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SUITABILITY OF HOST AGE AND NUMBER FOR PARASITIZATION BY *Apanteles* nr. *nepitae* (HYMENOPTERA: BRACONIDAE), AN ENDOPARASITOID OF *Amata passalis* (LEPIDOPTERA: ARCTIIDAE), A PEST OF SANDALWOOD[1]

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Abstract

Apanteles nr. *nepitae* Wilkinson is a gregarious endoparasitoid parasitizing only later stages larvae of *Amata passalis* (Fabricius) which passes through eight instars in one generation. The importance of host age and number in parasitism were investigated by providing larvae of different age groups and numbers to the parasitoid in the laboratory. It was found that the parasitoid attacks only fifth to eigth instar larvae and rejects the first four larval instars. Among the accepted larval stages for parasitization, sixth instar larvae was the most preferred stage and the exposure of 10 sixth instar larvae was recorded as the most suitable number per parasitoid per day. In the parasitism, causation of superparasitism was also studied.

Key words: *Santalum album*, *Apanteles* nr. *nepitae*, *Amata passalis*

Adequação da idade e da quantidade do hospedeiro à parasitação de *Apanteles* aff. *nepitae* (Hymenoptera: Braconidae), endoparasitóide de *Amata passalis* (Lepidoptera: Arctiidae), praga do sândalo

Resumo

Apanteles aff. *nepitae* Wilkinson é um endoparasitóide gregário que parasita apenas as larvas dos últimos ínstares de *Amata passalis* (Fabricius). Investigou-se a importância da idade e da quantidade dos hospedeiros para a parasitação colocando-se diferentes quantidades e grupos etários de larvas à disposição do parasitóide em laboratório. Encontrou-se que o parasitóide ataca somente as larvas situadas do quinto ao oitavo ínstares, rejeitando os quatro primeiros. Entre os estágios larvais aceitos para parasitação, o preferido foi o sexto, sendo 10 o número mais adequado de hospedeiros por dia. Foi estudada também a causa da superparasitação.

Palavras-chave: *Santalum album*, *Apanteles* aff. *nepitae*, *Amata passalis*

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Introduction

Though *Amata passalis* (Fabricius) (=*Syntomis passalis* (F.)) is known to be a defoliator of sandalwood, *Santalum album* L. (Chatterjee, 1935; Mathur and Singh, 1961) it has also been recorded on other host plants like cowpea, *Vigna sinensis* Endl. (Pillai, 1921); pulses (Ayyer, Ramakrishna, 1938); the ornamental plant, *Dahlia rosea* Cav. and orange cosmos, *Cosmos sulphureus* Cav. (Sevastopulo, 1941); mulberry, *Morus alba* L. (Singh, 1972) and winged bean, *Psophocarpus tetragonolobus* (L.) (Shanthichandra, Gunasekere and Price, 1990). In the studies conducted on the natural enemies of *A. passalis*, it could be recognised that *Apanteles* nr. *nepitae* Wilkinson was an efficient, larval, gregarious, primary endoparasitoid of the defoliator and was an important cause for regulating the pest population level to acceptable limits (Venkatesha and Gopinath, 1988). No information is available on this parasitoid except the record of seasonal activities and per cent parasitism in the field. Since a detailed investigation on the various aspects in the parasitism is essential for possible utilisation of this parasitoid as an agent in biological control programmes or as a component of integrated pest management during outbreak conditions, the present studies were undertaken.

The present investigations cover information on the influence of age and density of host on parasitism, host discrimination ability of the parasitoid and obviation of superparasitism.

Materials and Methods

Multiplication of host. *A. passalis* larvae used in this study were descendents of larvae collected from the sandalwood stand and reared in the laboratory in sterilized glass jars (4" in height and 7.5" in diameter). Larvae were provided daily with fresh sandalwood leaves as food. The resulting adults were allowed to mate in glass jars (4" x 7.5") and lay eggs on blotting paper or stretched muslin. Larvae emerging from such eggs were collected and taken into petri dishes (3" in diameter) and fed with fresh succulent leaves of sandalwood. This rearing procedure was continued to accumulate more host larvae for experimental purpose.

Multiplication of parasitoid. Stem individuals of *A.* nr. *nepitae* were obtained from field collected host larvae which were reared individually in the laboratory for possible emergence of parasitoids. Adults thus obtained were maintained in glass jars (4" in height and 6" in diameter) covered by musling cloth held in place by rubber bands. Diluted honey (50% in water) soaked in small cotton swabs served as a source of nutrition for the adult parasitoids. To further multiply them, age determined *A. passalis* larvae were introduced into the glass jars which contained adult mated female parasitoids. Immediately after ovipositional strikes, parasitised host larvae were removed and reared individually (to prevent cannibalism) in a glass tube (4" in height and 1" in diameter) and daily provided with fresh sandalwood leaves as food until the emergence of parasitic larvae or pupation of the host.

These operations were repeated periodically to maintain the parasitoid colony. Dead host larvae were carefully dissected and examined under stereobinocular microscope to determine possible causes of mortality.

Determination of optimal host age and density for parasitization. To determine the preferred age of the host for oviposition, 10 *A. passalis* larvae of different age groups like 0 to 6 days (first instar), 7 to 12 days (second instar), 13 to 18 days (third instar), 19 to 24 days (fourth instar), 25 to 30 days (fifth instar), 31 to 36 days (sixth instar), 37 to 42 days (seventh instar) and 43 to 48 days (eighth instar) were exposed to a single mated female for 24 hours. The number of resulting parasitoids and moths were recorded. The experiment was replicated 10 times for each host age group.

After knowing the optimal host age, optimal host density for host exploitation by the parasitoid was determined by offering groups of 31 to 36 days old larvae in 5, 10, 15 and 20 numbers to laying females. Such parasitised groups were reared separately and the number of parasites and moths produced were recorded. The experiment was replicated 10 times for each host density. Controls for comparison for each host density were also replicated 10 times.

Determination of superparasitization. Ten larvae of optimal age were exposed to a fresh gravid female parasite in an oviposition jar (4" x 6"). The ovipositional behaviour of parasitoid wasp towards each host larva was carefully watched. Each insertion of ovipositor into host larva was treated as an attack. Such parasitized hosts were dissected and examined for the load of parasitic eggs. The experiment was replicated 10 times.

In another experiment to determine whether *A.* nr. *nepitae* could distinguish between parasitized and unparasitized hosts, the laying parasitoid was given a choice between equal number of about one to five hours earlier parasitized host larvae and healthy ones for 10 minutes. Number of already parasitized and healthy hosts attacked by a female was noted. Each parasitized larvae was dissected and number of eggs present was recorded.

All experiments were carried out under ordinary laboratory conditions. During the experimental period recorded mean maximum and mean minimum temperature was 28 °C and 23 °C, respectively and humidity was 60 - 70% RH.

Results

Host selection and parasitization in relation to host age. The results of the experiment are summarised in Table 1. It was noticed that the parasitoids consistently rejected 0 to 24 days old (i.e. first to fourth instar) host larvae, whereas 25 to 48 days old (i.e. fifth to eighth instar) larvae were accepted for parasitization. Also from the table it can be made out that highest per cent parasitization occurred in the age group of 31 to 36 days old (sixth instar) larvae and it was significantly different from that of 25 to 30 days old ($t = 4.31$, $P<0.002$), 37 to 42 days old ($t = 3.50$, $P<0.01$) and 43 to 48 days old ($t = 4.88$, $P<0.001$) host larvae. The per cent parasitization occurring in other age groups was not significantly different from other except between 25 to 30 days old and 43 to 48 days old hosts ($t = 2.57$, $P < 0.05$).

The foregoing data thus show that the 31 to 36 days old (sixth instar) host was the most suitable age for parasitization resulting in highest per cent parasitization. Consequently, the age group also produced the largest number of adult parasitoids.

The average number of parasitic larvae emerging from the fifth, sixth, seventh and eighth instar host larvae, respectively, were 7.74 (SD ± 1.12, range 6-9, n = 31), 14.85 (SD ± 3.55, range 8-19, n = 47), 17.97 (SD ± 3.88, range 13-24, n = 32) and 24.53 (SD ± 4.74, range 18-32, n = 19). Dissected larvae which yielded parasitic eggs beyond these average numbers from age determined hosts were deemed as superparasitized.

Optimal host density and per cent parasitization. The mean progeny produced was lowest when a number of five larvae were exposed to the single parasite for 24 hours (Table 2). An analysis by 'Student's' t-test conducted on the mean number of parasite progeny produced showed that offsprings produced from group of five hosts was significantly different from that of other host numbers (Table 2). No noteworthy differences were encountered when host density was 10, 15 or 20 numbers in a group.

Consequently (to avoid wastage of host larvae and for convenience) a host density of 10 *A. passalis* larvae of optimal age was selected as the optimal host density to be exposed per day per female parasitoid.

Superparasitism. The results of the experiment conducted are given in Tables 3 and 4. When a single

Table 1 – Effect of age of *Amata passalis* larvae on parasitization by *Apanteles* nr. *nepitae*.

Age in days (stage) of host larvae at exposure	Mean no. of moths emerged[a]	Mean no. of larvae parasitized[a]	Per cent host larvae parasitized[b]	Mean no. of adults parasitoids emerged	
				Female	Male
25 – 30 (fifith)	2.00	3.10	31	17.30	6.60
31 – 36 (sixth)	3.10	4.70	47	50.00	19.80
37 – 42 (seventh)	5.30	3.20	32	39.30	18.10
43 – 48 (eighth)	7.20	1.90	19	31.20	15.70

[a] Mean of 10 replicates, each replicate consisted of 10 *A. passalis* larvae.
[b] Calculated on the basis of parasitic larvae egressed from the host.
0 – 24 days old larvae were not attacked.

Table 2 – Effect of host density on parasitization by a single mated female *Apanteles* nr. *nepitae*.

Test group[a]	Host density per replicate[b]	Mean of total host density exposed	Mean no. of host larvae parasitized[+]	Per cent host larvae parasitized[++]	Mean no. of larvae super-parasitized	Mean no. of host larvae died	Mean no. of moths emerged	Mean no. of adult parasitoids emerged[+]
A	5	5	1.30B	26	2.20	3.50	0.20	15.90B
B	10	10	4.80A	48	0.40	2.50	2.70	71.60A
C	15	15	4.70A	31.33	0.50	5.60	4.70	70.30A
D	20	20	4.90A	24.50	0.30	9.00	6.10	69.70A
Control A	5	–	–	–	–	2.10	2.90	–
Control B	10	–	–	–	–	3.70	6.30	–
Control C	15	–	–	–	–	6.50	8.50	–
Control D	20	–	–	–	–	8.90	11.10	–

[a] Each test group replicated 10 times.
[b] 31 – 36 days old host larvae exposed to a parasite for 24 hours, control none exposed.
[++] Calculated on the basis of parasitic larvae egressed from the host.
[+] Results followed by same letters in the same column are not significantly different at 5% level ('Student's' t-test).

Table 3 – Oviposition of *Apanteles* nr. *nepitae* in unparasitized host of *Amata passalis*.

Sample no.	No. of host larvae exposed	No. of larvae attacked	No. of larvae parasitized	No. of larvae superparasitized
1	10	7	7	–
2	10	4	3	1
3	10	5	5	–
4	10	3	3	–
5	10	6	4	1
6	10	4	4	–
7	10	8	7	–
8	10	3	3	–
9	10	4	3	1
10	10	6	5	–
Total	100	50	44	3

laying female was offered a group of 10 hosts, 31 to 36 days old, the parasitoid readily deposited the eggs into the hosts. It was also observed that more often the parasitoids refrained from attacking a host more than once. However, discrimination was not perfect as some hosts were superparasitized (Table 3). Sometimes, hosts attacked twice or thrice by a female parasite contained substainable number of parasite eggs that could develop in the host.

In a comparative experiment, the laying female was given a choice between healthy and 1 to 5 hours previously parasitised hosts. The results obtained are set out in Table 4. Out of 20 parasitised larvae only three were attacked for a second time. Possibly acceptance of attacked hosts was governed more by the load of eggs already deposited than by the mere fact of their having been attacked.

Table 4 – Ovipositional behaviour of *Apanteles* nr. *nepitae* when given a choice between healthy and parasitized host about 1 to 5 hours earlier.

Sample no.	No. of host exposed		No. of healthy host attacked	No. of healthy host parasitized[a]	No. of healthy host superparasitized[a]	No. of parasitized host attacked	No. of parasitized host superparasitized[a]
	Healthy	Parasitized					
1	2	2	2	2	–	–	–
2	2	2	2	2	–	–	–
3	2	2	1	1	1	1	–
4	2	2	2	2	1	–	–
5	2	2	2	2	2	1	1
6	2	2	2	2	–	–	–
7	2	2	2	1	–	1	1
8	2	2	2	2	–	–	–
9	2	2	2	2	–	–	–
10	2	2	2	1	–	–	–
Total	20	20	19	17	4	3	2

[a] Confirmed on the basis of number of eggs present in the dissected host larvae.

Discussion

Age of the host seems to be an important criterion in exercising preference in host selection. Female parasitoids never accepted 0 to 24 days old larvae. Host stages above the age of 25 days were readily accepted for parasitization Among the various acceptable age group, 30 to 36 days old larvae seemed to be the preferred one for parasitization as it accounted for the highest per cent parasitization. That size and age of hosts play an important role in insect parasitism is widely recognised (Vinson, 1976).

While a fairly wide range of host stages was acceptable for successful parasitization, it was also noticed that the resulting numbers in a progeny was positively correlated to the size of the host. It is well known that gregarious parasitoids regulate the number of eggs to be deposited according to the stages or size of the host (Salt, 1961; Klomp and Teerink, 1962; 1967; Wylie, 1967; Uematsu, 1981). But how exactly this is achieved among the gregarious parasitoids is not clearly known. Vinson (1976) has rightly observed that the importance of age and size of the host in insect parasitism will remain unanswerable until the chemicals involved in host selection have been investigated among various stages of the host. The picture may become even more clear if the interplay of various sensory factors in parasitoids is precisely assessed.

Studies conducted in the laboratory indicated that female *A.* nr. *nepitae* was less inclined towards eighth stage *A. passalis* larvae for parasitization in the presence of other stages. Perhaps, this may be owing to less suitability of advanced eighth stage larvae. Furthermore, often only male progeny issued from parasitized eighth stage larvae of *A. passalis*. This was probably due to parasitoids laying unfertilised eggs that produce males in unsuitable host as recorded by Flanders (1939) in hymenopteron parasites.

Optimal density of the host is generally recognised to be another important factor in incidence of insect parasitism. Five *A. passalis* larvae of optimal age per wasp for 24 hours appeared to be an insufficient number for parasitization as this always resulted in superparasitism. Resulting superparasitism in such situations was probably due to inability of the gravid female to supress her ovipositional stimulus beyond a point once it is set in motion. The ready availability of 10 *A. passalis* larvae of optimal age was found to be an optimal density per wasp for 24 hours since the number of host larvae above 10 neither accounted higher per cent parasitism nor higher number of parasitoid progeny as the number of host larvae parasitized per day is not significantly different among host larval group of 10, 15 or 20 numbers.

Laying females of *A.* nr. *nepitae* do exhibit an ability to discriminate between an unattacked host and one already parasitized. Such host discrimination is a common feature among the Hymenoptera and the discrimination is the ability of a parasite to avoid attacking or accepting a potential host that has already been parasitized (Vinson, 1976). Host discrimination capacity of many parasitic wasps to avoid superparasitism has been reported by various authors (for example, Salt, 1934; Wylie, 1970; Lenteren, 1976; Weseltch, 1976). According to Salt (1937), parasitoids leave some inhibitory factor on the parasitised host that prevents further attack. Probably, in the case of *A.* nr. *nepitae* also such inhibitory factors left behind on the parasitized host could have minimised superparasitism.

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THE INFLUENCE OF MANAGEMENT AND PLANTATION CHARACTERISTIC VARIABLES ON WITCHES' BROOM DISEASE INTENSITY LEVEL AND COCOA BEAN PRODUCTION IN RONDÔNIA, BRAZIL

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Abstract

The Brazilian state of Rondônia produces an amount of cocoa with an estimated worth of US$ 12 million annually. This level of production ranks Rondônia second only to Bahia for cocoa production in Brazil. However, the fungal disease Witches' Broom severely limits cocoa production in Rondônia. This study represents an attempt to quantify the factors that are involved in increasing the disease intensity level of Witches' Broom on a cocoa plantation. This was achieved by the development of a statistical model. A similar approach was used to identify the factors which influence cocoa production at the plantation level. The models were based on data for the município of Ouro Preto do Oeste in Rondônia. The models show that control of Witches' Broom is the single most important factor influencing the probability of the highest Witches' Broom disease intensity level occurring on a plantation. Control, along with disease intensity level, was also an important variable in predicting cocoa bean production. If control of the disease is attempted, production per hectare of cocoa increases. In addition to control, other management, plantation characteristic, and locational variables were important factors influencing both the probability of high disease intensity and production.

Key words: *Crinipellis perniciosa*, logit model, production

Influência do manejo e das características da plantação sobre o nível de intensidade da vassoura-de-bruxa e produção de amêndoas do cacau em Rondônia

Resumo

O Estado de Rondônia tem uma produção anual de cacau estimada em 12 milhões de dólares. Essa produção coloca Rondônia como o segundo maior produtor do Brasil, atrás apenas da Bahia. Entretanto, uma doença fúngica, a vassoura-de-bruxa, limita severamente essa produção. O presente estudo representa uma tentativa de, através do desenvolvimento de um modelo estatístico, quantificar os valores envolvidos no crescimento da intensidade da doença em cacauais. Uma abordagem semelhante foi adotada para identificar fatores que influenciam a produção a nível de fazenda. Os modelos se basearam em dados coletados no município de Ouro Preto do Oeste, Rondônia e mostram que o controle da vassoura-de-bruxa é, isoladamente, o fator mais importante que influencia a probabilidade de ocorrência de mais alto nível de incidência da doença em uma plantação. O controle, juntamente com o nível de incidência da enfermidade, mostra ser também uma importante variável na previsão da produção de amêndoas. A produção de cacau cresce quando é feito o controle da doença. Além do controle, outras variáveis de manejo, características da plantação e locais mostraram ser fatores que influem tanto na probabilidade de alta incidência da doença como na produção.

Palavras chave: *Crinipellis perniciosa*, modelo logístico, produção

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Introduction

Worldwide, cocoa production is constrained by one or a combination of various diseases . Three fungal diseases, Black Pod, Monilia Pod Rot, and Witches' Broom, are especially devastating (Fulton, 1989). Witches' Broom, caused by *Crinipellis perniciosa* (Stahel) Singer, may be the most damaging and difficult to control. Within Brazil, Witches' Broom has historically been limited to the upper Amazon region, but in 1989, the disease was reported on a few plantations in Bahia, the world's second largest concentration of cocoa plantings.

An estimated 60,000 hectares of land in Rondônia are devoted to cocoa production. Plantations in Rondônia produce approximately 32,560 tons of cocoa each year. This level of production ranks Rondônia as the second major cocoa producing state in Brazil (Laker and Mota, 1990). However, cocoa production in Rondônia is inhibited by three primary factors: labor shortages, the market price of cocoa, and Witches' Broom.

The economic impact of pod losses due to Witches' Broom can be devastating. Typical losses in Rondônia range from 50 to 70 per cent (Rudgard, pers. comm.). However, losses in excess of 90 per cent have been reported on high yielding varieties in the same area (Evans, 1981). Laker and Mota (1990) estimated that the losses due to Witches' Broom in Rondônia in 1989 totaled US$ 12 million.

Reduced cocoa bean production is exacerbated by the lack of an adequate chemical control for the management of Witches' Broom. The fungicides available have reduced utility due to the high cost of procurement or application, questionable performance and, in the case of systemic fungicides, unknown toxicity (Laker and Rudgard, 1989). Consequently, phytosanitation is the most widely recommended control practice. This is achieved by pruning and in some areas such as Rondônia, it is the only control method attempted (Rudgard, 1987).

Economic factors are important in determining to what extent various pruning recommendations are carried out on a farm. By way of a statistical model, it has been shown that with less than 85% removal of brooms the reduction in the number of diseased pods is small. Removal of 95 per cent of diseased brooms is necessary to achieve a 50 per cent reduction in disease occurrence (Rudgard and Butler, 1987). The high percentage of material removed results in a costly procedure and may be uneconomical when markets are depressed (Rudgard and Butler, 1987). In Benevides, Pará, for example, the cost of pruning is equal to 20 per cent of the farm's income, and climbs to 40 per cent if the pruned brooms are removed from the field (Andebrhan, 1987).

In this study, the relative importance of various management, plantation characteristic, and locational factors are evaluated to determine their relative importance to the disease intensity level that is observed on a cocoa plantation. These same factors, along with disease intensity, are then evaluated for their effect on cocoa bean production at the plantation level. These objectives are accomplished by the development of two statistical models. Special emphasis is placed on the importance of controlling for Witches' Broom.

Methodology

Data and sample. There are approximately 5,000 CEPLAC (Comissão Executiva do Plano da Lavoura Cacaueira) assisted holdings in Rondônia, representing 60,000 hectares of cocoa. The cocoa growing area in Rondônia extends south from Porto Velho to Cacoal along BR-364. This study was based on data collected for the município of Ouro Preto do Oeste.

Preliminary data were collected by the CEPLAC Extension division during routine farm visits in 1989. The data were expanded upon by the author during a 6-week field season in Rondônia in July and August 1990. Extension officers and farmers were interviewed to expand the data set and obtain locational information. The available data were categorized as either disease intensity, management, production, plantation characteristic, or locational variables.

Disease intensity data are categorized using the four level classification scheme developed by CEPLAC. The scheme is based on the number of brooms present on the majority of the trees (Table 1). Management data for Witches' Broom consist of whether or not the farmer prunes the cocoa trees on his lot to control the disease. Data regarding the number of share croppers (meeiros) were also placed in the management category.

Production data were not available for the entirety of the sample. Only 67 plantations had accurate

Table 1 – CEPLAC classification scheme for Witches'Broom disease intensity.

0	Nil	Absence of symptoms
1	Low	Presence of few (≤ 20) vegetative brooms per tree
2	Medium	Presence of many (> 20) vegetative brooms and none or only a few floral cushion brooms per tree
3	High	Presence of many vegetative and floral cushion brooms per tree

Source: Laker and Mota (1990).

records of cocoa production. The production data were for 1989. The plantation characteristic category consisted of information regarding total area of the plantation, the amount of land planted with cocoa trees, information concerning whether the owner lives on the farm, if cocoa is the principal cash crop on the farm, and the age of the cocoa. For the purposes of model development, age of cocoa was treated categorically. Laker and Mota (1990) used a four category system to describe the trees on cocoa plantations in Rondônia. Cocoa trees were categorized as being less than 3 years old (category 1), 4 to 6 years old (category 2), 7 to 9 years old (category 3) or 10 or more years old (category 4). The same system was used in this study. The variables used in this study are summarized in Table 2.

Probability of highest disease intensity level. A qualitative choice model was used to determine the probability of a plantation exhibiting the highest disease intensity level. Two categories of qualitative choice models were available for use in this study: linear probability models (LPM) and binary logit models. LPM models can produce probabilities of less than zero and greater than unity; therefore, the LPM model was not used in this study. The logit model does not assume a linear functional form, but instead is based on the logistic function. The logistic function, which describes the distribution of a logistic random variable with variance $\pi^2/3$, is constrained by zero and unity (Aldrich and Nelson, 1984) and therefore avoids the problems encountered when using LPM type models. A logit model was used in this study. The general form of the logit model is as follows:

$$P(D_i = 1|X) = \frac{e^{V_i}}{1 + e^{V_i}} \quad (1)$$

where, D_i equals 1 if plantation i exhibits the highest disease intensity level (Level 3), e is the base of the natural logarithm, and

$$V_i = \sum_{j=1}^{n} \beta_j X_{ij} \quad (2)$$

for n explanatory variables (X_j). The β coefficients were estimated using the LOGIT function in the software package LIMDEP.

The dependent variable in this model is disease intensity. The binomial logit model used in this study requires a dichotomous dependent variable. Disease

Table 2 – Description of variables used in qualitative choice and production models.

Variable	Description	Category
Level	Disease intensity level	Disease intensity
Meeiros	Number of sharecroppers	Management
Control	Dummy variable (1= farmer controls Witches'Broom; 0= no control attempted)	Management
Production	Cocoa bean production in kg/ha for 1989	Production
AgeCat	Age category of cocoa	Plantation characteristic
Area	Area planted in cocoa (ha)	Plantation characteristic
Mora	Dummy variable (1= farmer lives on lot; 0= farmer does not live on lot)	Plantation characteristic
Prin	Dummy variable (1= cocoa is most important crop; 0= cocoa is not the most important crop)	Plantation characteristic

intensity may assume values of 0, 1, 2 or 3 and therefore is not dichotomous. The dependent variable (D_i) was assigned the value 1 if the disease intensity on plantation i was equal to three, otherwise D_i was set equal to zero. This procedure created a dichotomous dependent variable which was then used in model development. The explanatory independent variables used in developing this model were of three types: management, plantation characteristic and locational.

Accessibility indices were developed based on the available locational, plantation characteristic and disease intensity data. Accessibility indices measure potential opportunities for interaction (Weibull, 1980). It was expected that the probability of a plantation exhibiting disease intensity level three would be influenced, to some degree, by the disease intensity levels on surrounding plots. This potential for interaction was quantified by two accessibility indices which incorporated the disease intensity levels found on plantations surrounding each sampled plantation. Index 1 (Equation 3) measures the sum of all disease intensity levels in the município divided by the distance from the plot of interest to all other plots in the sample. Index 2 (Equation 4) differs slightly in that disease intensity levels are weighted by the area of cocoa to which they correspond. Mathematical descriptions of the indices are as follows:

$$I1_i = \sum_{j=1}^{n} \frac{Level_j}{d_{ij}} \tag{3}$$

$$I2_i = \sum_{j=1}^{n} \frac{(Level_j)(Area_j)}{d_{ij}} \tag{4}$$

where I1 and I2 stand for Index 1 and Index 2 respectively; $Level_i$ is disease intensity level at point j; $Area_j$ is the amount of land devoted to cocoa trees on plantation j, and d_{ij} is the distance between plantations i and j. Each index has distance between plots (d_{ij}) in the denominator. This allowed for a greater interaction between plantations that were closer together. As the distance between plantations increases, the amount of interaction between them becomes negligible.

Municípios within Rondônia are organized into large parcels of land called glebas. Each gleba is subdivided into individual lots (**lotes**) along feeder roads (**linhas**). Lots were located on a map of Ouro Preto do Oeste by their gleba, linha, and lote. The necessary locational information was available for 329 plantations within the municípío of Ouro Preto do Oeste. The majority of the cocoa plantations are on lots which are 500 meters wide by 2,000 meters long with a total area of 100 hectares. The data collected do not pinpoint the exact location of a cocoa field on the lot; therefore, in all cases the cocoa field is assumed to be located with its center coincident with the center of the lot. All distance measurements are calculated from the center of one plantation to the center of another.

Production model. The final objective, elucidation of a model to explain production, was based on production, management, locational and plantation characteristic data from 67 plantations in the study area. Ordinary Least Squares (OLS) regression techniques were used to estimate the model. Production was regressed in a step-wise fashion against the various locational, management, and plantation characteristic variables mentioned above for use in the qualitative choice model. The general form of the model is as follows:

$$Production_i = \sum_{j=1}^{n} \beta_j X_{ij} \tag{5}$$

Production was also regressed against the two accessibility indices described in equations 3 and 4 in an attempt to add to the explanatory power of the model. Student's t-statistics were calculated to evaluate the relative strength of each variable's contribution to production.

Results of Statistical Analysis

Disease intensity level model. One hundred sixty eight farms in Ouro Preto do Oeste were used to develop the model that estimates the probability of occurrence of disease intensity level 3 in a cocoa field. The systematic component of the binary logit model is as follows:

$$V = \beta_1 X1_i + \beta_2 X2_i + \beta_3 X3_i \tag{6}$$

where X1 is a dummy variable indicating if the farmer lives on the lot at location i; X2 is the accessibility index, I2 (Eq. 4) dependent upon the position of farm i with respect to all other known cocoa plantations in the município; and X3 is a dummy variable indicating if the farmer controls Witches' Broom. All coefficients are significant at the $\alpha = 0.05$ level (Table 3) and the model significant at the $\alpha = 0.01$ level (X^2=138.60).

Table 3 – Summary statistics for logit model for occurrence of the highest disease intensity level of Witches' Broom on a cocoa plantation.

Variable	Coefficient estimate	Standard error	t-statistic
X1[a]	- 1.60	0.53	- 3.05
X2[b]	- 2.21	0.48	- 4.65
X3[c]	- 3.72	0.52	- 7.20

[a] Dummy variable equal to 1 if the farmer lives on the lot and equal to 0 if not.

[b] Geographic variable indicative of the location of the farm within the município with regard to all other cocoa plantations.

[c] Dummy variable equal to 1 if the farmer controls Witches' Broom and equal to 0 if no control is attempted.

In general the model shows that the probability of disease occurrence increases if the farmer does not live on the plot, and does not control the disease. Also, a geographic factor is significant in increasing the probability of disease intensity level 3 occurring on a plot. This index is a measure of the farm's location within the município and therefore some areas within the município tend to have an increased probability of level three occurring (Figure 1).

The effect of controlling the disease is the most important variable in the model. If Witches' Broom is controlled, the probability of disease level 3 occurring on that farm is reduced, on the average, by 63.0 per cent. If the farmer does not live on the plot the probability of level 3 is increased by an average of 20.1 per cent. The effect of I2 varies between increasing the probability of level 3 by 12.9 per cent in those areas of the município with the lowest values of I2 (0.5033) and increasing the probability by 24.0 per cent in the areas exhibiting the highest value of I2 (1.611).

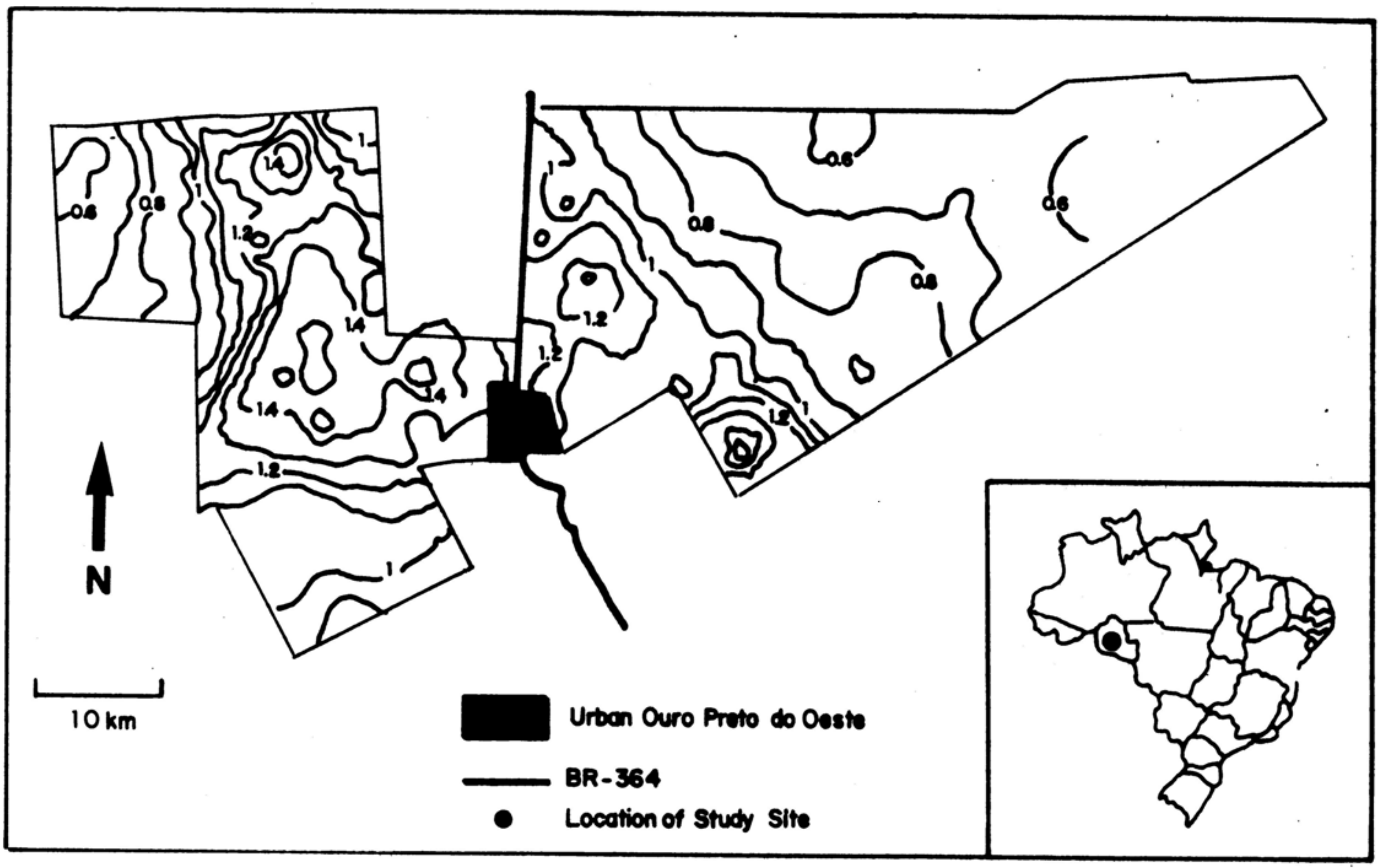

Figure 1 - Values for the accessibility index I2. I2 is an index which is indicative of the location of a cocoa farm within the município with regard to all other cocoa plantations. Higher values of this index indicate that a plantation at that location is nearer to potential sources of Witches' Broom inocula.

There is no way to determine the coefficient of determination (R^2) for a logit model. However, several substitute measures can serve the same purpose. One such statistic is the pseudo-R^2 proposed by Aldrich and Nelson (1984). The pseudo-R^2 is determined as follows:

$$\text{pseudo} - R^2 = \frac{\chi^2}{N + \chi^2} \qquad (7)$$

where N is the number of observations used in the model and X^2 is the goodness of fit statistic for the model. The pseudo-R^2 statistic for the model is 0.454. Therefore, this model accounts for 45.4 per cent of the variation.

Production model. The production model developed for Ouro Preto is based on 67 observations. Production for 1989 was found to be influence by the disease intensity level found on the plot (Y1), the age category of the cocoa trees (Y2) and whether or not Witches' Broom is controlled (Y3). The following model explained 47 per cent of the variation in production ($R^2 = 0.47$):

$$\text{Production} = \alpha + \beta_1 Y1 + \beta_2 Y2 + \beta_3 Y3 \qquad (8)$$

All coefficients are significant at the $\alpha = 0.05$ level (Table 4), and the model itself is significant at $\alpha = 0.01$ (F = 20.792).

There is no spatial autocorrelation exhibited by the residuals, and a visual investigation of the predicted versus actual productions values indicates that the model is homoskedastic (Figure 2). Therefore, the model produces unbiased results.

The four variables used in this model are all discrete. The variable Y1, representing disease intensity level, can only assume the values 0, 1, 2, 3; Y2, the age category variable, must be 1, 2, 3, or 4; and Y3, control, is a dummy variable. The magnitude of the coefficients represents their relative effect on production. The most important factor influencing production per hectare is the disease intensity level. For each, increase in the disease intensity level, holding all other variables constant, cocoa production (dry bean) per hectare is reduced by 155.7 kg.

Table 4 – Summary statistics for model describing cocoa production.

Variable	Coefficient estimate	Standard error	t-statistic
α[a]	368.43	100.40	3.67
Y1[b]	- 155.72	31.54	- 4.94
Y2[c]	88.46	21.79	4.06
Y3[d]	97.61	46.73	2.09

[a] Intercept term.
[b] Level of disease: 0 (nil) = no symptoms; 1 (low) = few vegetative brooms; 2 (medium) = many vegetative brooms and few floral cushion brooms; 3 (high) = many vegetative and floral cushion brooms.
[c] Age of cocoa: 1 = less than 3 years; 2 = 4 to 6 years; 3 = 7 to 9 years; 4 = more than 10 years (Laker and Mota, 1990).
[d] Dummy variable equal to 1 if the farmer controls Witches'Broom and equal to 0 if no control is attempted.

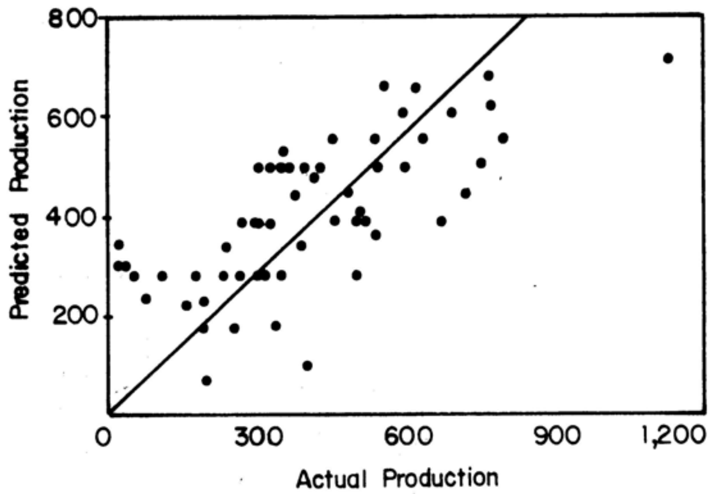

Figure 2 - Actual versus predicted cocoa production for plantations in Ouro Preto do Oeste. The graph illustrates the unbiased character of the model.

Discussion

The model developed in this study shows that, of the factors investigated, control was the single most important with regard to reducing the probability of a plantation exhibiting disease intensity level 3. The reduction in production per hectare with increasing disease intensity level indicates that farmers gain considerable benefits from ensuring that the disease intensity level on their plantations remains as low as possible.

The appearance of the accessibility index (I2) in the qualitative choice model is interesting. This indicates that some form of between plantation interaction is occurring. However, the nature of this between plantation interaction is unknown. The accessibility index is constructed from the disease intensity level, plantation area, and locational characteristics of each cocoa plantation. The inclusion of the area and disease intensity level suggests that there may be some flow of inocula between the plantations. A non-random pattern of plantations exhibiting the disease intensity level 3 would corroborate this hypothesis. However, Cairns (1991) was unable to conclusively show that clustering of this type occurred in Rondônia. Further research is necessary to elucidate the nature of the between farm interaction, and to verify that the presence of the accessibility index in the model is not merely a statistical artifact.

The results of this study indicated that disease intensity level is the most important factor influencing cocoa production. As Witches' Broom becomes more severe, the production of cocoa beans drops. However, farms afflicted with disease intensity level 3 can increase their production by almost 100 kg/ha if some control of the disease is attempted.

Although the age category variable is present in the model, its effect may be minimized over time. The cocoa trees in Rondônia are still relatively young; no cultivated cocoa trees in the state are over 20 years old. The economic life span of a cocoa plantation is defined as the length of time that cocoa trees are generating sufficient gross income to warrant the use of variable capital on a farm, and has been estimated to be 40 years (Tafani, 1977). This figure was estimated in a study carried out in Bahia, Brazil in the absence of Witches' Broom; therefore, the economic life span of cocoa trees in Rondônia may be considerably less. Consequently, over time the classification scheme used for this model may become inadequate to show the effect of age on cocoa yield.

The three variables found to be significant in the production model are all categorical and consequently the number of possible production estimates is finite. Obviously production is not limited to these 32 values. This results in the model accounting for only 50 per cent of the variation in production. The remaining 50 per cent may be heavily influenced by genetic diversity among the cocoa trees, and the two other factors not investigated in this study: labor availability and the market price of cocoa beans.

The only aspect of labor investigated in this study is the number of share croppers present on a lot. This did not prove to be an important factor in predicting either production or the probability of high disease intensity levels. Other aspects of labor that might prove to be important are the availability of contracted labor and family labor.

Contracted labor is at a premium in recently colonized areas (Moran, 1988) and this shortage has been aggravated in Rondônia by the discovery of gold in the interior of the state. In 1989 gold was discovered in Jaru not far from the major cocoa producing areas of the state. This discovery, in addition to an increase in cassiterite (tin ore) mining in the interior of the state, has resulted in the disappearance of migrant farm laborers and the abandoning of some cocoa fields when land owners have found mining a more profitable enterprise.

In addition, Rondônia farmers are unable to obtain a premium price for their product. This is due in part to transportation costs from the state to the Brazilian coast, the lack of adequate quality control, and the absence of a diversity of cocoa buyers in the state. The result of these factors is that the price of dry cocoa beans in Rondônia is almost always less than the price in Bahia (Figura 3).

Furthermore, the world market price of dry cocoa beans influences the price available for the product in Rondônia. World cocoa prices were high between 1977 and 1980, when much of the cocoa in Rondônia was planted, but in the last 3 years prices have dropped. This drop in price combined with the lack of

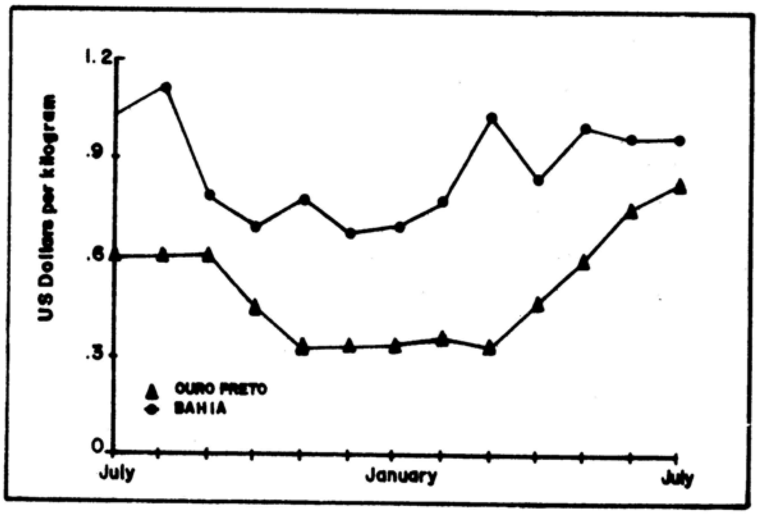

Figure 3 - Prices of cocoa in Ouro Preto and Bahia, July 1989 - July 1990.

labor aggravates the Witches' Broom problems in Rondônia and has resulted in the abandonment of some fields.

Conclusions

The results of this study begin to explain the factors which influence the disease intensity level and cocoa production per hectare that are observed on cocoa plantations in Rondônia, Brazil. However, a holistc study in which world market prices, the impacts of labor shortages due to tin and gold mining, along with the physical and management characteristics of Witches' Broom are investigated is necessary for complete understanding of disease intensity levels and cocoa production in Rondônia.

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CACAO STANDARD PRODUCTION COST MONITORING IN BAHIA, BRAZIL

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Abstract

This paper presents economic evaluation of cacao production in Bahia, Brazil, by the standard prime cost of production approach, using indicators like Price-Cost Break-Even Point - PCBEP - and Still Economic Maximum Price-SEMP. It is showed situation in two of the twelve scenarios designed by combination of three cases of fixed costs with four technologies. It is also achieved production cost function, used in evaluation. According to profitability, the situation is very unfavorable for the cacao producer.

Key words: *Theobroma cacao*, production cost, economic evaluation

Acompanhamento do custo padrão de produção de cacau na Bahia, Brasil

Resumo

Este trabalho apresenta avaliação econômica da produção de cacau na Bahia, Brasil, pelo enfoque do custo padrão de produção, fazendo uso de indicadores como Ponto de Nivelamento Preço-Custo-PNP-C e Preço Máximo Ainda Econômico-PMAE. Mostra-se a situação em dois dos doze cenários possíveis de se formar pela combinação de três casos de custos fixos com quatro tecnologias. Obtem-se também as funções custos usadas na avaliação. De acordo com a lucratividade, a situação se mostra muito desfavorável para o produtor de cacau.

Palavras-chave: *Theobroma cacao*, custo de produção, avaliação econômica

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1. Introduction

Standard prime cost of cacao has been accompanied in Bahia, Brazil, by Cacao Research Center (CEPEC - Centro de Pesquisas do Cacau) of CEPLAC, since 1981.

Quarterly one produces economic evaluation of cacao production systems in Cacao Grower Region of Bahia by special indicator called "Price-Cost Break-Even Point", which is applied to 12 hypothetical cases or scenarios of cacao production systems. This indicator shows the yield (output/hectare) at which unitary or average production cost equals product price or, in other words, income equals expenses. The scenarios are formed by the combination of three "fixed cost devices" with four "variable cost schemes", "technological packages" or "technologies", composed of several agricultural practices. One says that one evaluates the "technology (variable costs) x productive structure (fixed cost) combinations".

It is possible also to use another evaluation criterion for each of the isolated agricultural practice like "Fertilization", "Harvesting and Processing" and so on. This is done by the determination of the "Still Economic Maximum Price-SEMP", which is the biggest price the enterprise can afford by an input used in a practice, without causes loss to the firm, *caeteris paribus*. On the other hand, the same criterium can inform the input quantity it is possible to use by output unit, also without damage. Of course, both the above determination are done within given output and input price conditions (expected or observed).

This work assumes deterministic conditions and was developed in the field of the comparative statics. Cacao is a perennial crop, therefore being productive during several seasons and having initial unproductive years, but this work doesn't consider the complete productive cycle. It regards only the typical productive season of ripe or full grown cacao plants.

The model assumes also linear specification for total cost functions.

Input and output prices used in the evaluation are those practiced by the markets during the last month of the quarter (Mar, Jun, Sep, Dec), which is certainly a simplification of the real world, where the price are formed throughout the agricultural season.

Concerning to a crop year, the work refers to the short-run.

Monetaries values are expressed in US$ of Dec/1989 or of Dec/1987. Transformation of the latter in the former is done by the U. S. Consumer Price Index. Original tables about both fixed and variable costs are in "cruzados novos" (NCz$) and are changed in dollars by the official Brazilian Exchange Rate of the respective month.

The study considers only private costs.

The literature about cacao cost of production is not exactly abundant. Besides, the majority of the publications deals with "Cost Equations", which are not so rich of consequences like "Cost Functions". This paper, using both devices, provides useful instruments for economic evaluation of cacao production business. Of course, in this field are the importance and application of the procedure. The paper by Hasan and Chok (1988) does also use cost functions, with similar specification for the functions, so being both papers (and others produced by CEPEC, as informed in the starting of this "Introduction") rarities in their species.

Other important feature of the present paper, with obvious consequences in its utilization, is its "White Box" type, meaning that all the involved procedures are explicit. Unlike other ones, authentic "Black Boxes", which do not permit one neither reproduces the attainmnent of results nor does changes for local and circumstantial modifications, v. g., Ruf and Milly (1990).

2. Material and Methods

2.1. Data - Data come from systematic monthly input and output price survey done by special sector of CEPEC. Input/input (input by hectare) technical coefficients was defined by a technical group using the "Judges Method", i. e., based on the personal experience of each one member of the technical group, as described in Smith F. et al. (1980).

2.2. Methods

2.2.1. Classification of costs and criteria for cost determination - In real world, each actual production process has a unique and unmistakable associated cost of production, which is the total of the value of input and factor services used throughout the production activity.

However, in model world, the only place where we can manipulate reality profitably, the things aren't so clear. There is many misunderstanding in the empirical literature about agricultural prime cost caused by both conceptual inadequacies and real difficulties. Example of that is in Lee Jr. (1976), who shows as a problem the obliteration of "the true farm-to-farm variance in costs", when using data from "well-documented engineering trails". This looks like a typical conceptual misunderstanding, since there is a confusion of role of different categories of cost: only "effective cost" can inform about cost variance in real world. "Standard cost", as that obtained from engineering trails, by definition, hasn't this special role. And it is in fact so, because of the prosaic reason that there are many effective costs in a farm population, in a cross section series one for each farm, existing therefore, variability and, of course, variance; and only one standard cost for a set of farm.

Nevertheless there are several theories about production cost, it is lacking a thoroughly developed and systematic elaborate construct, "a concept with the additional meaning of having been created or appropriated for special scientific purposes" (Kerlinger, 1973) or, as says Bunge (1987), concepts, propositions, contexts and theories. Mainly it seems that lacks construct linking cost-object to cost-concept and considering the best way to go from the former to the latter. Indubitably this is a urgent task challenging Agricultural Economist. Best systematization of this issue certainly result in more effectiveness to the work of that professional. Systematicness is one of the most important feature of Science (Trujillo Ferrari, 1982).

Two important constructs in systematization are "Production Cost Classification" and "List of Criteria for Composition of Fixed Cost and Variable Cost Spreadsheets". The latter, because there is a lot of endless discussion about. Besides, criterion of the scientific truth is among the most important problems of the theory of knowlegde. As a matter of fact, the truth is "the exact reflex of the object in the mind, the adequacy between the thought and the thing; *adaequatio intellectus cum re*" (Bazarian, 1985).

Cost may be classified into different manners, according to different standpoints. Initially one must remember with Henderson and Quandt (1971): "the term cost function is used to denote cost expressed as a function of output. The term cost equation is used to denote cost expressed in terms of input levels and input prices". Naylor and Vernon (1969) present the same concepts. Besides the traditional categories Total Cost (TC), Total Variable Cost (TVC), Total Fixed Cost (TFC), Average Cost (AC), Average Variable Cost (AVC), Average Fixed Cost (AFC) and Marginal Cost (MC), one can take another ones into account, according to scope or purpose. By the way, Ferreira (1991) considers **Standard Cost,** "that in which determined production process will incide, if conducted according to prefixed technological norms (variable costs spreadsheet) and within defined productive structure (given fixed costs); **Effective Cost,** that really practiced by a productive process happened in real world. "**Opportunity, Social or Governmental Cost,** when considers the input shadow price; **Private Cost,** when considers input market price".

Criteria to establish variable costs:

1. Consider all the services of inputs and factors really used.
2. Consider general expenses on the actual cost used.
3. Cautions oneself against inflation illusion using dated monetary unit.
4. Consider interest on the amount of money used.

Criteria to set up fixed costs:

1. Exhaustibility - Consider only the fixed factors which are exhaustible throughout useful life. During successive crop years the enterprise must to do financial reserve funds which will be applied on the acquisition of new assets in the future, when it has occured wearing out of the old ones. The enterprise has this obligation with the community. Because land is a factor whose losses are covered (offset) by cost variable items (fertilization, conservation and so on), its expenses aren't allocated at all in fixed costs.
2. Use dated monetary unit against inflation effects.
3. Linear depreciation method with residual value of fixed assets equals zero.
4. Incidence of a 2.5 % per year maintenance rate on fixed assets.
5. Incidence of interest on the values of fixed assets, at a rate as near of opportunity cost of capital as possible.

2.2.2. fixed cost estimating - It is designed three case of fixed cost:

Case zero - The fixed cost of a farm which has a productive structure equal to the existent in the "Fazenda Sempre Viva", in the "Unitary Farm" of CEPEC. The farm proprietary receives a reward amounting 27.78 minimum wage for 22 ha of cacao. The cacao trees are also depreciated. Data of useful life and values come from the CEPLAC's Department of Extension, CEDEX. (see Table 1).

Case one - The anterior, reducing half a payment of the owner. (see Table 2).

Case two - The case zero without payment at all to the owner, and diminished some buildings, the refectory and one of the two sun driers. (see Table 3).

Values of fixed assets were surveyed in Dec/1987. From then onwards the new date values of fixed assets are arranged by inflation elimination in Brazilian currency by use of "Indice Geral de Preços" (General Prince Index) of Fundação Getúlio Vargas. This is done because the fixed asset market in the Region is quite inactive, through last years.

2.2.3. Variable cost estimates - Four Technological Packages or Technologies are monitored quarterly, according to special technical group, as note Smith et al. (1980):

T1 : Traditional technology, without modern inputs, based on Cox (1966).

T2 : Anterior technology, package generally recommended by CEPLAC, before the study by Smith F. et al. (1980).

T3 : Anterior technology weighted by producer adoption levels - The T2 technology modified by the possible level of adoption of each agricultural practice by the farmers, according to the perception of the members of expert group ("Judges Method") (Smith F. et al., 1980).

T4 : Proposed technology by Smith F. et al. (1980), for cost decrease.

Characterization of technologies may be see in Tables 4, 5, 6 and 7. The technical coefficients, deterministic, of the input/input (input/ha) kind, inform about each one technology. They are done in deterministic way. Using a such type of coefficients, the subsequent models formed with them will be deterministic and not stochastic. "A stochastic model includes random variable, whereas a deterministic model does not. Typically the pattern of model building involves construction initially of deterministic models and eventually, where appropriate, construction and utilization of stochastic models. Physics presents an excellent illustration of this pattern. Early models, such as those of Newtonian mechanics, are deterministic, while later models, such as those of quantum mechanics, are stochastic. In fact, the quantum revolution in physics consisted of the revolutionary observation that one could not identify, for example, the exact location of an elementary particle but one could determine a probability distribution for its location" (Intriligator, 1978).

Tables on variable and fixed costs reflect cost equation.

2.2.4. Cost function models - The cost function models used here for economic evaluation are mathematical, not statistical, because of operational reasons: they can be obtained straight from the cost spreadsheets; deterministic, not stochastic, by replaceable motives; static, not dynamic, by nature. The specified models are linear (at least the relating to total costs), because they can be derived straightway from the cost spreadsheets or tables, which doesn't occur with the rival ones, and more quoted in literature, the neoclassic models. In fact, these latter need regression methods to be fitted. So, it is impossible to get a standard neoclassic cost function, unless under special definition.

It is assumed each technology can achieve any productivity inside the possible specter. It is done because productivity is function not only of technology but also of environment, genetics, administration and so on.

The cost functions are:

$$TVC = B \cdot Y \quad (1)$$
$$TFC = A \quad (2)$$
$$TC = A + B \cdot Y \quad (3)$$
$$AVC = TVC / Y = B \quad (4)$$
$$AFC = TFC / Y = A / Y \quad (5)$$
$$AC = TC / Y = B + A / Y \quad (6)$$

where Y = yield or productivity, and A, B, parameters, defined as A = fixed cost by hectare, B = total spent on services of variable inputs and factors by unit of output. Certainly, these functions all refer to a very one hectare.

The accomplishment of cost functions requires the fulfillment of parameter B, which is, as already seen, the expenses with variables inputs by each one unit of output. This means, the sum of each input/output technical coefficient (quantity of input by unit of output) times its market price. This is done from the input/input type technical coefficients appearing in Tables from 4 through 7 for each one of the four technologies. These tables provide input/input coefficients, which is changed in input/output ones, by assuming one yield for each technology. See Table 8, which achieves that supposing the following productivities: T1, 50 arrobas/ha; T2, 100 arrobas/ha, T3, 70 arrobas/ha; T4, 100 arrobas/ha. By division of input/input coefficients by these yields one gets the desired input/output ones (see Table 8).

2.2.5. Price-cost break-even point - This indicator is defined as

$$PCBEP = Y = A/(P-B) = TFC/(P-AVC) \quad \text{since } P>AVC, \qquad (7)$$

obtained from the equalization between product price (P)and the average cost (AC) of produce it, PCBEP means the yield at which price of product (P) equals average cost (AC). At this point enterprise succeeds equal its income to its total costs. The lesser the PCBEP, the better to the farm. Cacao producers are price takers, so the only variables they can manage to get lesser PCBEP are just TFC and AVC. So to do that they must to take adequate technology and to be parsimonious on the fixed investments. PCBEP makes sense in real world only when P is greater than AVC (Ferreira, 1991).

2.2.6. Still economic maximum price - It is defined as

$$SEMP = p_j = (P - AC^*) / a_j \qquad (8)$$

where p_j is the price of input "j", here the SEMP; a_j, input/output technical coefficient of input "j", i. e. the quantity of "j" required to produce one unit of output (cacao beans). The AC* symbol means "average cost (average variable + average fixed) of all inputs except the cost related to the input "j"

The attainment of (8) is done starting from the condition

$$AC < P \qquad (9)$$

how one can see in Ferreira (1991a).

Given technical conditions in use (a_j and AC*), output price (P) and prices of the other variable and fixed factors (AC*), the SEMP indicates the maximum price the firm can pay to the services of input "j" without financial loss, *caeteris paribus*. SEMP varies with price of product (P), AFC (case of fixed cost), technology (Ti), input price (p_j), expenses by unit of product with the input j ($a_j.p_j$) and the coefficient a_j.

Being positive SEMP has the above interpretation. Being negative, SEMP means "the amount the input must to pay the enterprise" to compensate the loss of all other inputs and do not present prejudice at all, *caeteris paribus*, which, of course, doesn't make sense in real world.

It is possible to anticipate the signal of SEMP. Starting from (8) and reminding that

$$AC^* = AC - a_j \, . \, p_j$$

comes the condition by which SEMP of input j be positive:

$$P - AC + a_j \, . \, p_j > 0 \qquad \text{or}$$

$$a_j \, . \, p_j > AC - P \qquad (10)$$

On the other hand, one can achieve some kind of technical limitation, starting from the same condition (9), namely the maximum quantity of input "j" one can use by unit of output, without loss:

$$a_j < (P - AC^*) / p_j \qquad (11)$$

where the symbols have the same meaning of (8) (Ferreira, 1991a).

3. Results

3.1. Fixed costs

Fixed costs, for different cases are in Tables 1 through 3 already presented in "Material and Methods". In case zero the biggest shareholder is just owner's reward, with 53.8 % of the total; in case two, buildings responds for 60 % and cacao tree assets for 40 %. In case one, buildings 33 %, cacao plants 30 % and owner's reward 37 % (see Tables 1, 2 and 3).

Table 1 – Dec/1987-Cacao production fixed cost estimatives-in US$.Dec/1987. Case zero-based on Faz. Sempre Viva – Faz. Unitária – CEPEC/CEPLAC.

Item and unit	Unitary value US$/unit	Good's total value US$	Useful life years	Annual Linear Depreciation Maintenance				Invest. Interest		Total Fixed Cost - TFC		
				All the farm 22 ha/US$	One ha US$/ha	All farm 22 ha/US$ (2.5% per year)	One ha US$/ha (2.5% per year)	All farm 22 ha (18% per year) US$	One ha (18% per year) US$/ha	All the farm 22 ha/US%	One ha US$/ha	Share in TFC (unitary)
I. Buildings												
1. Masonry building (78 m²)	104.25	8131.32	20	406.57	18.48	203.38	9.24	1463.64	66.53	2073.49	94.25	0.0630896
2. Fermentation boxes (12 m³)	87.96	1055.57	20	52.78	2.40	26.39	1.20	190.00	8.64	269.17	12.24	0.0081900
3. Fert. warehouse (22.8m²)	104.25	2376.85	20	118.84	5.40	59.42	2.70	427.83	19.45	606.10	27.55	0.0184416
4. Bathroom (13.2 m²)	79.79	1053.27	20	52.66	2.39	26.33	1.20	189.59	8.62	268.59	12.21	0.0081722
5. Sun drier I (82.55 m²)	75.38	6222.27	20	311.11	14.14	155.56	7.07	1120.01	50.91	1586.68	72.12	0.0482776
6. Sun drier II (82.55 m²)	75.38	6222.27	20	311.11	14.14	155.56	7.07	1120.01	50.91	1586.68	72.12	0.0482776
7. Nursery (91.30 m²)	0.47	42.84	5	8.57	0.39	1.07	0.05	7.71	0.35	17.35	0.79	0.0005279
8. Refectory (63.91 m²)	79.79	5099.61	10	509.96	23.18	127.49	5.80	917.93	41.72	1555.38	70.70	0.0473252
Subtotal	-x-	30204.00		1771.61	80.53	755.10	34.32	5436.72	247.12	7963.43	361.97	0.2423017
II. Cacao trees planted at different times and conditions. (22 ha)	1600.63	35213.96	40	880.35	40.02	-x-	-x-	6338.51	288.11	7218.86	328.13	0.2196469
III. Owner's reward (US$/month) (27.78 minimum wage/month)	1473.62	-x-	-x-	-x-	-x-	-x-	-x-	-x-	-x-	17683.47	803.79	0.5380514
Total	-x-	65417.96	-x-	2651.96	120.54	755.10	34.32	11775.23	535.24	32865.75	1493.90	1

Note: Originally the values in this table was in 'cruzados' of Dec/1987. For transformation into US dolar was used brazilian official exchange rate for Dec/1987: Cz$ 67.86 Cz$/US$.

Table 2 – Case one – December/1987. Fixed costs estimatives. (Owner's reward reduced to a half of case zero) in US$ Dec/1987.

Itens	Total Fixed Cost – T F C All the farm 22 ha	One ha	Share in T F C (Unitary)
I .Buildings	7 963.43	361.97	0.3314777
II .Cacao trees	7 218.86	328.13	0.3004851
III.Owner's reward	8 841.73	401.90	0.3680372
Total	24 024.02	1 092.00	1

(Originally in cruzados of Dec/1987 – (Brazilian Official exchange rate (Dec/87) : Cr$ 67.86.

Table 3 – Case two – December/1987. Fixed costs estimative. (Without refectory, only one sun drier, without owner's reward) (in US$/Dec./1987 – originally in cruzados – Brazilian Official exchange rate Dec./87): Cz$ 67.86/US$).

Itens	Total Fixed Cost All the farm 22 ha US$	T F C One ha US$ ha	Share in T F C (Unitary)
I .Buildings	4821.37	219.15	0.4004382
II .Cacao trees	7218.86	328.13	0.5995618
Total	12040.23	547.28	1

3.2. Variable costs

Tables 4 through 7 show detailed fulfillment of variable costs to the four technologies under study. One can observe in December 1989 one hectare of ripe cacao needs US$ 423.54 for variable costs, 75.18% of them for personnel (52.18% for wages and 23% for social charges), if one considers the traditional technology. The anterior package, T2, employs US$ 1,282.31/ha, 45.76% of them to personnel (31.76% for wages and 14.00% for social charges). Modern inputs sums 22.74% of budget. T3, the package which try to catch the producer adoption level, expenses US$ 766.46/ha, 55.47% of them in personnel (38.50% on wages and 16.97% on social charges), being 16.65% the share of modern inputs in the total. The new recommended package, T4, presents 45.66% of expenses in personnel (31.69% on salaries and 13.97% on social charges), with modern inputs accounting for 24.66% of the total. So, by the budget criterion, T1, traditional technology is the most labor intensive and T4, the less. Conversely, T4 is the most modern input intensive and T1, the less (Tables 4, 5, 6 and 7).

Table 4 – Dec/1989-Standard cost spreadsheet-technology T1-traditional-in US$.Dec.1989-for one hectare-originally in NCz$. Dec/1989-exchange rate: NCz$ 9.403/US$. Cacao price: US$. 9.64/@ (@= 15 kg).

Specification	Man.day	Salary	Partial	Subtotal	Total	%
1. Average variable costs (AVC)					423.54	100.00
1.1. Labor				221.02		52.18
Harvesting and processing	40	2.68	107.28			25.33
Pruning	16	3.26	52.22			12.33
Chupon removing (desbrota)	3	2.62	7.87			1.86
Ground clearing (twice yearly)	20	2.68	53.64			12.67
1.2. Social charges				97.43		23.00
Holidays (1,33/12 of 1.1)			24.50			5.78
			18.42			4.35
13th salary (1/12 of 1.1)			36.84			8.70
Rewarded repose (1/6 of 1.1)			17.68			4.17
FGTS (0,08 of 1.1)						
1.3. Sub-total				318.45		75.19
1.4. Interest Upon Costs (18% per year upon 1.3)				57.32		13.53
1.5. Administration (5% of 1.3)				15.92		3.76
1.6. General expenses (10% of 1.3)				31.85		7.52

Table 5 – Dec/1989-standard cost spreadsheet-technology T2-CEPLAC former technological package-in US$ Dec.1989-for one hectare-originally in NCz$. Dec/1989-exchange rate: NCz$ 9.403/US$ 1.00. Cacao Price: US$ 9.64/@ (@= 15 kg).

Specification		Man.day by hectare	Salary by man.day	Partial	Subtotal	Total	Share %
1. Average variable costs (AVC)						1282.31	100.00
1.1. Labor					407.26		31.76
Harvesting and Processing		80.00	2.68	214.57			16.73
Pruning		16.00	3.26	52.22			4.07
Chupon removing (desbrota)		3.00	2.62	7.87			0.61
Ground clearing		20.00	2.68	53.64			4.18
Liming		3.00	2.61	7.84			0.61
Basic fertilization		6.00	2.63	15.77			1.23
Nitrogen Fertilization		4.00	2.63	10.51			0.82
Insect & pest control		0.50	3.57	1.79			.14
Disease control (3 times a year)		12.00	3.59	43.06			3.36
1.2. Inputs		Quant.	Price				22.74
Insecticide	(kg)	30.00	0.68	20.55	291.55		1.60
Fungicide	(kg)	14.40	6.57	94.57			7.37
Lime	(kg)	600.00	0.04	24.89			1.94
Fungicide adhesive	(ℓ)	0.50	1.28	0.64			0.05
Inseticide application fuel	(ℓ)	3.00	0.47	1.41			0.11
Fungicide application fuel	(ℓ)	27.00	0.47	12.72			0.99
Motor oil 2T	(ℓ)	1.50	2.90	4.36			0.34
NPK fertilizer (formula B)	(kg)	300.00	0.37	110.39			8.61
Urea	(kg)	80.00	0.28	22.04			1.72
1.3. Material transportation (50 kg bags)		20.50	4.18	–	85.79		6.69
1.4. Social charges							14.00
Holidays (1.33/12 of 1.1)				45.14	179.54		3.52
13th salary (1/12 of 1.1)				33.94			2.65
Rewarded repose (1/6 of 1.1)				67.88			5.29
FGTS (0.08 of 1.1)				32.56			2.54
1.5. Subtotal					964.14		75.19
1.6. Interest upon costs (18% per year upon/1.5)					173.55		13.53
1.7. Administration (5% of 1.5)					48.21		3.76
1.8. General expenses (10% of 1.5)					96.41		7.52

Table 6 – Dec/1989-standard cost spreadsheet-technology T3 - T2 weighted by producer adoption level-for one hectare-in US$ Dec.1989-originally in NCz$ 1989-exchange rate: NCz$. 9.403/US$ - Cacao price: US$. 9.64/@ (@= 15 kg).

Specification		Man.day by hectare	Salary by man.day	Adoption level	Weighted coeffic.	Partial	Subtotal	Total	Share %
1. Average variable costs (AVC)								766.46	100.00
1.1. Labor							295.11		38.50
Harvesting and processing		56.00	2.68	1.00	56.00	150.20			19.60
Pruning		16.00	3.26	1.00	16.00	52.22			6.81
Chupon removing (desbrota)		3.00	2.62	1.00	3.00	7.87			1.03
Ground clearing		20.00	2.68	1.00	20.00	53.64			7.00
Liming		3.00	2.61	0.06	0.18	0.47			0.06
Basic fertilization		6.00	2.63	0.45	2.70	7.10			0.93
Nitrogen fertilization		4.00	2.63	0.45	1.80	4.73			0.62
Insect & pest control		0.50	3.57	0.93	0.47	1.66			0.22
Disease control		12.00	3.59	0.40	4.80	17.22			2.25
1.2. Inputs		Quants.	Price				127.60		16.65
Insecticide	(kg)	30.00	0.68	0.93	27.90	19.11			2.49
Fungicide	(kg)	14.40	6.57	0.40	5.76	37.83			4.94
Lime	(kg)	600.00	0.04	0.06	36.00	1.49			0.19
Fungicide adhesive	(ℓ)	0.50	1.28	0.40	0.20	0.26			0.03
Insecticide application fuel	(ℓ)	3.00	0.47	0.93	2.79	1.31			0.17
Fungicide application fuel	(ℓ)	27.00	0.47	0.40	10.80	5.09			0.66
Motor Oil 2T	(ℓ)	1.50	2.90	0.67	1.01	2.92			0.38
NPK fertilizer (formula B)	(kg)	300.00	0.37	0.45	135.00	49.68			6.48
Urea	(kg)	80.00	0.28	0.45	36.00	9.92			1.29
1.3. Material transportation (50 kg bags)		5.61	4.18				23.48		3.06
1.4. Social charges							130.10		16.97
Holidays (1.33/12 of 1.1)						32.71			4.27
13th salary (1/12 of 1.1)						24.59			3.21
Rewarded repose (1/6 of 1.1)						49.19			6.42
FGTS (0.08 of 1.1)						23.61			3.08
1.5. Subtotal							576.28		75.19
1.6. Interest upon costs (18% per year upon/1.5)							103.73		13.53
1.7. Administration (5% of 1.5)							28.81		3.76
1.8. General expenses (10% of 1.5)							57.63		7.52

Table 7 – Dec/1989-standard cost spreadsheet-technology T4 - new CEPLAC package - In US$ Dec.1989-for one hectare-originally in NCz$ Dec./1989-exchenge rate: NCz$. 9.403/US$. Cacao price: US$. 9.64/@ (@ = 15 kg).

Specification		Man.day by Hectare	Salary by man.day	Partial	Sub-total	Total	Share %
1. Average variable costs (AVC)						1061.70	100.00
1.1. Labor					336.41		31.69
Harvesting and processing		80.00	2.68	214.57			20.21
Pruning (once in two years)		8.00	3.26	26.11			2.46
Chupon removing (desbrota)		3.00	2.62	7.87			0.74
Herbicide application (twice a year)		4.00	3.59	14.35			1.35
Liming (once in five years)		0.91	2.61	2.38			0.22
Basic fertilization		6.00	2.63	15.77			1.49
Nitrogen fertilization		4.00	2.63	10.51			0.99
Insect & pest control		0.50	3.57	1.79			0.17
Disease control (3 times a year)		12.00	3.59	43.06			4.06
1.2. Inputs		Quants.	Price		261.80		24.66
Insecticide	(kg)	30.00	0.68	20.55			1.94
Fungicide	(kg)	14.40	6.57	94.57			8.91
Lime	(kg)	90.00	0.04	3.73			0.35
Fungicide adhesive	(ℓ)	0.50	1.28	0.64			0.06
Fungicide application fuel	(ℓ)	27.00	0.47	12.72			1.20
Insecticide application fuel	(ℓ)	3.00	0.47	1.41			0.13
Phosphate rock	(kg)	300.00	0.10	29.67			2.79
Urea	(kg)	134.00	0.28	36.91			3.48
Potassium chloride	(kg)	50.00	0.23	11.38			1.07
Motor oil 2T	(ℓ)	2.10	2.90	6.10			0.57
Herbicide A	(ℓ)	2.00	10.42	20.83			1.96
Herbicide B	(kg)	3.00	7.58	22.73			2.14
Herbicide adhesive	(ℓ)	0.30	1.88	0.56			0.05
1.3. Material transportation (50 kg bags)		12.37	4.18		51.77		4.88
1.4. Social charges					148.30		13.97
Holidays (1.33/12 of 1.1)				37.28			3.51
13th salary (1/12 of 1.1)				28.03			2.64
Rewarded repose (1/6 of 1.1)				56.07			5.28
FGTS (0.08 of 1.1)				26.91			2.53
1.5. Subtotal					798.27		75.19
1.6. Interest upon costs (18% per year upon/1.5)					143.69		13.53
1.7. Administration (5% of 1.5)					39.91		3.76
1.8. General expenses (10% of 1.5)					79.83		7.52

3.3. Cost functions

To achieve cost functions one must previously to transform input/input technical coefficients into input/output ones. To do that, one uses Table 8.

Table 8 shows for each technology one yield and technical coefficients by hectare; technical coefficients by arroba (15kg), (a_j); price of input service (labor or material), (p_j); expenses for input service (labor or material) by unit of product (arroba of cacao), ($a_j \cdot p_j$).

From the Table 8 it is possible to obtain the cost functions, both the total cost functions and the average cost functions. Table 9 informs about the accomplishment of the former and Table 10 of the latter.

Table 8 – Input/output technical coefficients (ai), prices (pi) and expenses by agricultural practice for each output unit (ai.pi) for studied technologies, associated one productivity to each technology - Dec/1989.

Inputs and units		Tecnology T1		50 @/ha		Tecnology T2		100 @/ha		Tecnology T3		70 @/ha		Tecnology T4		100 @/ha	
		Tec. coef. by ha.	Tec. Coef. by @ (ai)	Price US$ Dec/89/ unit (pi)	Expense/@ US$/@ Dec/89 (ai.pi)	Tec. coef. by/ha	Tec. coef. by @ (ai)	Price US$ Dec/89/ unit (pi)	Expense/@ US$/@ Dec/89 (ai.pi)	Tec. coef. by/ hectare	Tec. Coef. by @ (ai)	Price US$ Dec/89/ unit (pi)	Expense/@ US$/@ Dec/89 (ai.pi)	Tec. Coef. by hectare	Tec. Coef. @ (ai)	Price US$ Dec/89/ unit (pi)	Expense/@ US$/@ Dec/89 (ai.pi)
I. Labor (in man.day/ha)																	
1 . Harvesting & processing		40	0.80	2.68	2.15	80	0.8	2.68	2.15	56	0.80	2.68	2.15	80	0.8	2.68	2.15
2 . Pruning		16	0.32	3.26	1.04	16	0.16	3.26	0.52	16	0.23	3.26	0.75	8	0.08	3.26	0.26
3 . Chupon removing (desb.)		3	0.06	2.62	0.16	3	0.03	2.62	0.08	3	0.04	2.62	0.11	3	0.03	2.62	0.08
4 . Ground clearing		20	0.40	2.68	1.07	20	0.2	2.68	0.54	20	0.29	2.68	0.77	–	–	–	–
5 . Liming		–	–	–	–	3	0.03	2.61	0.08	0.18	0.00	2.61	0.01	0.91	0.009	2.61	0.02
6 . Basic fertilization		–	–	–	–	6	0.06	2.63	0.16	2.7	0.04	2.63	0.10	6	0.06	2.63	0.16
7 . Nitrogen fertilization		–	–	–	–	4	0.04	2.63	0.11	1.8	0.03	2.63	0.07	4	0.04	2.63	0.11
8 . Insect & pest control		–	–	–	–	0.5	0.005	3.57	0.02	0.47	0.01	3.57	0.02	0.5	0.005	3.57	0.02
9 . Disease control		–	–	–	–	12	.12	3.59	0.43	4.8	0.07	3.59	0.25	12	0.12	3.59	0.43
10. Herbicide application		–	–	–	–	–	–	–	–	–	–	–	–	4	0.4	3.59	0.14
Labor Subtotal					4.42				4.07				4.22				3.36
II. Material																	
1. Insecticide	(kg)	–	–	–	–	30	0.3	0.68	0.21	27.9	0.40	0.68	0.27	30	0.3	.68	0.21
2. Fungicide	(kg)	–	–	–	–	14.4	0.144	6.57	0.95	5.76	0.08	6.57	0.54	14.4	0.144	6.57	0.95
3. Lime	(kg)	–	–	–	–	600	6	0.04	0.25	36	0.51	0.04	0.02	90	0.9	.04	0.04
4. Fungicide Adhesive	(ℓ)	–	–	–	–	0.5	0.005	1.28	0.01	0.2	0.00	1.28	0.00	0.5	0.005	1.28	0.01
5. Insecticide Applic. Fuel	(ℓ)	–	–	–	–	3	0.03	0.47	0.01	2.79	0.04	0.47	0.02	3	0.03	.47	0.01
6. Fungicide Applic. Fuel	(ℓ)	–	–	–	–	27	0.27	0.47	0.13	10.8	0.15	0.47	0.07	27	0.27	.47	0.13
7. Motor Oil 2T	(ℓ)	–	–	–	–	1.5	.015	2.90	0.04	1.01	0.01	2.90	0.04	2.1	0.021	2.90	0.06
8. NPK Fertilizer (Form. B)	(kg)	–	–	–	–	300	0.3	0.37	1.10	135	1.93	0.37	0.71	–	–	–	–
9. Urea	(kg)	–	–	–	–	80	0.8	0.28	0.22	36	0.51	0.28	0.14	134	1.34	.28	0.37
10 Phosphate Rock	(kg)	–	–	–	–	–	–	–	–	–	–	–	–	300	3	.10	0.30
11 Potassium Chloride	(kg)	–	–	–	–	–	–	–	–	–	–	–	–	50	0.5	.23	0.11
12. Herbicide A	(ℓ)	–	–	–	–	–	–	–	–	–	–	–	–	2	0.02	10.42	0.21
13 Herbicide B	(kg)	–	–	–	–	–	–	–	–	–	–	–	–	3	0.03	7.58	0.23
14. Herbicide Adhesive	(ℓ)	–	–	–	–	–	–	–	–	–	–	–	–	0.3	0.003	1.88	0.01
Material Subtotal					–				2.92				1.82				2.62
Total					4.42				6.99				6.04				5.98

From Table 9, one can see how it is achieved the total fixed cost function: the total expenses by hectare on fixed cost was considered. Values in US$ of Dec/1987 are changed into values in US$ of Dec/1989 by U.S. Consumer Price Index. And the former comes from the values in cruzados of Dec/1987, exchanged by Brazilian official exchange rate (see Tables 1, 2 and 3). Because the market of fixed factors was inactive, the values of 1987 are only inflated to 1989.

Tables 1, 2 and 3 give for respective cases the values of fixed cost by hectare (in US$/Dec/1987). First section of Table 9 translates these values in US$.Dec/1989, getting this way the total fixed cost functions (TFC), by definition, as in function (2), TFC = A, of course a constant. See the values accomplished in the first section of Table 9.

Second section of Table 9 achieves total variable cost functions (TVC), linear, TVC = B . Y, as defined in (1). Coefficient B is obtained partially from Table 8 (amount of expenses about labor and material by unit of output) and partially from Tables 4, 5, 6, and 7 (imputed expenses on material transportation, interests, social charges, administration and general expenses). See the obtained functions in Table 9, second section.

Total cost functions (TC), as defined in (3), TC = A + B.Y, is formed by combination the last ones, TFC and TVC. Thus, there are twelve TC functions, one for each one combination of the three fixed costs with the four variable costs. See the third part of Table 9.

Table 9 – Total cost functions - attainment

Total fixed costs (TFC) (by hectare)
Case zero = C0; Case one = C1; Case two = C2.
U.S. Consumer price index (quoted from 'Conjuntura Econômica' - Aug/1990):
(Base: 1985 = 100): Dec/1987: 105.5; Dec/1989: 116.5 Ratio: 1.10

TFC (Dec. 89) = TFC (Dec. 87) x Ratio

TFCc0 = 1,493.90 (see Table 1) x 1.10 =) TFCc0 = 1,643.29

TFCc1 = 1,092.00 (see Table 2) x 1.10 =) TFCc1 = 1,201.20

TFCc2 = 547.28 (see Table 3) x 1.10 =) TFCc2 = 602.01

Total variable costs (TVC) (by hectare)
Ti = tecnology i; Y = yield

TVCT1 = (4.42 + 4.05) Y = 8.47 Y (see Tables 8 and 4)

Soc. charg.	97.43
Interest	57.32
Adm.	15.92
Gen. exps.	31.85
	202.52 / 50 = 4.05

TVCT3 = (6.04 + 4.91) Y = 10.95 Y (see Tables 8 and 6)

Mat. trans.	23.48
Soc. charg.	130.10
Interest	103.73
Adm.	28.81
Gen. exps.	57.63
	343.75 / 70 = 4.91

TVCT2 = (6.99 + 5.84) Y = 12.83 Y (see Tables 8 and 5)

Mat. trans.	85.79
Soc. charg.	179.54
Interest	173.55
Adm.	48.21
Gen. exps.	96.41
	583.50 / 100 = 5.84

TVCT4 = (5.98 + 4.64) Y = 10.62 Y (see Tables 8 and 7)

Mat. trans.	51.77
Soc. charg.	148.30
Interest	143.69
Adm.	39.91
Gen. exps.	79.83
	463.50 / 100 = 4.64

Total costs (TC) (by hectare)

TCc0t1 = 1,643,29 + 8.47 Y	TCc1t1 = 1,201.20 + 8.47 Y	TCc2t1 = 602.01 + 8.47 Y
TCc0t2 = 1,643.29 + 12.83 Y	TCc1t2 = 1,201.20 + 12.83 Y	TCc2t2 = 602.01 + 12.83 Y
TCc0t3 = 1,643.29 + 10.95 Y	TCc1t3 = 1,201.20 + 10.95 Y	TCc2t3 = 602.01 + 10.95 Y
TCc0t4 = 1,643.29 + 10.62 Y	TCc1t4 = 1,201.20 + 10.62 Y	TCc2t4 = 602.01 + 10.62 Y

Mutatis mutandis, Table 10 gives similar information about average cost functions (AC). First section informs about average fixed cost (AFC) functions, defined as AFC = A/Y in (5). The values of A, in each one of the three cases of fixed costs comes from Table 9, section one.

Table 10 – Average cost functions - attainment

Average Fixed Costs (AFC) (by arroba (@))
Case zero = C0; Case one = C1; Case two = C2.
Ti = tecnology i; Y = yield

=) AFCc0 = 1,643.29/Y
=) AFCc1 = 1,201.20/Y
=) AFCc2 = 602.01/Y

Average variable costs (AVC) (by arroba (@))

AVCT1 = 8.47	AVCT3 = 10.95
AVCT2 = 12.83	AVCT4 = 10.62

Average costs (AC) (by arroba (@))

ACc0t1 = 8.47 + 1,643.29/Y	ACc1t1 = 8.47 + 1,201.20/Y	ACc2t1 = 8.47 + 602.01/Y
ACc0t2 = 12.83 + 1,643.29/Y	ACc1t2 = 12.83 + 1,201.20/Y	ACc2t2 = 12.83 + 602.01/Y
ACc0t3 = 10.95 + 1,643.29/Y	ACc1t3 = 10.95 + 1,201.20/Y	ACc2t3 = 10.95 + 602.01/Y
ACc0t4 = 10.62 + 1,643.29/Y	ACc1t4 = 10.62 + 1,201.20/Y	ACc2t4 = 10.62 + 602.01/Y

Second section of Table 10 fulfills the average variable cost functions (AVC), one for each of the four technologies, as the model AVC = B, in (4). Values of B come from Table 9, section two.

Third section of 10 shows the twelve average cost functions (AC), similarly defined as the model in (6), AC = B + A/Y (See Table 10).

3.4. Price-cost break-even point-PCBEP

Here one presents only the situation of two scenarios: the worst according to producer standpoint, COT2, Case Zero of fixed cost, combined with Technology T2 and the best according to the same standpoint, C2T1, Case Two of fixed cost with Technology T1. The situations of the other scenarios may be easily achieved by utilization of information in Tables 9 and 10.

3.4.1. COT2 scenario

In December 1989 the market was extremely unfavorable to the cacao producer in Bahia. In the worst case, the very variable cost is not been paid, as one can see in Table 11.

This table shows AVC, AFC, AC and the price received by producer in the interval of yield 30 - 100 arrobas/ha. Market price of product is not enough to pay the AVC, so it is impossible to calculate the PCBEP, which is in this case negative, having no real sense.

Table 11 – Dec / 1989 C0T2 – Fixed cost case zero – technology T2.

Y (@/ha)	AVC (US$/@)	AFC US$/@	AC US$/@	Price US$/@
30	12.83	54.78	67.61	9.64
40	12.83	41.08	53.91	9.64
50	12.83	32.87	45.70	9.64
60	12.83	27.39	40.22	9.64
70	12.83	23.48	36.31	9.64
80	12.83	20.54	33.37	9.64
90	12.83	18.26	31.09	9.64
100	12.83	16.43	29.26	9.64

Price-cost break-even point: – 515.14 @/ha

3.4.2. C2T1 Scenario

In the best situation for the producer, C2T1, the product market price is greater than AVC. This means that the producer is paying the variable costs, and, one says, the firm is in short-run equilibrium. But it is not in long-run equilibrium, because only with the yield of 514.54 arrobas/ha (a so far biological and technological impossibility) the PCBEP is achieved. That is to say, the enterprise is consuming the own fixed capital (See Table 12).

Table 12 – Dec/1989 C2T1 – Fixed cost case two – technology T1.

Y (@/ha)	AVC (US$/@)	AFC US$/@	AC US$/@	Price US$/@
30	8.47	20.07	28.54	9.64
40	8.47	15.05	23.52	9.64
50	8.47	12.04	20.51	9.64
60	8.47	10.03	18.51	9.64
70	8.47	8.60	17.07	9.64
80	8.47	7.53	16.00	9.64
90	8.47	6.69	15.16	9.64
100	8.47	6.02	14.49	9.64
Price-cost break-even point:				514.54 @/ha

3.5. Still economic maximum price-SEMP

The unfavorableness of the market to cacao production in Bahia in the studied time is also evident by SEMP indicator. All the values of SEMP are negative. There is no "expense by unit of output" ($a_j \cdot p_j$) of any input which greater than the difference between the least AC and the cacao price (P), condition for existence of positive SEMP, as one can see in (10). So, all SEMP one can achieve for each input and in all conditions, are no significant in real world. Table 13 shows some SEMPs for labor and material inputs for the same scenarios for which it calculated PCBEP, i. e., C0T2 and C2T1 and for the yields 30 and 100 arrobas/ha (Table 13)

Table 13 – SEMP: still economic maximum price – Bahia – Brazil – Dec/1989.

Kind of Input		Market price US$/unit	SEMP by productive structure, tecnology and productivity			
			C0T2 30 @/ha US$/unit	C0T2 100 @/ha US$/unit	C2T1 30 @/ha US$/unit	C2T1 100 @/ha US$/unit
I. Labor (man.day)						
1 . Harvesting and processing		2.68	- 69.775	- 21.8375	- 20.9375	- 3.375
2 . Pruning		3.26	- 359.063	- 119.375	- 55.8125	- 11.9063
3 . Chupon removing (desbrota)		2.62	- 1929.67	- 651.333	- 312.333	- 78.1667
4 . Herbicide application)		3.59	–	–	–	–
5 . Ground clearing (roçagem)		2.68	- 287.15	- 95.4	- 44.575	- 9.45
6 . Liming		2.61	- 1929.67	- 651.333	–	–
7 . Basic fertilization		2.63	- 963.5	- 324.333	–	–
8 . Nitrogen fertilization		2.63	- 1446.5	- 487.75	–	–
9 . Insect and pest control		3.57	- 11590	- 3920	–	–
10. Disease control		3.59	- 479.5	- 159.917	–	–
II. Material						
1. Insecticide	(kg)	0.68	- 192.533	- 64.7	–	–
2. Fungicide	(kg)	6.57	- 395.972	- 129.653	–	–
3. Lime	(kg)	0.04	9.62	- 3.22833	–	–
4. Fungicide adhesive	(ℓ)	1.28	- 11592	- 3922	–	–
5. Fungicide application fuel	(ℓ)	0.47	- 214.222	- 72.1852	–	–
6. Insecticide application fuel	(ℓ)	0.47	- 1932	- 653.667	–	–
7. NPK Fertilizer (formula B)	(kg)	0.37	- 18.9567	- 6.17333	–	–
8. Phosphate rock	(kg)	0.10	–	–	–	–
9. Urea	(kg)	0.28	- 72.1875	- 24.25	–	–
10 Potassium chloride	(kg)	0.23	–	–	–	–
11. Motor oil 2T	(ℓ)	2.90	- 3862	- 1305.33	–	–
12. Herbicide A	(ℓ)	10.42	–	–	–	–
13 Herbicide B	(kg)	7.58	–	–	–	–
14. Herbicide adhesive	(ℓ)	1.88	–	–	–	–

4. Discussion and Conclusion

4.1. Business results

Cacao production in Bahia in December 1989 underwent difficult economic situation. In all scenarios the PCBEP is extremely high, meaning that the activity is unbalanced at the long-run. Even in certain cases, the market price of output isn't enough to pay the variable cost, indicating short-run unbalance. SEMP indicator says the same story about this economic activity, being negative in productivity levels possible to be attained, meaning that the business can't afford the costs of inputs and factors (See Tables 11, 12 and 13).

Certainly these results refer to a crop year. In a such situation the enterprise is spending the own fixed capital and if this lasts many years the business will not substitute the wasted assets in the future.

4. 2. Fixed asset costs

One can argue the fixed cost is overestimated, but it is possible to refute, since many assets aren't considered in the cost assembling. Even some exhaustible one, like worker houses.

The fixed asset pricing is a simplification, of course. The market situation was surveyed in December/1987 and the price corrected by inflation since then. And this is done just because the market is not working last years: the farmers are not investing, since profitability is too low.

4.3. Cost function model specification

This study specifies linear models for total cost functions. Generally the specialized literature presents neoclassic model as being **the** specification of cost functions in the short-run. So do, v. g., Naylor and Vernon (1969), Ferguson (1972), Leftwich (1974), Bilas (1970), Intriligator (1978), Rossetti (1977). Garofalo and Carvalho (1976) present the neoclassic specification:

$$TC = A \cdot Y^3 - B \cdot Y^2 + C \cdot Y + D \quad (12)$$

$$TFC = D \quad (13)$$

$$TVC = A \cdot Y^3 - B \cdot Y^2 + C \cdot Y \quad (14)$$

$$AC = A \cdot Y^2 - B \cdot Y + C + D \cdot Y^{-1} \quad (15)$$

$$AFC = D \cdot Y^{-1} \quad (16)$$

$$AVC = A \cdot Y^2 - B \cdot Y + C \quad (17)$$

Certainly this isn't the only model for these functions. Henderson and Quandt (1971) say: "specific cost functions may assume many different shapes. One possibility which exhibits properties often assumed by economists is depicted in figures (not reproduced here). Total cost is a cubic function of output. ATC, AVC, and MC are all second-degree curves which first decline and then increase as output is expanded".

Intriligator (1978) points out: "A variety of cost curves, including total, average, and marginal cost curves, have been estimated for particular industries". The author presents the **cubic cost curve** as an example of a total cost curve that satisfies the curvature postulated previously:

$$C = a_0 + a_1 y + a_2 y^2 + a_3 y^3$$

and affirms the parameters must satisfy the following restrictions for make average and marginal cost curves U – shaped:

$$a_0 \geq 0, a_1 > 0, a_2 < 0, a_3 > 0, a_2^2 < 3a_3 a_1$$

He continues: "In the long-run case, a_0 in the cubic cost curve, which is fixed cost, vanishes . . ." The quadratic long-run (without a_0) average cost curve has been estimated for many industries. "For a wide variety of industries, including manufacturing, mining, distribution, transportation, and trade, it has been found that the long-run average cost curves are L-shaped, rather than U-shaped. . . Various explanations have been suggested for the L-shaped nature of the long-run average cost curve. Some are based on econometric reasoning, involving certain biases present in the estimation or in the measurement of cost or output. Other are based on economic reasoning. For example, a profit-maximizing firm would, assuming the cost curve applies to a particular plant, build new plants (until the minimum average cost level is attained) rather than move up the rising portion of the average cost curve for its existing plants. Thus the rising portion of the curve would never be observed."

This author informs the connections between cost functions and production functions is signalized by the fact that elasticity of production is the reciprocal of elasticity of cost.

He also glances on the cost curve shape, presenting the cases of linear, translog, and the generalized Leontief cost functions, without forget the special cost function related to Cobb-Douglas production function.

Of course, there isn't any reason - logical, theoretical, empirical - one considers only the neoclassic cost function model. It is an undesirable situation to have only a theory to explain a phenomenon. Popper (1978) says it is needed not only to maintain alive alternative theories by their discussion but also to look for new ones when they don't exist. Something like monopoly of a theory is too dangerous for progress of science.

According to Intriligator (1978), Henderson and Quandt (1971), Garofalo and Carvalho (1976) and Simonsen (1979) cost function is obtainable by the consideration of points pairs of output (isoquants) and cost (isocost) in the expansion path, i. e., assuming highest efficiency: the biggest output for a given cost or the least cost for a given output.

As a matter of fact, one can point out the following features of neoclassic and linear cost function models:

MODELS	ADVANTAGES	DISADVANTAGES
Linear	– Simplicity – Achieved by definition straightway from cost spreadsheet. – presents PCBEP.	– AC hasn't minimum, being not optimizable.
Neoclassic	– AC has minimum, being optimizable.	– Achievable only by regression (parameters A,B,C). – Not achievable by definition from cost spreadsheet. – "**average**" values and not on the "**lowest frontier**".

The great advantage of neoclassic model is the possibility to be optimized, because presents a point of minimum in TC and AC curves, what linear one doesn't. But it isn't sure whether this is congruent with real world or it is only "using one's wits". In fact, as says Galbraith (1982), the scientific truth in Economics isn't always that which really exists. The fact remains that it is not worthless the linear model be achievable straightway from the cost tables. This make possible to accomplish standard linear cost functions easily, since one has information enough to set up technological cost table or spreadsheet like Tables 4, 5, 6 and 7 presented above. These cost function models, fulfilled by definition, are mathematical models not econometric or statistical. So they don't need to be validate while mathematical. Whereas the neoclassic cost function model may be not applied to standard costs unless under special restrictions, because this model needs to get three parameters A, B, C, relating respectively to third, second and first degree terms of function (12), which can't be achieved from cost tables or spreadsheets. Only parameter D, total fixed cost, may be got from fixed cost tables. So, unless on special cases, to get neoclassic cost functions one needs data from real world - a real production process - on cost and output, to which must to apply methods of regression, observing all restraints associated to those methods (see Hoffmann and Vieira, 1977). Thus, hardly one can get standard neoclassic cost functions.

Other difficulty linked to neoclassic models relates to the fact that classical regression methods provide models in the "average" of the observed points, not in the lowest frontier, as required by the definition of cost function. And that is a difficulty not prevailing to the linear models, since the cost spreadsheets or tables present technological coefficients in the most efficient frontier. Certainly there are special methods of regression to deal with this case. But they are not the traditional ones, which of course becomes additional difficulty.

The neoclassic cost curves may be approached by linear ones, with different technical coefficients for each equal width part of the output axis. And the linear model will be a good proxy for the neoclassic.

Doubtless, the linear approach is good to explain and to evaluate production cost. Existing conditions for its utilization, certainly the approach by neoclassic cost functions is also good. One may complete the other.

As Newtonian Physics explains usual motion, Linear Models is enough to explain costs.

Despite the difficulties attached to the prime cost approach, it has worldwide utilization, as one can see in a sample of literature like Mello et al. (1988), Zakharov (1986), Harza(1986), Nakajima (1981), Delestre (1989), Walter and Schneider (1987) and McElroy (1986).

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ERRATA

Características físicas e químicas de frutos de cupuaçuzeiro (*Theobroma grandiflorum*) do Sudeste da Bahia.
Neide Cléa de Almeida Ribeiro, Célio Kersul do Sacramento, Waldemar G. Barreto e Lindolfo Pereira dos Santos Filho.
Agrotrópica 4 (2): 33 - 37 (maio - agosto, 1992).
Informamos, a pedido dos autores, que o original continha incorreções. Para sanar essa falha, providenciar as seguintes modificações:
p. 33, linha 6, leia-se:
Waldemar de S. Barretto,
p. 36, Quadro 3, leia-se:

Açúcares totais	(%)	8,44	7,98	7,20

AGRADECIMENTOS
AOS CONSULTORES CIENTÍFICOS

Em 1992, a Comissão de Editoração do CEPEC contou com a colaboração de especialistas, pertencentes ou não aos quadros da CEPLAC, que, como consultores científicos, revisaram os trabalhos recebidos para publicação, contribuindo, dessa maneira, para melhorar o seu conteúdo e apresentação.

A todos eles, essa Comissão expressa os seus mais sinceros agradecimentos, esperando continuar recebendo deles a sua valiosa colaboração.

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