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PHYSIOLOGICAL RESPONSES OF CACAO TO ENVIRONMENTAL FACTORS *

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In a previous review on physiology and ecology of the cacao tree (6) an attempt was made to summarize and appraise available information on effects of environmental factors on shoot-growth rhythms, cambial activity, flowering, fruit growth, and cherelle wilt. A few papers dealing with growth and flowering rhythms of cacao have appeared since then (7, 9, 15, 21, 22, 23, 24, 25). In Brazil, additional research has been carried out during the last 6 years on physiological responses of cacao to environmental factors. Although most of these studies in Brazil are still in progress it is felt that some of the results so far obtained are worth discussing in the light

of recent findings reported in the literature. This paper will review studies on leaf water potential, growth rhythms (flushing and leaf fall), flowering, and fruit development.

LEAF WATER POTENTIAL

Field measurements of leaf water potential were made with the pressure chamber technique (26). The method consists of enclosing an excised leaf in a pressure chamber, with the petiole projecting through the lid and applying a gas pressure (nitrogen) until sap exudes from the cut surface. The pressure necessary to displace the sap is taken to be equivalent to

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the tension or water potential in the xylem before excising the leaf.

Initial trials were performed by sampling leaves at random over the whole tree, a procedure that soon proved to be inadequate since wide variation was observed in water potential in leaves of the same tree, and even for the same branch. Subsequent measurements were oriented toward the influence of leaf age and position on its water balance.

Figure 1 shows diurnal variation in water potential of 4-month-old leaves taken from the upper part of the tree, all facing in the same direction. The measurements were made hourly on a cloudy day in a

field where a leaf retention experiment was being conducted. This permitted an accurate estimate of leaf age. The number of leaves sampled, which was never less than five, varied according to the degree of variability found in exploratory measurements.

Differences in leaf water potential within the hourly samples were small, especially in those taken in the early morning and at dusk. Water potential decreased (became more negative) progressively to midday, then increased during the afternoon.

Water potential of leaves of different age and with the same position in relation to the sun was evaluated using 4, 7 and 10 month-old-leaves. The results (Figure 2) followed the pattern already described with respect to diurnal variation, with no clear differences shown in water potential of leaves of different ages.

Since leaves having the same position on the tree with uniform orientation in relation to the sun showed no significant differences in water potential, independently of leaf age, water potentials of shaded leaves and those exposed to the sun were determined. Ten-month-old leaves were sampled from the upper part of the trees (leaves directly exposed to the sunlight) and compared with shaded leaves taken from the lower part of the tree.

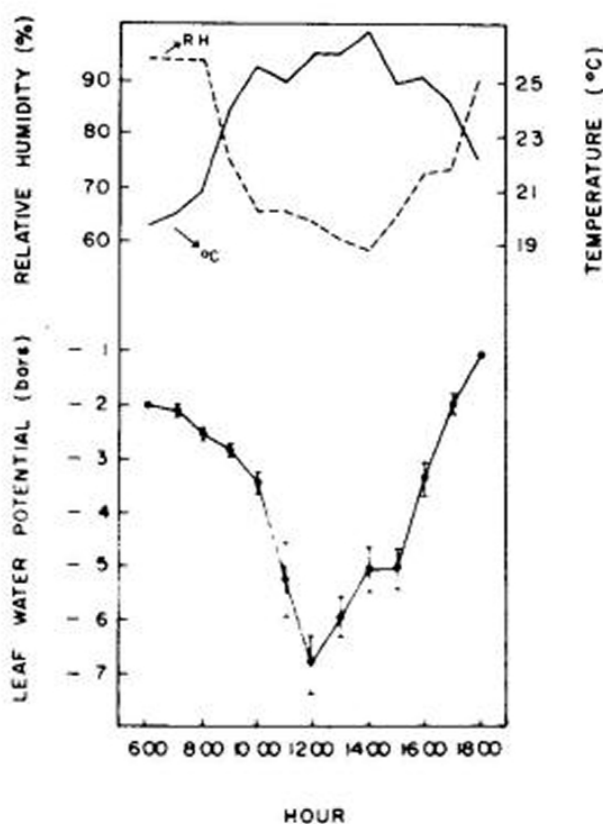


Figure 1 — Diurnal variation in water potential of 4-month-old cacao leaves.

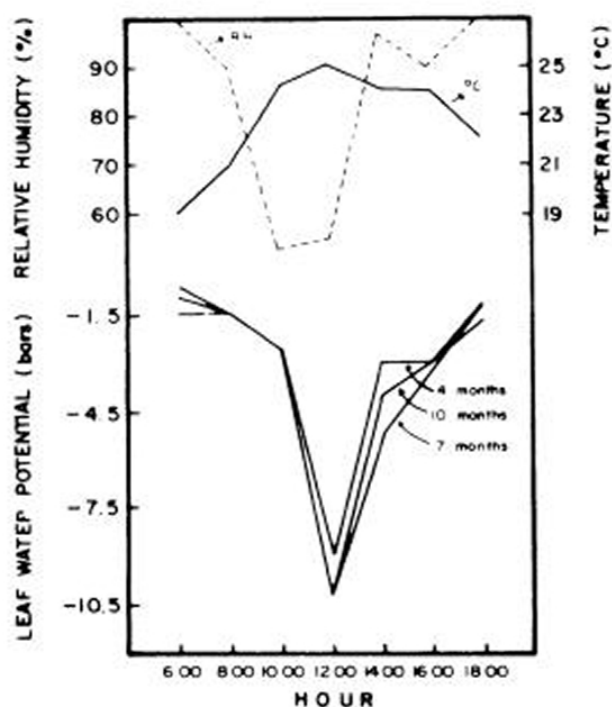


Figure 2 – Diurnal variation in water potential of leaves of different ages.

Substantial differences in water potential occurred as illustrated in Figure 3. The three pairs of curves shown were obtained on alternate days and provide a good example of the effect of atmosphere humidity of leaf water potential in the absence of a soil moisture stress. The first pair of curves refers to a cloudy day, during which it rained between 10:30 and 11:30 a.m.; the middle pair to a brighter day with a rain shower around 9:20 a.m.; and the third pair to a clear and warm day without rain. The water potential of the upper exposed, leaves was appreciable lower than that of shaded leaves, and the difference was accentuated with decrease in rel-

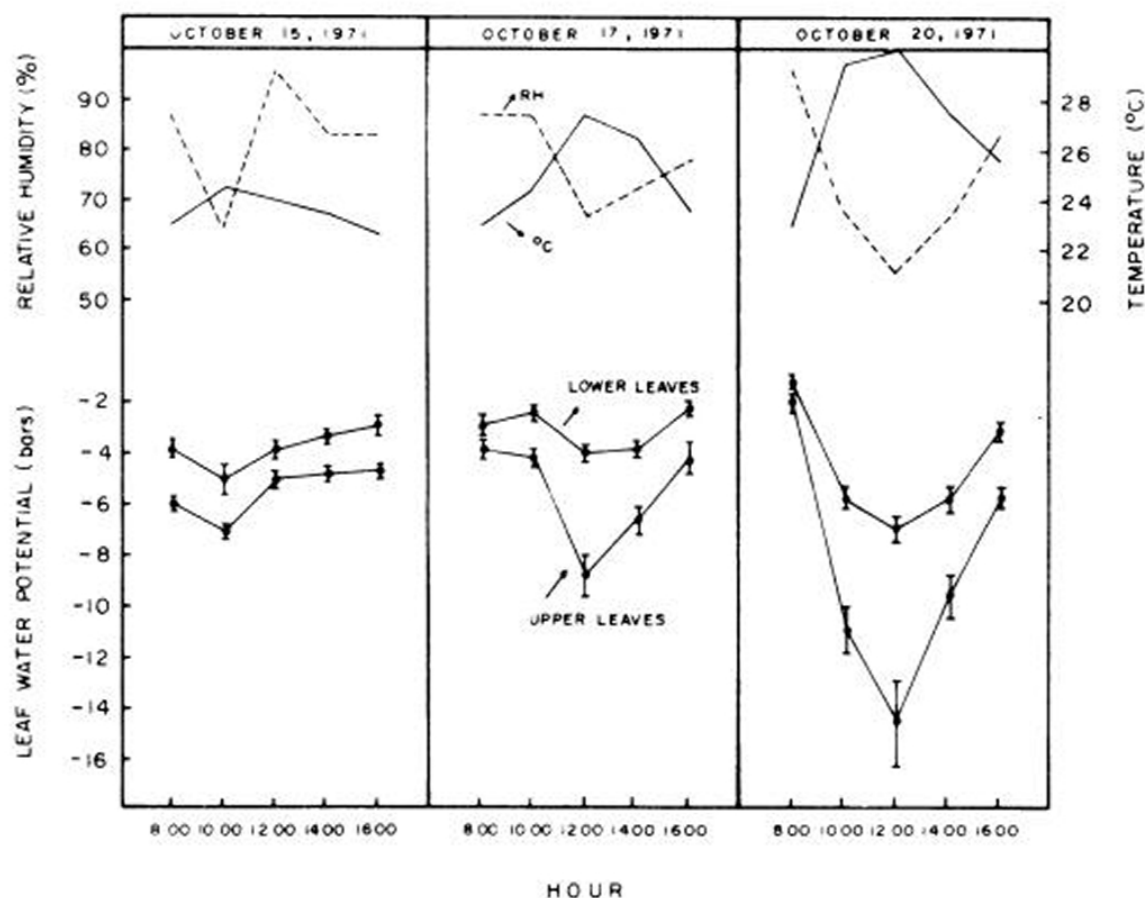


Figure 3 – Diurnal variations in leaf water as related to air temperature and relative humidity, for 3 different days.

ative humidity. Since all data were taken during a relatively rainy period it is clear that the daily variation in water potential of cacao leaves is much more dependent on relative humidity of the air than on soil water availability. Naturally, during periods of prolonged drought soil moisture supply becomes increasingly important in influencing leaf water balance.

In a recent experiment on effects of shade removal on periodicity of leaf fall and leaf flushing of cacao, leaf water potentials were measured in an open area and in a densely shaded ones. The selected areas were near each other and had similar slope and soil characteristics. The initial results (Table 1) showed that leaves in the shaded area were under considerably less water stress than the leaves in the open area. Differences in water potential between upper and lower leaves were minimal whereas there was wide variation for the same leaves in the unshaded plot. In addition, tem-

perature of the upper sunlit leaves in the unshaded plot was 10°C higher than ambient temperature. As expected, such a difference was not observed with the lower and shaded leaves of both plots.

GROWTH RHYTHMS

In spite of growing in areas with little seasonal variation in climate, particularly with regard to temperature and day-length, cacao, like many tropical trees does not grow continuously throughout the year but behaves as an intermittently growing evergreen, exhibiting periods of intensive leaf growth alternating with periods of vegetative rest. These growth pulses are generally recognized as "seasonal" in the sense that they are repeated at about the same time of year, varying according to region but within a region usually showing little change from year to year. Attention will be given in this discussion to the role played by environmental factors in control of shoot flushing and leaf abscission.

Table 1 — *Effect of shade and time of day on leaf water potential.*

Time	Leaf water potential (bars)			
	With shade		No shade	
	Upper leaves	Lower leaves	Upper leaves	Lower leaves
10:00	-6.3 ± 0.9	-4.3 ± 0.4	-13.7 ± 1.2	-5.3 ± 0.6
12:00	-5.0 ± 0.2	-4.3 ± 0.4	-12.4 ± 0.2	-7.3 ± 1.1
14:00	-4.9 ± 0.1	-4.2 ± 0.1	-12.7 ± 0.4	-6.1 ± 0.9

Age effect

When studying growth rhythms of trees it is most important to recognize that juvenile plants behave very differently from adult plants. Greathouse, Laetsch and Phinney (15) recently studied growth rhythms of young cacao plants (about 1 year old) under controlled environmental conditions (29°C; 75-100% relative humidity; 600 ft C light intensity, and 12-hr photo-period). The growth cycle of a shoot showed an average duration of about 65 days, and in their opinion, once this cycle was completed a new flushing cycle automatically started, provided environmental conditions were suitable for growth. Greathouse et al (15) observed that plants under controlled conditions were not synchronous with each other with regard to shoot-growth "as it appears to be in the field" (*sic*), and concluded that their data "strongly suggested that flushing was controlled by an endogenous mechanism".

The fact that young cacao plants are asynchronous with regard to growth rhythms is well known (5, 6). Equally well known is the fact that mature plants in the field exhibit close synchronism in growth behaviour. The underlying physiological reasons for this difference between mature and juvenile plants are not well understood. There is little doubt, however that growth rhythm of mature plants in the field is strongly con-

trolled by environmental factors and not by endogenous rhythms.

Internal factors

Whatever the nature of the external stimulus which induces growth flushes in cacao, there is little doubt that internal factors — be they growth promoters, growth inhibitors, nutrients, or a balance of such internal requirements — are obviously involved in the mechanism of growth and rest. With certain species of temperate regions, some progress has been made on endogenous hormones controlling growth rhythms (8, 10, 13, 30). In the case of cacao, good data are scarce but some indirect evidence illustrates the role of internal factors in the mechanism of flushing.

Studies in Brazil (6, 7) and in the Camerouns (9) have shown that flushing and leaf fall are closely related phenomena. Intensive leaf fall invariably occurs simultaneously of just before or after an intensive flush of shoot growth. Ordinarily, the main flush in Bahia occurs in September-October and is followed by two or three minor flushes between November and April, with flushing in February-March usually second in importance. Maximum leaf fall as a rule takes place soon after the intensive growth flush of September-October. From May to mid-September the plants remain in a state of

rest, with practically no flushing and very limited leaf-fall taking place (Figure 4).

Two hypothesis may be suggested to explain the synchronism between leaf-fall and flushing; a) the concentration of an inhibitor responsible for bud dormancy and originating in the leaves is reduced as a consequence of leaf abscission, thus triggering bud expansion; b) flushing imposes a strain for nutrients and/or hormones, which would accelerate

senescence and abscission of old leaves. The first hypothesis is supported by the fact that flushing can be induced during any period of the year by means of heavy pruning or by various degrees of defoliation. Studies in Bahia have shown that leaf removal caused intensive flushing even during a period when plants normally are in a state of rest (e.g. in June) (7).

In 1971, a drought occurred during June/July, normally the wettest period of the year in Bahia,

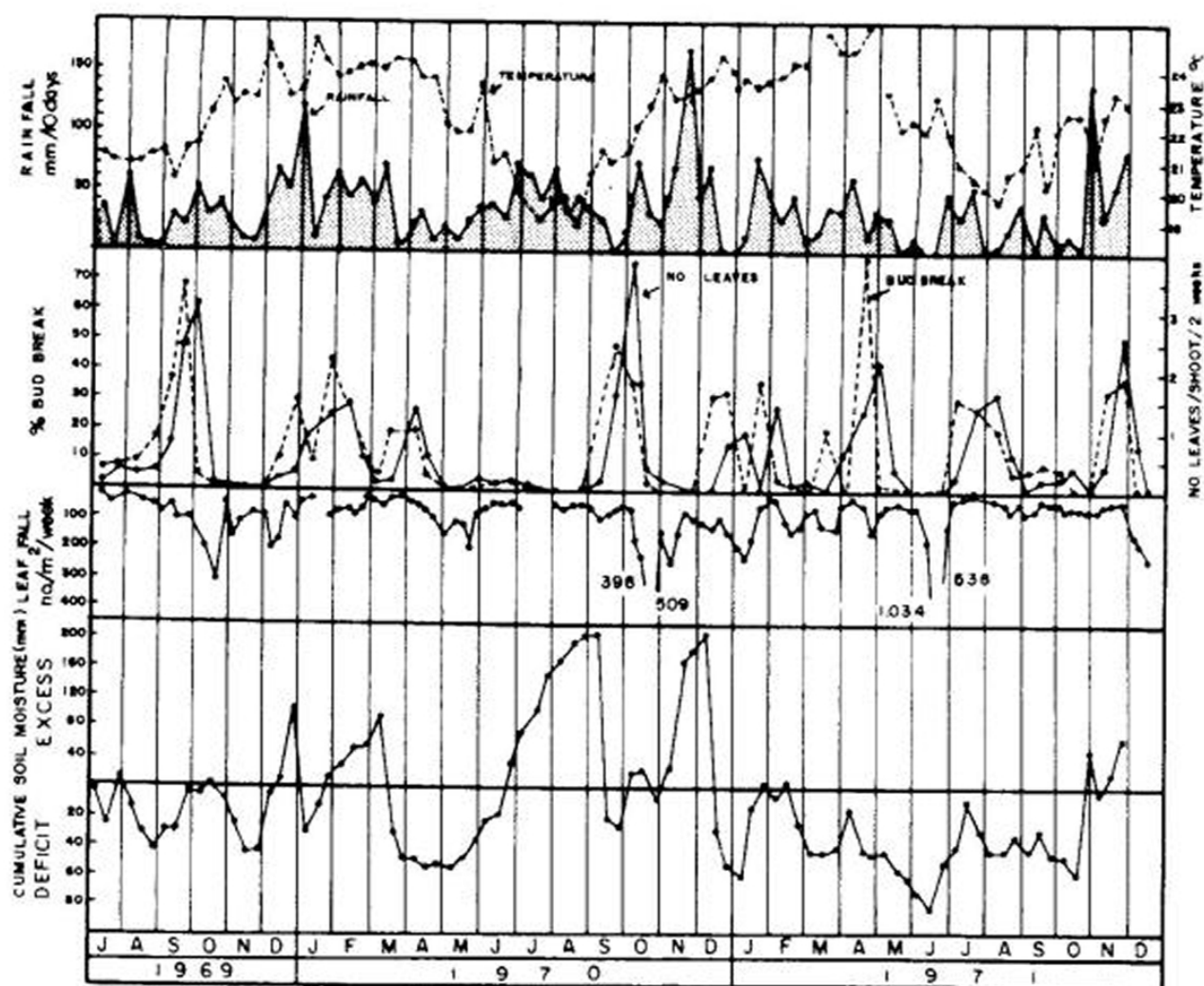


Figure 4 – Bi-weekly data on flushing of cacao in Juçari, Bahia, from July 1969 to November 1971. Data are expressed in % of bud break and number of newly formed leaves, together with data on leaf fall/m²/week, temperature, rainfall, and cumulative soil moisture deficit and excess.

causing off-season leaf-drop which was immediately followed by intensive flushing in July-August (Figure 4). This was the first time in many years that flushing was observed in Bahia during this period.

As shown in Figure 4, leaf fall in October 1969, October 1970, and December 1971 occurred 2-3 weeks after flushing. This does not necessarily invalidate the first hypothesis, as the abscission layer is obviously formed before actual leaf shedding takes place and could therefore precede onset of flushing.

A growth promoter moving from the roots to the shoots through the phloem also appears to play an important role in the mechanism of flushing. The indirect evidence which appears to justify the assertion is the following (7): a) when a complete ring of bark is removed from the trunk or from one of the main branches of a cacao tree thereby preventing upward phloem transport, flushing is inhibited in the whole tree or in the ringed branch, respectively; b) when all but one of the main branches are ring-barked, the ungirdled branch is stimulated to flush off-season, whereas all ringed branches do not flush (suggesting that the growth promoter originating in the roots moved in higher concentrations to the ungirdled branch); c) flushing is also inhibited when some lateral roots are "pruned" by opening a trench about 25 cm deep with a circumference 2 m in diameter around the tree.

Competition for food between growing pods and shoots also appears to reduce flushing intensity. This was observed in the seed garden plots of the Cacao Research Center, in Itabuna, Bahia, in 1970 and 1971. Plants of the Catongo cultivar about 4-5 years old, which had been intensively hand pollinated to produce hybrid seeds exhibited very little flushing when compared with other Catongo plants in the same area which had not been hand pollinated. Heavy fruit setting on the hand pollinated plants also appeared to be responsible for die-back and even death of a few trees. Die-back symptoms disappeared and normal flushing was promptly resumed when the affected plants were stripped of all fruits.

Environmental factors

Earlier theories about the effect of environmental factors on growth rhythms of cacao were reviewed in a previous paper (6). Research carried out between 1966 and 1972 (7, 24, 25) gives support to a theory first suggested by McDonald (19) which attributed particular importance to the effect of soil moisture and/or air relative humidity on flushing. On the basis of field studies in Brazil, the following hypothesis was proposed to explain the relationship between moisture availability and flushing (7): a) decreased rainfall (or increased moisture stress) induces leaf abscission; b) abscission breaks bud dormancy (because of

reduced production of an inhibitor or dormancy inducing substance originating in leaves); c) flushing occurs soon after abscission or, under conditions of severe moisture stress, after the onset of rains.

Sale (25) demonstrated that each time cacao plants were watered following a period of soil moisture deficiency vigorous flushing occurred about 10 days after watering. Many of the flushes were produced from axillary buds as well as from terminal buds. Plants which were irrigated frequently flushed less vigorous than droughted plants and only at the terminal buds, with peaks of flushing occurring every 5-6 weeks. In spite of flushing less intensively, the total leaf area was higher for the frequently watered plants than for droughted ones because of reduced leaf shedding or longer leaf of the former. Sale (21) also demonstrated under controlled conditions that flushing was not induced by increase in temperature above 83°F, as previously advanced by Humphries (17) and Greenwood and Posnette (16), or by increase in temperature range (thermo-periodicity) as suggested in earlier papers of Alvim (2). Sale (21) found however, that the intervals between flushes were reduced when temperature was raised, with plants growing at 74°F flushing approximately every 95 days and plants growing 80°F and 86°F flushing every 36 and 20 days, respectively.

Figure 4 shows data on flushing and leaf shedding in Juçari, Bahia, from July 1969 to November 1971, together with data on rainfall, mean temperature, and cumulative soil moisture deficit and excess. Flushing was recorded on 20 plants, about 12 years old, by weekly counting of newly formed leaves on 200 well exposed shoots (10 shoots per plant). The percentage of shoots initiating flushing (bud break) was also recorded at weekly intervals. Twenty, 1 sq.m wooden boxes were placed under the trees for weekly counting of leaf fall. For the sake of simplicity, data on bud break and number of newly formed leaves are presented for 2-week intervals.

Cumulative soil moisture deficits were estimated following the method of Smith (27), assuming a soil depth (root space) of 45 cm, an apparent specific gravity of the soil of 1.4, a field capacity of 32% and a wilting point of 16%. These values give a "K" value of 0.01, and a water retention capacity of 100 mm. The cumulative soil moisture excess was derived from the balance between rainfall and potential evapotranspiration. Data on solar radiation as measured with a solarigraph, relative humidity, and vapour pressure deficit, were also analysed in this study but are not included in Figure 4 as they did not show any correlation with growth rhythms.

By comparing the data on flushing with that on cumulative soil

moisture deficit and excess – and to a lesser extent with rainfall at 10-day intervals – it becomes apparent that periods of increased bud break and subsequent leaf expansion were always preceded by a period of soil moisture depletion. In most cases the beginning of a flushing cycle took place simultaneously with/or soon after the first rainy days following a relatively dry period. There were cases, however, (e.g. in December 1970) when flushing apparently started before the onset of rain. Further studies are needed to determine whether a dry-wet sequence is always necessary to initiate flushing or if moisture depletion alone can trigger flushing (provided it does not reach the point of checking growth or causing wilting).

The importance of moisture stress in breaking dormancy has been clearly demonstrated for coffee flower buds (3). Moisture stress was shown to be an essential prerequisite for breaking dormancy, but anthesis could take place only following irrigation or rain. A similar type of response to a relatively dry period followed by a wet one has been observed in citrus, in connection with flowering and flushing cycles (11) and probably is of common occurrence among tropical trees. The term "hydroperiodicity" has been suggested for this physiological response to a succession of dryness and wetness (5).

Special attention should be given to the fact that between 1963 and 1970 (6, 7), flushing had never been reported in Bahia during the months of May to August, which corresponds to the period of relatively frequent rainfall, reduced solar radiation and low temperature. In 1971 intensive leaf fall followed by vigorous flushing occurred for the first time during the month of July, and this was clearly associated with an unusually severe drought which occurred in June (Figure 4). Temperature and solar radiation showed no apparent relationship to this off season flush. These results seem to indicate that the absence of flushing normally observed from May to August in Bahia cannot be attributed to low temperature or low solar radiation, as previously believed (6, 7), but to normal absence of moisture stress during the period.

In Sale's experiments (25) plants which were frequently watered ("wet treatment") did not flush at all after they reached the age of about 2 years, whereas plants of the same age but previously submitted to soil moisture stress exhibited vigorous flushing. Sale carried out his experiments with plants aged 12 to 30 months and it seems likely that the "juvenility effect" overshadowed responses to the water regime during the earlier part of his experiments, i.e., when plants were younger. He agreed with the previous suggestion of Alvim, Machado and Grangier (7) that water stress caused the

buds to develop to a stage where they were ready to grow and appeared to be a "necessary requirement for the plants to continue to either initiate or expand new leaves". Sale recognize that this conclusion did not invalidate the suggestion of Cheesman (12) "that the absence of a dry season may be wholly favourable to cacao - for under most field conditions it is probable that soil water would be depleted occasionally to at least 50%, and thus provide any growth check that might be necessary for continued flushing".

It is well known that cacao growing without shade flushes much more intensively than does shaded cacao. This probably is associated with higher internal moisture stress in unshaded plants, as shown by our studies on the effect of shade on leaf water potential.

Studies with species of temperate regions have shown that moisture stress increases the amount of abscisic acid in the leaves, this apparently being the main factor controlling leaf shedding (30). Abscisic acid has been found also to impose bud dormancy in some species (8,10,13,29,30). Our previous hypothesis to explain the effect of moisture depletion on flushing could be tentatively rewritten as follows:

- a) Moisture stress increases the concentration of abscisic acid, thus accelerating senescence and leaf shedding;

- b) Translocation of abscisic acid or another rest-imposing substance from the leaves to buds decreases as a result of formation of abscission layer or because of actual leaf drop;
- c) Buds start growing;
- d) Shoots and leaves expand, provided water is available for growth.

FLOWERING

As in the case of flushing, age effects and internal factors deserve attention when studying the influence of environmental factors on the flowering cycles of cacao.

Age effect

The age at which cacao starts producing flowers in the field varied a great deal with genetic origin and cultural practices. Under good management conditions, most of the new hybrids now being planted in Brazil start flowering at an age of about 18 months after transplanting to the field. An extreme case of genetically controlled premature flowering was observed by Soria (28) on some seedlings of pure criollo cacao from Mexico, which began to produce normal flowers at the age of 3 months when the cotyledons had not yet fallen from the plants. Plants growing in nutrient solution under greenhouse conditions in Bahia, usually start producing flowers at the age of about 12 months from seed. Unselected amelonado plants under traditional

cultural practices used by farmers in Bahia take from 3 to 4 years, on the average, to start flowering.

As previously reported (6), the flowering cycle of mature cacao plants in Bahia follows a clearly established seasonal pattern, with practically no flowers appearing during the months of July, August, September or October. In young plants flowering is reduced but not completely arrested during the same period. The difference be-

tween mature and young plants with regard to flowering has recently been confirmed in a study comparing the flowering cycle of the cultivar Catongo aged 5, 12 and 23 years old growing in neighboring areas, in Uruçuca, Bahia. To estimate flowering intensity, the soil surface under each tree was covered with a layer of sand and the number of unfertilized flowers falling on the sand was counted at intervals of 2 or 3 days. Figure 5 shows the total number

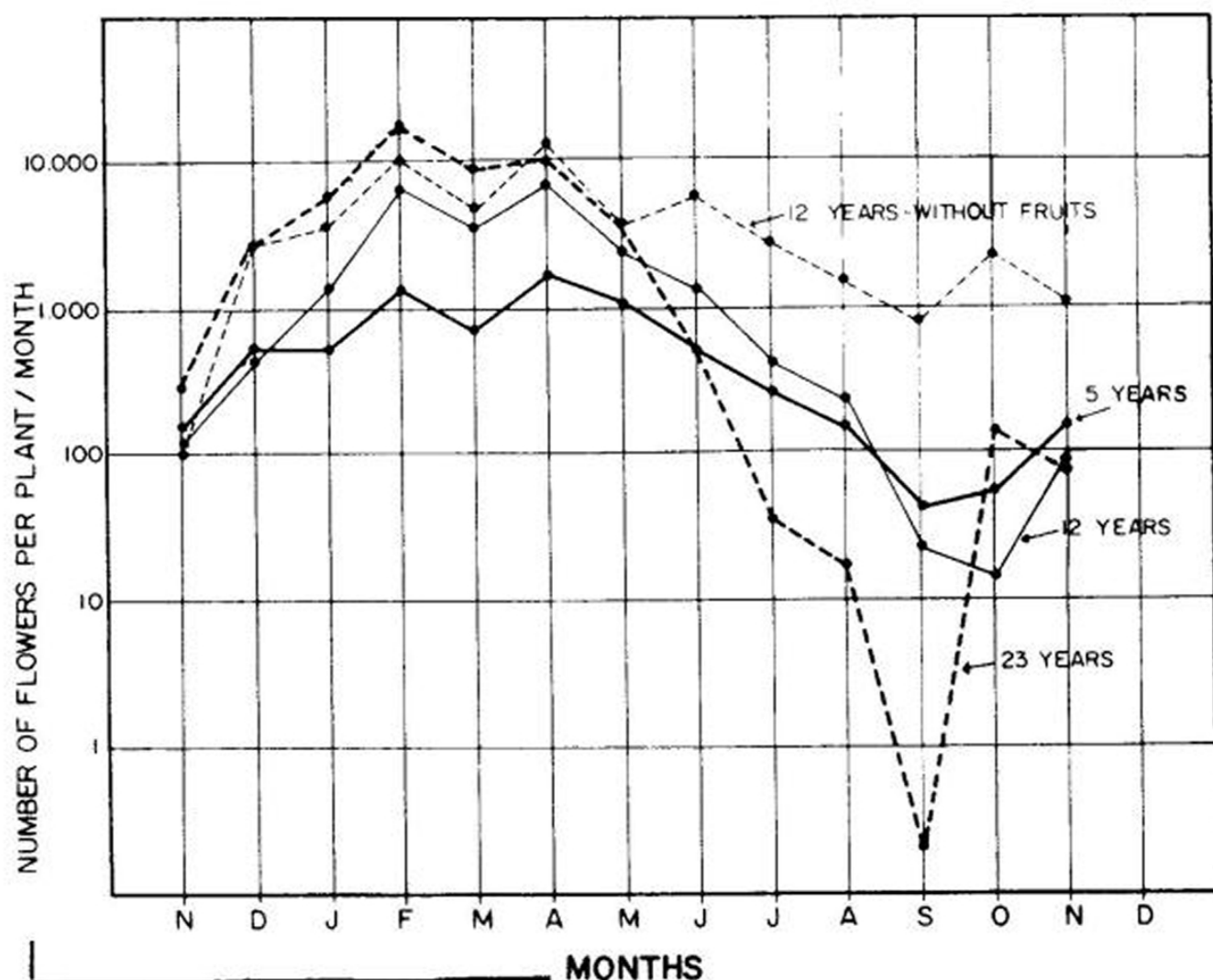


Figure 5 — Monthly flower production in Catongo trees, aged 5, 12, and 23 years, in Uruçuca, Bahia, from November 1970 to December 1971 (average for eight trees in each age group). Data for a sterile 12 year old tree which produced only one pod during the period of the study, are included for comparative purpose (see text).

of flowers produced per month (average of eight trees for each group) from November 1970 to November 1971. Attention should be called to the fact that because of the very wide changes in the number of flowers during the course of this study — particularly in the case of older plants — a logarithmic scale was used. As shown in Figure 5 seasonal variability in flowering increased in direct proportion to plant age. The 23-year-old plants produced about 10 times more flowers than the 5-year-old plants during the peak of flowering (February-April) and about 10 times less during the low flowering period (August-September). The figures for the 12 year old plants fell between the other two age groups.

It may be possible that the microclimate around the plant rather than plant age is responsible for the difference between mature and young plants with regard to flowering and cropping patterns. Among other things, younger plants, because of their lower leaf area index, receive more solar energy per unit-leaf area than older plants, and this might be one important factor associated with the difference in their response to variations in climate. Another possibility is that older plants, because of their larger proportion of non-photosynthetic tissues (roots, trunks etc) or large "sink", would be more easily depleted of flower-forming substances than younger

plants. Further research is obviously needed on this point.

Internal factors

A chemical stimulus originating in the leaves and moving down through the inner bark (phloem) appears to play an important role in the mechanism of flowering. This can be demonstrated by removing a ring of bark from the trunk of mature cacao trees. Studies in Brazil have shown that following such stem girdling during the normal blooming season, flowering was very profuse on the portion of the trunk above the ring and was completely arrested below the ring, this response occurring within 2-3 weeks following treatment. Accumulation of photosynthates and/or flowering hormones is apparently responsible for the enhancement of flowering above the stem girdle. Similar responses to bark ringing has been reported for citrus (14).

The fruit load of the plant also affects flowering intensity. This was observed during the course of our study on the effect age. One of the 12-year-old Catongo plants included by chance in the experiment has proven to be practically sterile, as it produced only one pod during the course of the study. The flowering cycle of this plant is also included in Figure 5 (12 years without fruits). It not only bloomed much more heavily than the normal bearing 12-year-old plants, but showed a relatively

slight decrease in flowering from July to November when other plants, irrespective of age, showed much lower flowering intensity. Together with our observations on the effect of ringing, these results seem to indicate that fruits compete with flowers for a substance or substances (which could very well be carbohydrates) whose concentration is related to flowering intensity. Competition between fruits and flowers is known to play an important role in determining flowering intensity of other tree crops, such as citrus (18).

Environmental factors

Accurate data on flowering cycles of cacao have been obtained at the Experimental Station in Juçari, for a period of 38 months (January 1968 to February 1971), using 12 clonal plants which about 8-years-old at the beginning of the study. A circular nylon sheet about 3 m in diameter was placed under the canopy of each tree at a height of about 50 cm from the ground, resembling an inverted umbrella with the trunk of the cacao tree as the central rod. The number of flowers which dropped into the umbrella was recorded every two days. The average number of flowers per day/plant is given in Figure 6 for 10-day intervals. Data on cumulative soil moisture deficit and excess, calculated by the method mentioned under growth rhythm as well as data on mean temperature, are also presented. In Figure 6 other climatological

data, such as solar radiation as measured by a solarigraph, relative humidity, and vapor pressure deficit, did not seem to show any relevant relationship with the flowering data and will not be included in this discussion.

As shown in Figure 6, the period of intensive flowering usually occurred from November to June, whereas the months of least flowering were August to October. Previous studies carried out at another station (Uruçuca) with older trees (6) showed minimum flowering from June to September. It is not known if this discrepancy is due to difference in climate, age of trees, varietal differences, or methods of study. It must be recognized, however, that the observations of Figure 6 as well as of Figure 5, were more accurately taken than those previously reported, and are thus probably more reliable.

In previous studies on flowering carried out in Bahia (6) it was suggested that the decrease in flowering from June to September was a result of low temperature alone. Because temperature drop in Bahia starts in May, when flowering is still quite intensive, it was postulated that the effect of low temperature was indirect in the sense that it first affected vegetative growth which in turn affected flowering, this accounting for the time lag between supposed cause and effect. This theory needs now to be revised in view

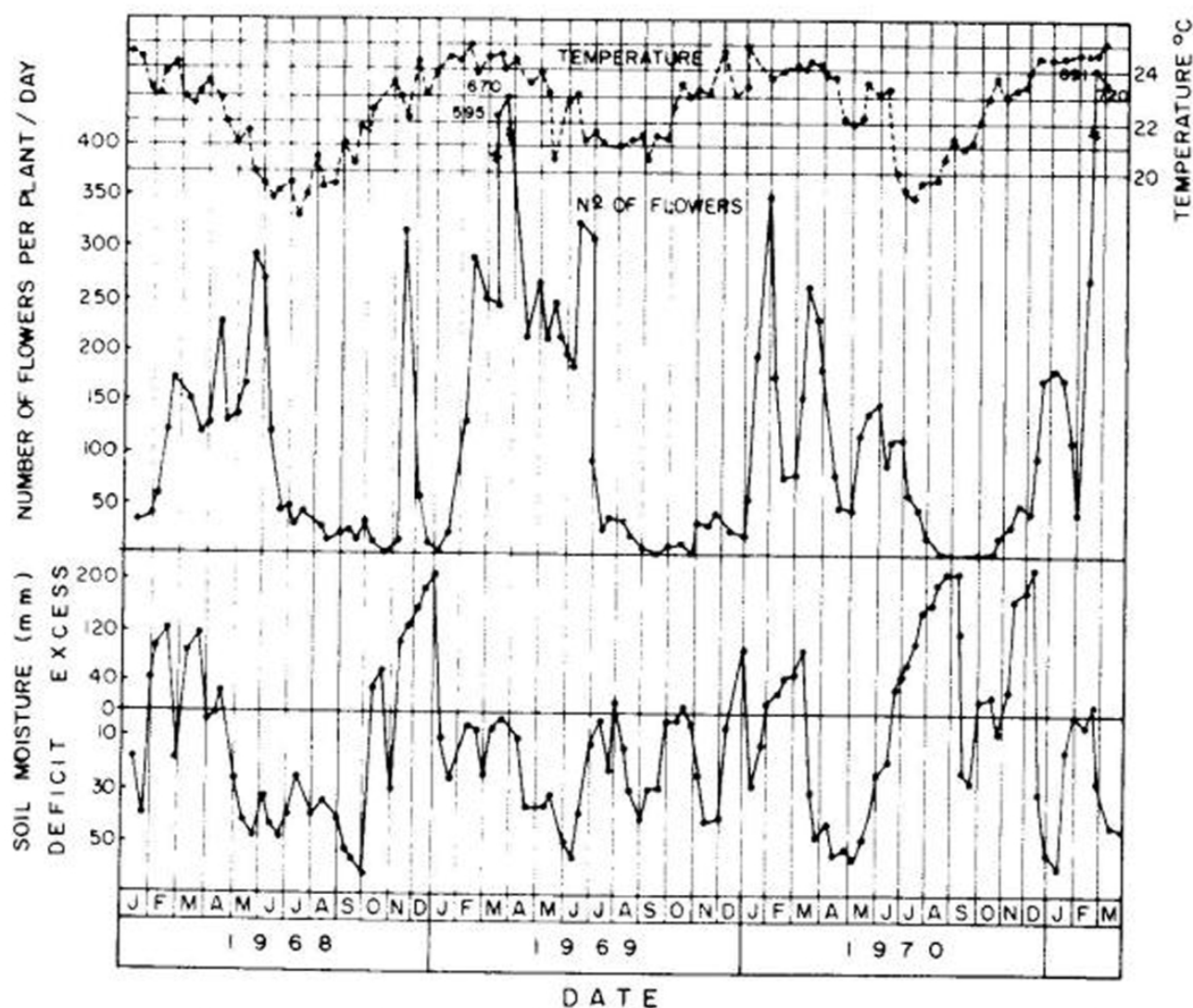


Figure 6 – Flowering intensity of cacao as expressed in number of flowers/plant/day (mean figures for 12 clonal plants), in Juçari, Bahia, together with data on temperature and cumulative soil moisture deficit and excess, at 10 day intervals from January 1968 to March 1971.

of recent findings. As shown in our studies on flushing (Figure 4), temperature did not show any relationship with growth rhythms of cacao. Intensive bud break and leaf expansion could take place even during period when temperatures were relatively low (e.g., in July 1971). Sale (23) also did not find support for an "indirect" effect of temperature on flowering. He confirmed that low temperature decreased flowering, but the effect

seemed to be direct. We are inclined to think that reduced flowering in Bahia from June-July to September-October is caused by internal competition between fruits and flowers, with the effect of low temperature apparently being of lesser importance. As will be shown later (Figure 8) the period of maximum fruit load in Bahia, as expressed in total dry weight of hanging pods, coincides with the period of minimum flowering.

The flowering season for plants in our studies occurred from November to June. It is worth pointing out that the beginning of this season coincided every year with the period when plants had the lowest fruit load (Figure 8). This lends support to our hypothesis about the importance of internal competition between fruits and flowers. It appears from our results that, as long as this competition exists, flowering shows practically no response to changes in environmental conditions. Only after the plants reach the period of minimum fruit load or decreased internal competition between fruits and flowers, blooming becomes responsive to environmental conditions, and exhibits wide fluctuation from time to time. It is well established that flowering of cacao is inhibited during period of moisture stress (1, 4, 6, 20, 25). It has also been demonstrated that flowering becomes particularly profuse after the first heavy rains following an extended dry period (6).

By investigating the data on cumulative soil moisture deficit and excess with the number of flowers per plant (Figure 6) during the flowering season, it may be observed that periods of increased flowering were usually preceded by a relatively dry period followed by a wet period and that decreased flowering was associated either with a dry spell (e.g. April 1970) or excessive soil moisture (e.g. December 1968, December 1969,

February 1970, and November 1970). In some instances, such as in December 1970 and January 1971, increased flowering appeared to result from decreased soil moisture following a period of moisture excess.

Sale (25) obtained profuse flowering in potted cacao plants whenever the soil was watered following a period of moisture stress, and concluded that flower initiation had been enhanced during the dry period and only flower growth was inhibited by moisture deficiency. With regard to coffee, the flower buds remain in a state of complete rest for as long as the plants are frequently watered and kept under high atmospheric humidity, a "dry-shock" being apparently needed for rest breaking (3). As pointed out by Sale (25) this does not seem to be the case with cacao, as the flower buds do not go through a rest period imposed by high water potential, some flowering always occurring even under conditions of frequent watering or high humidity. Sale (24) also demonstrated, under controlled conditions, that profuse flowering can be induced by transferring the plants from a low (50-60%) and medium (70-80%) relative humidity to a high one (90-95%).

It is worth pointing out that flowering of citrus in tropical areas has been shown to be controlled by alternations between dry and rainy periods and that in irrigated citrus orchards it is pos-

sible to induce out of season flowering by irrigation following a drought stress (11).

From the foregoing discussion it may be concluded that the main factors controlling flowering of cacao appear to be, internally, the competition between fruits and flowers, and externally, the alternation between dry and wet periods, or *hydroperiodicity* of the environment.

FRUIT PHYSIOLOGY

Cacao harvesting in Bahia usually extends for about 8 or 9 months, i.e. from mid-April to mid-January. Plants up to 4-6 years old, tend to produce fruits throughout the year, but the crop is usually much reduced from mid-January to mid-April. In August-September the crop from mature plants is also reduced but its production is not completely stopped. The harvest from April to August is referred to as "temporão" or mid-crop, and from September to mid-January, "safra" or main crop. The cropping pattern shows some variation from year to year but on the average there is practically no difference between "temporão" and "safra" in volume of production.

Temperature effect on fruit development

In a study carried out with the white seeded cultivar "Catongo", it was found that the period from

pollination to fruit ripening varied in Bahia from 140 to 205 days, the average being $167 \pm 0,78$ days. As previously reported (6) when pods of the "temporão" crop (pollinated in November-January and harvested in April-August) were compared with the "safra" crop (pollinated in March-June and harvested in September-January) it was found that the former matured in 140-175 days whereas the latter took 168-205 days reach maturity.

A highly significant negative correlation was found between the number of days from pollination to harvest and the mean temperature during the period. Based on this correlation the following equation was developed to estimate the number of days from pollination to harvest for the Catongo cultivar in Bahia:

$$N = \frac{2500}{T - 9}$$

Where N is the number of days and T the daily mean temperature ($^{\circ}\text{C}$) during the period.

Figure 7 gives the estimated number of days from pollination to harvest for fruits set at different periods of the year calculated on the basis of the above equation, using the mean temperature values for Uruçuca, Bahia.

Seasonal changes in fruit load

In order to estimate changes in fruit load during the year, careful pod counts were made monthly on

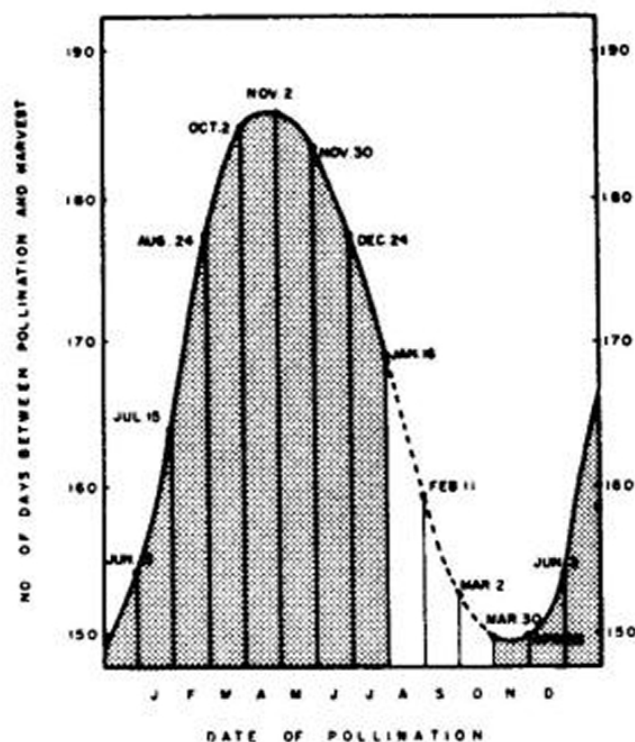


Figure 7 – Theoretical periods between fruit setting (pollination) and harvest, expressed in days, as a function of date of pollination. Dates on the curve were calculated on the assumption that pollination occurred on the first day of each month. In Bahia, as a rule, there is no crop between mid-January and mid-April.

the same 12 clonal plants used in the study on flowering cycles. Figure 8 shows the monthly numbers of harvested pods, developing pods, and wilted cherelles. On the basis of a previous study on changes in pod dry weight as re-

lated to fruit age (6), and using the final number of harvested pods as a reference, the total dry weight of the hanging pods could be estimated. Wilted cherelles were not included in this estimation. As indicated in Figure 8, the period of maximum fruit load on a dry weight basis did not coincide with the period of maximum number of pods per tree. As a rule, the latter occurred from March to July with the peak in May/June,

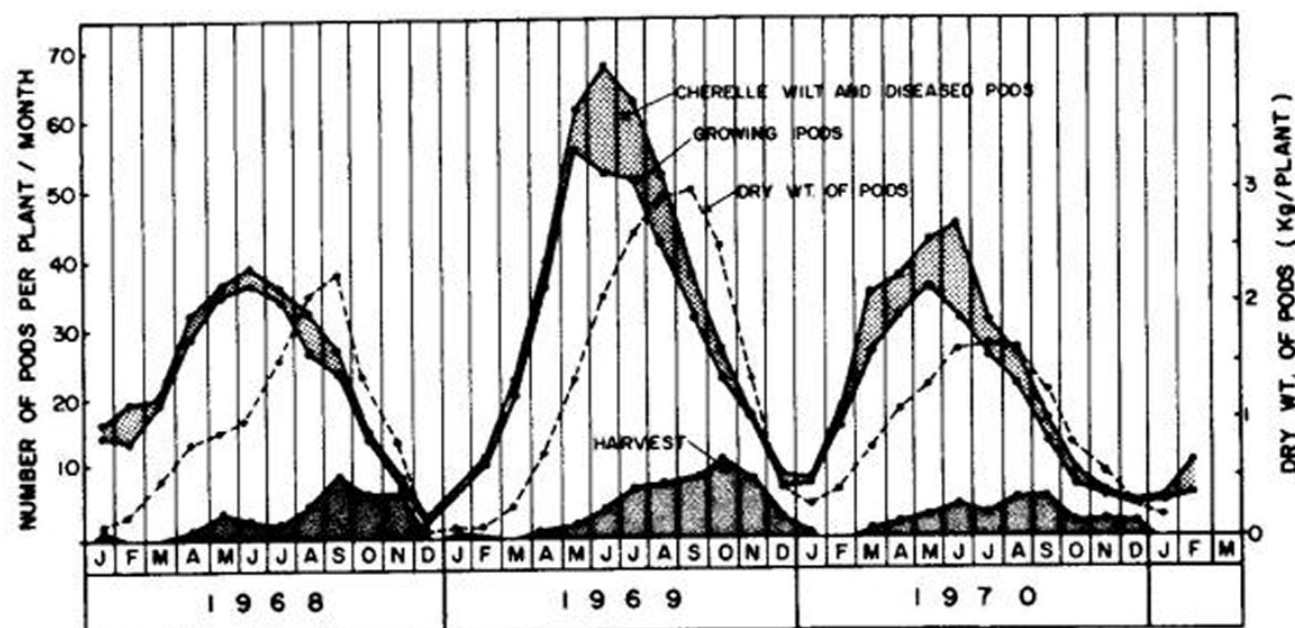


Figure 8 – Pod counts at monthly intervals for 12 clonal plants from January 1968 to February 1971, in Juçari, Bahia, together with estimated total dry weight of pods per plant/month.

whereas the former came about 3 months later, with the peak in August/September. The period of minimum fruit load occurred from December to February. As previously stated, changes in flowering intensity appeared to be related to changes in fruit load.

Very likely, internal competition between fruit growth and vegetative growth (flushing, root and cambial growth) plays an important role in determining changes in fruit load during the year. In other words, when external conditions are favorable for growth (October-April) the vegetative sink increases and fruit load decreases;

when is arrested (May-September) the vegetative sink decreases and fruit load increases. This hypothesis implies that vegetative tissue always are the strongest sinks and that changes in fruit load during the year are primarily due to environmental effects on vegetative growth, this in turn affecting fruiting.

Seasonal changes in fruit setting

In our study on flowering and fruit load at Juçari, data on fruit setting were also obtained by counting the number of newly formed pods at monthly intervals. Results are presented in Figure 9 together with data on wilted

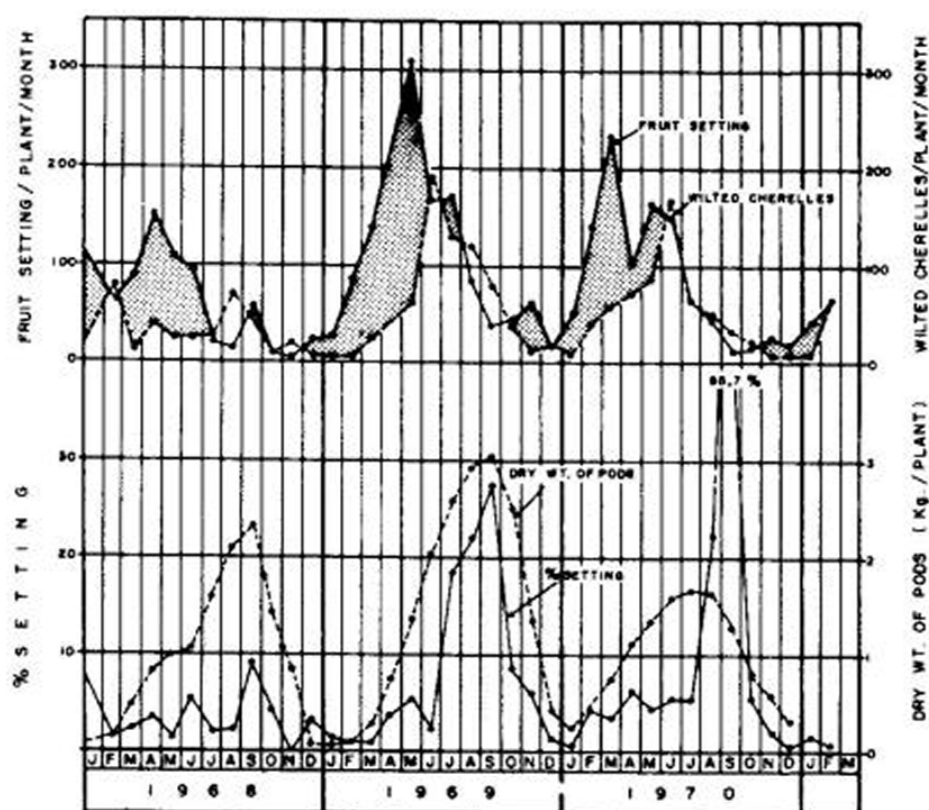


Figure 9 — Fruit setting, cherelle wilt, percentage of setting (no. newly formed pods \times 100 / total number of flowers), and estimated total dry weight of pods per plant, at monthly intervals, in 12 clonal plants grown in Juçari, Babia, from January 1968 to February 1971.

cherelles. Also included are data on the percentage of setting (number of newly formed pods x 100/number of flower) and the estimated fruit load on a dry weight basis.

By comparing these results with Figure 6 it will be noticed that the heaviest fruit setting periods occurred when the plants were flowering heavily but the percentage of setting reached its peak (up to 85.7%) during the low-flowering periods. The population of pollinating insects shows great variation during the year (31) but changes in the ratio of pollinating insects to number of flowers appear to be related more to this

wide variation in percentage of setting.

In earlier papers (6) the absence of crop in Bahia from mid-January to mid-April was attributed to reduced flowering in July-October. Results in Figure 9 indicate quite clearly that the actual cause was not absence of fruit setting in July-October but greater loss of young cherelles overruling fruit setting during that period. As shown Figure 9 the incidence of cherrille wilt appears to be related to fruit load. This indicates that, under the conditions of this study competition between fruits probably was the main cause of wilt.

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SUMMARY

Effects of environmental factors on leaf water potential, growth rhythms, flowering, and fruit development of cacao are discussed in the light of recent research in Brazil and elsewhere. Some plant factors, such as age and internal competition between fruits and flowers must be considered when studying growth and flowering responses to environmental factors. Flushing and leaf abscission were found to be correlated with each other. Among various environmental factors studied in connection with flushing, moisture stress appeared to be the most critical one, both for bud break (flushing initiation) and leaf abscission. Rain following a dry period apparently stimulates intensive flushing (including leaf expansion). No support has been found for earlier theories according to which flushing would be controlled by changes in air temperature.

Flowering seems to be controlled internally by competition with fruits (fruit load) and externally by a succession of dry-wet periods. The term "hydroperiodicity" is proposed to refer to growth and flowering responses to a dry wet sequence. Flowering is inhibited by extended dry periods as well as by excessive soil moisture.

Data on leaf water potential, fruit setting, rate of fruit development, and seasonal changes in fruit load, are also discussed in connection with environmental influence.

INFLUÊNCIA DE FATORES AMBIENTAIS SOBRE A FISIOLOGIA DO CACAUEIRO

RESUMO

São discutidos à luz de pesquisas recentes, efetuadas no Brasil e no exterior, os efeitos de fatores ambientais sobre o potencial de água das

folhas, o ritmo de crescimento, a floração e o desenvolvimento do fruto do cacauieiro. Alguns fatores da planta, tais como idade e competição interna entre frutos e flores devem ser considerados no estudo das respostas de crescimento e floração a fatores ambientais. Encontrou-se que o fluxo de crescimento e a abscisão das folhas se correlacionam mutuamente. Entre os vários fatores ambientais estudados em relação aos fluxos de crescimento, a deficiência hídrica parece ser o mais crítico, tanto para a abertura das gemas (iniciação do lançamento) como para a abscisão da folha. A chuva logo após período seco aparentemente estimula o fluxo foliar intensivo (inclusive desenvolvimento foliar). Não se encontrou apoio para as teorias anteriormente formuladas segundo as quais os fluxos foliares seriam controlados por mudanças na temperatura ambiental.

A floração parece ser controlada internamente pela competição com os frutos (carga de frutos) e externamente por uma sucessão de períodos secos e úmidos. O termo "hidroperiodicidade" é sugerido para designar a correlação entre crescimento e floração em resposta a uma sequência de período seco-úmido. A floração é inibida por um período seco prolongado bem como por excesso de água no solo.

Dados sobre o potencial de água em folhas, frutificação, taxa de crescimento do fruto e mudanças sazonais na carga de frutos são também discutidos em relação à influência do ambiente.



**NEMATÓDIOS DA REGIÃO CACAUEIRA
DO ESPÍRITO SANTO, BRASIL**
I — NEMATÓDIOS ASSOCIADOS AO CACAUEIRO
(*Theobroma cacao* L.)*

*Ravi Datt Sharma***
*Samuel Alexis Sher****

Pouco se sabe a respeito de nematódios associados com o cacaueiro no Espírito Santo; as informações disponíveis sobre o assunto são de Sharma (4). Em vista disso, um levantamento nematológico sistemático foi efetuado na região cacaueira desse Estado com o objetivo de determinar a ocorrência e distribuição dos nematóides fitoparasitas associados com diversos cultivos de modo geral, e no cacaueiro, de modo particular.

MATERIAIS E MÉTODOS

O levantamento foi conduzido em 27 propriedades, distribuídas em três municípios do Espírito Santo (Linhares, Colatina e São Mateus), no período de outubro de 1971 a março de 1974. Foram coletadas 89 amostras de solos e

raízes de cacaueiros sadios e doentes. A amostragem e extração dos nematódios foram realizadas segundo técnica de Sharma e Loof (5). Para a identificação e montagem permanentes desses nematódios, foi utilizado o processo descrito por Sharma e Sher (6). Os locais de amostragem bem como o número de amostras, sintomas apresentados pelas plantas e tipos de solos estão mencionados no Quadro 1. Os sintomas apresentados pelas plantas doentes foram anteriormente descritos por Sharma e Sher (6).

RESULTADOS

Foi detectada uma população mista de 20 gêneros e 26 espécies de nematóides fitoparasitas (Quadro 2). Os gêneros encontrados com

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Quadro 1 – Levantamento nematológico do cacauzeiro no Espírito Santo (loais de coleta, número de amostras, sintomas apresentados pelas plantas e tipo de solo), outubro/71 a março/74.

Locais de coleta (Fazendas e municípios)	Nº de amostras	Sintomas	Tipos de solo
Angélica (L)	2	D,S	Franco
Batista (L)	3	SD	Argila pesada
Boa Esperança (C)	17	S,MS	Franco
Brazilândia (L)	1	MS	Franco
Brejo Grande (L)	1	SD	Argila pesada
Bugrinha (L)	4	S,SD,MS	Franco
Contendas (L)	1	SD	Argila pesada
Esperança (C)	1	SD	Argila pesada
Est. Exp. Minist. Agricultura (L)	2	SD	Argila pesada
Est. Exp. Filogônio Peixoto (L)	11	SD	Franco
Goiana (L)	1	SD	Argila pesada
Guanabara (L)	8	S,SD,MS	Argila pesada
Grafite Sossego (L)	1	SD	Franco
Havaí (L)	2	MS	Franco
Ipanema (L)	2	SD,MS	Argila pesada
Ipiranga (L)	2	SD	Argila pesada
Paraíso (L)	1	SD	Argila pesada
Piraquê (L)	1	SD	Argila pesada
Relíquia (L)	4	S	Argila pesada
Santo Antônio (L)	11	S,MS	Argila pesada
Santa Rita (L)	2	SD	Argila pesada
Santa Terezinha	1	SD	Argila pesada
São Jorge (SM)	2	MS	Argila pesada
São Pedro (SM)	1	MS	Argila pesada
São Sebastião (L)	1	SD	Franco
Três Marias (L)	1	SD	Argila pesada
Vila Nova (L)	5	SD	Argila pesada

Municípios: (L) = Linhares
(C) = Colatina
(SM) = São Mateus

Sintomas: S = sadio
SD = seca descendente
MS = morte súbita

mais freqüência foram: *Helicotylenchus*, *Meloidogyne*, *Hemicriconemoides*, *Xiphinema*, *Criconemoides* e *Paratylenchus*. Foram constatadas também em todas as amostras, espécies saprofíticas e predadoras.

Criconemoides mauritiana, *Dolichodorus* sp., *Gracilacus aculen-*

tus, *Tylenchus davainei*, *Tylenchorhynchus martini* e *Xiphinema setariae* estavam associadas aos cacauzeiros que apresentavam sintomas de seca descendente (die-back). *Aphelenchus avenae*, *Aphelenchoides* sp., *Boleodorus* sp., *Helicotylenchus multicinctus*, *Longidorus* sp., *Xiphinema americanum* e um gênero não identificado

Quadro 2 — *Frequência de ocorrência de nematóides parasitas de plantas associados ao cacauero (Theobroma cacao L.) em 89 amostras na região cacaueira do Espírito Santo.*

Nematóides	Frequência de ocorrência	
	Locais de amostragens *	% das 89 amostras
<i>Aphelenchus avenae</i>	Y, Zo	4.5
<i>Aphelenchoides</i> sp.	C, Zo	7.9
<i>Boleodorus</i> sp.	M	1.1
<i>Criconemoides</i> sp.	A, E, F, H, J, L, N, O, P, R, S, T, V, W, Z, Zo	29.2
<i>C. mauritiana</i>	U	1.1
<i>Dolichodorus</i> sp.	N, U	3.4
<i>Gracilacus aculeatus</i>	H, K	2.2
<i>Helicotylenchus</i> sp.	A, B, C, D, F, G, H, I, J, K, L, N, O, P, R, T, U, V, Z, Zo	56.2
<i>H. dihystra</i>	C, I, J, S, V, Y, Zo	20.2
<i>H. multicinctus</i>	J, P, Zo	3.4
<i>Hemicycliophora</i> sp.	G, I, P, Zo	4.5
<i>Hemicriconemoides</i> sp.	A, C, F, G, J, M, N, R, S, U, X, Zo	35.9
<i>Longidorus</i> sp.	Zo	2.2
<i>Meloidogyne incognita</i>	A, B, C, F, G, I, J, L, M, N, O, P, R, S, T, V, W, X, Y, Z	58.4
<i>Paratylenchus</i> sp.	A, F, I, J, L, M, Q, S, T, U, Zo	25.8
<i>Peltamigratus</i> sp.	B, H, L, N, S, U, Zo	19.1
<i>Rotylenchulus reniformis</i>	C, J, L, S, X, Z, Zo	20.2
<i>Trichodorus</i> sp.	C, Zo	3.4
<i>Trophurus</i> sp.	B, J, L, M, O, P, Q, Y, Z, Zo	18.0
<i>Tylenchorhynchus martini</i>	B, Zo	2.2
<i>Tylenchus</i> sp.	B, L, Z, Zo	6.7
<i>T. davainei</i>	Zo	1.1
<i>Tylenchulidae</i> (familia)	F, W, Zo	4.5
<i>Xiphinema</i> sp.	A, C, D, H, I, J, L, N, O, P, R, S, U, V, X, Y, Z, Zo	34.5
<i>X. americanum</i>	Zo	1.1
<i>X. setariae</i>	Y	1.1

* Fazendas ou estações experimentais.

A = Angélica; B = Batista; C = Boa Esperança; D = Brasilândia; E = Brejo Grande; F = Bugrinha; G = Contendas; H = Esperança; I = Estação Exp. Min. Agric.; J = Estação Exp. F. Peixoto; K = Goiana; L = Guanabara; M = Grafite Sossego; N = Havaí; O = Ipanema; P = Ipiranga; Q = Paraíso; R = Piraquê; S = Relíquia; T = Sta Rita; U = Sta Terezinha; V = São Jorge; W = São Pedro; X = São Sebastião; Y = Três Marias; Z = Vila Nova; Zo = Stº Antônio.

da família *Tylenchulidae* foram encontrados associados aos cacauzeiros com sintomas de morte súbita. Os outros nematóides apresentados no Quadro 2 estavam associados com os dois tipos de sintomas acima mencionados.

DISCUSSÃO

Meloidogyne incognita foi a espécie mais freqüente no levantamento e tem sido registrada neste cultivo em diferentes partes do mundo (6, 7). A mesma espécie foi também encontrada parasitando cafeeiros no Espírito Santo, demonstrando sua ampla distribuição (1). *M. exigua*, parasita comum de cafeeiros (2), não foi encontrada no presente levantamento, assim como *Rotylenchus robustus*, detectado em cacauzeiros em Trinidad (7). *M. incognita* foi encontrado em solos argilosos e pesados,

quando normalmente ocorrem em solos leves e arenosos (3).

Aphelenchoides sp., *Boleodorus* sp., *Criconemoides mauritiana*, *Gracilacus aculentus* e o gênero não identificado da família *Tylenchulidae* foram encontrados associados ao cacauzeiro pela primeira vez, o mesmo acontecendo no Brasil com as espécies *Helicotylenchus multicinctus*, *Tylenchorhynchus martini* e *Xiphinema americanum*.

Os resultados deste levantamento indicam um grande número de espécies de nematóides fitoparasitas amplamente distribuídos e associados ao cacauzeiro. Pelo exposto, há necessidade de se definir esta associação e de se determinar o papel desses nematóides nos processos patológicos das raízes do cacauzeiro e sua possível relação com a morte súbita e seca descendente.

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RESUMO

Vinte gêneros e 26 espécies de nematódios fitoparasitas foram encontrados associados ao cacaueiro (*Theobroma cacao* L.) em 89 amostras de solos e raízes provenientes de 27 fazendas localizadas em três municípios do Estado do Espírito Santo. Doze espécies estavam associadas a cacaueiros com sintomas de seca descendente (die-back) e morte súbita (seis de cada). Os gêneros mais comuns foram: *Helicotylenchus*, *Meloidogyne*, *Xiphinema*, *Criconemoides* e *Paratylenchus*. As espécies identificadas foram: *Aphelenchus avenae*, *Aphelenchoides* sp., *Boleodorus* sp., *Criconemoides* sp., *C. mauritiana*, *Dolichodorus* sp., *Gracilacus aculentus*, *Helicotylenchus* sp., *H. dibystra*, *H. multicinctus*, *Hemicycliophora* sp., *Hemicriconemoides* sp., *Longidorus* sp., *Meloidogyne incognita*, *Paratylenchus* sp., *Peltamigratus* sp., *Rotylenchulus reniformis*, *Trophurus* sp., *Trichodorus* sp., *Tylenchorhynchus martini*, *Tylenchus* sp., *T. davainei*, *Tylenchulidae* (família), *Xiphinema* sp., *X. americanum* e *X. setariae*.

NEMATODES OF THE COCOA REGION OF ESPIRITO SANTO, BRAZIL.

I – NEMATODES ASSOCIATED WITH COCOA (*Theobroma cacao* L.)

SUMMARY

A total of 89 soil and root samples from 27 farms, from three municipalities in Espírito Santo (Linhares, Colatina and São Mateus) contained mixed populations of 20 genera and 26 species of plant parasitic nema-

todes. Twelve species associated with cocoa trees had symptoms of die-back and sudden death (six each). The most common nematode genera were: *Meloidogyne*, *Helicotylenchus*, *Hemicriconemoides*, *Xiphinema*, *Criconemoides* and *Paratylenchus*. The plant nematode species identified were: *Aphelenchus avenae*, *Aphelenchoides* sp., *Boleodorus* sp., *Criconemoides* sp., *C. mauritiana*, *Dolichodorus* sp., *Gracilacus aculentus*, *Helicotylenchus* sp., *H. dihystra*, *H. multicinctus*, *Hemicycliophora* sp., *Hemicriconemoides* sp., *Longidorus* sp., *Meloidogyne incognita*, *Paratylenchus* sp., *Peltamigratus* sp., *Rotylenchulus reniformis*, *Trichodorus* sp., *Trophurus* sp., *Tylenchorhynchus martini*, *Tylenchus* sp., *T. davainei*, *Tylenchulidae* (family), *Xiphinema* sp., *X. americanum* and *X. setariae*.



FATORES QUE INFLUEM NA CAPTURA
DE *Erinnyis ello* L. (LEPIDOPTERA: SPHINGIDAE)
POR ARMADILHAS LUMINOSAS *

João Manuel Abreu **

A lagarta da mariposa *Erinnyis ello* L. é a praga mais importante da seringueira (*Hevea brasiliensis* Muell. Arg.) na Bahia. Alimenta-se das folhas, podendo provocar a desfolhação completa por ocasião de surtos violentos.

Tratando-se de um inseto de vôo noturno, fototrópico positivo, as amostragens da sua população são efetuadas com armadilhas luminosas. No entanto, é preciso considerar alguns fatores ambientais que interferem na sua captura por estas armadilhas.

Os fatores que influem na captura de insetos por armadilhas luminosas foram estudados por diversos pesquisadores (1, 2, 3, 5, 6, 9, 10, 14, 16, 17) com espécies de insetos associados aos mais diversos cultivos, tendo Holloway

(7) citado que a temperatura mínima noturna, chuva, vento, neblina, lua, periodicidade e nuvens são os mais importantes para as mariposas.

Na Bahia, Winder e Abreu (18), em experimentos preliminares com uma armadilha luminosa "omnidirecional" instalada em um seringal adulto, no município de Ituberá, obtiveram resultados preliminares sobre o comportamento de vôo de *Erinnyis ello* e *Erinnyis alope*.

Na Malásia, Rao (11) usou armadilhas luminosas para controlar o escarabeídeo *Lechnosterna bidentata* Burm., praga dos seringais em crescimento. Para tanto, estudou modelos de armadilhas, fontes luminosas, efeito de altura, hábitos de vôo e proporção dos sexos desse besouro.

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O presente trabalho foi efetuado com o propósito de determinar o efeito da temperatura mínima noturna, chuva, lua, altura e periodicidade de vôo, proporção dos sexos e atração pela luz artificial na captura de *E. ello*, em seringais. A determinação destes fatores tem importância para estabelecer métodos mais seguros nos estudos básicos e aplicados, visando o controle dessa importante praga dos seringais.

MATERIAL E MÉTODOS

A captura das mariposas foi efetuada com armadilhas luminosas modelo "Luiz de Queiroz" (13), instaladas na Fazenda Marimbu, município de Ituberá (13° 40'S e 39° 10'W), em dois mastros de madeira com 13 m de altura, distanciados 500 m um do outro (Figura 1). Os dois mastros foram fixados no topo de duas colinas em meio a seringais em produção. As alturas das seringueiras variavam entre 8 e 11 metros.

A determinação da periodicidade de vôo foi conduzida com uma armadilha colocada a 13 m de altura, acima, portanto, do nível superior das copas mais altas, e provida de uma lâmpada fluorescente ultravioleta modelo F15 T8/BL (black-light). As coletas foram feitas durante a noite de hora em hora, pela substituição do saco coletor. A primeira série de amostragens cobriu o período de 25/01 a 05/06/73, tendo a armadilha operado durante 10 noites consecutivas. A



Figura 1 – Armadilhas luminosas modelo "Luiz de Queiroz" instaladas em seringal. Fazenda Marimbu, Ituberá, Bahia, 1973.

segunda série cobriu o período de 23/10 a 25/11/73, operando a armadilha em 15 noites, alternadamente.

As determinações da atração pela luz e altura de vôo foram realizadas utilizando-se nas armadilhas lâmpadas fluorescentes modelos F15 T8/LD (luz do dia), com emissão máxima entre 550 e 600 nm, e F15 T8/BLB (black-light blue) com emissão máxima de 365 nm. As armadilhas operaram a 1; 5; 9 e 13 m do nível do solo.

As demais determinações foram efetuadas operando-se as armadi-

lhas equipadas apenas com a lâmpada modelo F15 T8/BL, colocadas a 13 m de altura. A pesquisa cobriu o período de janeiro de 1973 a março de 1974.

RESULTADOS E DISCUSSÃO

Temperatura mínima noturna – Nas áreas de clima com estações bem definidas, a temperatura é um fator que tem influência sobre a atividade de vôo dos insetos. Estes, em geral, só voam a partir de uma temperatura limiar, que permite tal

atividade (4, 15). É sabido também que a temperatura mínima noturna está diretamente relacionada com as capturas noturnas das mariposas pelas armadilhas luminosas. As capturas diminuem com a queda de temperatura (7).

Considerando que nesta latitude não ocorrem mínimas muito baixas, o fato das capturas diminuírem com a queda de temperatura, não é aplicável para o caso de *E. ello*, conforme pode ser observado nas Figuras 2 e 3, onde as captu-

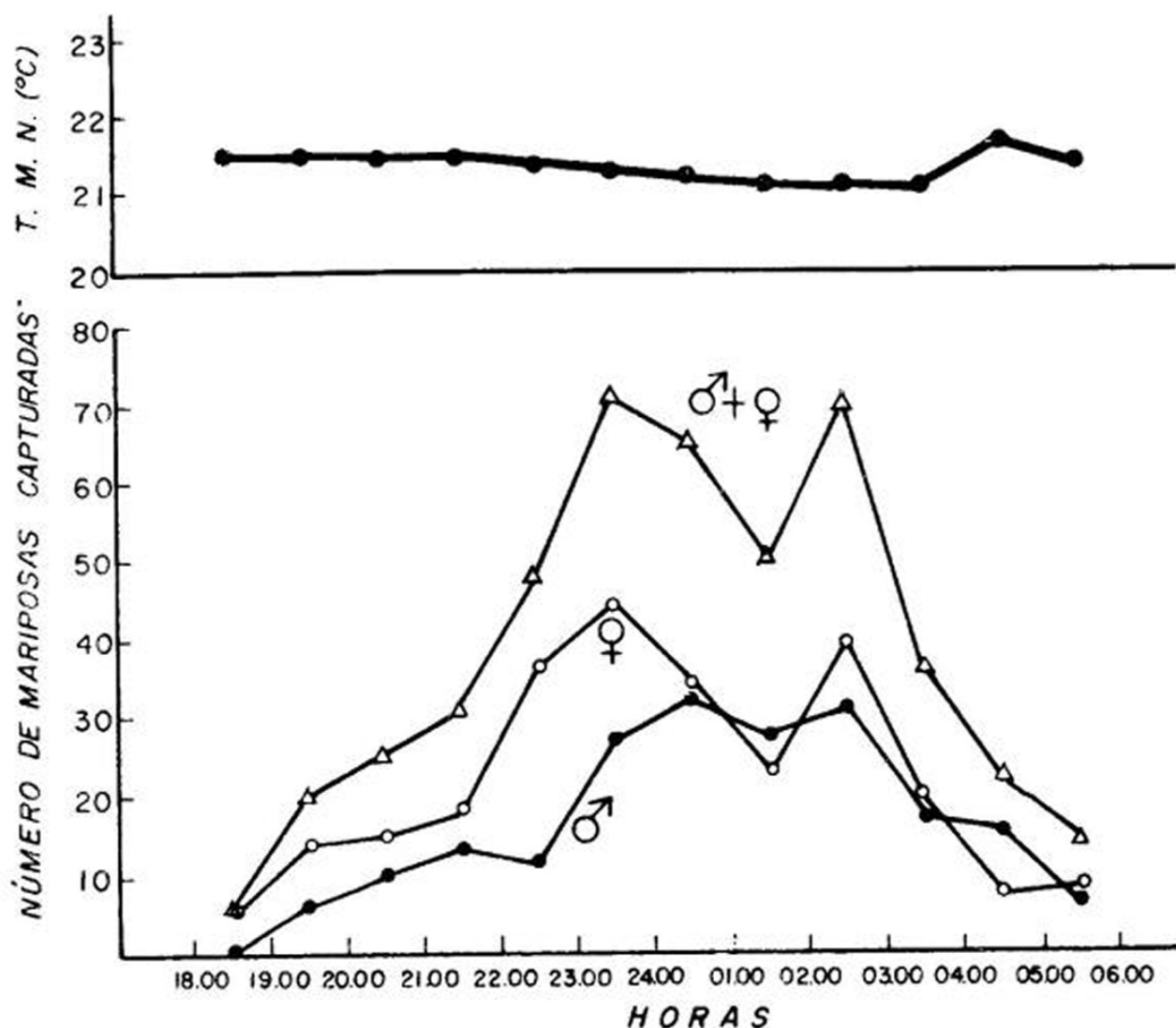


Figura 2 – Periodicidade de vôo de *E. ello* capturadas por armadilhas luminosas. Ituberá, Bahia, período maio-junho, 1973.

ras ainda são acentuadas após a meia-noite, quando ocorrem as mínimas, particularmente nas coletas de outubro-novembro (Figura 3). Em maio-junho, o máximo de capturas se concentra próximo da meia-noite.

Chuva — Para determinar a influência da chuva sobre a atividade de *E. ello*, foram consideradas as capturas das mariposas feitas em noites sem luar e as precipitações ocorridas durante a noite. A Figura 4 mostra que a precipitação, mesmo intensa, não interferiu so-

bre a atração das mariposas pelas armadilhas.

Lua — A lua é a fonte natural de luz que orienta o voo de insetos noturnos. Ao voar em direção à lua, eles atingem uma zona de correntes aéreas acima das barreiras naturais, sendo favorecida, deste modo, a dispersão e possibilitando, inclusive, o entrecruzamento de populações (7, 13).

As amostragens para estudos da flutuação sazonal da população de *E. ello*, evidenciaram a influência da fase lunar na captura das

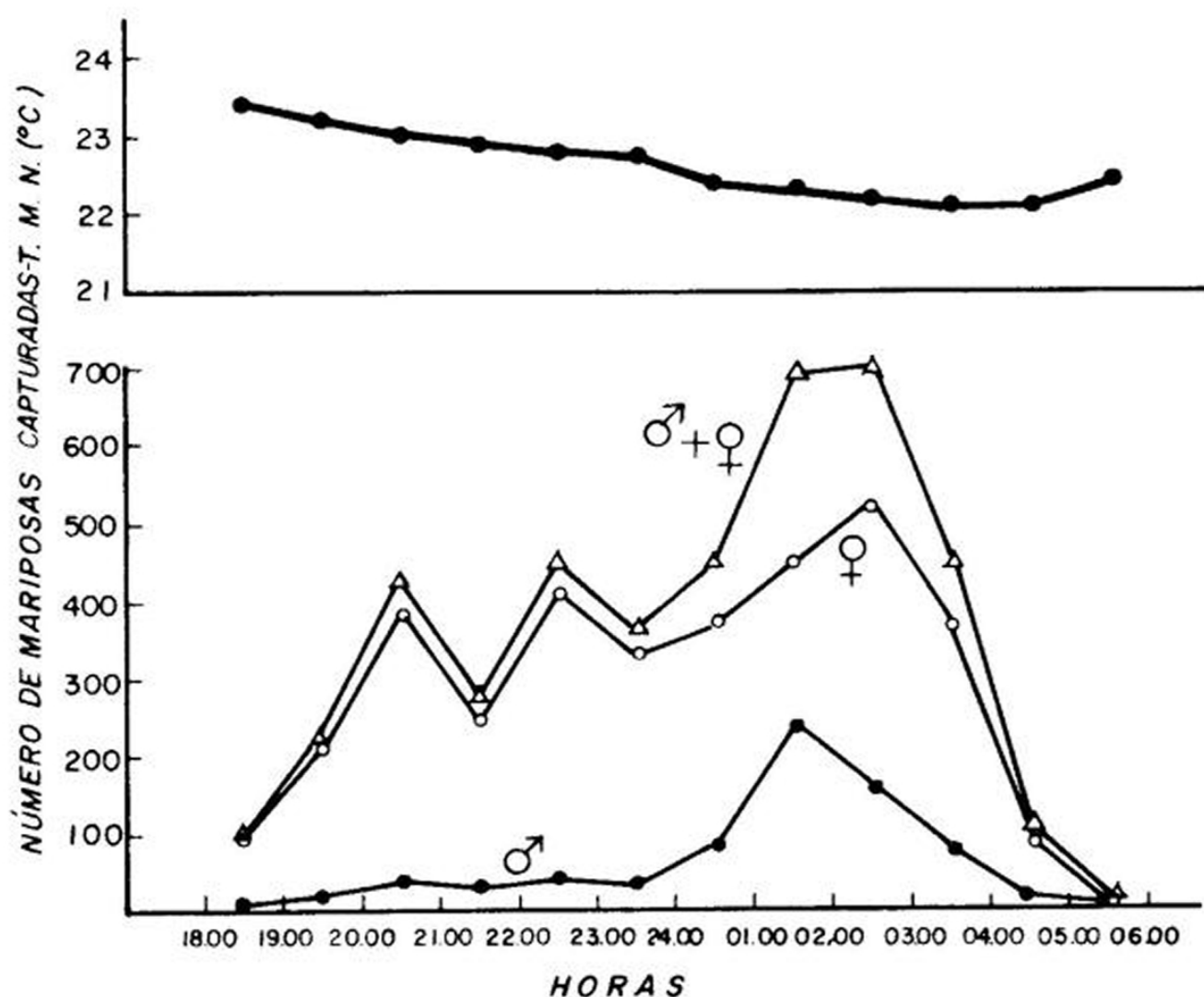


Figura 3 — Periodicidade de voo de *E. ello* capturadas por armadilhas luminosas. Ituberá, Bahia, período de outubro-novembro, 1973.

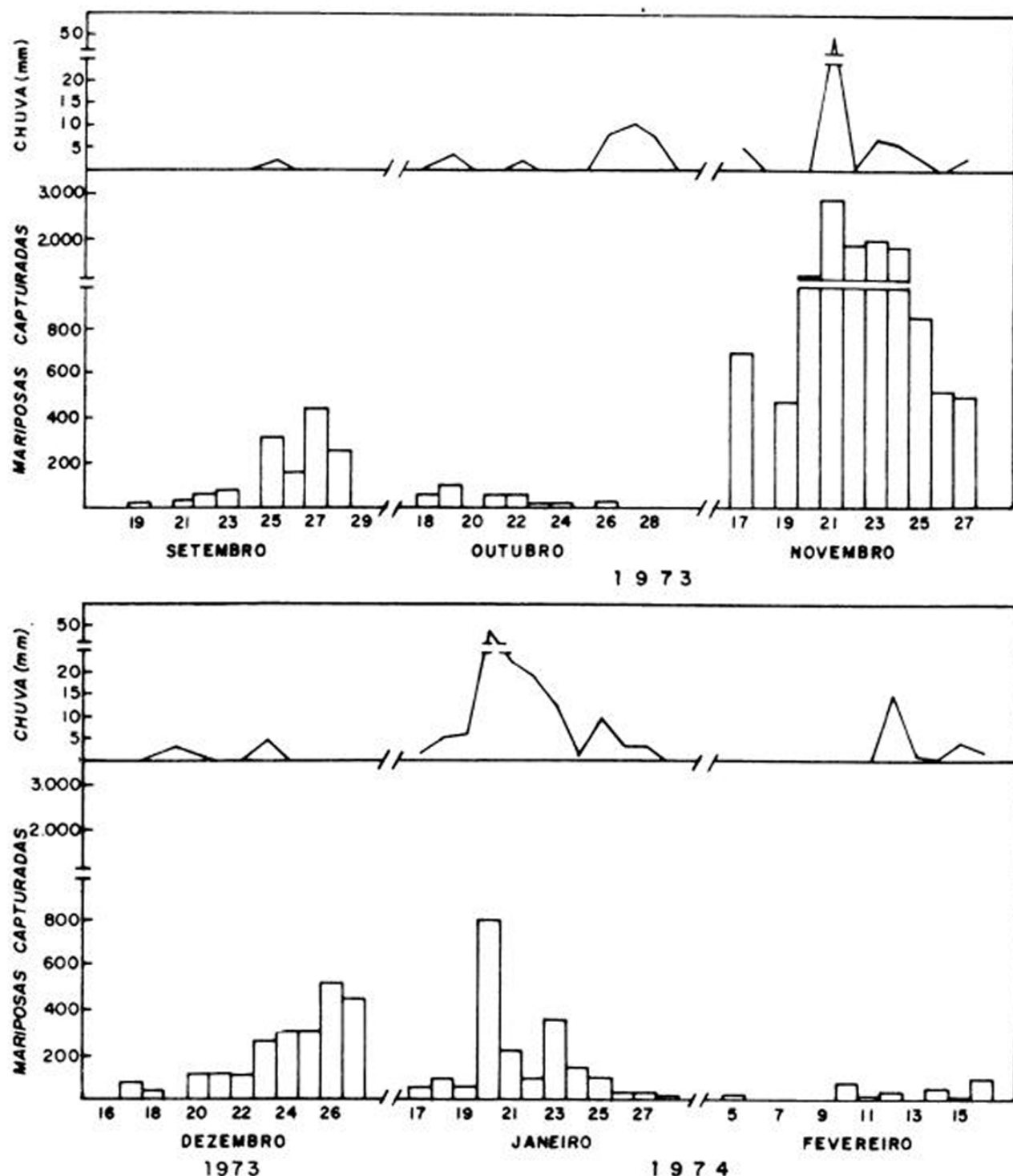


Figura 4 – *Influência da chuva na captura de Erinnyis ello por armadilhas luminosas em noite sem luar. Ituberá, BA, 1973/74.*

mariposas. As fases da lua, com as diferentes intensidades luminosas, têm influência marcante na captura dessas mariposas pelas armadilhas luminosas conforme pode ser observado na Figura 5, onde se verifica uma relação pronunciada entre as capturas e a fase

lunar. Nas fases de quarto minguante e lua nova, o número de mariposas capturadas é mais abundante que no quarto crescente e lua cheia. Este fenômeno se repete todos os meses, independentemente da flutuação sazonal da população.

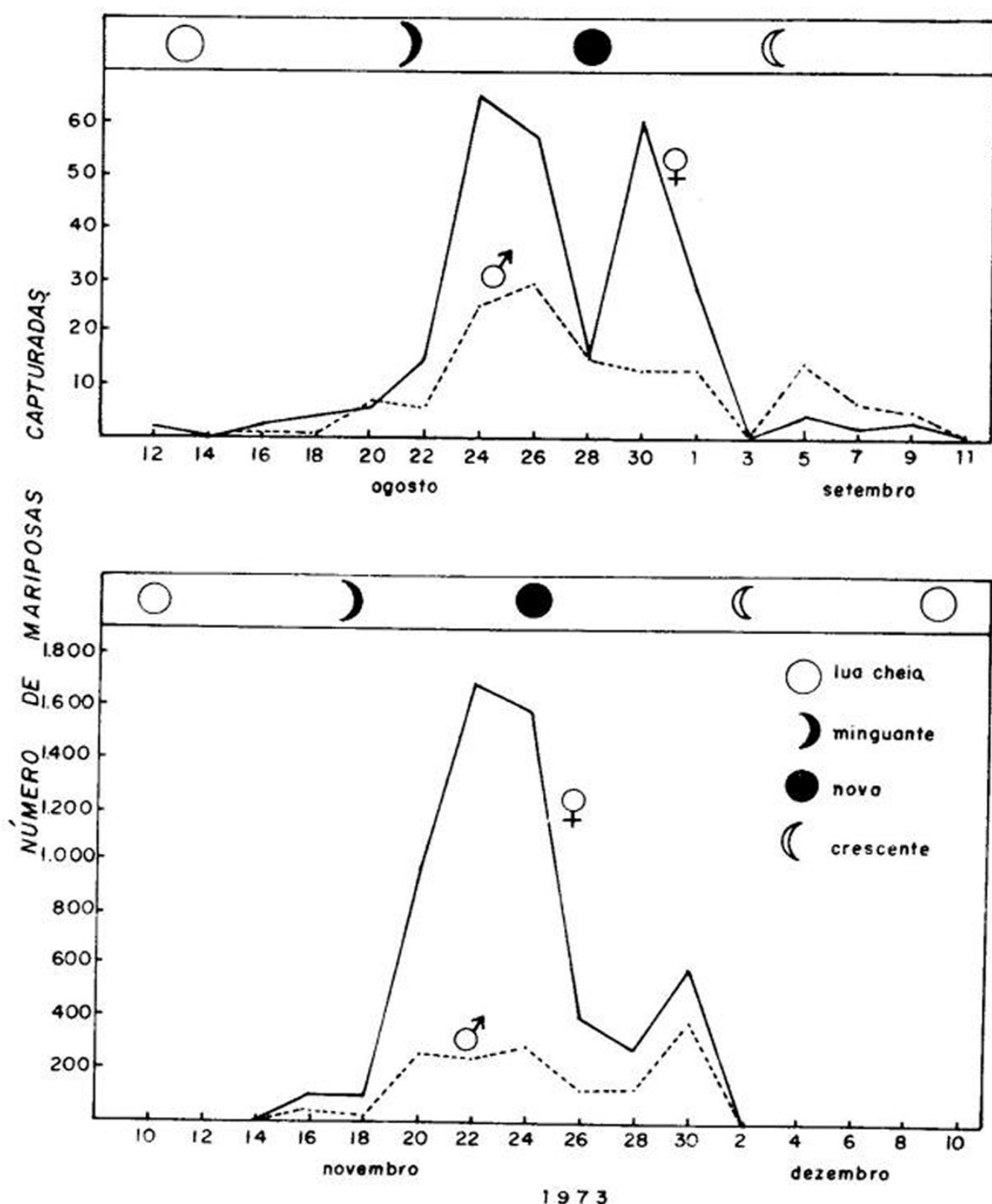


Figura 5 – Efeito da fase lunar sobre a captura de *Erinnyis ello* por armadilha luminosa. Ituberá, Bahia, 1973.

Williams, mencionado por Holloway (7), sugere que, além do efeito competitivo do luar em rela-

ção à fonte luminosa da armadilha, deve existir um fator fisiológico reduzindo a atividade de uma ma-

riposa devido à luminosidade provocada pela lua. Outro fator importante é a posição da armadilha, desde que se considere ser a lua responsável pela dispersão. Como as mariposas tendem sempre a subir em direção à fonte luminosa ou voar no mesmo plano, as armadilhas capturarão apenas aquelas que estiverem abaixo ou no mesmo plano da armadilha, conforme demonstra Silveira Neto (12), com *Azochis gripusalis* Walker, praga da figueira. Deste modo, no caso de *E. ello*, mesmo as armadilhas colocadas no nível superior da copa das seringueiras, onde as mariposas são mais abundantes, só atrairiam aquelas que estivessem neste nível ou abaixo dele e na zona de influência da armadilha. As mariposas acima deste plano, segundo a hipótese, escapariam à atração da armadilha em noites de luar.

Periodicidade de vôo – Segundo Johnson (8), a periodicidade de vôo reflete os movimentos migratórios e é influenciada também pela atividade dos insetos para a alimentação, acasalamento e oviposição.

As curvas de periodicidade de vôo (Figuras 2 e 3) mostram para maio-junho atividade mais intensa entre 22:00 h e 5:00 h, e para outubro-novembro a partir das 20:00h, atingindo o máximo entre 1:00 h e 3:00 h. Considerando os sexos, no período maio-junho, a atividade do macho se concentra entre as 23:00 h e 4:00 h, enquanto a da fêmea apresenta dois picos: um entre

23:00 e 24:00 h e outro entre 2:00 e 3:00 h. No período de outubro-novembro, há certa variação na periodicidade de vôo. Nesta época do ano, os machos intensificam a atividade entre 1:00 e 3:00 h e as fêmeas a partir das 20:00 h, atingindo o pico máximo entre as 2:00 e 3:00 h.

As curvas de periodicidade de vôo dos machos são unimodais, variando apenas o pico de acordo com a época do ano. Nos meses mais frios (maio-junho), a atividade é intensificada mais cedo (23:00 h) e cobre um período de 5 horas, enquanto nos meses mais quentes é intensificada mais tarde (1:00 h) e cobre um período de 3 horas. Estas diferenças podem estar relacionadas com as temperaturas mínimas noturnas, conforme discutido anteriormente, que atingem níveis mais baixos em maio-junho do que em outubro-novembro. Com as fêmeas, o fenômeno é similar: o maior pico de maio-junho ocorre antes da meia-noite e o de outubro-novembro após a meia-noite, possivelmente pelas mesmas razões apresentadas para os machos. Cabe salientar que a população total é mais elevada nos meses quentes.

Atração pela luz artificial e altura de vôo – Os resultados do Quadro 1 mostram que a captura das mariposas pela armadilha equipada com a lâmpada F15 T8/BLB é 8 vezes superior à equipada com a lâmpada F15 T8/LD. Nos experimentos em que foram comparadas as lâmpadas F15 T8/BLB e F15 T8/BL não houve diferença significativa

Quadro 1 – *Mariposas capturadas a diferentes alturas do solo, utilizando-se armadilhas luminosas equipadas com lâmpadas LD (luz do dia) e BLB (luz negra). Ituberá, BA, período de 10/01 a 01/02/73.*

Altura da armadilha	Lâmpada F15 T8/LD		Lâmpada F15 T8/BLB		Total
	Macho	Fêmea	Macho	Fêmea	
1 m	6	5	98	72	181
5 m	18	17	156	140	331
9 m	40	41	457	372	910
13 m	149	108	993	771	2.021
Total	213	171	1.704	1.355	3.443

nas capturas (Quadros 2 e 3). As capturas foram mais abundantes nas armadilhas situadas a 13m, independentemente do tipo de luz (Quadros 1 e 2).

Quando foram comparadas as capturas nas armadilhas instaladas a 9 e 13m, as situadas a 9m de altura efetuaram capturas mais abundantes (Quadro 3). Embora estas diferenças não sejam expres-

sivas, elas foram mais evidentes nas armadilhas equipadas com a lâmpada F15 T8/BL. É provável que, para este caso, a maior captura nas armadilhas a 9m se deva ao fato da lâmpada atrair as mariposas em atividade no plano ou abaixo do plano desta armadilha, considerando serem as lâmpadas acionadas ao mesmo tempo, no mesmo mastro, e também, como já foi dito anteriormente, pelo fato de

Quadro 2 – *Mariposas capturadas a diversas alturas do solo, utilizando-se armadilhas luminosas equipadas com lâmpadas BL e BLB. Ituberá, BA, período de 03 a 09/04/73.*

Altura da armadilha	Lâmpada F15 T8/BL		Lâmpada F15 T8/BLB		Total
	Macho	Fêmea	Macho	Fêmea	
1 m	9	8	16	11	44
5 m	40	25	34	25	124
9 m	63	46	64	48	221
13 m	65	53	63	44	225
Total	177	132	177	128	614

Quadro 3 — *Mariposas capturadas em armadilhas luminosas, instaladas a 9 e 13 m de altura do solo, equipadas com lâmpadas BL e BLB. Ituberá, BA, período de 10 a 20/03/73.*

Altura da armadilha	Lâmpada F15 T8/BL		Lâmpada F15 T8/BLB		Total
	Macho	Fêmea	Macho	Fêmea	
9 m	1.081	1.092	912	937	4.022
13 m	970	947	914	927	3.758
Total	2.051	2.039	1.826	1.864	7.780

que a tendência de vôo das mariposas é sempre para cima, a fim de ultrapassarem as barreiras para dispersão.

Proporção dos sexos — Os dados apresentados nos Quadros 1, 2 e 3, mostram que a proporção dos sexos permaneceu praticamente inalterada em relação à altura de vôo. No período em que os dados foram obtidos (janeiro, março e abril de 1973), a proporção sexual foi de 1 : 1. A proporção dos sexos varia também com a flutuação sazonal da população, sendo que, na época dos surtos, a captura de fêmeas chega a atingir 80%, o que dá a proporção de 1 : 4.

Em relação à periodicidade de vôo, ocorre também variação na proporção dos sexos, conforme pode ser observado nas Figuras 2 e 3. As fêmeas predominam durante toda a noite no período de outubro-novembro, mas a proporção sexual é reduzida entre 1 e 3 horas da madrugada (Figura 3).

CONCLUSÕES

1. Com a queda de temperatura, há uma tendência para aumentar a atividade das mariposas;
2. A chuva não influencia a atividade de vôo de *E. ello*;
3. O luar reduz a captura destas mariposas pelas armadilhas luminosas, criando, deste modo, uma variável adicional nas amostragens;
4. A atividade do macho é mais acentuada a partir da meia-noite. A da fêmea apresenta dois picos: um antes da meia-noite e outro pela madrugada;
5. A atividade das populações de *E. ello* está concentrada ao nível da copa das seringueiras;
6. A captura de fêmeas chega a atingir 80% nas épocas em que a população é mais abundante;
7. As fêmeas predominam durante toda a noite no período de outu-

bro-novembro, a proporção sexual porém, é reduzida entre 1 e 3 horas da madrugada; e

8. As armadilhas luminosas devem ser instaladas ao nível supe-

rior da copa das seringueiras e providas, de preferência, com lâmpadas do tipo F15 T8/BL. Na falta desta, a F15 T8/BLB também oferece bons resultados.

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RESUMO

Foram realizados experimentos de campo com a finalidade de determinar a influência da temperatura mínima noturna, chuva, lua, altura e periodicidade de vôo, atração pela luz artificial e proporção dos sexos na captura de *Erinnyis ello* L., praga da seringueira na Bahia, por meio de armadilhas luminosas.

A chuva e temperatura mínima noturna não têm influência sobre a atividade de vôo de *E. ello*. As fases da lua têm influência marcante na captura de *E. ello* pelas armadilhas luminosas, ocorrendo coletas mais abundantes na ausência de luar. O macho apresenta atividade de vôo mais acentuada a partir da meia-noite, enquanto a fêmea apresenta dois picos: um antes da meia-noite e outro de madrugada. As armadilhas luminosas devem ser instaladas ao nível da copa das seringueiras e equipadas preferencialmente com lâmpadas modelo F15 T8/BL. As variações na proporção dos sexos são apresentadas em função da altura de vôo, época do ano e periodicidade de vôo.

THE INFLUENCE OF SOME FACTORS ON LIGHT TRAP CATCHES OF THE HAWKMOTH *Erinnyis ello* L. (LEPIDOPTERA: SPHINGIDAE)

SUMMARY

Field trials were carried out to find the influence of some physical and biological factors on light trap catches of the hawkmoth *Erinnyis ello* L., which is the major pest of rubber tree in Bahia, Brazil.

The results showed that the rainfall and the lowest nocturnal temperature has no influence on the flight activity of *E. ello*. The moon phases have strong influence on the light trap catches of the moth, and the most abundant catches occurred in absence of moonlight. The male flies are more active after midnight, while the female presents two flight peaks; one before midnight and another at dawn. These same results showed that the artificial light traps must be located a little above the canopy of the rubber trees, and must be equipped with F15 T8/BL model lamps. Preliminary observations related to sex ratio variability in function of the height, seasonal fluctuation and flight periodicity were also included.



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