

Flowering and Fruiting Times on Four Species of *Annona* (Annonaceae) in Purwodadi Botanic Garden

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ABSTRACT

Annona is a genus belongs to Annonaceae family, consisting of numerous species that produce edible fruit. Four species namely *A. glabra*, *A. montana*, *A. muricata* and *A. squamosa* collections of Purwodadi Botanic Garden were recorded for its flowering and fruiting times, since November 2010 to April 2013. The data were scored and complemented with climate data (temperature, rainfall intensity, humidity) then analyzed using multiple linear regression analysis. The result showed that humidity was the most affected climate factors on the flowering and fruiting times of those species. Specifically, rainfall intensity (0-550 mm) affected to *Annona muricata*, temperature (25,56-28,33°C) and humidity (66,83-85,02%) to *Annona squamosa*, and humidity to *A. glabra* (71,62-85,02%) and *A. montana* (71,62 to 82,94 %) as well. Flowering time of *A. glabra* occurs three times a year in wet and dry, and fruiting occurs twice a year in the same month. *Annona muricata* is flowering throughout the year and fruiting twice a year in wet. *A. montana* and *A. squamosa* recorded one a year during the wet month.

Keywords: *Annona*, climatic factor, flowering and fruiting times, Purwodadi Botanic Garden

INTRODUCTION

Annona is a genus belongs to Annonaceae family, consisting of numerous species that produce edible fruit. *Annona* is economically important in many countries of Africa and Asia as well as in South, North and Central America. The name *annona* derives from the Latin “annual harvest” and indicates their typical annual producing cycle. In general, the *annona* are shrubs or small trees, with height from 5,0 to 7,5 m; they are erect or somewhat spreading and possess grey-brown bark, often rough and corrugated. The characteristic feature of the genus, *Annona* fruit is a syncarpium, formed by the amalgamation of many pistils and the fleshy receptacle. The hermaphrodite flowers are yellowish with 3 to 6 tepals and numerous stamens and pistils. The genus *Annona* has about 120 species namely *A. squamosa* L., *A. cherimola* Mill., *A. reticulata* L., *A. muricata* L., *A. dioica* among others. Its was found in Central and South America, Africa, Asia, and Australia [1-3]. Examples of edible *Annona* fruits are *A. cherimola* Mill., *A. diversifolia* Saff., *A. montana* Macfad., *A. muricata* L., *A. purpurea* Moc. Et Sesse, *A.*

reticulata L., *A. squamosa* L. and *A. squamosa* x *A. cherimola* [1]. Purwodadi Botanic Garden as one of the ex-situ conservation institution have a plant collection from genus *Annona*, namely *A. glabra*, *A. montana*, *A. muricata* and *A. squamosa*. The fourth species are periodically of flowering and fruiting. A plant has different behavior on the pattern of flowering and fruiting, but begins with the appearance of flower buds and ends with fruit ripening [4].

Climate elements affect the phenology of plants such as the vegetative phase and reproductive components. This effect can be minor or major. It is suggested that climatic factors not be directly responsible for triggering and synchronization of phenological events [5,6]. Also to climatic variables, flowering, and fruiting phenology also affected by biotic factors. Plants as part of a community in a habitat will be affected by the elements around it, through competition, herbivory, pollination and seed dispersal [7].

Time fruiting and flowering plants are correlated with climatic conditions that will be best for offspring survival in its habitat. This is one of the plants adaptations. In tropical regions with a pronounced dry season receives more annual sunlight available for photosynthesis compared with temperate climate region. Therefore simply be the consequence of selection for the same favorable time for reproduction about climate.

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Fruiting often occurs at the beginning of the rainy season, which presumably minimizes the exposure of seeds to seed predators. Its also provides maximum time for seedlings to develop the root systems needed to survive drought during their first dry season [8]. The phenological patterns are recorded about climatic 'triggers' (proximate factors) and plant-animal interactions or ultimate factors [9]. The aim of this study was to determine the climatic factors that most affect on *Annona* flowering and fruiting times in Purwodadi Botanic Garden, accompanied by flowering and fruiting times of four species.

MATERIALS AND METHODS

The research was conducted in Purwodadi Botanic Gardens on *Annona* collection (*A. glabra*, *A. montana*, *A. muricata* and *A. squamosa*) in vak XVIII.C. dan XIX.B.I., since November 2010 to April 2013.

Each phenological characteristic was observed from the whole canopy of selected trees. Some characters plant observed as follow; immature leaves, mature leaves, red or yellow leaves, flower buds, flowering, young fruits, immature fruits, and ripe fruits. Observations were made once a week. Another variable was observed is climate data, include temperature (°C), humidity (%) and rainfall intensity (mm).

Data were analyzed using multiple linear regression analysis with MINITAB 14 statistic program, resulting models to determine the most affected climate factors on the flowering and fruiting times of those species.

Then data were determined by the phenomena of phenological records. Phenomena under the following criteria were quantitatively described by the phenological records (Table 1) [10]. Its namely, vegetative growth, which consist of evergreens and deciduousness, patterns of stem elongation and seasonal synchronism of stem elongation. The second one is reproductive growth, which consist of flowering frequency, flowering period, the seasonal synchronism of flowering and fruiting.

RESULTS AND DISCUSSION

The result showed that humidity was the most affected climate factors on the flowering and fruiting times of those species. The models of each species were listed in Table 2. For *A. glabra*, each derivation of 1°C temperature will increase immature leaves as much as 6,05%. Each derivation of 1 mm rainfall intensity will increase immature leaves as much as 0,0217%. The derivation of 1% moisture will reduce immature leaves as much as 1,05% of *A. glabra*. The interpretation

model is increasing of each humidity 1°C temperature will reduce yellow leaves as much as 1,05%. Then, increasing 1 mm rainfall intensity will increase yellow leaves as much as 0,0036%. The other one is enhancement 1% humidity will reduce yellow leaves as much as 1,13. The humidity affected to *A. glabra* as much as 71,62 to 85,02%. Flowering time of *A. glabra* occurs three times a year in wet and dry, and fruiting twice a year in the same month. These species include weeds that need water and humidity are sufficient to germinate and produce a flower or fruit [11].

Humidity being the most influential factor on flowering and fruiting time in *A. montana* as much as 71,62 to 82,94%. The increasing of each 1°C temperature will reduce flower buds and flowering as much as 0,182%. Each increase of 1 mm rainfall intensity will reduce flower buds and flowering as much as 0,00027%. The increasing of each 1% humidity will reduce flower buds and flowering as much as 0,139%. The increasing of each 1°C temperature will increase young fruit as much as 0,03%. Increasing each of 1 mm of rainfall intensity will increase young fruit as much as 0,0010%. Then, each increase of 1% humidity will reduce young fruit as much as 0,393%. *A. montana* has flowering and fruiting time recorded one year during the wet month.

Rainfall intensity becomes the most influential factor to flowering and fruiting time on *A. muricata* with interval 0-550 mm. *A. muricata* flowering throughout the year and fruiting twice a year in a wet month. There are no climate factors that influence the emergence of flower buds, flowering, and ripe fruit. The seasonality of rainfall might influence the evolution of flowering and fruiting in tropical forests [12]. *A. muricata* can be well adapted to the area that has heavy rain (up to 4.000 mm/year) and also intolerant to an area

Table 1. The proportion of shoots in the phenological categories [10].

Ranks	Phenological categories	Means
1	Nothing (0%)	There were no shoots on vegetative and generative growth in whole canopy (no shoots at all)
2	Rare (30%)	Abundance of shoot on vegetative and generative growth less than 30% in whole canopy
3	Moderate (60%)	Abundance of shoot on vegetative and generative growth less than 60% in whole canopy
4	Moderately abundant (80%)	Abundance of shoot on vegetative and generative growth less than 80% in whole canopy
5	Abundant (80%)	Abundance of shoot on vegetative and generative growth more than 30% in whole canopy

Table 2. Models of phenological characteristics of four species of *Annona* collection.

Species	Phenological characteristics	Models
<i>A. glabra</i>	Immature leaves	$-69,2 + 6,05 \text{ temperature} + 0,0217 \text{ rainfall intensity} - 1,05 \text{ humidity (all factors)}$
	Mature leaves	$88,0 - 0,000000 \text{ temperature} + 0,000000 \text{ rainfall intensity} - 0,000000 \text{ humidity (no factors)}$
	Red/ yellow leaves	$125 - 1,05 \text{ temperature} + 0,0036 \text{ rainfall intensity} - 1,13 \text{ humidity (humidity)}$
	Flower buds	$-27 + 1,32 \text{ temperature} + 0,0216 \text{ rainfall intensity} - 0,006 \text{ humidity (rainfall intensity)}$
	Flowering	$-51 + 0,67 \text{ temperature} + 0,0220 \text{ rainfall intensity} + 0,52 \text{ humidity (rainfall intensity)}$
	Young fruits	$-89 + 5,30 \text{ temperature} + 0,0364 \text{ rainfall intensity} - 0,60 \text{ humidity (temperature and rainfall intensity)}$
	Immature fruits	$-119 + 2,02 \text{ temperature} + 0,0187 \text{ rainfall intensity} + 0,971 \text{ humidity (humidity)}$
	Ripe fruits	$-51,1 + 0,18 \text{ temperature} + 0,0201 \text{ rainfall intensity} + 0,633 \text{ humidity (rainfall intensity and humidity)}$
<i>A. montana</i>	Immature leaves	$7 - 0,46 \text{ temperature} - 0,0418 \text{ rainfall intensity} + 0,263 \text{ humidity (rainfall intensity)}$
	Mature leaves	$96 + 2,18 \text{ temperature} + 0,0328 \text{ rainfall intensity} - 0,999 \text{ humidity (rainfall intensity and humidity)}$
	Red/ yellow leaves	$59 - 2,88 \text{ temperature} + 0,0083 \text{ rainfall intensity} + 0,334 \text{ humidity (temperature and humidity)}$
	Flower buds	$16,2 - 0,182 \text{ temperature} - 0,00027 \text{ rainfall intensity} - 0,139 \text{ humidity (humidity)}$
	Flowering	$16,2 - 0,182 \text{ temperature} - 0,00027 \text{ rainfall intensity} - 0,139 \text{ humidity (humidity)}$
	Young fruits	$32,2 + 0,03 \text{ temperature} + 0,0010 \text{ rainfall intensity} - 0,393 \text{ humidity (humidity)}$
	Immature fruits	$-60,6 + 2,32 \text{ temperature} + 0,0043 \text{ rainfall intensity} + 0,045 \text{ humidity (no factors)}$
	Ripe fruits	$2,7 + 0,34 \text{ temperature} + 0,0115 \text{ rainfall intensity} - 0,145 \text{ humidity (rainfall intensity)}$
<i>A. muricata</i>	Immature leaves	$-102 + 2,96 \text{ temperature} - 0,0389 \text{ rainfall intensity} + 0,626 \text{ humidity (rainfall intensity)}$
	Mature leaves	$118 - 0,73 \text{ temperature} + 0,0150 \text{ rainfall intensity} - 0,198 \text{ humidity (rainfall intensity)}$
	Red/ yellow leaves	$5,9 + 1,82 \text{ temperature} + 0,0056 \text{ rainfall intensity} - 0,582 \text{ humidity (temperature and humidity)}$
	Flower buds	$41,8 - 0,16 \text{ temperature} + 0,0121 \text{ rainfall intensity} - 0,387 \text{ humidity (no factors)}$
	Flowering	$79,4 - 1,04 \text{ temperature} + 0,0169 \text{ rainfall intensity} - 0,596 \text{ humidity (no factors)}$
	Young fruits	$8 + 0,47 \text{ temperature} + 0,0543 \text{ rainfall intensity} - 0,25 \text{ humidity (rainfall intensity)}$
	Immature fruits	$-164 - 0,82 \text{ temperature} - 0,0065 \text{ rainfall intensity} + 2,70 \text{ humidity (humidity)}$
	Ripe fruits	$-1,86 - 0,13 \text{ temperature} - 0,0036 \text{ rainfall intensity} + 0,358 \text{ humidity (no factors)}$
<i>A. squamosa</i>	Immature leaves	$55,3 + 3,54 \text{ temperature} + 0,0232 \text{ rainfall intensity} - 1,86 \text{ humidity (all factors)}$
	Mature leaves	$-21,2 + 1,17 \text{ temperature} - 0,00643 \text{ rainfall intensity} + 0,999 \text{ humidity (humidity)}$
	Red/ yellow leaves	$173 - 3,91 \text{ temperature} - 0,0202 \text{ rainfall intensity} - 0,713 \text{ humidity (all factors)}$
	Flower buds	$-29,3 + 480 \text{ temperature} - 0,0006 \text{ rainfall intensity} - 1,19 \text{ humidity (temperature and humidity)}$
	Flowering	$-89,5 + 4,01 \text{ temperature} - 0,00450 \text{ rainfall intensity} - 0,169 \text{ humidity (temperature and rainfall intensity)}$
	Young fruits	$-11,5 + 1,72 \text{ temperature} + 0,0041 \text{ rainfall intensity} - 0,427 \text{ humidity (temperature and humidity)}$
	Immature fruits	$-256 + 7,41 \text{ temperature} + 0,0238 \text{ rainfall intensity} + 0,85 \text{ humidity (temperature and rainfall intensity)}$
	Ripe fruits	$-149 + 3,30 \text{ temperature} - 0,0075 \text{ rainfall intensity} + 0,844 \text{ humidity (temperature and humidity)}$

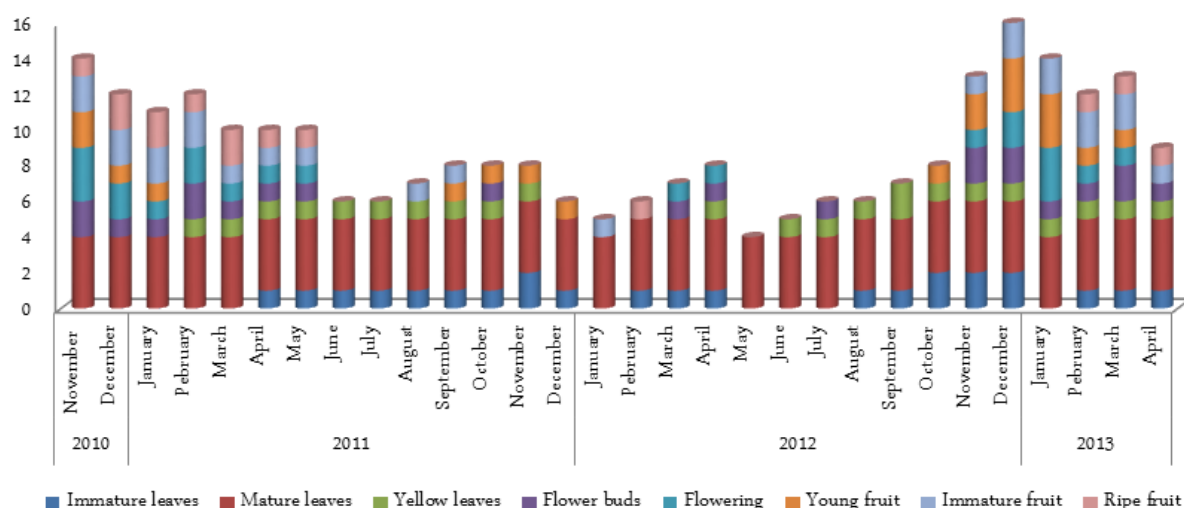


Figure 1. Proportion of shoots on the *Annona glabra* flowering and fruiting times

that has bad drainage. Two important climatic factors are rain and strong winds. Both, when they occur in high intensity and during flowering, greatly reduce pollination. Principally, rain factor happened when out of season [13,14].

Temperature (25,56-28,33°C) and humidity (66,83-85,02%) become the most influential factor to flowering and fruiting time on *A. squamosa*, and recorded one a year during the wet month. Each derivation of 1°C temperature will increase flower buds as much as 480%. Each derivation of 1 mm rainfall intensity will reduce flower buds of *A. squamosa* as much as 0,0006% and 0,00075% for ripe fruit. Each derivation of 1% humidity will reduce flower buds as much as 1,19%. Each derivation of 1°C temperature will increase young fruit as much as 1,72%. Each derivation

of 1 mm rainfall intensity will increase the young fruit of *A. squamosa* as much as 0,0041%, and derivation 1% humidity will reduce young fruit of it as much as 0,427%. Each derivation of 1°C temperature will increase the ripe fruit of *A. squamosa* as much as 3,30%. Then, each derivation of 1% humidity will increase the ripe fruit of *A. squamosa* as much as 0,844%. Figure 1 show that vegetative growth on *A. glabra* is evergreenness (evergreen (with continuous defoliation)). The mature leaves are present (rank 4-5) throughout the year while senescent leaves are usually present at Rank 2. According to Department of Employment, Economic Development and Innovation of Queensland [15], *A. glabra* is a semi-deciduous tree. This is likely due to significant differences in the season, so the effect on the vegetative growth of *A. glabra*. Patterns of stem

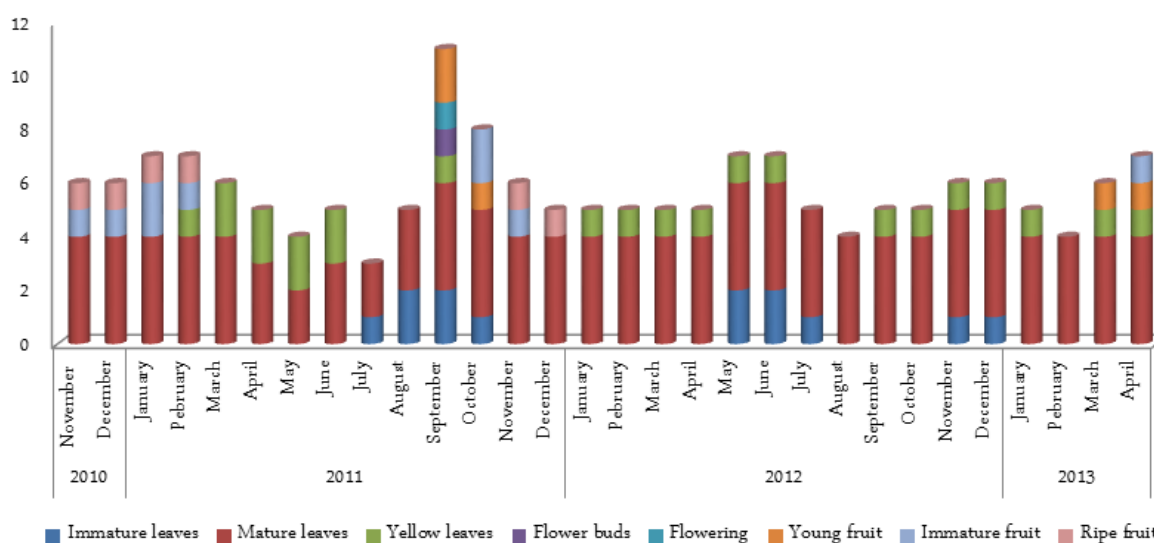


Figure 2. Proportion of shoots on the *Annona montana* flowering and fruiting times

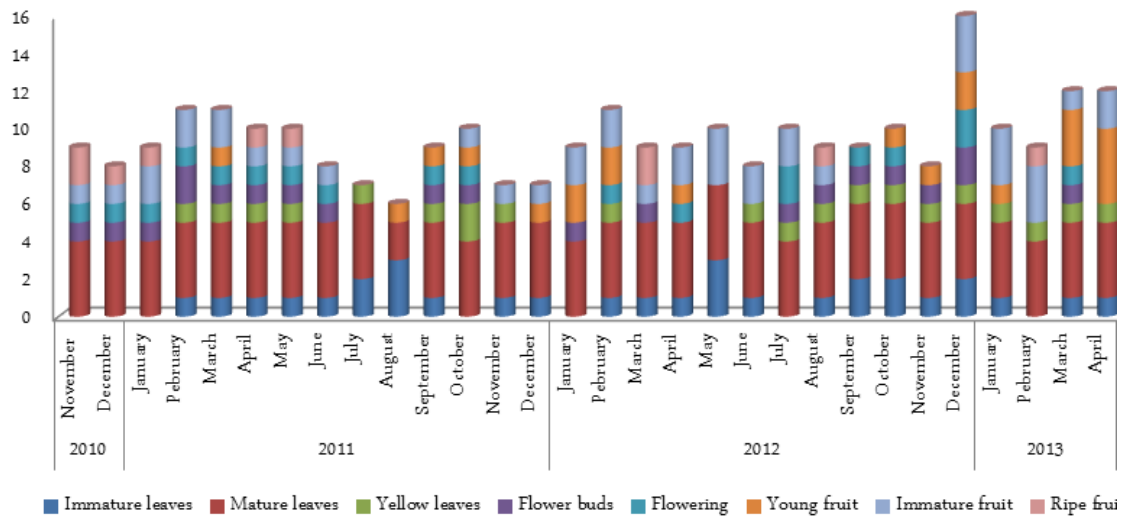


Figure 3. Proportion of shoots on the *Annona muricata* flowering and fruiting times

elongation is continuous growth (semicontinuous growth); stem elongation keeps rank 4 or 5 more than consecutive four months or 6 months in total. With seasonal synchronism is low synchronism (more than 50% of stem elongating periods occurs at the same time of the year. Flowering frequency on *A. glabra* is more than 4 to 5 times at rank 2 to 5, that is *A. glabra* is flowering on rank 2 to 5 occurs more than 4 to 5 times every year. Flowering period from rainy to the early dry season. Based on observation, *A. glabra* occurs three times a year in wet and dry. The seasonal synchronism of flowering is high synchronism; that is more than 80% of flowering periods occurs at the same time of the year. Ripe fruits present during the period of investigations, which is fruiting twice a year in the same month.

The main flowering period in the wet tropics is from December to February with fruit formation following in January to March. The fruit falls from the trees and matures on the ground in February to April. Sporadic flowering and fruiting can also occur at other times of the year [11,15]. The fruit form over summer and autumn. Leaves of mature trees turn yellow and fall in the dry season. Germination peaks after rainfall and requires a period of temperatures above 25°C. The general pattern of growth (flowering in January – February, December; Fruit formation on January – March; Fruit drop on February – April; Leaf fall from August – November. However, growth pattern in suitable conditions are flowering in March and November; Fruit formation on April and December; Fruit drop on January and May [16]. Different from *A. glabra*, the

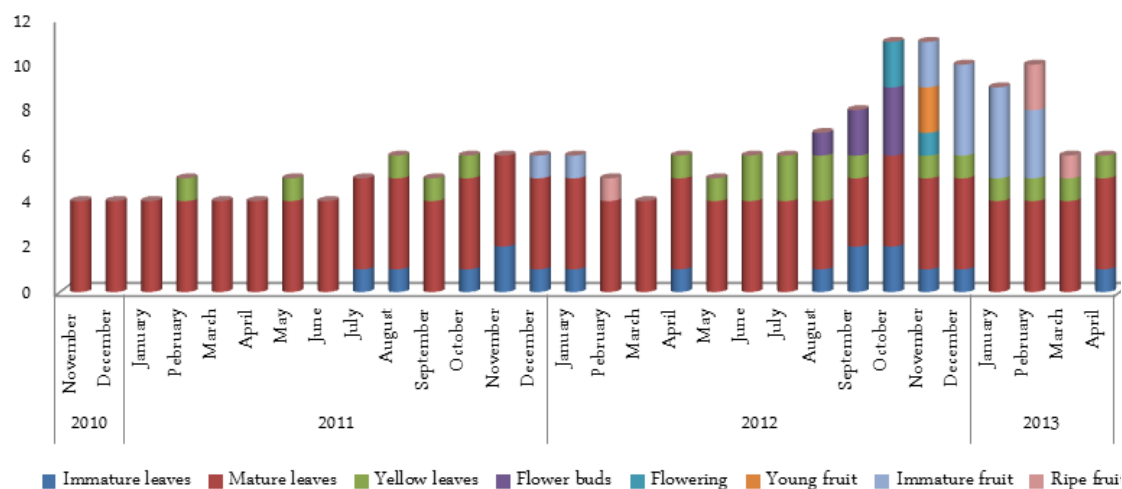


Figure 4. Proportion of shoots on the *Annona squamosa* flowering and fruiting times

Table 3. Comparison of flowering and fruiting time on four species of *Annona* based on phenological categories [10].

Growth	Phenological categories	Four species of <i>Annona</i>			
		<i>A. glabra</i>	<i>A. montana</i>	<i>A. muricata</i>	<i>A. squamosa</i>
Vegetative	Evergreens	Evergreen (with continuous defoliation)	Semi-evergreen	Evergreen (with continuous defoliation)	Evergreen (with seasonal defoliation)
	Patterns of stem elongation	Semicontinuous growth	Rhythmic growth with 1 peak	Continuous growth	Rhythmic growth with 2-3 peaks
	Seasonal synchronism of stem elongation	Low synchronism	Non synchroni- zation	High synchronism	High synchronism
Reproductive	Flowering frequency	More than 4 to 5 times at rank 2 to 5	1 to 3 times at rank 2 to 3	Continuous flowering at rank 2 to 5	1 to 3 times at rank 2 to 3
	Flowering period	From rainy to the early dry season	Dry season	Throughout the year	Rainy season
	Seasonal synchronism of flowering	High synchronism	Non synchroni- zation	Low synchronism	Non synchronization
	Fruiting	Ripe fruits present	Ripe fruits present	Ripe fruits present	Ripe fruits present

vegetative growth of *A. montana* is semievergreen. This condition is about evergreen, but the amount of mature leaves occasionally decrease to rank 2 or 3 with patterns of stem elongation is rhythmic growth with 1 peak. One peak is that elongation occurs once a year, and the resting period extends over half a year or longer. However, seasonal synchronism of *A. montana* stem elongation is non-synchronization, that is stem elongation periods in a calendar year are a variable year by year. Flowering frequency of *A. montana* is 1 to 3 times at rank 2 to 3, that is flowering (rank 2-3) occurs 1 to 3 times every year with a flowering period during dry season. Seasonal synchronism of flowering is non-synchronization (flowering periods in a calendar year are a variable year by year). Ripe fruits present during observations is recorded once a year during the wet month.

Based on [17], *A. montana* flowering on October until December. However, during the period of investigation, *A. montana* is flowering to September. Differences in flowering time are not too far probably influenced by climatic factors that differ between the tropical and sub-tropical climates. In the area with the extreme seasonal cycle, the climate has been a very influential factor for plant growth and development, especially in the phase of flowering and fruiting plant. Whereas, in the weakly seasonal area, climatic factors must have less influence on the phenological phases than in strongly seasonal ones [18]. Vegetative growth of *A. muricata* is evergreen (with continuous defolia-

tion). This fact is same with *A. glabra* that the pattern of the stem elongating is continuous growth (most of shoots (rank 4 or 5) continue to elongate nearly throughout the year (more than ten months). Then, with seasonal synchronism of stem elongation is high synchronism (more than 80% of stem elongating periods occurs at the same time of the year). Flowering frequency of *A. muricata* is continuous flowering at rank 2 to 5 (continuous flowering (rank 2-5) throughout the year). Flowering period throughout the year (continuously flowering throughout the year) and seasonal synchronism of flowering is low synchronism (more than 50% of flowering periods occurs at the same time of the year). Ripe fruits present and fruiting twice a year in wet.

This species is adapted to areas of high humidity and relatively warm winters; temperatures below 5°C will cause damage to leaves and small branches, and temperatures below 3°C can be fatal. The fruit becomes dry and is no longer suitable for concentrate. Leaf fall happened in all soursop cultivars in May and June (after harvest) and September and October (dry season). Flowering occurs during the rainy season, with extremes in February and July. Fruit development was expressive from December to March [19]. Figure 4 show that the vegetative growth of *A. squamosa* is evergreen (with seasonal defoliation). The condition about mature leaves that are usually present (rank 4-5) throughout the year, while senescent leaves reach rank 2 or 3. The pattern of stem elongation is rhythmic

growth with 2-3 peaks, that is elongation occurs two or three times per year at regular intervals. Seasonal synchronism of stem elongation same with *A. muricata*. Flowering frequency on *A. squamosa* is 1 to 3 times at rank 2 to 3; that is flowering (rank 2-3) occurs 1 to 3 times every year. A flowering period occurs during rainy season; based observation occurs from October until January. Seasonal synchronism of flowering on *A. squamosa* is non-synchronization (flowering periods in a calendar year are a variable year by year. Ripe fruits present in February until March (wet month). *A. squamosa* recorded one a year during the wet month of flowering and fruiting.

Flowering and fruiting In Puerto Rico and the Virgin Islands occur throughout the year. In India, the leaves of *A. squamosa* fall in January to February and are renewed in April to May when the flowers appear. Fruiting of *A. squamosa* is in July to August. Flowering occurs gradually over many months, so harvest time is spread over a period of months also [2,20].

Comparison of flowering and fruiting times on four species of *Annona* can be seen on the Table 3.

CONCLUSIONS

Humidity was the most affected climate factors on the flowering and fruiting times of those species. Specifically, rainfall intensity (0-550 mm) affected to *Annona muricata*, temperature (25,56-28,33 °C) and humidity (66,83-85,02%) to *Annona squamosa*, and humidity to *A. glabra* (71,62-85,02%) and *A. montana* (71,62 to 82,94 %) as well. Flowering time of *A. glabra* occurs three times a year in wet and dry season. Fruiting time occurs twice a year in the same month. *Annona muricata* flowering throughout the year and fruiting twice a year in wet, while *A. montana* and *A. squamosa* recorded one a year during the wet month.

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