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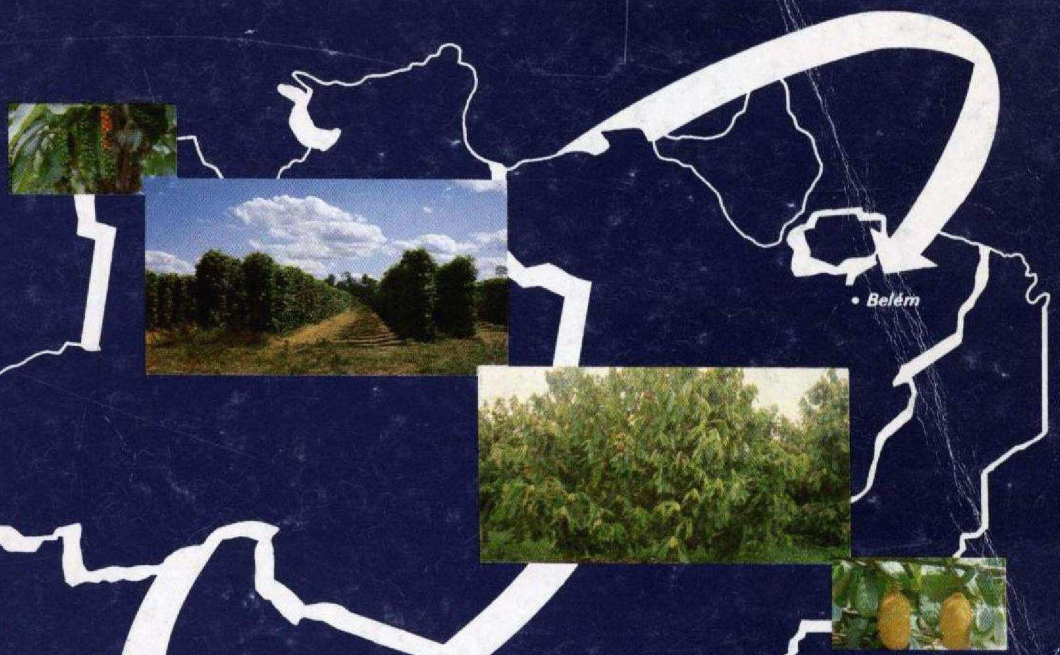

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EFFECT OF INTERCROPPING AND ENVIRONMENTAL FACTORS ON ANTHESIS IN CUPUAÇU (*Theobroma grandiflorum* - STERCULIACEAE)[1]

Giorgini Augusto Venturieri[2] and Márcia Motta Maués[3]

*ABSTRACT: Cupuaçu (**Theobroma grandiflorum**), one of the most profitable new crops of Amazonia, is now attracting world-wide attention as an exotic fruit, used in juices, ice cream and sweets. Nevertheless, its yields are low and prices are consequently high. The low fecundity of cupuaçu is due to the low rate of natural effective pollination, that takes place in only 1.6 % of the flowers. The scarcity of pollinators and the limited time during which the flower is attractive to the effective pollinator, the mosquito bee (**Plebeia minima**), are seen as the principal limiting factors to natural pollination. Observed variation in the timing of flower opening suggests the possibility of selection for earlier flower opening in order to give bees more time to pollinate. Contributions of individual genotypic variation, humidity, shading, and changes in light quality (provided by coloured cellophane filters on flowers) on flower opening are reported. Shading was not the only factor influencing anthesis. The timing of anthesis in less illuminated plants seemed to be more influenced by rainfall than in the more illuminated trees. Relative humidity of the air was higher with the intercropped plants and may be associated with earlier anthesis. Treatments using coloured cellophane filters were not found to influence on the time of flower opening.*

EFEITO DE CONSORCIAMENTO E FATORES AMBIENTAIS NA ANTESE EM CUPUAÇUZEIRO (*Theobroma grandiflorum* - STERCULIACEAE)

*RESUMO: O cupuaçuzeiro (**Theobroma grandiflorum**) é uma das culturas mais rentáveis da Amazônia, usada em sucos, sorvetes e doces, e que como fruta exótica vem atualmente atraindo a atenção mundial. Entretanto, a sua produção é pequena e os preços são, conseqüentemente, altos. A baixa fecundidade do cupuaçuzeiro é devida à baixa taxa de polinização natural, que ocorre em somente 1,6% das flores. A raridade do polinizador e o período limitado em que a flor está atrativa para o polinizador, a abelha mosquito (**Plebeia minima**), são vistos como os principais fatores limitantes à polinização natural. A variação observada no tempo de abertura das flores sugere a possibilidade de seleção para antese precoce das flores para dar às abelhas mais tempo para efetuarem a polinização. A contribuição da variação genotípica individual, umidade, sombreamento e modificações no comprimento de onda da luz incidente (provocada pela colocação de filtros de celofane sobre as flores) na antese das flores são reportados. O sombreamento não foi o único fator que influenciou na antese. O horário da antese nas plantas menos iluminadas parece ser mais influenciado pela chuva do que o horário das plantas mais iluminadas. A umidade relativa do ar, maior nas plantas em consórcio, pode estar associada à antese precoce. Tratamentos que usaram os filtros de celofanes coloridos não demonstraram qualquer influência no tempo da antese das flores.*

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INTRODUCTION

*Cupuaçu (**Theobroma grandiflorum** - STERCULIACEAE) is a tree relative of cocoa (**T. cacao**) and is currently attracting world - wide attention as an exotic fruit for use in juices and ice creams. It has an agreeable strong, acid-sweet flavour that has gained it a rapid increase of popularity. Nowadays, cupuaçu is undergoing a rapid expansion into the world market for exotic fruit flavours (Cement & Venturieri, 1991) and is considered one of the most profitable crops in the Amazon, recommended as a cash crop for integrated agroforestry systems (Moraes et al. 1994; Smith et al. 1992; Venturieri, 1993).*

*Three stingless bees (Hymenoptera: Apidae: Meliponinae) are mentioned in the literature as possible pollinators of cupuaçu. These are **Ptilotrigona lurida** (Smith), **Plebeia minima** (Gribodo) and **Trigonisca pediculana** (Silva, 1976; Venturieri, 1994). However, the biology of these social bees is not well known (Roubik, 1989).*

Cupuaçu exhibits very low fecundity. Falcão & Lleras (1983), for example, reported that some 2,500 flowers were necessary for the production of only four mature fruits. The factors already pointed out as an explanation for this are: low rates of natural pollination, estimated at 1.6% for pistils pollinated with more than 60 pollen grains; a hypothetical self-incompatibility system; limited time period during the day which flowers are attractive to insects (i.e., presenting "rewards" to flower visitors); and rarity of pollinators (Venturieri, 1994).

*Cupuaçu flowers split their sepals during the day, but they open fully only at the end of the afternoon between 16:00 (62.3%) and 18:00 (29.3%). Occasionally, flowers open at noon (6.42%) or more uncommonly between 18:00 to 20:00 (1.8%). Open flowers are receptive until 10:00 of the next morning (Venturieri, 1994). **P. minima** gathers pollen from cupuaçu flowers, especially during the late afternoon when the anthers are still covered with pollen grains. These bees generally begin to forage early, leaving their nests in the morning at approximately 7:30, and remain active until about 17:30. This means that there is a relatively short time period during the day for pollen collection from cupuaçu (Venturieri, 1994). Nevertheless, the observed variation in the timing of flowering suggests that it may be possible to anticipate the time of flowering in order to give the bees more time in which to pollinate flowers. The basis of the observed variation could be individual genetic variation, or general environmental conditions, like humidity, light intensity, or changes in light quality due to shading by other trees in inter-cropped plantings*

In this paper we report studies of cupuaçu flower behaviour in shaded and unshaded trees and the effect of artificial changes in light quality on flowering.

MATERIAL AND METHODS

Field investigations were carried out in the ***Theobroma germplasm*** *bank of CEPLAC/ERJOH, in the municipality of Benevides (1°12`S; 49°13`W) and at Embrapa-CPATU in Belém (1°20'S; 48°30`W), both in the state of Pará, Northern Brazil. The climate of these localities is classified as "Afi" in the Köppen system (mean temperature of 26°C, average relative humidity of the air 84%, and 2,600mm of rainfall per year). Observations were made from September to December 1992.*

*At the first locality, cupuaçu trees were inter-cropped with several other useful tree species as an agroforest. The size of the trees suggested that they were more than 40 years old, possibly derived from the typical home garden of an Amazon peasant agriculturalist. At the second locality, the analysed trees were 11 years old, part of an experiment at planting of cupuaçu that compared trees in pure plots with those inter-cropped with peach palm (****Bactris gasipaes****), "ingá" (****Inga edulis****) and açai (****Euterpe oleracea****). Due to this on-going experiment, these trees were pruned, fertilised and kept under an agronomic management. The inter-cropped trees were less illuminated than the trees planted as a single crop. The studied plants were in an Oxisol with red and yellow argilites with a low drainage capacity and poor fertility.*

In an attempt to assess the influence of light quality and a possible greenhouse effect on flower opening, coloured cellophane light filters were used, much as was done by Prance & Arias (1975) for ***Victoria amazonica****. Five flowering trees (identification numbers F13-2, 229-25, 296-1, 283-57 and 332-17) were randomly chosen at the CEPLAC study site. From 18:00 to 18:30 on 9 November 1992, 90 mature buds were marked on each tree. Flowers were individually protected with red, blue, green, transparent and superposed blue and red cellophane paper tubes. Three flowers on each tree were covered with the same colour cellophane. Transparent cellophane was used to test the greenhouse effect (raising the temperature of the bud). As a control, three uncovered flowers were observed on each tree. Flowers were then observed at 12:00, 15:00, 16:00, 17:00 and 18:00 on the following day, and the time at which each flower opened fully was recorded.*

The same experiment was conducted at Embrapa-CPATU, using two cupuaçu trees inter-cropped with other fruit trees, in an environment similar to that at CEPLAC/ERJOH, and with two trees from pure stands planted in a plantation. The treatments in this experiment were randomly applied between 6 and 22 October 1992, according to the availability of flowers. As an additional observation, anthesis of uncovered flowers, from two trees of a cloned seedless variety of cupuaçu planted in the shade and in full sunshine, was observed on 3 November 1992, at Embrapa-CPATU.

Survival analysis approach was applied using Logistic Regression Analysis (Collet, 1994) to anthesis time by environments. The calculations were done using the Logistic procedure from the SAS statistics package (SAS Institute, 1991).

RESULTS

The times when flowers covered with different colours of cellophane opened in the three studied environments are shown in Table 1. No statistical differences were observed among the different treatments, so changes in light quality induced by the cellophane or the possible greenhouse effect did not affect flower opening schedules (Table 2).

*TABLE 1. Time of cupuaçu flower anthesis. Environment a: ◆ = plant F13-2; ✠ = plant 229-25; ◘ = plant 296-1; ♁ = plant 283-56 and ♌ = 332-17; environment b: * = plant 1; + = plant 3; environment c: # = plant 2; @ = plant 4.*

Environment a: Cupuaçu trees inter-cropped with other trees at CEPLAC/ERJOH.

Treatment	Time (hours)				
	12:00	15:00	16:00	17:00	18:00
Blue		◆◆✠✠✠	◆	◘ ♌♌♌	◘ ◘ ♁♁♁
Red		◆✠✠	◆◆✠	◘ ◘ ◘ ♁♌	♁♁♌
Transparent	♌	◆◆◆✠	✠✠	◘	◘ ◘ ♁♁♁♌♌
Green			◆◆◆✠✠✠◘ ◘	◘♁♁	♁♌♌♌
Red & Blue		◆◆✠	◆✠✠	◘ ◘ ♌♌♌	◘ ♁♁♁
Control		◆✠✠✠	◆◆	◘	◘ ◘ ♁♁♁♌♌♌

Environment b: Well illuminated cupuaçu trees at EMBRAPA-CPATU.

Treatment	Time (hours)				
	12:00	15:00	16:00	17:00	18:00
Blue			**++	*+	
Red			*	**+++	
Transparent				***++	
Green			+++	**	*
Red & Blue	*		++	**+	
Control		*	*+	*++	

Environment c: Cupuaçu trees inter-cropped with other trees at EMBRAPA-CPATU.

Treatment	Time (hours)				
	12:00	15:00	16:00	17:00	18:00
Blue			###@@@		
Red			###	@@	@
Transparent	#		#@@	#@	
Green			##@@@	#	
Red & Blue	#	#	#@@@		
Control	@		##@	#@	

*TABLE 2. Effect of different colours of cellophane on time of flower anthesis. (**ns** = difference not statistically significant).*

Treatment	*Average time of anthesis (hours)*	*Wald c^2-Square test applied to time of anthesis of each treatment against the control*	*Probability to be equal and level of significance*
Control	*17:00*		
Blue	*16:44*	*0,86*	*0,34* **ns**
Red	*16:56*	*0,06*	*0,80* **ns**
Transparent	*17:03*	*0,03*	*0,87* **ns**
Green	*16:48*	*0,53*	*0,46* **ns**
Red & Blue	*16:41*	*1,31*	*0,25* **ns**

Statistical differences were observed, however, among environments. Anthesis in the inter-cropped trees at Embrapa-CPATU occurred earlier than in the unshaded trees at the same locality ($p<0.01$). Nevertheless, anthesis in the inter-cropped cupuaçu trees at CEPLAC/ERJOH occurred later than in inter-cropped trees at Embrapa-CPATU (Table 3).

*TABLE 3. Time of anthesis in different environments. * = difference barely significant; *** = difference very significant.*

Environment	*Average time of anthesis (hours)*	*Differences between environments according to the Wald c^2- Square test*		
Inter-cropped cupuaçu trees with other trees at CEPLAC/ERJOH = a	*17:04*	*a x b* *0:26* *(p= 0.018)* *		*a x c* *0:55* *(p= 0.0001)* ***
Well illuminated cupuaçu trees at Embrapa/CPATU = b	*16:38*		*b x c* *0:29* *(p= 0.004)* ***	
Inter-cropped cupuaçu trees with other trees at Embrapa-CPATU = c	*16:09*			

The same tendency was observed in the seedless cupuaçu clone, where flowers of the inter-cropped tree opened earlier than those of the trees planted in the pure stand (Table 4).

*TABLE 4. Time of anthesis in two trees of a seedless clone of cupuaçu, planted in two environments. * Flowers opened during the night.*

Environment	Time (hours)					
	12:00	15:00	16:00	17:00	18:00	>18:00 *
Inter-cropped	0	0	0	0	9	15
Cultivated alone	0	0	0	0	1	13

DISCUSSION

At Embrapa-CPATU, anthesis in inter-cropped plants occurred earlier than in well-illuminated trees. Inter-cropped plants (heavily shaded) at CEPLAC/ERJOH reached anthesis later than the others, showing that shade is not the only factor influencing anthesis and that other environmental factors must also influence time of anthesis.

Venturieri (1994) observed that when flowers were protected prior to hand pollination, coverings had to be placed on them earlier than usual on rainy days because the flowers generally opened earlier on rainy days. Anthesis in the shaded plants may have been more influenced by rainfall than in unshaded ones. Since the relative humidity of the air is higher near inter-cropped plants, early anthesis may be associated with higher humidity.

Several treatments using cellophane filters decreased light intensity considerably, for example the superposition of red and green papers and green paper alone. These treatments might be expected to shade the flowers and lead to early anthesis, but this did not occur, reinforcing the suggestion that humidity, not shade, controls flower anthesis.

CONCLUSIONS

The quality of light did not influence on anthesis. Humidity may influence early anthesis in cupuaçu.

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