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FRUIT PRODUCTION IN BYRSONIMA KUNTH (MALPIGUIACEAE): RELATIONSHIP BETWEEN PLANT SELF-IN-COMPATIBILITY AND PRESENCE OF ANTS

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Abstract: Studies on the effect of ants on pollination and fruit production in the *genus Byrsonima* need to be expanded. It was verified whether there is similarity in fruit production between a self-compatible Byrsonima (*Byrsonima coccolobifolia*) and another self-incompatible (*Byrsonima sericea*) and relationship with the presence of ants. Analyzes were carried out from September 2017 to August 2018. The phenology of the species was observed and correlated with climatic data. The number of fruits was obtained in the treatments: exclusion of ants, exclusion of other insects (pollinators and/or herbivores); presence of ants and free inflorescences (natural conditions). The weight and average diameter of the fruits were calculated, compared using the T test, in Statistic. Ants were collected, checking the most frequent ones. *Byrsonima coccolobifolia* showed high budding and *caducifolia* synchrony. It was characterized as evergreen and has a Steady State flowering strategy. Fruit formation was asynchronous for most of the year. *Byrsonima sericea* has a cornucopia flowering strategy, with restricted fruit production. No correlation between B. coccolobifolia phenophases and climatic factors was recorded. Data such as temperature, humidity and photoperiod were correlated with the reproductive phenophase of *B. sericea*. No influence of ants on the quality of the fruits of the two species was detected, regardless of self-incompatibility.
Keywords: Flowering, Fruiting, Formicidae

INTRODUCTION

In ecosystems, there are numerous associations between insects and plants, and there may be mutual benefit. Some plants develop natural mechanisms to attract pollinating insects and these help them reproduce (Fonseca, 1994). Insects can play a role in the biological control of herbivores, seed dispersal, pollination and soil fertilization, based on the accumulation and movement of organic matter (Jordano et al, 2006; Del-claro, 2005; Conceição et al, 2004; Abril & Bucher, 2004). In return, plants offer shelter and food (Vasconcelos, 1991).

The *genus Byrsonima* can be found in forest, big savannah and open savannah (Pott, 1994). Known as murici, its fruits are used by traditional populations in folk medicine, as a healing and anti-inflammatory, due to their high astringency (Castro, 2003). They are used in the production of sweets, juices, liqueurs, ice cream and for fresh consumption (Almeida et al, 1998), a source of income for families.

Among the insects that help in the reproduction of plants, ants stand out. As they make contact with the plants' reproductive organ, a large quantity of pollen grains pass through (Gómez & Zamora, 1992). They are very active when patrolling inflorescences, protecting against herbivory, contributing to increased fruit production (Vasconcelos & Davidson, 2000). There are cases of reduction in production and increase in herbivores, in plants where they were excluded (Oliveira et al, 1999).

Although the integument of many ants is not very hairy, making it difficult for pollen to adhere for pollination, in many species it is hairier than that of some arthropods, such as bees and wasps (Beattie, 1985). Despite having their limitations, such as the absence of wings and often foraging on the same plant, making cross-pollination difficult (Hölldobler & Wilson, 1990; Rico-Gray, 1989), they have some potential for pollination.

Therefore, the objective of the study was to verify whether there is similarity in fruit production between species of *Byrsonima* Rich (Malpighiaceae), self-compatible and self-incompatible and its relationship with ants.

MATERIAL AND METHODS

The areas of native vegetation where the study was carried out are in Alagoinhas-BA: One in BA 504 (in Calu, 12°09'53"S, 38°23'06"W) (Figure 1) and the other in UNEB vegetation complex, 12°10'42" S; 38°24' 43" W, in Alagoinhas- BA-BR. In the first area, species of *Byrsonima coccolobifolia* Kunth and in the second, Byrsonima sericea DC.

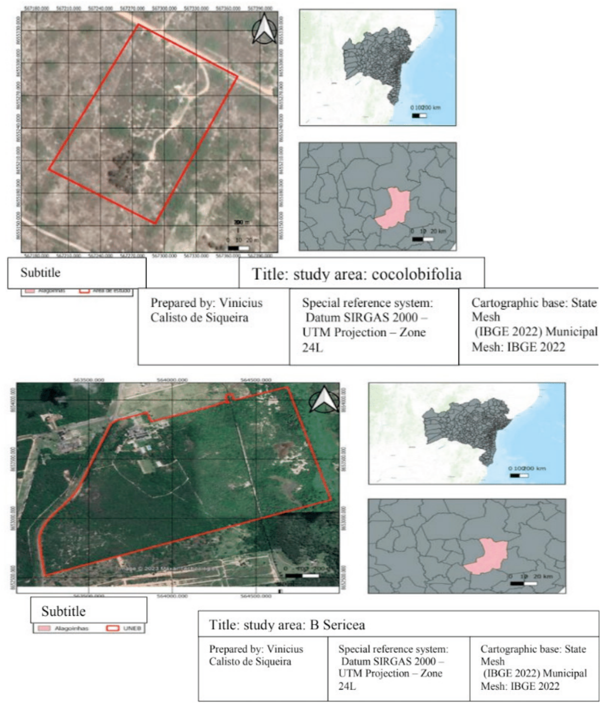

Figure 1: Study area of *B. cocolobifolia* in "Calu" and *B. sericea*, Alagoinha – BA, Brazil.

The study was carried out between August 2017 and July 2018, with phenological assessments adapted from (Bencke & Morellato, 2002), on 28 individuals of *B. coccolobifolia* and 21 of *B. sericea*. The reproductive (flowering and fruiting) and vegetative (budding and caducifolia) phenophase was recorded and the synchronism of each population was assessed: highly synchronous (number of individuals with phenophase above 60%); little synchronous (between 20% and 60%) or asynchronous (20% or less). The Fournier Intensity Percentage (1974) was measured for

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the phenophases of each plant.

Ants were manually collected from plant species, capturing them for 10 minutes, with entomological tweezers and also with honey and sardine baits, on each branch, for 1 hour. The Formicidae were identified at the UNEB Zoology Laboratory, Campus II. For the most frequent species, the 95% percentile was calculated in Excel 2016.

To test the ants' ability to enhance fruit production, the number of fruits produced, their weight and average diameter were calculated under the following conditions: exclusion of ants; exclusion of other insects (pollinators or herbivores), presence of more frequent ants and free inflorescences (natural conditions). The relationship between aggressiveness between ants and pollinators and fruit production was compromised due to the absence of pollinators during the year of study. The calculations of fruit weight and diameter were made in Excel and the differences in weight and diameter were performed using ANOVA and, subsequently, the t-test, using Statistics.

RESULTS AND DISCUSSION

Byrsonima coccolobifolia showed high synchronism, both in budding and deciduous, for a large part of the year (Figure 2). In November and December/2017, there was little synchrony for deciduous leaves, with March for budding.

Due to the constant rate of budding, with regular leaf fall, it is characterized as evergreen. In this pattern, new leaves sprout before the older ones fall, so that when leaf abscission occurs, the plant already has mature leaves (Pirani & Pedroni, 2009). This strategy differs from the literature, in which it is considered deciduous or brevidecidual (Benezar & Pessoni, 2006; Silvério & Lenza, 2010). It may be a characteristic of the plant in the region, due to climatic factors without great variation during the year.

The plant also showed bud formation with high timing in the months of November/2017 to January/2018, low timing for most of the year, being observed in October 2017 and February, April, May and June 2018. From August to September 2017, March and July 2018, there was no synchronization (Figure 2).

Flowering was highly synchronous in the months of December/2017 and February/2018. However, low synchronism in November 2017, January and June 2018. It was asynchronous from August to October 2017, February to May 2018 and July 2018. The flowering strategy was of the Steady State type, with continuous flower production, associated at low intensity, occurring throughout most of the year.

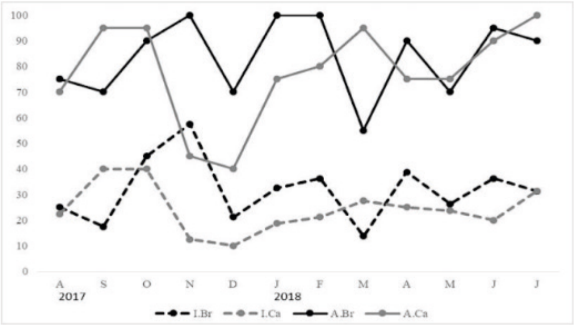

Figure 2: Activity and intensity of vegetative phenophases between species of B. coccolobifolia, August 2017 to July 2018, Alagoinhas – BA.

I = Intensity; A = Activity; Br = Leaf sprouting; Ca = Caducifolia

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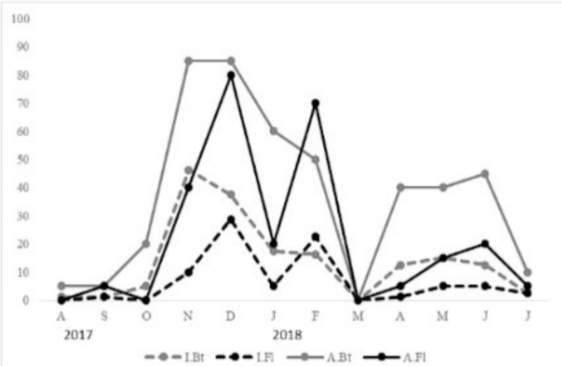

Figure 3: Activity and intensity of reproductive phenophases (buds and flowers) between B. coccolobifolia species, August 2017 to July 2018, Alagoinhas – BA. I = Intensity; A = Activity; Bt = Button; Fl = Flowers

In the months of December/2017, March, May and June/2018, there was low synchronism in the fruiting rate of immature fruits. In the months of September, October and November/2017, April and July/2018, this phenophase was asynchronous. The months of August/2017, January and February/2018 have high synchronization (Figure 3).

The formation of ripe fruits was synchronous only in the first month of the study, August 2017, with asynchrony in part of the year. The intensity of immature fruits was notably greater than that of mature fruits, probably due to the rapid period between maturation and dispersal of these fruits and their attractiveness to insects and other animals (Benezar & Pessoni, 2006; Bocchese et al, 2008).

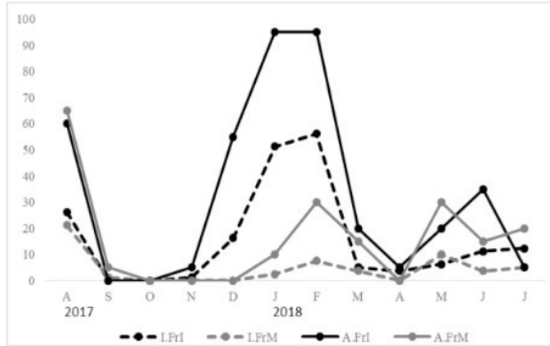

Figure 4: Activity and intensity of reproductive phenophases (fruiting) between species of B. coccolobifolia, August 2017 to July 2018, Alagoinhas – BA. I = Intensity; A = Activity; FrI = Immature Fruit; FrM = Ripe Fruit in *B. sericea*, high synchrony was noted in the population during the budding and deciduous phenophases, which were constant throughout its cycle (Figure 4). The appearance of buds began in October/2017 and, at this stage, the population was not very synchronous, with an increasing activity rate until January/2018, when it began to decline.

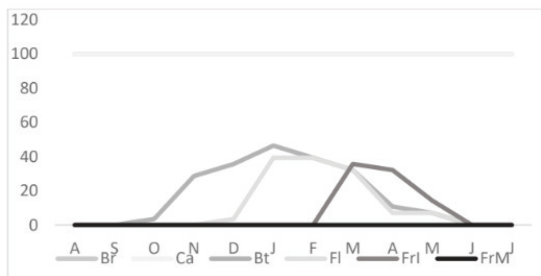

Figure 5: Reproductive and vegetative phenophases of B. sericea. Alagoinhas, August 2017 to July 2018. Br = budding; Ca = deciduous; Bt = buttons; FrI = immature fruits; FrM = ripe fruits

Close to this period, flowering began in November/2017, with flowers opening in December, continuing in January/2018. During this period, the population, as in the previous phase, was also not very synchronous. But during this stage, flowers opened every day of the month, as the species has a "cornucopia" type flowering pattern. This is a factor that favors pollination, as plants that have high flower production are often pollinated by bees (Gentry, 1974). Flowering lasted until February/2018, with fruit formation gradually, also showing low synchrony, but with a peak of activity at the beginning of March/2018, ending at the end of April.

Regarding intensity, the budding phenophase occurred more intensely during January/2018, with the highest peak in February, reaching more than 70% (Figure 5). The deciduous phenophase was constant from September/2017 to January/2018 and had some variations from February to June/2018.

Bud formation began in October/2017 and gradually increased until January/2018. Flowering began in November, with flowers opening at the end of December/2017, with more vehemence from January to February 2018.

Fruit formation increased in February/2018 and continued until March of the same year, but as there was less intensity in the production of flowers, it had an impact on the emergence of fruits. In these cases, it happens that the specialist pollinator is pollinating the same individual on a plant, as mentioned (Teixeira & Machado, 2000). Since the species is self-incompatible, these circumstances can influence the productivity of the population. Even though there were individuals starting these phases mentioned, as shown in Figure 6, it was possible to notice the difference in relation to the intensity of occurrence of these phenomena, in each of the individuals.

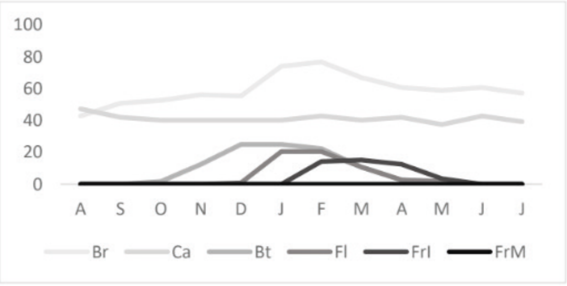

Figure 6: Intensity in the reproductive and vegetative phenophases of B. sericea. Alagoinhas-BA, August 2017 to July 2018. Br = budding; Ca = deciduous; Bt = buttons; FrI = immature fruits; FrM = ripe fruits

As in *B. sericea*, there was low flowering intensity. This result interfered with the quantity of fruits, with a percentage that was not very synchronous, between 20% and 60%.

A total of 21 species of ants were found throughout the study year, associated with *B. coccolobifolia*. Of these, Camponotus blandus (FR SMITH, 1858) and *E. tuberculatum* (Olivier 1792) were most frequent. The same number of species was found in B. Sericea. The most frequent were Cephalotes pusillus (Klug, 1824) and E. tuberculatum.

With regard to phenophases and climatic data in *B sericea*, there was a positive correlation between temperature and photoperiod, as well as a negative correlation between humidity and budding activity and intensity (Tables 1 and 2). Furthermore, positive correlation between temperature and flowering.

According to (Talora & Morellato, 2000), climatic factors can induce the emergence of phenophases during their life cycle, such as budding and flowering, in which temperature and an increase in photoperiod are associated with the stimulation of each of these phenophases.

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	Bt		Fl		FrI	
	rs	p	rs	p	rs	p
Temperature	0,94	**4,97E-06**	0,78	**0,002**	0,24	0,43
Moisture	-0,83	**0,0007**	-0,51	0,08	0,19	0,54
Precipitation	-0,3	0,32	-0,22	0,48	0,36	0,24
Photoperiod	0,8	**0,0017**	0,4	0,19	-0,21	0,51

Table 1. Correlation between climatic and phenological data (activity) of B. sericea. Alagoinhas -BA, 2017-2018.

Br = budding; Bt = buttons; FrI = immature fruits

	Br		Ca		Bt		Fl		FrI	
	rs	p	rs	p	rs	p	rs	p	rs	p
Temperature	0,7	0,01	-0,11	0,71	0,9	6,09E-05	0,79	0,002	0,54	0,06
Moisture	-0,28	0,36	-0,04	0,9	-0,84	0,00057	-0,52	0,08	-0,09	0,75
Precipitation	-0,14	0,66	0,072	0,82	-0,26	0,4	-0,22	0,47	0,1	0,73
Photoperiod	0,09	0,76	-0,09	0,76	0,86	0,00025	0,4	0,18	-0,03	0,91

Table 2. Correlation between climatic and phenological data (intensity) of B. sericea. Alagoinhas – BA, 2017-2018. Br = budding; Ca = deciduous; Bt = buttons; FrI = immature fruits; FrM = ripe fruits

Budding and flowering of *B. sericea* occurred from October to January (2017 -2018), in the dry period. The increase in temperature may have influenced the appearance of buds and inflorescences, it is during this period that flowering occurs.

In tropical regions, the influence of precipitation on phenology is not evident, with factors often related to plants, temperature and photoperiod (Morelato et al, 2000; Marques & Oliveira, 2004). However, correlation between B. coccolobifolia phenophases and climatic factors were not significant (Table 3).

	Br	Ca	Bt	Fl	FrI	FrM
Temperature	0,45	0,53	0,12	0,14	0,20	0,44
Moisture	0,22	0,21	0,14	0,27	0,16	0,43
Precipitation	0,26	0,62	0,88	0,75	0,30	0,46
Photoperiod	0,54	0,14	0,06	0,15	0,46	0,08

Table 3 - Correlation between climatic factors and vegetative reproductive phenophases of B. coccolobifolia for the period from August 2017 to July 2018, in an area of Cerrado phytophysiognomy in the Municipality of Alagoinhas, BA. $p<0.05$

As for the weight of the fruits, despite a small difference between the values with and without ants, it was smaller in their absence, with no significant difference (Tables 4). This only indicates a tendency that without ants there is a reduction in fruit quality.

The inflorescences, from branches isolated with grease to avoid contact with ants, fell before the fruits ripened. Due to the absence of ants to protect the plant from other insects, herbivores may have easily accessed the plant, as they are more mobile than ants. Since ants would play a role in regulating insects harmful to plants (Diamé et al, 2018), a reduction in production was expected.

	B. coccolobifolia	B. sericea	B. coccolobifolia	B. sericea
Inflorescence	Fruit weight (g). Mean + or minus the standard deviation (g)		Fruit diameter (g). Mean + or minus the standard deviation (cm)	
Free	0,27 ± 0,07 A*	0,30 ± 0,03 A*	0,79 ± 0,11 A*	0,95 ± 0,06 A*
Without ants	0,21 ± 0,07 A	0 A*	0,76 ± 0,14 A	0 A*

Table 4. Weight and diameter of B. cocolobifolia and B. sericea fruits in free inflorescences (with ants) and without ants. Alagoinhas, July 19, 2018.

* Equal letters in the same column, means do not differ significantly from each other using the t test at 95% confidence

Regarding diameter, as well as weight, using the t test, there was no significant difference between treatments, which indicates that with or without ants, the diameter of the fruits also decreases.

In the case of B. sericea, it was presumed that there would not be a high difference in the diameter of the fruits, since the species is self-incompatible (Gentry, 1974) and, therefore, there would be no effective pollination by ants, the chances of gain would be due to the plant protection, which these ants could favor, indirectly contributing to reproductive success. Mainly because colonization by ants reduces herbivory, increasing the probability of fruit production (Izzo & Petini-benelli, 2011).

In the case of *B. cocolobifolia*, there was a greater chance of pollination by ants, as the plant is self-compatible. As stated (Conceição et al, 2004), ants would have their limitations when moving with enough intact pollen from one plant to another or even from one inflorescence to another of the same individual to favor cross-pollination, most often done by bees, so self-pollination by these insects is more likely, unlike the first mentioned plant.

In the test without ants on *B. sericea* there was no result, as there were few individuals with fruits and those branches that were free had a greater quantity of fruits.

During the study, the absence of bees in the area was observed, which may have interfered with fruit production, even if the plant provided its resources, and this made it difficult to test whether the ants were aggressive and hindering their role as pollinators. This is a worrying factor, especially because the decline of insects has occurred due to the loss of habitats, replacement of natural areas with urbanized or agricultural ones, pesticides and agricultural fertilizers, as well as introduced species and climate change (Sánchez-Bayo & Wyckhuys, 2019).

With *B. cocolobifolia* it is likely that ants help with fruit production. Benezar & Pessoni (2006) found the presence of Formicidae of the genus Camponotus in a beneficial relationship with the plant, to the point of defending it if the raceme was touched.

This species is self-compatible, in addition to having a mixed reproductive system, being able to perform allogamy and autogamy (Benezar & Pessoni, 2006), which facilitates pollination by other insects, in addition to bees. Therefore, there is a tendency that in these species, ants may play an important role in pollination, whether directly or indirectly. Studies have shown that there is no difference in the number and weight of fruits between trees pollinated by winged insects, such as bees, wasps, butterflies, and ants (Diamé et al, 2018). However, from this study it is not yet possible to say.

CONCLUSION

The species *B. sericea* has a cornucopia flowering strategy, with restricted fruit production. Climatic data such as temperature, humidity and photoperiod are correlated with the plant's reproductive phenophase, therefore also influencing fruit production. Byrsonima coccolobifolia was characterized as evergreen and has a Steady State flowering strategy, with continuous flower production, associated with its low intensity. The formation of ripe fruits was asynchronous for most of the year. Ants did not influence fruit quality in the plants of the *genus Brysonima* studied, regardless of their self-compatibility and incompatibility.

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