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Phenological Study Of Two Populations Of *Cnidoscolusquercifolius*pohl(Faveleira) In Semiarid Region Of Brazil

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Abstract; *The phonological patterns of two populations of Cnidoscolus quercifolius Pohl were evaluated in the caatinga biome western Seridó region of Paraiba State, Brazil. Was analysis represented by activity indices for both population growing seasons (fall and sprout) and reproductive (flowering and fruiting), and also studied the intensity index Borchert, who evaluated the flow leaves. Phenology were tested against variations in precipitation, water potential and quantum efficiency of photosystem II. The bud in the two populations occurred in the late dry season and transition into the rainy season, with peak leafing in January and November 2010 and was negatively correlated with rainfall (rs = -0.54 p <0.05). Leaf fall showed the peak phase in October 2009 and 2010, showing a direct relationship with water potential and photosynthetic quantum efficiency. The flowering and fruiting had greater synchrony in the seasonal rainy period, fruit set was positively correlated with precipitation values during the study period (rs = 0.56 p <0.05). The phenological events of C. quercifoliusshow marked seasonality in relation to precipitation, water potential and the quantum efficiency of photosystem II.*

Key-Words: Phenological patterns,Seasonality, Semiarid tropics.

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I. Introdution

Phenological studies are essential to our understanding of the dynamics of plant growth and plants responses to environmental factors, especially precipitation, water stress, solar irradiation, and photoperiod in their native ecosystems.

Phenological research projects at the community and species levels in the semiarid tropics have contributed greatly to our understanding of the adaptive aspects of the plants occupyingin the caatinga biome characterized by climatic extremes and high degrees of endemism(MACHADO et al., 2002; SANTOS et al., 2005; LIMA, 2007; AMORIM et al., 2009; GUEDES et al., 2009; PEREIRA et al., 1989; BARBOSA et al., 1989 and 2003; MOREIRA, 1996;QUIRINO, 2006).

Measurements of the photochemical quantum efficiency and water potential are important ecophysiological parameters (CORREIA et al., 2014), which account for adaptive behavior, reflecting the environmental conditions in which the plant grows, thus providing an understanding of the ecology of species adapted to growth limiting conditions. The photosynthetic rate is an important variable for understanding the plant physiology.

Water stress causes diverse physiological, biochemical and molecular responses in plants, which depend on the rate and the intensity of the stress (CORREIA et al., 2014; BASCUNAN-GODOY et al., 2015), for example, the plant physiological state, their stability and full efficiency in water use. Less negative levels of the water potential reflect water availability in the soil or successful adaptations to the stressful conditions. Knowing the variations in water potential of the plant species that comprise the caatinga, it is possible to analyze the changes related to this factor and evaluate its influence in others physiological factors.

Analyses of the phenological profiles of caatinga species have demonstrated strong seasonal characteristics in most species, with their flowering and fruiting periods generally preceding leaf flush after the start of the rainy season (MACHADO et al. 1997).

The water status in the plant is also responsible for the structure and leaf life span, leaf fall, the depth and density of their root systems, wood densities, and the photochemical efficiencies of photosystem II(BORCHERT et al., 2004; SINGH and KUSHWAHA 2005; LIMA, 2007; TROVÃOet al.2007).

C. quercifolius has great potential in wooden handicraft production, fodder, production of oil for human consumption, biodiesel production, medicine and other uses (NOBREGA, 2001; SILVA et al., 2007).

We analyzed the adaptive strategies and phenological behaviors of two populations of *Cnidoscolus quercifolius* Pohl in caatinga areasof the Paraíba State, Brazil, in relation to variations in rainfall and the physiological factors of water potential and photosynthetic efficiencyindividuals of that species.

II. Materials And Methods

The present study was undertaken in the municipalities of Santa Luzia (6°52’ 19”S 36° 55’ 08” W) and São Mamede (6°55’ 19”S 37° 05’ 45” W), with a distance of about 20 km of each other, in the tropical semiarid of Paraíba State, northeastern Brazil. Regional temperatures vary between 25 °C and 30 °C, with the average annual rainfall of approximately 550 mm concentrated between January and April (although there can be many periods ofabundant rainfall or extended droughts). The westernregion of Paraíba State has a hot semiarid climate (classified as BSw’h according to the Koppen system) (OLIVEIRA et al., 2014). Monthly phenological observations were made of the vegetative phenophases of leaf flushing and leaf fall, and the reproductive phenophases of flowering and fruiting of two populations of *C. quercifolius* located in Santa Luzia (Yayu Farm) and São Mamede (Promissão Farm)municipalities during both the rainy and dry seasons during the period between March/2009 and February/2011.

The definitions of the phenophases used here follow Fournier (1974), Morellato (1991), and Morellato et al. (1989), considering the presence or absence of a given phenophase (FOURNIER, 1974) and indicatingactivity peaks according to Benker&Morellato (2002) that allow the Borchert Intensities to be determined (BORCHERT et al., 2002).

We analyzed all of the flowering adult plants encountered when the fieldwork first began, totaling 21 individuals in the São Mamede and 15 individuals in the Santa Luziamunicipalites respectively. The phenological patterns of these populations were examined in relation to precipitation and plant water potentials and photosynthetic quantum efficiencies, following Oliveira et al. (2014).

Rainfall measurements were corrected EASA-PB between 2009 and 2011. Analysis of the quantum efficiency were performed with a fluorescence detector PEA (Plant Effciency Analyzer) determining F_0 (minimal or initial fluorescence), Fv (increase fluorescence from F_0 to Fm), Fm (maximum fluorescence) and Fv/Fm ratiothat allows the quantum yield determination of the photochemical phase of photosynthesis. Stems with 10 cm were removed from plants and placed in a Scholander pressure chamber, and the reading being taken after the first liquid expulsion from the cut (OLIVEIRA et al. 2014).

We recorded the initial, peak, and final phases of the phenophase of both leaf flushing and leaf fall. In terms of reproductive stages, we evaluated flowering (the formation of floral buds, flower opening, until the absence of flowers) and fruiting (the initiation of fruiting, young fruits, and mature fruits).The durations of the flowering and fruiting periods corresponded to the period between the emergence of the first flower and fruit on any individual until when the last individual in the population was observed displaying either of these phenophases.Analyses of the flowering and fruiting patterns followed the classifications proposed by Newstrow et al. (1994).

We also estimated the intensities of each phenophase in the tree crowns of individual trees using the methodology proposed by Borchert et al. (2002), which is based on assigning scores (on a scale of 0 to 3) to the quantities of leaves in any tree crown, with 0 = the absence of leaves, 1 = few leaves (< 33%), 2 = many leaves (33 to 66%), and 3 = abundant leaves (> 66%) and subsequently calculating the percentages of leaves using the following formula: 100 (∑ scores) / maximum score.

This technique therefore analyzes the proportions of leaves by summing the scores (0, 1, 2, 3) of the individuals in a plant population (multiplied by 100) divided by the maximum value possible for all individuals of that population with abundant leaves (score = 3), according to the methodology described by Lima (2007).The normalities of the data were verified using the Shapiro-Wilktest, and the Spearman correlation test was used to determine the existence of correlations between the phenophases and rainfall indices for the period analyzed.Statistical analyses of the data were performed using the Statistica 6.0 software package.

III. Results

Leaf flushingdemonstrated notable synchrony in the two populations during the first cycle analyzed, with 80% of the individuals in Santa Luzia and 80.95% inSão Mamede, initiating leaf flushing synchronously. During the next cycle of leaf flushing, 100% of the individuals isplayed this phenophase. The periods of greatest leaf flushing were observed in January and November of 2010 (Tables 1 and 2).Leaf flushing occurred between the end of the dry season and the transition period just before the rainy season.

Examinations of the water potentials of individual trees in theleaf flushingphase indicated that this phenophase was preceded by very negative water potential values in the Santa Luzia population (-0.82 MPa, Nov/Dec-2009 and -0.97 MPa, Sep/Oct-2010)(Figure 1). As well as in the São Mamedepopulation(-0.74 MPa, Nov/Dec-2009 and -0.97 MPa, Sep/Oct-2010)(Figure2),confirming that these plants initiatedleaf flushing while demonstrating high water deficits.

During these periods, the average values of photosynthetic quantum efficiency were 0.591 and 0.667 for the Santa Luzia and São Mamede populations, respectively.

A significant negative correlation was observed between the phenophase of leaf flushing and precipitation for the period just before this phenological event (r_S= - 0.54; $p<0.05$) in the populations examined.

Leaf fallinitiated between the months of July and August/2009 andfrom June to October/2010 for the Santa Luzia population(Figure 1) and between the months of July and November/2009 and June to October/2010 for the São Mamedepopulation (Figure 2). This phenophase lasted from 4 to 5 months, with peak phases occurring in October/2009 and 2010 (Tables 1 and 2), having initiated at the end of the rainy season and beginning of the dry season.

Leaf fallwas observed to be directly related to the water status of the plant and with photosynthetic quantum efficiency, as leaf fall intensity increased with decreasing plant water potentials. No significant Spearman correlation was observed between precipitation and leaf fall at a 5% level of probability.

The activity index indicated that leaf flushing peaked in January and November/2010, and demonstrated the synchrony of this phenological eventwithin the population.The analyses of intensity indicated that when this phenological event was most intense during the study period (from March to June/2009 and February to April/2010)as those, which occurred in greater leaf, coverindividuals studied(Figures 3 and 4).

The first complete flowering cycle observed during the present study occurred between January and April/2010, with a duration of four months; the peak of flowering activity occurred in March/2010 with high degrees of synchrony within the two populations (Tables 1 and 2).

Flowering occurred in both populations during the rainy season (Figures 5 and 6), with the flowering peak coinciding with less negative water potential values (-0.41 MPa) in the two populations between March and April/2010. The recorded values of the photosyntheticquantum efficiency of photosystem II during this period indicated that the individuals were not stressed and demonstrated optimal photochemical efficiency (0.751MPa and 0.812 MPa for the Santa Luzia and São Mamede populations respectively). No significant correlation was observed between precipitation values and flowering by the Spearman correlation coefficient, at a 5% level of probability.

Fruiting occurred in parallel with flowering during the rainy season and continued for 4 to 5 months in 2009, with peak activity between March and April/2009. During the year 2010, fruiting continued for approximately 8 months, with a peak between March and May of that same year (Figures 5 and 6). The phenophase of fruiting demonstrated a significant positive correlation with rainfall (r_S= 0.56; p= 0.004).

The periods of both flowering and fruiting demonstrated variations related to the water potentials and photosynthetic quantum efficiencies of the plants, as the peaks of these phenophases were associated with less negative water potential values and higher average values of photosynthetic quantum efficiency (between 0.75 and 0.85).

IV. Discussion

Leaf flushingoccurred at the end of the dry season and during the transition period into the rainy season in the present study, corroborating other studies of the phenological patterns of shrub-arboreal vegetations in arid and semiarid regions (CHAPOTIN et al., 2006; QUIRINO, 2006; LIMA, 2007). Although leaf flushingoccurred during the seasonal dry period, the leaves of all the individuals of both populations examined attained maximum blade expansion only during the rainy season. It is worth noting that the individuals of the populations examined here were at their points of maximum deciduousness immediately before leaf flushing – an important strategy for water economy, allowing the continuity of phenological events that would culminate in flowering (SINGH; KUSHWAHA, 2005).

The significant negative correlation of the leaf flushingphenophase observed in the present work differed from the results reported by Amorim et al. (2009), who noted a strong correlation between rainfall indices and leaf formation in other woodycaatinga species in the Seridó region of Rio Grande do Norte State, Brazil.

Mooney et al. (1995) likewise noted that the phenological events of plants growing in tropical climates are determined by the duration and intensity of the dry season. Our study of*C. quercifolius*indicated there was no large temporal separation of the phenophases of leaf flushing and flowering, as the plants flowered when leaf flushingterminated – an important strategy in the semiarid caatinga biome of Brazil that usually experiences only a short and often irregular rainy period (between January and June). According to Fenner (1998), reproductive events in the dry tropics generally occur during periods of low photosynthetic activity or after periods of high reserve accumulation.

In study in Pernambuco State, Lima (2007)noted that most of woody species that replaced their leaves during the dry season had low wood densities supporting the observation that they can store greater quantities of water in their trunks. However, our studiesdemonstrated very negative water potential levels in the branches of *C. quercifolius*directly preceding leaf flushing.

The valuesofwater potentialonly becameless negativeafter the beginning of the rainy season, as was expected, during which time the individuals of the two populations were in their final phases of leaf flushing and beginning leaf blade expansion. Maximum leaf fall activity was observed during the dry season, in agreement with other published results of phenological studies of woody caatinga plants (LIMA, 2007; AMORIM et al., 2009).

The leafless period of woody plants generally occurs in response to water stress conditions and represents that portion of their annual cycle in which resources (such as light, water, nutrients) are not being consumed, or only consumed at very low intensities(SINGH; KUSHWAHA, 2005). Theseauthorsalsonotedthatthefullydeciduousperiodis aviableindicator ofdroughtexperiencedseverewaterstressconditions reflecting the integrated effects of seasonal dryness, morpho-functional characteristics of the plants, and the levels of soil humidity; they also stated that leaf fall has a determinate role ininitiating flowering.

*C. quercifolius*is typically deciduous at the peak of the dry season and experiences increasingly intense water limitations as the dry season advances – culminating in leaf abscission as a strategy for reducing its maintenance metabolic levels in preparation for the dynamics of up-coming phenological events of leaf flushing at the end of the dry season followed by flowering (SINGH; KUSHWAHA, 2005).

Krause & Weiss (1991) reported that fluorescence studies of the quantum efficiency of photosystem IIrepresent an important tool for studying plant water stress. Maxwell&Johnson (2000) reported that plants demonstrated quantum efficiency values between 0.75 and 0.85 under non-stress conditions (values seen in *C. quercifolius* during the rainy period), with lower values indicating water stress, reductions of the maximum quantum efficiencies of photosystem II, and the possibility of damage to the plant's photosynthetic apparatus. As wasobservedbyBascuñan - Godoy et al. (2015) in native species of swamp forests of Chile when subjected to water déficit.

Flowering and fruitingin *C. quercifolius*occurred during the rainy season when plant water potentials were less negative and quantum efficiency values were between 0.751 and 0.812. With high metabolic activity levels and the equally high energetic demands of the phenophases of flowering and fruit development and maturation. The highest peaks of floweringand fruiting inthese plantswere observed during the rainy season, with flowering closely following the period of leaf flushing and leaf blade expansion.

Fruiting, on the other hand, continued for a longer period of time, extending into the phenophase of leaf fall –similar to the results reported by Lima (2007) and Amorim et al. (2009) in other plant communities in the caatinga biome. This close relationship between water resource availability and fruiting wasconsidered by Griz and Machado (2001) to be a determinant factor in plant reproduction in tropical regions, especially in tropical dry forests. The phenophases of flowering and fruiting were observed to have annual patterns in *C. quercifolius* this studyandfor the periodin whichit developed.

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TABLES

Table 1 –Percentages of phenological events and leaves in the crowns of individuals trees in the population of *C. quercifolius*on the Yayu Farm, municipality of Santa Luzia,Paraíba State, Brazil,during the period between March/2009 and February/2011.

Months/ phenological events	Average % of leaves	Leaf flushing	Leaf fall	Flowering	Fruiting
March – 2009	100.00	0	0	100.00	100.00
April	100.00	0	0	86.67	100.00
May	93.36	0	0	0	86.67
June	84.80	0	0	0	46.67
July	47.73	0	20.00	0	0
August	32.52	0	26.67	0	0
September	11.01	0	66.67	0	0
October	0	0	100.00	0	0
November	0	0	0	0	0
December	30.60	80.00	0	0	0
January – 2010	56.47	100.00	0	20.00	20.00
February	78.23	100.00	0	40.00	40.00
March	91.35	0	0	80.00	80.00

April	86.64	0	0	40.00	80.00
May	70.17	0	0	0	80.00
June	48.57	0	20.00	0	60.00
July	27.90	0	33.33	0	13.33
August	15.30	0	53.33	0	13.33
September	5.04	0	66.67	0	6.67
October	0	0	100.00	0	0
November	32.02	100.00	0	0	0
December	70.84	100.00	0	100.00	0
January – 2011	94.87	0	0	100.00	73.30
February	98.41	0	0	100.00	100.00

Table 2 – Percentages of phenological events and leaves in the crowns of individuals trees in the population of *C. quercifolius*on the Promissão Farm, municipality of São Mamede, Paraíba State, Brazil, during the period between March/2009 and February/2011.

Months/ phenological events	Average % of leaves	Leaf flushing	Leaf fall	Flowering	Fruiting
March – 2009	100.00	0	0	100.00	100.00
April	100.00	0	0	66.67	90.48
May	87.64	0	0	4.76	76.19
June	71.32	0	0	4.76	42.86
July	37.45	0	28.57	4.76	28.57
August	22.00	0	38.10	4.76	4.76
September	10.38	0	61.90	0	4.76
October	1.24	0	90.48	0	0
November	1.24	0	90.48	0	0
December	32.57	80.95	0	0	0
January – 2010	62.55	100.00	0	19.05	19.05
February	84.24	100.00	0	33.33	33.33
March	87.15	0	0	85.71	85.71
April	81.40	0	0	76.19	76.19
May	66.81	0	0	0	47.62
June	49.13	0	19.05	0	47.62
July	31.64	4.76*	33.33	4.76*	42.86
August	18.11	4.76*	52.38	4.76*	23.81
September	5.62	0	80.95	0	4.76
October	0.93	0	95.24	0	4.76
November	36.90	100.00	0	0	0
December	71.01	100.00	0	100.00	4.76
January – 2011	95.18	0	0	100.00	100.00
February	100.00	0	0	100.00	100.00

FIGURES – LEGENDS

Figure 1-Precipitation and the phenological events of leaf flushing and leaf fall in *C. quercifolius* during the period between March/2009 andFebruary/2011 in areas of caatinga vegetation in the municipality of Santa Luzia, Paraíba State, Brazil.

Figure 2- Precipitation and the phenological events of leaf flushing and leaf fall in *C. quercifolius* during the period between March/2009 and February/2011 in areas of caatinga vegetation in the municipality of São Mamede,Paraíba State, Brazil.

Figure 3 - The phenology of leaf flux of *C. quercifolius* as indicated by the index of leaf flushing and the Borchert Intensity percentage (proportions of leaves) in an area of caatinga vegetation (Santa Luzia) in the Seridó region of Paraiba State during the period between March/2009 and February/2011.

Figure 4 - The phenology of leaf flux of *C. quercifolius* as indicated by the index of leaf flushing and the Borchert Intensity percentage (proportions of leaves) in an area of caatinga vegetation (São Mamede) in the Seridó region of Paraiba State during the period between March/2009 and February/2011.

Figure 5- Precipitation and the phenological events of flowering and fruiting in *C. quercifolius* during the period between March/2009 and February/2011, in an area of caatinga vegetation in the municipality of Santa Luzia,Paraíba State, Brazil.

Figure 6- Precipitation and the phenological events of flowering and fruiting in *C. quercifolius* during the period between March/2009 and February/2011, an area of caatinga vegetation in the municipality of São Mamede, Paraíba State, Brazil.

FIGURES

Figure 1

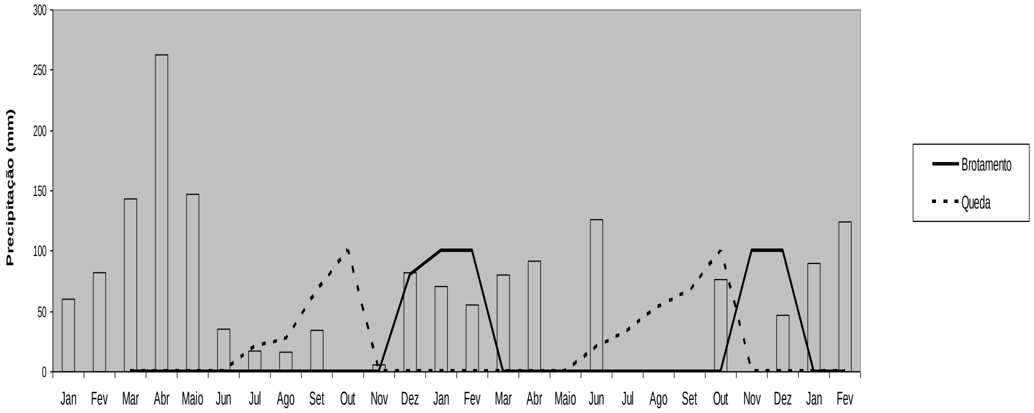


Figure 2-

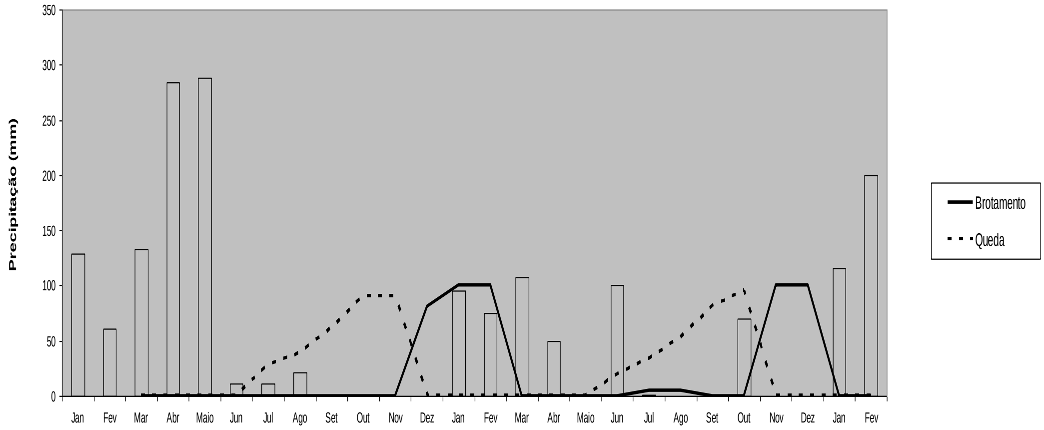


Figure 3-

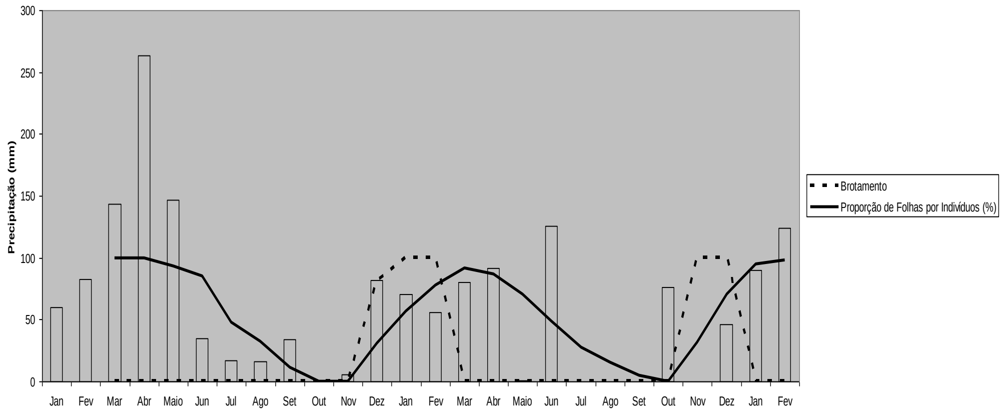


Figure 4-

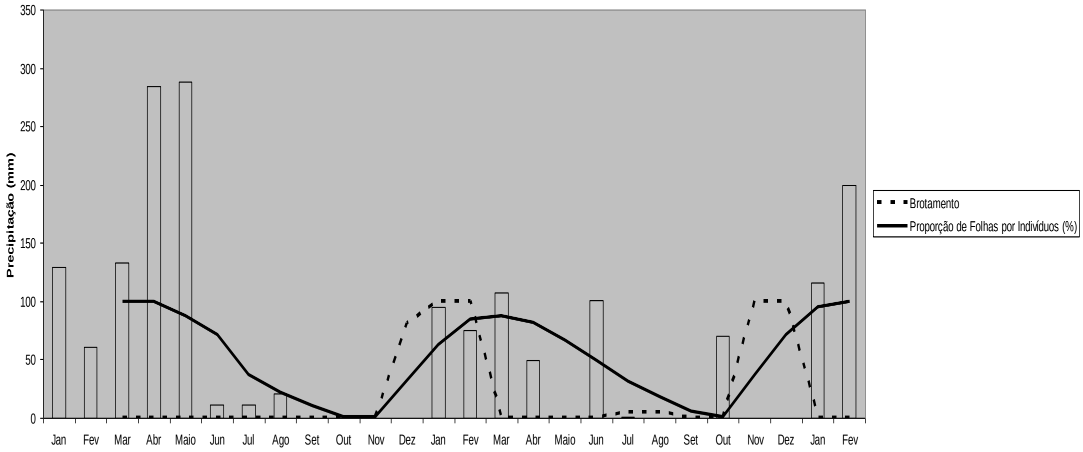


Figure 5-

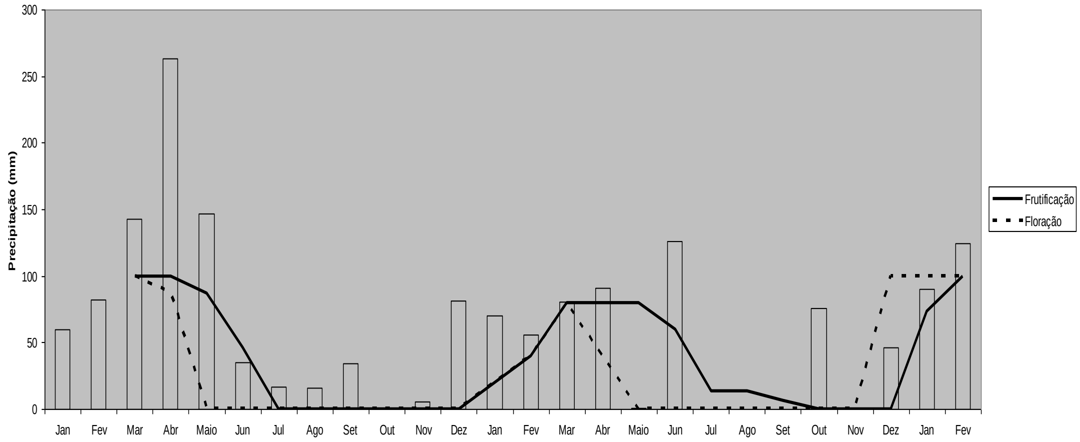
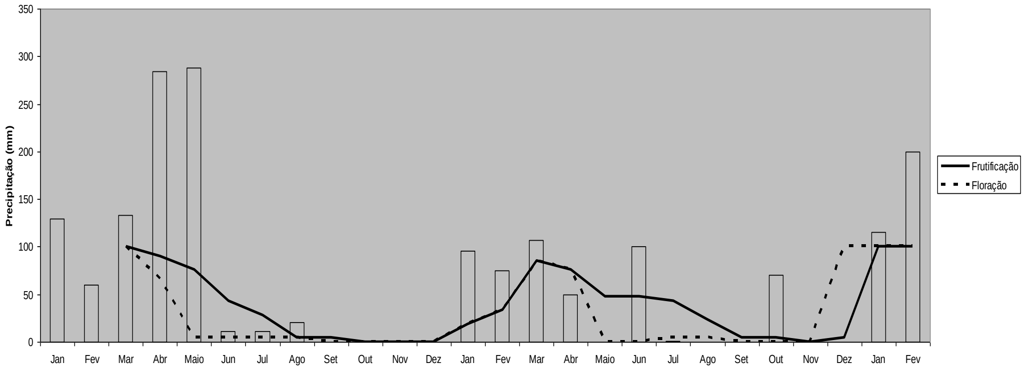


Figure 6-



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