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Reproductive phenology of *Carapa guianensis* Aubl. (Meliaceae) in two forest areas of the Central Amazon

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Abstract— *This article presents the phenological study of Carapa guianensis Aubl species from 1974 to 2000, in ADFR and TFES forests stations research in Central Amazon, Brazil. The objective was to analyze and compare the phenological pattern (flowering and fructification) and the influence of the climatic factors. The flowering in the TFES started in a higher precipitation season; meanwhile at ADFR it was irregular. The fruiting in both areas occurred more frequently rainiest season, but in the ADFR the mature fruits were more irregular. The frequency of occurrence was annual from "flower bud" to "immature fruit" phenophases in TFES, but was over-annual only in "mature fruits". But in ADFR, was annual from "flower bud" to "anthesis" and was over-annual in immature fruit" and "mature fruit", both with irregular pattern and duration from intermediate to prolonged. The duration of the floral bud phenophase and anthesis was similar in the two areas; however, 'immature fruits" in the TFES, in general, was higher than in the ADFR. But "mature fruits" were higher in ADFR. The phenophases did not occurred at same time in all trees studied, possibly due the influence of the intraspecific genetic variability in interaction with the environment.*

Keywords— crabwood, flowering, fruiting, raining season.

I. INTRODUCTION

The long-term phenological study began in 1963 in the Adolph Ducke Forest Reserve (ADFR) and in 1974 at the Tropical Forest Experiment Station (TFES), both located in the region of Manaus, Amazonas, Brazil [1, 2].

In these areas, there is a major investigation of phenological events of about 120 species of tropical forests to generate subsidies to the management and reforestation plans in the Amazon forest. This research has generated several publications on the phenology of trees in the Central Amazon, which analyze the data collected in the ADFR. The former studied the phenology of Amazonian forest species occurred in a period of seven years (1962-1968) and the latter analyzed the phenology of forest species in upland tropical rainforests in the Central Amazon [1, 2, 3, 4, 5, 6, 7, 8].

In what concerns to the population of a single species or family, studies present results on the phenology of *Aniba rosaeodora* Ducke (Lauraceae) for a period of eleven years (1968-1978) [3]. The phenology of *Copaifera multijuga* Aubl (Fabaceae) was evaluated in seven years (February 1979 to December 1985), and there in relation to weather elements [4]. Also, was analyzed the phenological behavior of *Diplotropis purpurea* Rich. (Fabaceae) in six years (1980-1985) [5]. Among the studies on families, two must be highlighted: the phenology of five species of Lecythidaceae over an eleven-years period (1978-1988) [6] and the phenology analysis of five species of Sapotaceae in one twenty-one-year period (1970-1990) [7].

The species *Carapa guianensis* Aubl. (Meliaceae), commonly known as crabwood or andiroba in Brazil, was selected for the analysis of phenological behavior, due to its economic, social and ecological importance, also abundant in the Amazon region. The trees of andiroba can reach up to thirty meters high with a cylindrical trunk, straight and buttresses at the base [8,9]. It is a species of multiple uses, having a high-quality wood, which can be used in carpentry, construction, shipbuilding, boards and plywood, furniture, beams, interior works, pencils, masts and others. Another extraordinary use is the oil extracted from its seeds, which is currently one of the most important products in the regional market. Andiroba oil is a clear and transparent liquid, that at temperatures below 25°C it solidifies as vaseline [9,11, 12].

The oil can be used in the manufacture of soaps, candles, in the composition of cosmetics and in different medicines because andiroba oil is a rich source of essential fatty acids, including oleic, palmitic, myristic and linoleic acids, and contains no fatty components such as triterpenes, tannins, and alkaloids. The bitter taste of the oil is attributed to a group of terpene chemicals called meliacins, which are very similar to the bitter antimalarial chemicals. Recently, one of these meliacins, called gedunin, was documented to have pest control properties and antimalarial effects equal to that of quinine. A chemical analysis of andiroba oil identified the anti-inflammatory named andirobina, which has healing and insect repelling properties that are attributed to the presence of limonoids. The interest in using andiroba oil in cosmetics has increased significantly, especially after the patenting of a cream by Yves Rocher, from France, that has moisturizing and anticellulite properties based on this oil. [13].

The phenological study of this species is essential, as it enables the determination of the regularity and predictability in the supply of this natural resource, which allows more rational use in the Amazon.

The phenological patterns would be most affected by the intrinsic characteristics (genetic, physiological and reproductive) of the species and by ecological factors (pollination, predation, competition) and not only by climate variables [7]. Researchers also report the influence of climatic elements (precipitation, solar radiation, evaporation, relative humidity) basis on phenological studies on *Copaifera multijuga* and five Sapotaceae species [4, 7].

Phenology studies were installed in ADFR in 1963 and in TFES in 1970. Since then, phenophases of flowering, fruiting and leaf change have been studied. However, the ADFR is no longer surrounded by native forests, because all the perimeter has been deforested by the urban expansion in Manaus city. While the EEST is 43 km away from the nearest town and surrounded by native forest. Consequently, the climatic conditions and the interaction with other biotic components, especially pollinators, predators and dispersers, are under different conditions and, therefore, may influence the patterns of occurrence of the phenophases studied in this work.

This study aimed to determine the patterns of flowering (flower bud and anthesis) and fruiting (mature and immature), of *C. guianensis* and compare the phenological events in order to determine whether this species has similar phenological behavior in two distinct areas of upland forest (ADFR and TFES) and if it responds to the climatic factors over time between the years from 1974 to 2000. It is important to determine the pattern of flowering and fructification of phenophases to characterize the ecological group of forest succession (climax) to which these species belong [14]. The knowledge of the phenological pattern allows more specific studies on the reproduction of the species and also to provide basic information to support the planning of silvicultural projects for species plantations, timber and oil production and for the recovery of degraded areas, since there are good growth results in experimental plantations [15,16,17]. Therefore, the hypothesis of the study is that the climatic changes affect the phenophases of the Amazonian species and impair the production of fruits, thus reducing the supply of seeds for trees' reproduction and reducing the source of food for animals, changing the forest's ecological balance.

II. MATERIALS AND METHODS

The studies were conducted in the ADFR, located 26 km north of Manaus, on AM-010 Road, measuring 10,072 ha in an upland rainforest at 59º52'40" to 59º52'00" west longitude and 03º00'00" to 03º08'00" south latitude [18] and in the TFES, located at approximately 45 km north of Manaus, on BR-174 Road, measuring 21,000 ha, at 2º37' to 2º38' south latitude and 60º09' to 60º11' west longitude [19].

According to the Köppen classification system, local climate is designated *Afi*: *A* - tropical climate with virtually no winter, the average temperature for the coldest month is never lower than 18ºC; *f* - rains throughout the year; *i* - indicating isotherm, that is, the annual average temperature fluctuations do not reach 5ºC; there is no winter or summer [19]. Climatological data used in this study were provided by the Coordination of Research on Environmental Sciences of the National Institute of Amazonian Research (INPA) and collected at the climatological station of the ADFR for the two experimental areas, which is located approximately 30 km away from the TFES.

The Figure 1 shows annual rainfall and minimum, average and maximum temperatures from in twenty-seven years data (1974-2000).

The driest month was August with 101 mm and the month with the highest average precipitation was April with 304.34 mm. The average monthly temperature ranged from 25.5°C to 26.7ºC. The average of minimum temperatures that predominated were around 22°C. Maximum temperatures ranged from 31.3ºC to 33.4ºC at the end of the dry season, whereas the lowest values were observed in the rainy season 22,1ºC.

The frequent rainfall which extend from November to May, called rainy season, reached monthly averages over 263 mm and lower average temperatures of 25,8º C. There is also a less humid period between June and October, with less constant rainfall, but no water deficit. In this period, there was an average rainfall of 121 mm per month and higher temperatures of 32,5 º C, considered as the dry season.

The predominant vegetation in the region was classified as a tropical upland rainforest, characterized by a great diversity of tree, shrub and herbaceous species [20,21].

The forest that covers the areas studied in this work is part of the Amazon Moist Forest [22] which is always green, as the trees never lose all the foliage, at the same time, and has a large number of tree species that are usually divided into three distinct strata.

The upper or dominant stratum is formed by large trees with DBH (diameter at breast height) greater than 1 m and height sometimes reaching 45 m or more, as happens with *Cedrelinga catenaeformis* Ducke (Mimosoideae) and *Dinizia excelsa* Ducke (Fabaceae). The intermediate stratum (vegetation layer) is composed of smaller trees, whose DBH may exceed 1 m, but their height is usually below 45 m, as happens with *Enterolobium schomburgkii* Bth (Fabaceae), *Aniba duckei* Kostermans (Lauraceae), and palm trees such as *Euterpe oleracea* Mart. (Arecaceae) and *Mauritia aculeata* H.B.K. (Arecaceae). The lower stratum consists of species that develop in heavy shade conditions, such as *Geonoma deversa* (Poit) Kunth. (Arecaceae), *Manicaria saccifera* Gaertn (Arecaceae) and other shrubs and herbaceous plants [23].

The trees of the phenological study were previously selected in the forest according to their habitat, height, DBH and stem form [1]. Five *C. guianensis* individuals were sampled from the ADFR and five from the TFES. Subjects were observed with the aid of binoculars to record the phenological phases. Monthly observations were carried out in this study. The following phenophases were analyzed: flowering and fruiting. The flowering was divided in “flower buds” (appearance) and “anthesis” (early flowering). The Fruiting, divided into “immature fruits” (appearing new fruits) and “mature fruits” (presence of ripe fruits). The analysis was done from data collected monthly to verify the frequency of events, from 1974 to 2000 [2].

Phenological patterns are described according to “frequency” - number of cycles with and without phenophases per year, “regularity” - variation in the time of occurrence and, "duration of cycles or phases" - time in months that an individual remains in a phase or cycle [23,24].

The repetitive occurrence of phenological events in the year is called “annual frequency”. According to the annual frequency of flowering and fruiting, the species are classified as: “sub-annual” (more than one event per year), “annual” (one event each year) and “over-annual” (events at intervals of two years or more) [24].

The phenological data of ADFR and TFES were stored in DBASE III software and analyzed in FENOLOG, which is a software developed at the Coordination of Research on Tropical Forestry of INPA. The relationships between phenological data and climate variables was calculated by the non-parametric analysis of Spearman's correlation coefficient, considering the monthly average values of climate variables [25].

III. RESULTS

3.1 – Occurrence and pattern of phenophases

3.1.1 “Flower bud” phenophase

The “flower bud” phenophase of *C. guianensis* in TFES presented annual frequency, normally occurring at the beginning of the rainy season and positive correlation with the minimum temperature (r_s = 0.11, $p <0.05$) and day length (r_s = 0.24, $p <0.01$).

The greatest number of trees (3-4) with “flower bud” per month occurred in the years 1975 (Jan), 1976 (Dec), 1977 and 1978 (Nov), 1979 (Set), 1980 (Oct), 1983 (Jan), 1984 end 1986 (Oct), 1987 (Dec) and 1988 (Nov). In the years 1981, 1985, 1989, 1990 and 1991, there were no trees with flower buds. Only in 1992 two trees produced bud flower, but only one tree in the years 1982, 1992 until 1999 (Fig 2A).

The peaks of occurrence (three or more trees per year) were registered in 1975 (Jan and Nov), 1976 (Nov and Dec), 1977 and 1978 (Nov), 1979 (Feb, Sep and Oct), 1980 (Oct and Dec), 1983 (Jan), 1984 and 1986 (Oct), 1987 (Dec), and 1988(Nov) (Fig 2A).

The “flower bud” phenophase of *C. guianensis* in ADRF presented annual frequency occurring at the beginning of the rainy season, and positive correlation with the minimum temperature (r_s=0,12; p<0,05) and day length (r_s=0,21; p<0,01).

The greatest number of trees (3-5) with “flower bud” per month occurred in the years 1976 (Jan, Nov and Dec), 1977 (Nov and Dec), 1979 (Feb, Ago, Sep and Oct), 1989 (Nov), 1980 (Oct) But without flower bud, were observed in 1975, 1978, 1980, 1986, 1988, 1990, 1991, 1992, 1994, 1997 e 1998. Only in 1985 (Jun), 1995 (Nov and Dec) and 1999 (Sep) two trees produced bud flower, but only one tree in the years 1974 (Jul),1976 (Jan), 1979 (Aug, Sep and Oct), 1981 and 1982 (Nov), 1983 (Oct and Nov), 1984 (Feb, Oct, Nov and Dec), 1987 (Jul), 1993 (Aug), 1996 (Oct), 1999 (Oct and Nov) and 2000 (Nov) (Fig 2B).

The peaks of occurrence were registered in 1976 (Jan, Nov and Dec), 1977 (Nov and Dec), 1979 Feb, Aug, Sep an Oct), 1984 (Feb, Oct, Nov and Dec), 1989 (Nov), 1995 (Nov and Dec), 1999 (Sep, Oct and Nov) (Fig 2B).

3.1.2 - Anthesis phenophase

The Anthesis of *C. guianensis* in TFES, had the tendency of usually starting during the higher precipitation season and presented a positive correlation with minimum temperature (r_s = 0.14; p < 0.01).

The greatest number of trees (3-5) per month occurred the anthesis in the years 1975 (Jan and Feb), 1976 (Dec), 1977 (Nov and Dec), 1978 (Nov), 1979 (Sep and Oct), 1980 (Oct, Nov and Dec), 1983 (Jan and Feb), 1984 and 1986 (Oct and Nov), 1988 (Jan, Nov and Dec). But without anthesis were observed in 1981, 1985, 1988, 1990 and 1991. Only in 1978 (Dec) and 1979 (Jan) two trees they were in anthesis, but only one tree in the years 1975 (Nov and Dec), 1976 (Nov), 1979 (Sep and Nov), 1982 (Sep and Oct), 1992 (Mar), 1993 (Jan, Sept and Oct), 1994, 1995 and 1997 (Oct and Nov), 1998 (Sep and Oct) and 1999 (Feb) (Fig 3A).

The peaks of occurrence were registered in 1975 (Jan, Feb, Nov and Dec), 1976, 1977 and 1978 (Nov and Dec), 19779(Jan, Feb, Sep, Oct and Nov), 1980 (Oct, Nov and Dec), 1983 (Jan and Feb), 1984 and 1986 (Oct and Nov), 1987 (Dec), 1988 (Jan, Nov and Dec), 1992 (Mar, Apr and Dec) and 1993 (Jan, Sep and Oct) (Fig 3A).

The greatest number of trees (3-5) per month in ADFR occurred the anthesis in the years 1976 (Jan and Nov), 1977 (Jan and Dec), 1978 (Jan), 1982 and 1983 (Jan), 1989 (Nov) and 2000 (Jan). But without anthesis were observed in 1974 to 1975, 1980, 1986, 1988, 1991 to 1992, 1994, 1997 to 1998. Only in 1985 (Jun), 1995 (Dec) and 1999 (Oct) two trees they were in anthesis, but only one tree in the years 1976 (Feb), 1979 (Feb, Sep, Oct, Nov and Dec), 1981, 1982, 1983 (Jan, Nov and Dec), 1984 (Feb, Mar, Oct, Nov and Dec), 1985 (Jan, Jun and Jul), 1987 (Jul and Aug), 1990 (Jan), 1993 (Ago and Sep), 1996 (Oct, Nov and Dec), 1999 (Dec) and 2000 (Nov and Dec) (Fig 3B).

The peaks of occurrence were registered in 1976 (Jan, Feb and Nov), 1977 (Jan and Dec), 1978 (Jan), 1979 (Feb, Sep, Oct, Nov and Dec), 1982 and 1983 (Jan, Nov and Dec), 1984 (Feb, Mar, Oct, Nov and Dec), 1985 (Jan, Jun and Jul), 1989 (Nov), 1996 and 1999 (Oct, Nov and Dec) and 2000 (Jan, Nov and Dec) (Fig 3B).

3.1.3 - Immature fruit phenophase

The production of immature fruits in the TFES presented highest annual frequency, usually occurring during rainy season (Dec, Jan and Feb) (Fig. 4A). It showed significant positive correlation with precipitation ($r_s = 0.19$; $p < 0.01$) and minimum temperature ($r_s = 0.20$; $p < 0.01$), and significant negative correlation with maximum temperature ($r_s = - 0.24$; $p < 0.01$).

The greatest number of trees (3-5) per month the immature fruit occurred in the years 1975 (Mar), 1979 (Nov and Dec), 1980 (Jan), 1981 (Jan and Feb), 1983 (Mar), 1986 (Dec), 1987 (Jan), 1988 (Feb and Mar). But without immature fruit was observed in 1985, 1990, 1991 and 2000. Only in 1975 (Apr), 1977 (Jan), 1978 and 1989 (Jan and Feb), two trees had immature fruit, but in only one tree in the years 1976 and 1978 (Dec),1982 (Nov and Dec), 1984 (Dec), 1992 (May, Jun, Jul, Aug, Sep and Oct), 1993 (Mar, Apr, May, Nov and Dec), 1994 (Dec and Jan), 1995(Jan, Feb, Mar and Dec), 1996 (Jan and Feb), 1997 (Jan, Feb, Mar, Apr, May and Dec), 1998 (Jan, Feb, Nov and Dec), 1999 (Mar) (Fig 4A).

The peaks of occurrence were registered in 1975 (Mar and Apr), 1978 (Jan, Feb and Dec), 1979 (Feb, Nov and Dec), 1980 (Jan), 1981 (Jan and Feb), 1983 (Mar), 1986 (Dec), 1987 (Jan), 1988 (Feb and Mar), 1989 (Jan and Feb), 1992 (May, Jun, Jul, Aug, Sep and Oct), 1993 (Mar, Apr, Nov and Dec), 1995 (Jan, Feb, Mar and Dec), 1997 (Jan, Feb, Mar, Apr, May and Dec) and 1998 (Jan, Feb, Nov and Dec) (Fig 4A).

In the ADFR, the phenophase "immature fruit" presented an over-annual pattern that occurred during rainy season.

The greatest number of trees (3-5) per month in ADFR occurred the "immature fruit" in the years 1974 (Jan), 1976 (Mar), 1982 (Feb) and 1983 (Mar and Apr). But without "immature fruit" was observed in 1975, from 1977 to 1981, 1986, 1988, 1989, 1991, 1992, 1994, 1995, 1996 and, from 1998 to 2000. Only in 1982 (Mar), two trees had "immature fruit", but only one tree in the years 1984 (May), 1985(Jan), 1987 (Sep, Oct), 1990 (Mar), 1993 (Out) and 1997(Jan and Feb) (Fig 4B).

The peaks of occurrence were registered in 1974 (Jan), 1976 (Mar), 1982 (Feb and Mar), 1983 (Mar and Apr) (Fig 4B).

The longest intervals were observed from 1977 to 1981, in a 5-years period, and from 1994 to 1996 as well as from 1998 to 2000, in a 3-years period (Fig. 4B).

3.1.4 - Mature fruit phenophase

The phenophase "mature fruits" in the TFES presented an annual pattern and happened during rainy season (Fig. 5A). In this area, the occurrence of mature fruits was considered rare. Nonetheless, it tended to occur during rainy season, and showed significant positive correlation with precipitation ($r_s = 0.22$; $p < 0.05$) and minimum temperature ($r_s = 0.11$; $p < 0.05$).

The greatest number of trees (3) per month the mature fruit occurred in the years 1983 (Mar), 1987 (Feb) and 1988 (Apr). Only in 1974 (Mar), two trees had "mature fruit". But without immature fruit was observed from 1975 to 1982, in 1984, 1986, from 1989 to 1993 and 1996. Only in one tree occurred in 1985 (Jan), 1994 (Mar), 1995 (Apr), 1997 (Jun), 1998 (Mar) and 1999 (Apr) (Fig 5A).

The peaks of occurrence were registered in 1983 (Mar), 1987 (Feb) and 1988 Apr) (Fig 5A).

The phenophase "mature fruits" in the ADFR presented annual frequency irregular (Fig. 5B). It tended to happen during rainy season and showed a significant positive correlation with precipitation ($r_s = 0,12$; $p < 0,05$).

The greatest number of trees (3-5) per month the mature fruit occurred in the years 1974 (Feb) and 1983

(May and Jun). But without mature fruit was observed in 1975, from 1977 to 1981, 1984, 1986, 1988, 1989, 1991, 1992, from 1994 to 1996, and 1998 until 2000. Only in 1976 (April), two trees had mature fruit. Only in one tree in 1982 (Apr), 1985 (Feb), 1987 (Oct and Nov), 1990 (Apr), 1993 (Nov) and 1997 (Mar, Apr, May and Jun) (Fig 5B).

The peaks of occurrence were registered in 1974 (Feb), 1983 (May, Jun) and 1997 (Mar, Apr, May, Jun) (Fig 5B).

3.2. Duration of phenophase

The variation of "flowering" phenophase duration (flower buds and anthesis) in *C. guianensis* in TFES and ADFR, was lower than that of "fruiting" phenophase. While "flower buds" ranged from one to three months in TFES, in ADFR it was one to four months. The "anthesis" had no differences and the variation was from one to five months. However, "immature fruits" in the TFES ranged from one to six months and in ADFR ranged from one to two months. "Mature fruits" did not change in the TFES and occurred in one month, but in the ADFR the variation was one to four months (Table 1).

The differences in phenophases duration, mainly fruiting of *C. guianensis*, between the two areas may be related to the adaptation strategies to the environment, especially herbivory by mammals and insects, since the area of the ADFR is limited by the urban expansion of Manaus city, concentrating the action of predators, whereas in TFES with larger area, it does not have physical barriers with other parts of the native tropical forest in the Manaus region.

IV. DISCUSSION

4.1 – Occurrence and pattern of phenophases

The flowering (flower buds and anthesis) of *C. guianensis* in the TFES and ADFR tends to happen in October, November, December and February. Similarly, flowering of *Couepia edulis* Prance, (Chrysobalanaceae) was observed in areas of the cities of Coari and Tefé, in the State of Amazonas, between February and March (rainy season), but found no differences in the phenological pattern of both study areas [26].

For the species *Caryocar villosum* Aubl (Caryocaraceae) within the ADFR, it was observed the occurrence of flowering during July and August (dry season). The same species being observed at Curuá-Una, another Experimental Station in the State of Pará, showed bloom in September and October, and also in the dry season [1, 27].

The fruiting (immature and mature fruits) in the TFES and ADFR tended to start in the period of most precipitation (November to May), what evidences the tendency of fruit production during the rainy season in agreement with what was verified for most of the species assessed in the ADFR [2] and for species assessed in an area near Belém - Pará [28]. However, the production of mature fruits of *C. guianensis,* in both study areas, showed intervals between the occurrences, which suggest a predation tendency of the fruit before maturation. These data are in agreement with the studies carried out on the evaluation of the production of mature fruits by species of the Amazonian forest [2, 8].

Meanwhile, the flowering and fruiting of *C. guianensis*, in twenty-seven years, occurred at the maximum in four among five trees, except the fruiting in the year 1974 in the ADFR. These result shows that the species can flowering and fruiting annually, but not all adult trees of the species flower and fruit each year.

4.2. Duration of phenophases

In the TFES, the highest frequency of flowering and immature fruits was two months, whereas of mature fruits was one month. In the ADFR, the highest frequency of flowering was two months and of mature and immature fruits was one month.

Different authors reported similar results. Flowering intervals ranging from one to seven months for in twenty-seven species were evaluated in the ADFR, and the most frequent duration was observed in twelve years of the study, it was three months. For fruiting, the intervals ranged from one to nine months, and the most frequent duration was five months [2]. An average fruiting duration ranging from three to six months was observed in a study of five species of Lecythidaceae in ADFR [6]. The fruiting period was the phenological event with the longest duration in the populations of *Psychotria nuda* (Cham. & Schltdl.) *Wawra* (Rubiaceae) and *P. brasiliensis* Vell. (Rubiaceae), and which more than 50% of its individuals presented mature fruits during most of the fruiting, which shows a high synchrony between the two populations. [29]. A study of *Guatteria australis* St. Hill (Annonaceae) in lowlands and sandbank forests reported duration of fruiting ranging from four to five months. [30].

We also observed that the duration of the phenophase "immature fruits" of *C. guianensis* in the TFES was longer than the duration of the flowering and mature fruits, whereas in the ADFR, the total duration of fruiting was longer than the duration of the flowering. Such observations are in agreement with other studies that verified a longer duration of fruiting (seven months) than flowering (six months) in a study of *Diplotrapis purpurea* [5].

The extended fruiting period of tropical plants might as well be explained by the fact that; besides dispersion, angiosperms must also have the strategy to defend their fruits from damages caused by herbivores

[31]. Plants can reduce the exposure time of ripe fruits by remaining with their unripe fruits for several months and ripening them little by little during fruiting [32]. Andiroba fruits are a source of primary food for rodents, armadillos, wild pigs, deer, etc. [33]. The Seeds can also be predated by insects (*Hypsipyla ferrealis* Hampson (Lepidoptera: Pyralidae) [34]. The area of the ADFR, surrounded by Manaus city may have influenced the local microclimate and the interaction with plants and animals and the modifications in regularity of phenophases.

V. CONCLUSIONS

The frequency of occurrence was annual from "flower bud" to "immature fruit" phenophases of *C. guianensis* in TFES, but was over-annual only in "mature fruits". But in ADFR, was annual from "flower bud" to "anthesis" and was over-annual in immature fruit" and "mature fruit".

The "flowering" in the TFES started in a higher precipitation season; meanwhile at ADFR it was irregular. The "mature and "immature fruits" in both areas occurred more frequently in rainiest season, but in the ADFR the "mature fruits" were more irregular.

The duration of the "flower bud" phenophase and "anthesis" were similar in areas; however, "immature fruits" in the TFES, in general, was higher than in the ADFR. But "mature fruits" were higher in ADFR.

The annual flowering and fruiting of *C. guianensis* did not occur at the same time in all trees of the species, possibly due do the influence of the great intraspecific genetic variability in native forests in interaction with the environment.

DISCLOSURE STATEMENT

The authors declare no conflict of interest. They also declare that the founding sponsors had no role in the design of the study; in the collection, analysis, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

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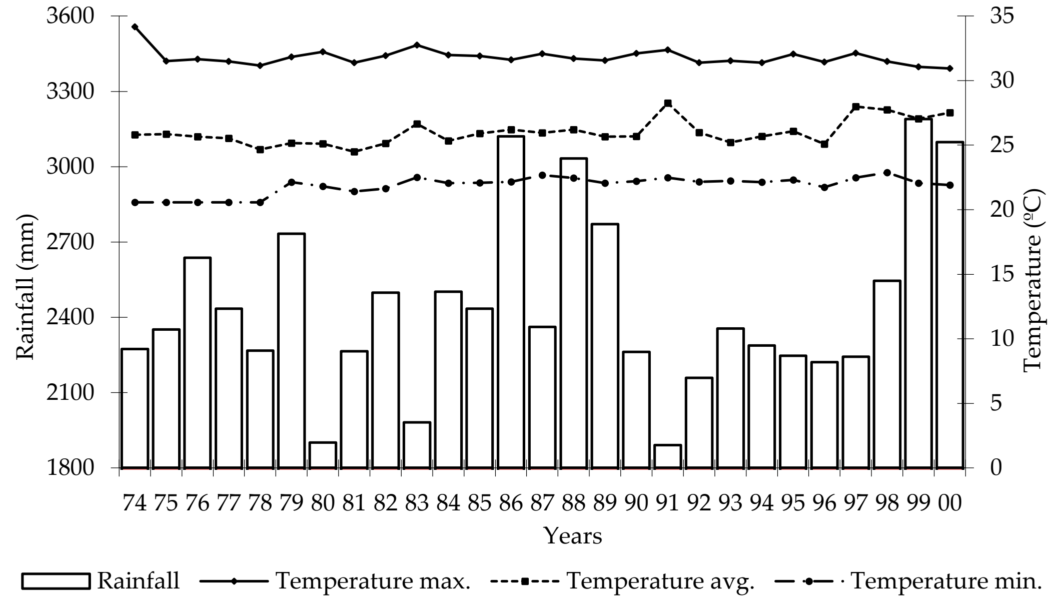

Fig.1: Annual rainfall, minimum, average and maximum temperatures between years 1974 to 2000 in Manaus, Central Amazon Brazil.

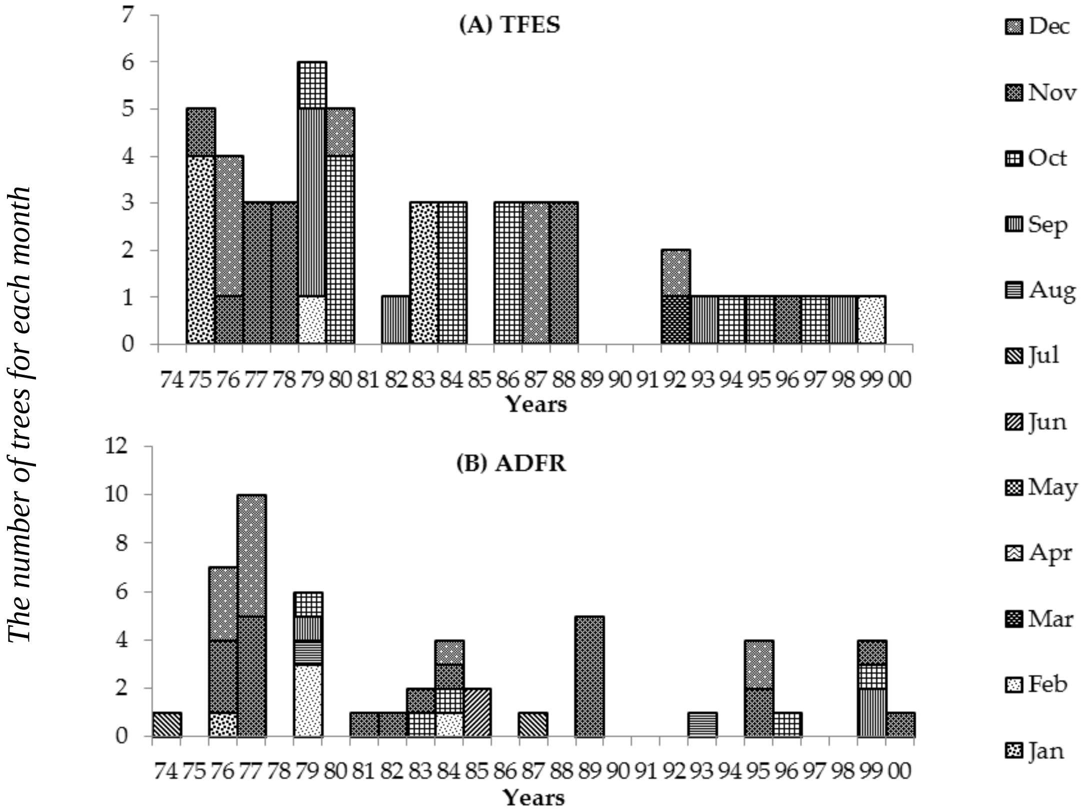

Fig.2: Flowering pattern (Flower bud) of Carapa guianensis in number of trees with flowers buds per month, in each year of observation. (A) Tropical Forestry Experimental Station – TFES (n=5) and (B) Adolpho Ducke Forest Reserve - ADFR (n=5) belonging to the National Institute of Amazonian Research - INPA, Manaus, Central Amazon Brazil.

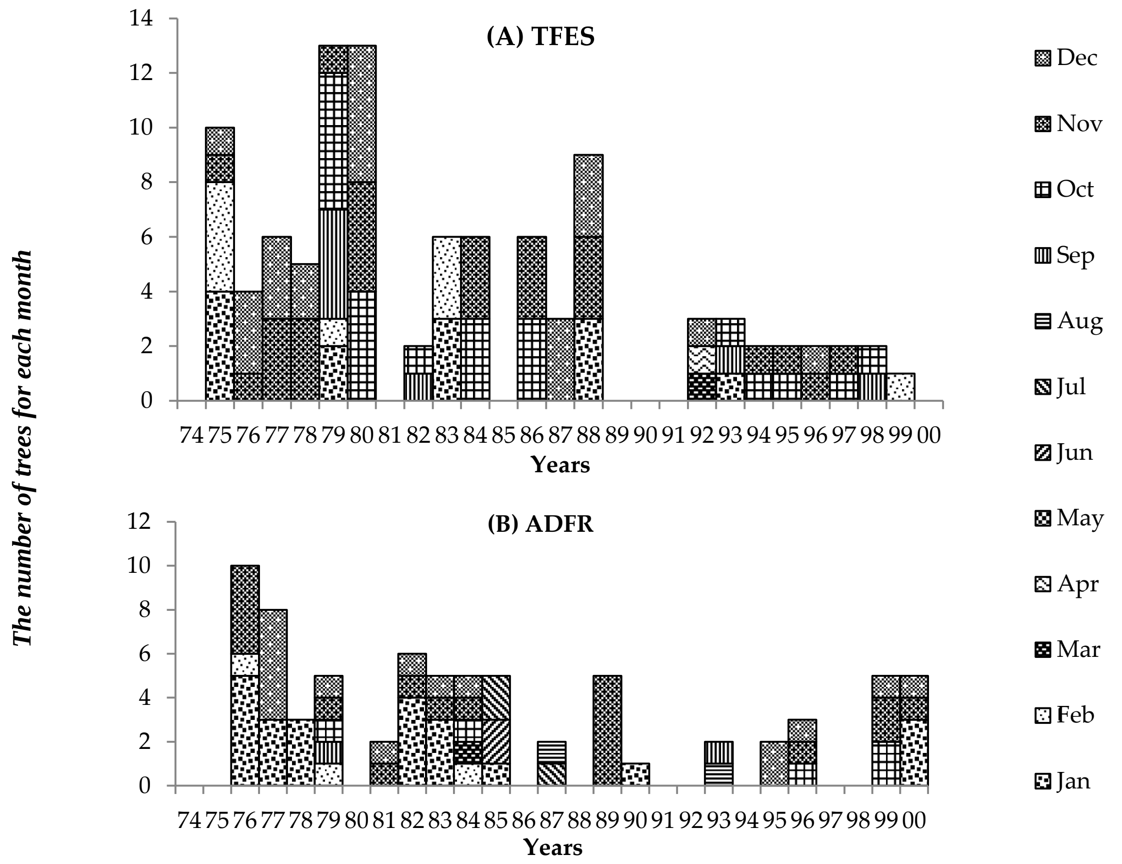

Fig.3: Flowering pattern (anthesis) of Carapa guianensis in number of trees flowering per month, in each year of observation. (A) Tropical Forestry Experimental Station – TFES (n=5) and (B) Adolpho Ducke Forest Reserve - ADFR (n=5) belonging to the National Institute of Amazonian Research - INPA, Manaus, Central Amazon Brazil.

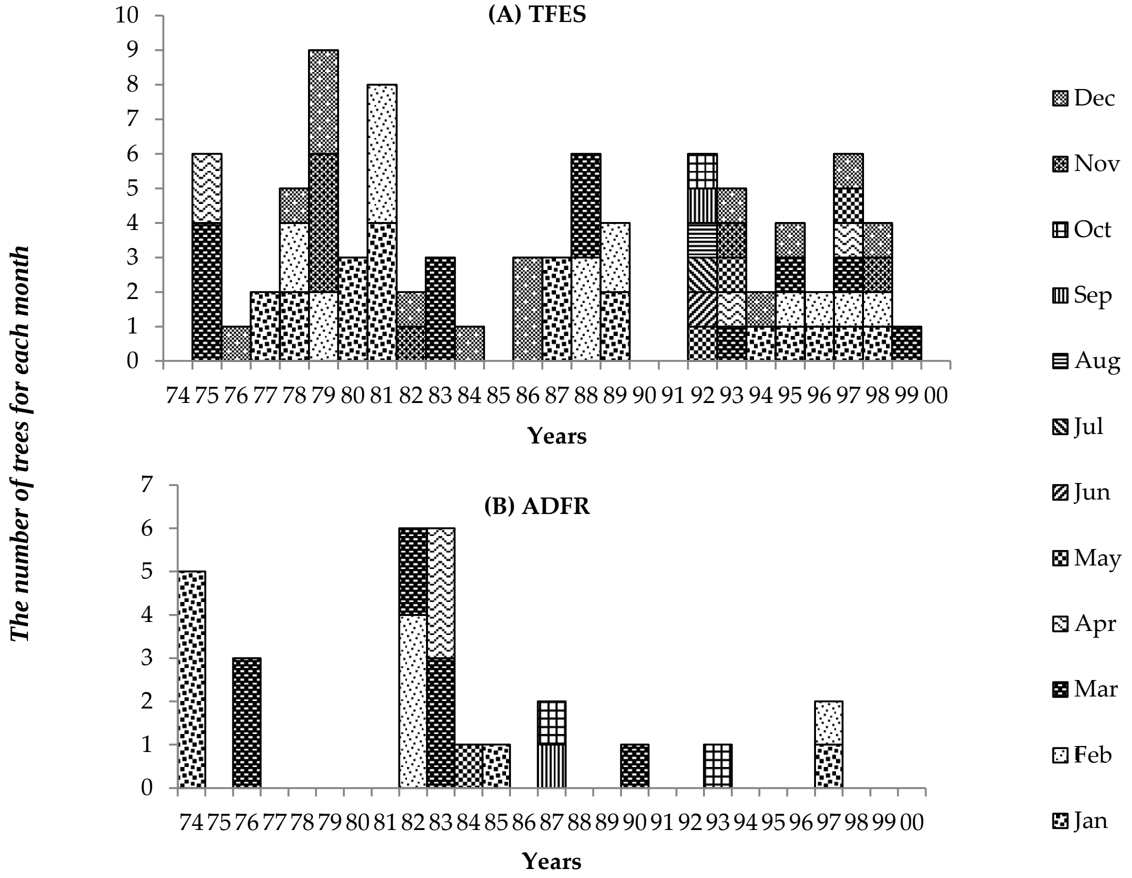

Figure 4. - Fruiting pattern (immature fruits) of *Carapa guianensis* in number of fruiting trees per month, in each year of observation. (A) Tropical Forestry Experimental Station – TFES (n=5) and (B) Adolpho Ducke Forest Reserve - ADFR (n=5) belonging to the National Institute of Amazonian Research - INPA, Manaus, Central Amazon Brazil.

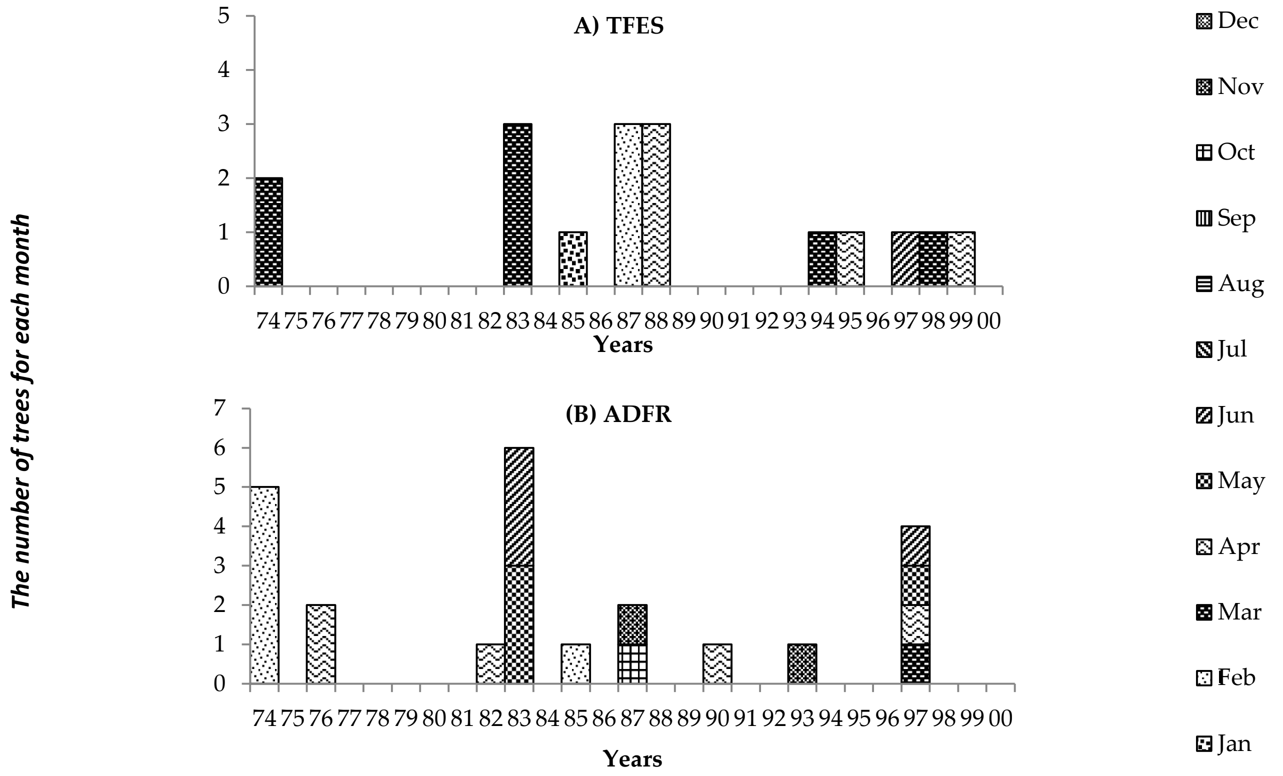

Fig.5: Fruiting pattern (mature fruits) of Carapa guianensis in number of trees fruiting per month, in each year of observation. (A) Tropical Forestry Experimental Station – TFES (n=5) and (B) Adolpho Ducke Forest Reserve - ADFR (n=5) belonging to the National Institute of Amazonian Research - INPA, Manaus, Central Amazon Brazil.

Table.1: Duration (months) of Flower buds, Anthesis, Immature fruits and Mature fruits phenophases of Carapa guianensis Aubl. (Meliaceae) in Tropical Forest Experimental Station (TFES) and Adolpho Ducke Forest Research (ADFR) in Manaus, Central Amazon Brazil.

Local study	Phenophase			
	Flower buds	Anthesis	Immature fruits	Mature fruits
TFES	1-3	1-5	1-6	1
ADFR	1-4	1-5	1-2	1-4