producing well-formed fruits. In controlled experiments, Mendes et al. (2020) obtained fruits in both morphs but did not trace their origin in relation to sexual functionality. Thus, given the apparent dichogamy of the flowers and the presence of vestigial organs that may have functionality, it becomes necessary to conduct experiments to confirm the functionality of these reduced organs and elucidate their sexual mechanism. Therefore, this study aims to analyze the different floral morphs of *S. terebinthifolia* in the context of floral biology, seeking to answer the following questions: 1) Considering the existence of two floral morphs in *S. terebinthifolia*, how does floral morphology differ between male (apparently hermaphroditic) and female flowers? 2) Can apparently male individuals produce fruits, characterizing a possible gynodioecy?

2. Materials and Methods

2.1. Study Area

The study was conducted in two distinct populations. Population A containing 25 mother plants is located in the region of the Tejucupapo district, municipality of Goiana, Pernambuco (7°33'47"S and 35°0'47"W), along the PE-49 highway, comprising kilometers 16 and 17 within the Mata Norte region of the state of Pernambuco. The predominant vegetation type is Subperennial Forest, with some areas of Subdeciduous Forest. The terrain is characterized by the presence of coastal plains, with sandbanks, mangroves, and dunes. The average altitude of the region varies between 50 and 100 meters. The predominant soils are deep, although their natural fertility is relatively low, and the climate is rainy tropical, with an average annual precipitation of 1,634.2 mm (Andrade-Lima, 2007). Population B has 25 mother plants and is located in the Mata do Jardim Botânico of the State University of Paraíba (UEPB), covering an area of approximately 10 hectares, situated in the municipality of Campina Grande, Paraíba (7°12'44.2"S and 35°54'36.0"W). In this area, there is a vegetation transition between the Atlantic Forest and the Caatinga. It is situated at an altitude of 518 meters, with Argisols, Litholic Neosols, rocky outcrops, Luvisols, and a rainy tropical climate, with an average annual precipitation of 1,200 mm (Francisco and Santos, 2019). The distances between populations A and B total 106.71 km in a straight line from one point to another.

2.2. Study Species

Schinus terebinthifolia (Anacardiaceae) is a large tree that can reach heights between 8 to 15 meters (Carvalho, 1994). It is distributed in various regions around the world and considered an invasive species, which intrudes into a system causing disturbance or damage to native species, as reported by Discover of Life (2023). In Brazilian

territory, it is found in several phytogeographic formations, including Anthropogenic Areas, Open Fields, Cerrado (in a broad sense), Riparian or Gallery Forests, Semideciduous Seasonal Forest, Rainforest (Ombrophilous Forest), Mixed Ombrophilous Forest, Mangroves, and Sandbanks (Silva-Luz et al., 2023). Its distribution extends from the northern region of Pará to the states of Alagoas, Bahia, Rio de Janeiro, Espírito Santo, Minas Gerais, São Paulo, Santa Catarina, and Rio Grande do Sul (Silva-Luz et al., 2023). This species plays a significant role in the restoration of degraded areas (Costa et al., 2022) and is relevant in the production of fruits used for medicinal and culinary purposes (Ronchi et al., 2022).

The flowers are white, small, pentamerous, actinomorphic, dialysepalous, and dialypetalous, arranged in compound inflorescences of the racemose panicle type (Cesário and Gaglianone, 2008). The species presents two floral types in the populations; there are individuals with hermaphroditic flowers (apparently atrophied pistil), coexisting with individuals with only pistillate flowers, presenting only one floral type per inflorescence.

2.3. Floral Morphometry

The morphometric analysis of the flowers was conducted by capturing images using a stereomicroscope and subsequent processing in the Image J software (Collins, 2007). Given that the species in question presents actinomorphic flowers with several morphological variations, measurements were made in millimeters for the total length of the flower (from the base of the corolla to the highest point of the flower), corolla diameter, pistil height (from the base of the ovary to the point of separation of the stigmatic lobes), ovary diameter, stamen and anther length for both hermaphroditic flowers (with apparently atrophied pistil) ($n = 220$) from 22 mother plants, and pistillate flowers (with anthers without pollen grains) ($n = 30$) from three mother plants in population A, as well as hermaphroditic flowers (with apparently atrophied pistil) ($n = 180$) from 18 mother plants and pistillate flowers (with stamens without pollen grains) ($n = 70$) from seven mother plants in population B.

The number of flowers per inflorescence was counted ($n = 10$), and to determine the number of pollen grains produced, a single anther from 10 floral buds was examined, using 5 flowers from one mother plant of population A and 5 flowers from one mother plant of population B (Dafni et al., 2005). On a slide, the anthers were subjected to a crushing process to release the pollen, and the total number of pollen grains per flower was estimated by multiplying the quantity of grains per anther by the number of stamens present in each flower. The pollen viability was subsequently checked by staining the pollen grains with 2% acetic carmine (Dafni et al., 2005). The ovules produced by the same 10 flowers were counted to calculate the pollen-ovule ratio.

2.4. Sexual Systems

In the field, a total of 25 mother plants were selected in population A and another 25 in population B. This selection was based on direct observation of the flowers

present in the tree canopies, focusing on the identification of pistils (robust and apparently atrophied) and anthers (containing pollen or absent). To confirm this classification and ensure the accuracy of the floral type present in the mother plants, we proceeded to collect buds ($n = 125$) and flowers ($n = 125$) from these mother plants, which were subsequently fixed in 70% alcohol. Additionally, during field observations, we identified hermaphroditic mother plants (with apparently atrophied pistils) that were able to produce fruits.

In the laboratory setting, detailed analyses of the collected flower samples were conducted, employing a stereomicroscope to verify the presence of fertile anthers and the development of well-formed ovules in the ovaries. Additionally, in the field, we observed whether fruits were formed or not in individuals with collected flowers and compared these results with the respective floral types identified in the mother plants, without quantifying the number of fruits formed per inflorescence.

The sexual system of *S. terebinthifolia* was thoroughly investigated through morphological analysis of flowers in different individuals from both study areas. Each morphotype was carefully classified and determined based on the evaluation of reproductive elements in 10 flowers per individual ($n = 50$), using a stereomicroscope. The analyzed morphotypes were compared with existing descriptions of sexual systems in the literature and categorized for the species, following the characters observed by Renner (2014).

2.5. Data Analysis

The analyses were conducted using the Jamovi software (Version 2.3) (The Jamovi Project, 2022). Differences in corolla length and diameter, stamen length, and anther length between both areas were tested using MANOVA. Interpopulation differences among floral morphological types were subjected to independent samples t-tests, with a significance level of 0.05 after confirming the normality of the data using the Shapiro-Wilk test. The correlation effects between sexual elements were tested by the Pearson correlation coefficient. A Principal Component Analysis (PCA) was performed to visualize the difference between the different flower sexes.

3. Results

3.1. Floral Morphometry

The floral morphological characteristics were similar between populations (MANOVA: $F = 2.50$, $df = 4$, $p = 0.056$) for the mean values of floral variables per population. By applying PCA to the floral morphometry data (carpel length and diameter; ovary circumference; length of the longer stamen and length of the shorter stamen), PC1, PC2 components together explain 98.99% of the total variation related to sexual structures, with PC1 responsible for 89.06% and the second PC2 for 9.93% of data variations (Figure 1). The sampled inflorescences produced an average of 44 ± 14.5 (28-70; $n = 10$) hermaphroditic flowers and an average of 57 ± 22.8 (22-96; $n = 10$) pistillate flowers.

The dimensions of the flowers and their parts per population are provided in Table 1.

The flowers are fragrant, white, with two morphotypes (pistillate and hermaphrodite) actinomorphic, and have five oblong petals and alternate sepals (Figure 2).

The average width of the petals and corolla diameter were 1.494 ± 0.21 mm and 2.023 ± 0.22 mm, respectively, considering both morphotypes and areas together. There was a significant difference between flower height and sex ($t = 4.66$, $df = 498$, $p < 0.001$) for both combined areas.

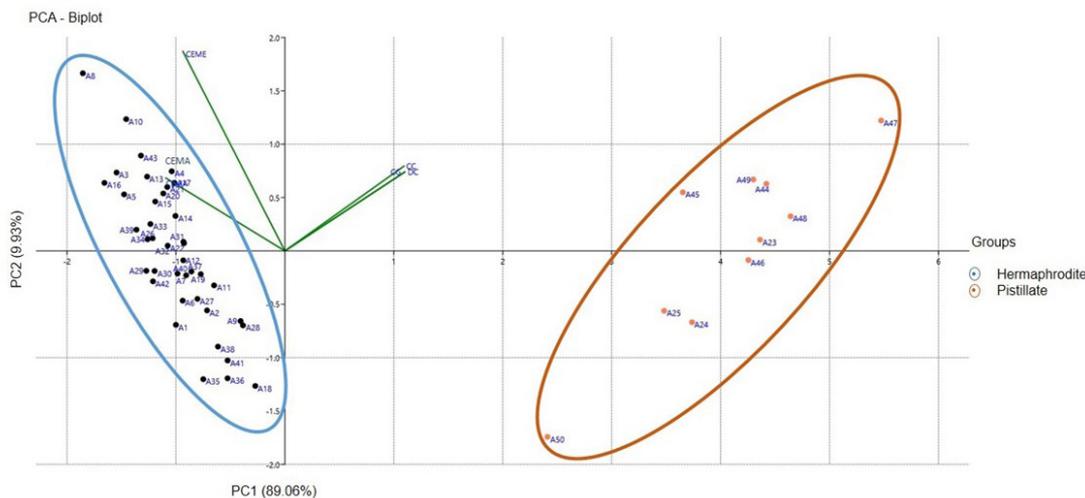


Figure 1. A biplot of the 50 matrices of *Schinus terebinthifolia* based on the first two principal components derived from the variation in morphometric characteristics of the sexual elements. Carpel length (CC); Carpel diameter (DC); Ovary circumference (CG); Length of the longest stamen (CEMA); and Length of the shortest stamen (CEME). Where: Hermaphrodite Group: A1; A2; A3; A4; A5; A6; A7; A8; A9; A10; A11; A12; A13; A14; A15; A16; A17; A18; A19; A20; A21; A22; A26; A27; A28; A29; A30; A31; A32; A33; A34; A35; A36; A37; A38; A39; A40; A41; A42; A43. And Pistillate Group: A23; A24; A25; A44; A45; A46; A47; A48; A49; A50.

Table 1. Mean Values (\pm SD) of Floral Variables for hermaphrodite (HER) and Pistillate (PIS) Morphotypes of *Schinus terebinthifolia*, Area A ($n = 25$) and Area B ($n = 25$). SD: Standard Deviation.

Floral Variables (mm)	Morphotype	Population A	Population B
Flower length	HER	2.145 (\pm 0.31)	2.135 (\pm 0.27)
	PIS	1.932 (\pm 0.25)	2.008 (\pm 0.33)
Corolla diameter	HER	2.161 (\pm 0.48)	2.275 (\pm 0.52)
	PIS	1.782 (\pm 0.37)	1.898 (\pm 0.42)
Pistil length	HER	0.382 (\pm 0.08)	0.348 (\pm 0.07)
	PIS	1.094 (\pm 0.21)	1.320 (\pm 0.40)
Pistil diameter	HER	0.208 (\pm 0.08)	0.179 (\pm 0.05)
	PIS	0.857 (\pm 0.23)	0.913 (\pm 0.31)
Length of the larger filament	HER	1.759 (\pm 0.40)	1.710 (\pm 0.41)
	PIS	-	-
Length of the larger anther	HER	0.532 (\pm 0.09)	0.513 (\pm 0.09)
	PIS	-	-
Length of the smaller filament	HER	1.141 (\pm 0.25)	1.049 (\pm 0.21)
	PIS	0.665 (\pm 0.11)	0.737 (\pm 0.14)
Length of the smaller anther	HER	0.452 (\pm 0.10)	0.423 (\pm 0.09)
	PIS	0.296 (\pm 0.07)	0.287 (\pm 0.05)

The gynoecium of the pistillate morphotype is surrounded by the androecium, which consists of 10 free and isodiametric stamens and a nectar disc. The anthers are whitish and do not contain pollen grains. The style is short and cylindrical, ending in a lobed stigma (trifid) that secretes a viscous fluid (Figure 2). The ovary is superior (Figure 3), unilocular, and contains one ovule.

The gynoecium of the hermaphrodite morphotype (apparently atrophied pistil) is surrounded by the androecium, which consists of 10 free and heterodiametric stamens, with five larger and five smaller stamens alternated, and a nectar disc (Figure 2). The anthers open longitudinally and produce an average of 7,270 (4,530 -

9,150; n = 10) pollen grains with over 94% viability, estimated for the whole flower in both stamen heights. The style is longer and cylindrical, ending in a lobed stigma (trifid) that appears senescent (Figure 3). The ovary is superior and contains one ovule. The average pollen-ovule ratio was 7,270.

3.2. Sexual System

The morphotypes occurred in separate individuals, and fruit formation was observed in both pistillate and hermaphrodite morphotypes (with apparently atrophied gynoecium) (Figure 4). The ratio of hermaphrodite to pistillate matrices was 7:1 and 3:1 for both populations A and

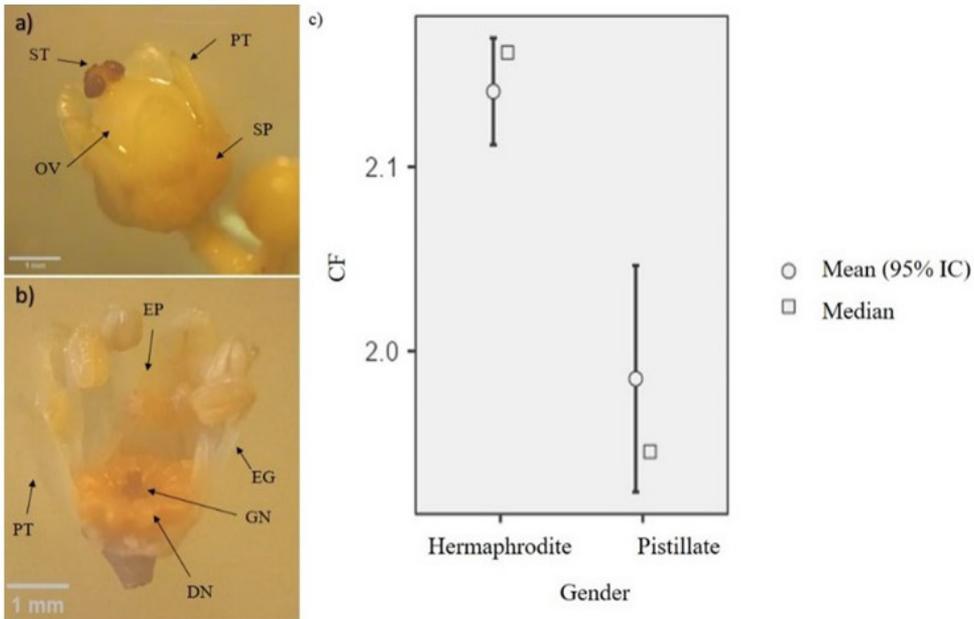


Figure 2. Flower of *Schinus terebinthifolia* a) Pistillate morphotype, ST= stigma; PT= petal; OV= ovary; SP= sepal b) Hermaphrodite morphotype, PT= petal; EP= smaller stamen; EG= larger stamen; GN= gynoecium; DN= nectar disc c) Comparison of floral type (CF). The intervals represent the standard errors around the mean values of the sample length.

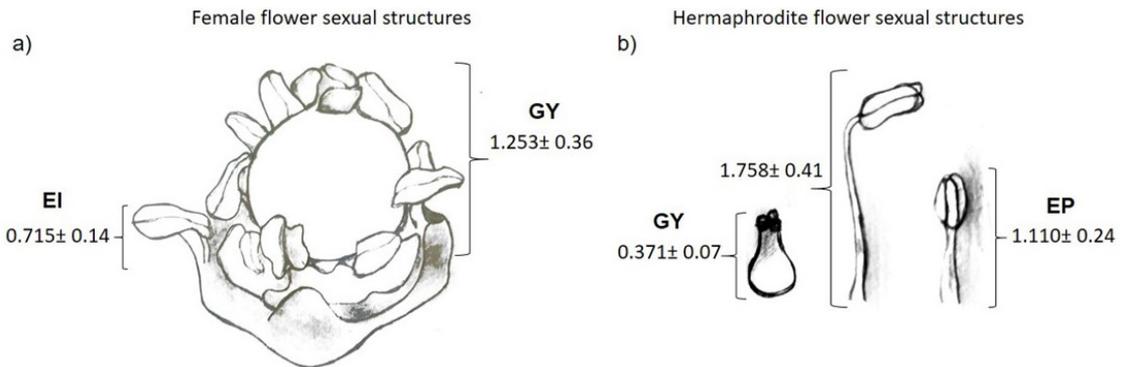


Figure 3. Mean values (mm) and (± SD) of sexual structures per hermaphroditic and pistillate morphotypes for *Schinus terebinthifolia*, a) Pistillate Morphotype, GY = Gynoecium; EI = Isostemonous Stamen b) Hermaphroditic Morphotype, EG = Larger Stamen; EP = Smaller Stamen.

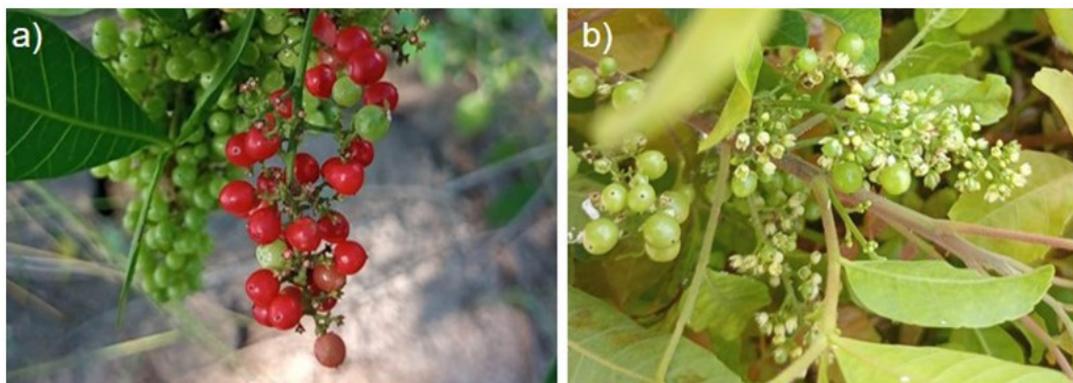


Figure 4. Fruits of *Schinus terebinthifolia* a) Fruits formed by the hermaphrodite morphotype b) Fruits in early stage of maturation of the pistillate morphotype.

B, respectively. Field observations and laboratory analyses converge to identify *Schinus terebinthifolia* as a species exhibiting gynodioecious behavior. In hermaphrodite flowers, there is a noticeable difference in gynoecium size compared to pistillate flowers (see Figure 3). Matrices with pistillate flowers accounted for approximately $12 \pm 15.0\%$ of the total in population A ($n = 25$ individuals) and $28 \pm 12.7\%$ of matrices in population B ($n = 25$ individuals). The proportion of each floral morphotype varied considerably among individuals during the flowering period. Ovary circumference between populations ($r = 0.821$; $df=208$; $p<0.001$) showed correlation, as well as in population A for the shorter stamen and atrophied gynoecium ($r=0.173$; $df=218$; $p= 0.010$). Population B occurred similarly for the sexual elements longer stamen and atrophied gynoecium ($r=0.275$; $df=178$; $p< 0.001$) and gynoecium diameter and ovary circumference ($r=1.000$; $df=248$; $p<0.001$) (see Figure 5). There was no correlation between stamens of the hermaphrodite morphotype and the developed gynoecium of the pistillate morphotype.

4. Discussion

In both areas, the results indicate no differences among morphotypes, although adaptive mechanisms have been previously documented, enabling its widespread global distribution (Discover of Life, 2023). Thus, while there is no morphological difference among areas, this lack of floral variation between them may signify success for species reproduction, as it presents a generalist morphology allowing visits from a wide diversity of insects (Ollerton et al., 2007; Dellinger, 2020). However, it's important to note that there is morphological differentiation among morphotypes. In species pollinated by specialist insects, female flowers are generally similar in size or even larger than male ones, making them more attractive to pollinators. In contrast, in species pollinated by generalists, this pattern may not be as pronounced, resulting in less attraction of pollinators to female flowers (Ushimaru et al., 2023).

The diversity of mechanisms regulating plant sexual interactions in the Anacardiaceae family reveals a complex

and intriguing panorama (Silva-Luz et al., 2023). Data obtained on floral morphometry and the proportion of hermaphrodite flowers compared to female ones provide valuable insights not only into the reproductive dynamics of this specific species but also into explaining crossings involving apparently atrophied floral structures. This knowledge is essential for filling gaps in our understanding of pollination and fruiting processes under natural conditions, thereby contributing to a more comprehensive view of the reproductive biology not only of *S. terebinthifolia* but also of other species within the Anacardiaceae family.

Based on observations both in the field and the laboratory, the data clearly indicate that the species exhibits a gynodioecious sexual system. Gynodioecy refers to the presence of individuals with hermaphrodite (bisexual) flowers coexisting with others that have only pistillate flowers, less than 1% of angiosperms exhibit this sexual system (Barrett 2002; Charlesworth, 2006; Barrett and Hough, 2013; Godin and Demyanova, 2013; Käfer et al., 2017; Cardoso et al., 2018). This phenomenon is relatively rare, considering that only 1.4% of all angiosperm genera harbor dioecious and monoecious species, while an even smaller percentage, 0.4%, encompasses dioecious and gynodioecious species (Renner, 2014). Additionally, it was observed that angiosperm genera containing gynodioecious and dioecious species occur more frequently than would be expected based on the trajectory of gynodioecy. It is relevant to note that this trend persists even when analyzing different classes (or subclasses), orders, and families separately, suggesting that the occurrence of gynodioecy is not restricted to specific groups but, on the contrary, seems to be widely distributed in angiosperms (Dufay et al., 2014). This discovery has significant implications not only for understanding the reproductive biology of this specific species but also for providing insights into the evolution and sexual diversity of angiosperms in proportions and improvements of their own transmission through sex ratio distortion (Taylor et al., 1999).

However, it is important to note that despite hermaphrodite flowers having smaller stamens with sizes similar to those of pistillate flowers, the anthers of the latter do not contain pollen, rendering them functionally female flowers, observations previously made (Lenzi and

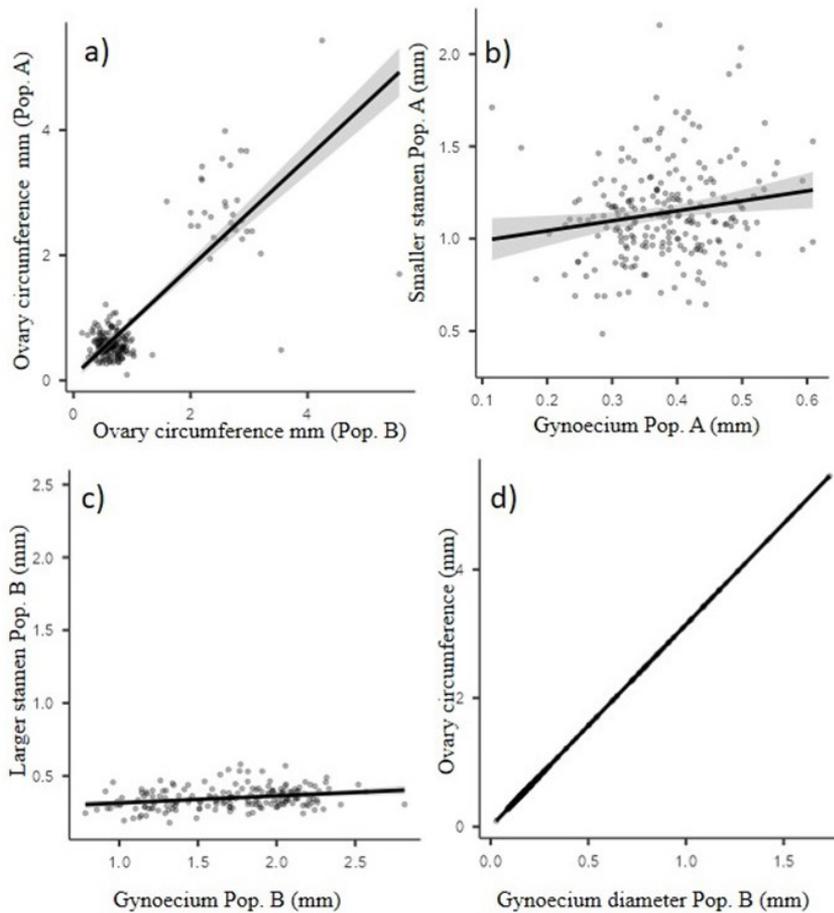


Figure 5. Pearson's Relationship between: a) Ovary circumference; b) Smaller stamen and atrophied gynoecium in Population A; c) Larger stamen and atrophied gynoecium in Population B; and d) Ovary circumference and gynoecium diameter in Population B.

Orth, 2004; Cesário and Gaglianone, 2013; Carvalho et al., 2014; Mendes et al., 2020). Therefore, *S. terebinthifolia* is characterized as a gynodioecious species, presenting individuals with both hermaphrodite flowers, with sexual functionality in their gynoecium (apparently senescent and atrophied), and pistillate morphotype with non-functional stamens. Understanding the sexual system of this species is essential, as it is used for the production of condiment fruits. The scarcity of both quality and quantity of pollen on stigmas can severely compromise fruit production, resulting in a significant reduction in yield. Orchard managers relying on cross-pollination of species with separate sexes face decisions that impact crop yield (Castro et al., 2021; Li et al., 2022). Understanding plant sexual systems directly influences the type of cultivation management to be adopted, providing crucial information to optimize orchard yields.

It is important to mention that the data regarding the sexual system of *S. terebinthifolia* obtained from the studied populations do not coincide with the information present in the literature, where the species was previously classified as functionally dioecious (see Lenzi; Orth, 2004). However, this study describes the sexual system based on morphological characteristics observed in the field and in the laboratory.

Observations of fruit formation in hermaphrodite matrices, previously believed to be staminate flowers, were also recorded, as observed in previous studies (Cesário and Gaglianone, 2008; Mendes et al., 2020). Therefore, the results obtained in this work offer new perspectives on the sexual system of *S. terebinthifolia*.

The observed gynodioecious configuration is of utmost relevance for understanding the species' reproductive biology, indicating complex adaptations in response to particular ecological challenges. Understanding reproductive dynamics has far-reaching implications for plant ecology and can provide essential insights for future research related to reproduction, conservation, and the development of genetic improvement programs (Dufay et al., 2014; Montalvão et al., 2021).

Although hermaphrodite floral samples with little fruit formation were found in these matrices, additional observations revealed that, in all cases, there were no individuals presenting both types of flowers or a specific staminate type. This disparity in floral type proportions observed is a common occurrence in monoecious, gynomonocious, and andromonocious species, which may complicate the diagnosis of the sexual system of these species (Gross, 2005). Spatial segregation of floral

sexual functions is a phenomenon commonly observed in species with small flowers grouped in inflorescences and dependent on imprecise pollination, where pollen from flowers of the same plant may hinder the deposition of pollen from conspecific plants (Bawa and Beach, 1981; Montalvão et al., 2021; Barbot et al., 2023).

Given that functionally pistillate flowers are fewer in quantity compared to the bisexual morphotype, their similarity to hermaphrodite flowers in terms of color, shape, presence of nectar, and odor becomes of great importance to ensure they also receive visits from pollinators. However, it is crucial to note that the production of female flowers may result in reduced pollinator visits, as these flowers may be avoided even by pollinators that do not feed on pollen but use anthers as a visual guide for orientation (Charlesworth, 1993; Barbot et al., 2023). *Schinus terebinthifolia* flowers exhibit entomophily as the pollination syndrome, and in natural areas, they benefit from a wide diversity of pollinators (Lenzi and Orth, 2004; Somavilla et al., 2010; Cesário and Gaglianone, 2013; Carvalho et al., 2014).

The remarkable morphological similarities among different floral morphotypes offer a deeper insight into the species' reproductive biology while providing valuable insights into how the plant adapts to diverse reproductive strategies in its natural environment. These observations play a fundamental role in guiding future research related to its reproductive ecology. Additionally, the coexistence of diverse floral morphotypes, combined with the ability of hermaphrodite flowers to produce fruits, raises intriguing questions about the pollination and reproduction strategies of this species (Dufay et al., 2014). The morphological plasticity evidenced in pistillate flowers may be correlated with the search for specific pollinators (Montalvão et al., 2021), opening up new opportunities for future studies on pollination biology in *Schinus terebinthifolia*.

5. Conclusion

While there has been remarkable scientific and technological advancement related to the reproductive biology of economically important wild species in recent decades, understanding sexual mechanisms remains essential for achieving abundant production and facilitating the implementation of cultivation and genetic improvement programs. Within the broader context of plant reproduction, differentiation in floral morphs has provided a deeper understanding of phenotypic diversity and reproductive adaptations in a gynodioecious system, as observed in *S. terebinthifolia*. Therefore, by enriching our knowledge about the sexual system, we lay a solid foundation for future research to elucidate the role of pollinators and gain a better understanding of the fruiting process in hermaphroditic flowers (previously recorded as staminate). Moreover, these insights have the potential to significantly enhance management practices aimed at efficient fruit production, thereby promoting its economic and ecological relevance in the evolution and conservation of this species, as well as its impact on the ecosystems in which it is situated.

Acknowledgements

We Thank the Botanical Garden of the State University of Paraíba for permitting and supporting our fieldwork, and to the Graduate Program in Forestry Sciences at the Federal Rural University of Pernambuco for their logistical and financial assistance. We also thank the Coordination of Superior Level Staff Improvement (CAPES) for providing a scholarship to Ph.D. candidate R.S. Santos.

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