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EVALUATION OF DEVELOPMENT POSSIBILITIES
ECUADOREAN CACAO INDUSTRY

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RUSSELL DESROSIERS

EVALUATION OF DEVELOPMENT POSSIBILITIES

ECUADOREAN CACAO INDUSTRY

Russell Desrosiers

Quito, Ecuador, July 7, 1979

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PARTIAL LIST OF PERSONS CONTACTED

INSTITUTO NACIONAL DE INVESTIGACIONES AGROPECUARIAS (INIAP)

Dr. Enrique Ampuero, Director General, Quito
Ing. Carlos Cortaza, Acting Sub Director, Guayaquil
Ing. Marat Rodríguez, Acting Director, Pichilingue
Dra. Carmen Suárez, Plant Pathologist, Pichilingue
Ing. Héctor Calle, Plant Pathologist, Pichilingue
Ing. Guido Solórzano, Plant Pathologist, Pichilingue
Ing. Jaime Aragundi, Plant Pathologist, Pichilingue
Ing. Jorge Mendoza, Entomologist, Pichilingue
Ing. Manuel Moreira, Plant Breeder, Pichilingue
Ing. Jaime Vera, Horticulturist, Pichilingue
Mr. William Hadfield, Plant Physiologist, Pichilingue
Ing. Nelson Motato, Soils Specialist, Pichilingue
Ing. Kléber Muñoz, Weed Control Specialist, Pichilingue
Dr. Sam Portch, Soil Fertility Advisor, Quito
Dr. Julio C. Delgado, Plant Pathologist, Boliche
Ing. José Laínez, Soils Specialist, Boliche

PROGRAMA NACIONAL DEL CACAO

Ing. Jorge Gutiérrez, Director Executive, Guayaquil
Ing. Nicolás Fuentes, Marketing, Guayaquil
Ing. Alfonso Pincay, Vinces
Ing. Vincencio Moncayo, Machala
Ing. Angel Veintimilla, Machala

PROYECTOS AGRICOLAS DEL CACAO CIA LTDA. (PROCACAO)

Ing. Fernando Jiménez, Gerente General

GUAYAS RIVER BASIN DEVELOPMENT COMMISSION (CEDEGE)

Ing. Carlos Zavala, Guayaquil

CACAO INDUSTRY, GUAYAQUIL

Sr. Fernando Salcedo, SALCO
Ab. Carlos X. Icaza, SALCO
Sr. Luis Fernando Gómez, INCACAO
Sr. Santiago Maspons, INCACAO
Ing. Fernando González, RITEC-Santa Fé
Sr. José Aray M., Export Agent

I. INTRODUCTION

At the beginning of this century cacao was Ecuador's principal export product and Ecuador was the world's foremost producer of cacao. The advent of two diseases; Witches' Broom and Monilia Pod Rot, brought about a drastic decline in the productivity of the country's cacao plantations and to its status as a producer. The spectacular rise of the banana industry in Ecuador during the past 25 years, accompanied by a cutting down of cacao plantations to plant bananas, has brought about a further reduction in production. Ecuadors' former reputation as a producer of a high quality flavor cacao has been tarnished and made suspect.

The present report attempts to examine means by which the health of the cacao industry might be improved and suggestions are made regarding measures which could contribute to the attainment of this goal.

Cacao research being carried out by the Instituto Nacional de Investigaciones Agropecuarias (INIAP) and extension activities by the Programa Nacional del Cacao, as well as developments in the Ecuadorean chocolate industry are reviewed.

II. CACAO RESEARCH

Personnel of five departments at the Pichilingue Experiment Station are involved in research on cacao (see Table 1). The people whose names appear do not necessarily work full time on cacao, but may be involved in other research as well. A loose coordination is maintained among people from the different departments involved in cacao research and the fact that proposed research projects must be approved by an interdepartmental committee before being put into execution tends to avoid duplication of effort.

There is a strong feeling among most of the personnel involved that cacao research would be strengthened by the establishment of a Department of Cacao Research which would contain its own pathologists, horticulturists, and representatives of other disciplines, and would be free of the distraction of having responsabilities in other crops. This type of commodity orientation already functions well in the case of oil palm research, which has not only its own technical specialists but its own production people as well. A reorganization of cacao research along these lines would be highly recommendable.

The following discussion of cacao research is intended to cover items of particular interest to the future development of the research program and the production of information which will be useful, in the short or medium term, to the farmer.

TABLE 1. TECHNICAL PERSONNEL ENGAGED IN CACAO RESEARCH.
PICHILINGUE EXPERIMENT STATION
1979

DEPARTMENT			SPECIALTY	
PLANT PATHOLOGY				
I.A. Ph.D.		Carmen Suárez C.	Plant Pathology	Head of Dept.
I.A.		Marat Rodríguez	" "	
I.A.		Héctor Calle	" "	
I.A.		Guido Solórzano	" "	
I.A.		Jaime Aragundi	" "	
Agr.		Rigoberto Moreira	Agronomy	
ENTOMOLOGY				
I.A.		Vicente Páliz*	Entomology	
I.A.		Jorge Mendoza	"	Acting Head
PROGRAMA DE CAFE-CACAO				
I.A.	M.Sc.	Jaime Vera	Plant Breeding	Head of Dept.
I.A.		Manuel Moreira	Horticulture	
I.A.		Eduardo Mogrovejo**	Plant Breeding	
I.A.		Jacinto Chong Achong	Plant Physiology	
Egr.	I.A.	Vicente León	" "	
	M.Sc.	William Hadfield	" "	MOD, Great Britain
Agr.		Bosco Solórzano	Agronomy	
Agr.		Pedro Ocyburo	" "	
SOILS AND FERTILIZERS				
I.A.		Francisco Mite***	Soil Fertility	
I.A.		Nelson Motato	" "	Acting Head
Agr.		Ignacio Rodríguez	Agronomy	
WEED CONTROL				
I.A.		Kléber Muñoz	Weed Control	Acting Head

* Studying in Mexico
** Studying in Brazil
*** Studying in the United States

A. Plant Pathology

1. Selection for Resistance

The plant pathology department is conducting two studies involving the genetic improvement of cacao with regard to disease resistance. The first of these, started in 1966, involves the evaluation for resistance to Witches' Broom of hybrids having as parents clones collected in the Amazonan Valley for resistance to the disease. The breakdown of resistance in Ecuador. probably due to the appearance of one or more new races of the pathogen to which this material is susceptible, has resulted in the elimination of much material from consideration. There is an annual apparent increase in susceptibility and an elimination of additional individual plants. At last report, the hybrid SCA - 12 x Silecia 1, both parents originally selected for resistance, seemed to be bearing up better than most. Some of the surviving trees, appearing to have good yield potential and quality and demonstrating an above-average tolerance to the disease may be sources of seedling populations worth testing on the property of cooperating farmers.

The other study involves repeated artificial inoculation since 1969 of large numbers of seedling progeny derived from Amazonian clones for the purpose of evaluating their resistance to Witches' Broom and the elimination of susceptible individuals With the completion of the current year's work, this resistant or tolerant material will be turned over to the Programa de Cacao-Café for multiplication and further study.

2. Chemical Control of Diseases

A promising development in the search for a control for Witches' Broom is the use of agricultural spray oil applied to the dry brooms for the inhibition of sporophore (basidiocarp)

formation. It has been found that an emulsion of 30% oil in water will effect a reduction in sporophore formation and is not toxic to the plant. Work thus far has been limited to the spraying of brooms on the ground for greater ease in the observation of sporophore formation and the taking of data, but the project is now to be expanded to field scale and the spraying of trees.

The purpose of this sort of application is to interrupt the life cycle of the pathogen prior to the stage of sporophore formation, thus interfering with the ability of the fungus to initiate the next cycle of infection. The spray would be applied late in the dry season when the brooms are dry and before the start of the cycle of infection normally brought on by the beginning of the rainy season.

The inclusion of additional chemicals in the oil emulsion offers interesting possibilities for the future development and improvement of the effectiveness of this procedure.

Table 2 shows early results of the effect of the oil in sporophore inhibition.

Table 2. Effect of agricultural spray oil on the formation of basidiocarps of *Crinipellis perniciosa* on cacao[1/].

Month	No. of basidiocarps[2/] P. Chavez (oil)	N. Bambu (control)
Jan.	2	10
Feb.	3	21
March	138	826
April	682	5431
May	191	576
June	279	913
July	0	26
August	0	0

1/ Annual Report, 1977, INIAP.

2/ Data from 500 brooms per plot.

An interesting study combining fungicide spraying with hand pollination is in progress. The hand pollination permits a concentration of the crop so that it may be more effectively sprayed and no attempt is made to spray the whole tree. Five fungicides were tested, of which Daconil 2787, Aerial Perenox and Macuprax gave very promising results for the control of pod infections caused by Crinipellis (Witches' Broom), Monilia and Phytophthora. Dithane M-45 gave better control of Phytophthora than the three fungicides already mentioned but was less effective against the other diseases. Antracol proved to be a fungicide of little promise against these diseases. Under the very severe disease conditions of this trial, the three better fungicides produced increases in numbers of disease-free pods of as much as 10 times the unsprayed control (see Table 3). These trials will be expanded to larger acreages and the use of oil emulsions to carry the fungicides will be tested.

An experiment involving sprays of different dosages of the fungicide Kocide 101, combined with the removal of brooms from the trees either once or twice annually, begun in 1973, was termined in 1977 because of poor results and the fact that the treatments would be commercially uneconomical.

Table 3. Yield and disease incidence in trial of protective fungicides and hand-pollination[1/] [2/].

Treatment	gm/l	Numbers of Pods							Percentage of Pods						Kgs Wet weight seeds
		Monilia	Witches' Broom	Phy-tophthora	Unde-termined	Total Diseased	Total Healthy	Total	Monilia	Witches' Broom	Phy-tophthora	Unde-termined	Total Diseased	Total Healthy	
Acrial Perenox	7.0	39	55	7	1	102	180	282	13.8	19.5	2.5	0.4	36.2	63.8	25.9
Antracol	5.0	24	65	38	8	135	59	194	12.4	33.5	19.6	4.1	69.6	30.4	8.8
Daconil 2787	6.0	20	39	40	5	104	209	313	6.4	12.5	12.8	1.6	33.3	66.7	30.2
Dithane M-45	3.0	39	69	9	4	121	116	237	16.5	29.1	3.8	1.7	51.1	48.9	16.8
Hacuprex	7.0	38	54	32	0	124	206	330	11.5	16.4	9.7	0.0	37.6	62.4	31.4
Control	-	60	126	59	8	253	18	271	22.1	46.5	21.8	3.0	93.4	6.6	2.8

1/ Annual Report, INIAP, 1977

2/ Data from January-June, 1977

3. Regional Disease Evaluation

It had been observed several years ago that dry areas, such as Machala, seemed to have much less Witches' Broom infection than other parts of the country. In fact, plantations of mature trees were observed there on which no witches' brooms at all were to be seen. The possibility of the selection of zones in which cacao would be less subject to disease seemed to exist and seven farms were selected in different parts of the litoral to examine this possibility. The original intention was to record climatological data at each site in order to attempt to correlate this with disease incidence but it was not possible to acquire sufficient equipment and it was not possible, either, to obtain cooperation by the farmers in the recording of data from the equipment that was available.

Hda. Beatriz in Machala was a site on which no witches' brooms were originally observed. A steady development of the disease took place, however, during the course of the study and now Hda. Beatriz has plenty of brooms (see Table 4). Beatriz shows abundant Monilia as well but no Phytophthora, the climate there being too hot and dry to favor this disease. It is, however, a Capsid pocket and shows a severe infestation of those insects (Monolonion spp.). Capsid damage was not recorded in this study.

As can be seen in Table 4, Monilia is, by far, the most serious direct cause of pod loss in all areas, with Phytophthora being of relatively minor importance by comparison. Viche and Montalvo moist areas, appear to have the highest incidence of Monilia. Naranjal, however, a much drier area, also shows a high incidence of that disease. The effect of Witches' Broom is more difficult to evaluate since, in addition to the loss of pods directly infected by the disease

there is the loss of the considerable quantities of leaf and stem tissue involved in the growth of the vegetative brooms as well as loss in yield caused by the infection of fruit cushions.

Considerable fluctuation in disease incidence is noted from year to year and among zones. No solid trends occur which would be helpful in the selection of areas where cacao ought, by preference, to be grown. The yields recorded in Naranjal and Machala are, however, quite impressive, and this in spite of rather high incidence of diseases. These high yields may be due to the fact that the plantations concerned receive irrigation and may, therefore, be an argument in favor of the irrigation of cacao rather than an indication that the culture of cacao should be shifted towards Naranjal and Machala. In any case, it can be seen that an effective control of pod infections mostly Monilia, in Naranjal and Machala, without attempting the control of Witches' Broom on the entire tree would bring the yield up to the neighborhood of 1800 kg/ha., a very respectable figure. The achievement of even a fair control of Witches' Broom should bring the yield to a level well over two metric tons per hectare.

Table 4. Incidence of diseases of cacao in different parts of the Ecuadorean litoral[1/]

Z O N E (Hacienda)	Total Witches' Brooms (Av. per tree)			Percent diseased pods: Monilia			Witches' Broom			Phytophthora			Others			Partially diseased[1/]			Healthy Pods Percent			Yield kgs. Dry Beans/ha./year			Average per year
	72-73	73-74	74-75	72-73	73-74	74-75	72-73	73-74	74-75	72-73	73-74	74-75	72-73	73-74	74-75	72-73	73-74	74-75	72-73	73-74	74-75	72-73	73-74	74-75	
VICHE (Viche)	187	40	272	50	44	43	8	4	2	1	1	2	1	1	9	-	-	2	40	50	42	422	600	448	490
CHONE[2/] (Ana María)	-	22	125	-	17	23	-	2	1	-	1	10	-	1	1	-	-	1	-	79	64	-	997	233	525
QUEVEDO (Acuarius)	191	227	588	20	38	26	12	5	4	1	2	4	1	0	1	-	-	2	56	55	63	714	662	526	634
MONTALVO (Independencia)	66	60	51	50	36	37	20	9	2	0	1	1	1	0	1	-	-	1	29	54	58	231	260	199	230
SAN ANTONIO (San Antonio)	250	178	272	29	27	24	17	6	1	3	1	3	5	1	2	-	-	1	46	65	69	248	336	623	402
MARIANA[2/] (Mariana Trinidad)	-	35	469	-	32	59	-	5	2	-	1	1	-	0	0	-	-	2	-	62	36	-	1229	834	1036
MANTA (Manarfi)	0	37	466	39	15	37	2	1	1	0	0	0	0	0	1	-	-	1	59	84	60	1154	1454	990	1199

Data taken from INIAP annual reports for the years indicated.

Not included 72-73.

This category separated only in 74-75.

4. The Possibility of Delimiting Zones for Cacao

Despite the inconclusive appearance of the data shown in Table 4, it is still possible to make some judgments, based on observations and experience, regarding areas suitable for cacao from the standpoint of reducing the incidence of diseases. Black Pod (Phytophthora Pod Rot) is a disease favored by cool, rainy weather and severe infections from this disease are to be expected under those conditions. This sort of climate prevails close to the mountains and that is where more Black Pod is normally to be found. As one moves south and east to the warmer and drier areas, this disease becomes less prevalent and eventually disappears. Witches' Broom is a disease also favored by rainy weather. While the disease will not disappear under drier conditions, it may be expected to be less severe. On the island of Trinidad, for example, Witches' Broom is less severe than in Ecuador, and Trinidad has a drier climate. It is logical to expect, therefore, that there should be some reduction in severity of Witches' Broom in the less rainy areas of the litoral. As is to be seen in Table 4, Monilia Pod Rot seems not to be greatly retarded by drier and warmer weather. The existing rains appear sufficient to initiate infection and result in severe damage from this disease. The drier climate should, however, favor the application of cultural practices and control methods intended to reduce the severity of attack.

The Commission for the Development of the Guayas River Basin (CEDEGE), with the cooperation of the Programa Nacional del Cacao, is preparing a detailed study of recommendations for the zonification of cacao which includes soil classification as well as climate

and availability of water[1/]. This study demarks three zones on the basis of rainfall intensity as a factor favoring the development of fungus diseases:

Zone 1. 1250 - 1800 mm. - good for cacao production.
Zone 2. 1801 - 2400 mm. - suffering restrictions because of diseases.
Zone 3. above 2400 mm. - diseases become serious factor limiting production.

These limits seem reasonable and conform to field observations. Map 1 shows lines of average annual rainfall for Guayas and Los Ríos provinces. It is to be seen that Montalvo, together with the Santo Domingo de los Colorados and San Juan de Maná areas fall within Zone 3, receiving an excessive amount of rainfall. The Quevedo area, including the Pichilingue Experiment Station, and Ventanas fall within Zone 2, suffering restrictions as a result of diseases. Viche, not shown on the map, would fall on the borderline between zones 1 and 2. Vinces, Babahoyo, Chone and Milagro would fall in Zone 1 and provisions for irrigation would be highly recommendable. Naranjal and Machala, also not shown on the map, would both fall in Zone 1 (or below) and would definitely require irrigation.

It may be assumed that, in general and over a period of years, cacao grown in Zone 1 with irrigation, good management, and disease control will yield better and cost less to produce than cacao grown under similar conditions in zones 2 or 3. In the absence of hard experimental data, however, this is an entirely subjective opinion, derived from observation and inference.

1/ Zonificación de Cacao en la Cuenca del Guayas. CEDEGE. In preparati

B. Entomology

A collection of insects on cacao has been built up over a period of several years. No major insect problems have been noted except Mirids (Capsid Bugs), Monolonion spp. These are of sporadic and scattered occurence and are being kept under observation.

A study of the principle insect responsible for the pollination of cacao, Forcipomyia spp., has disclosed the presence of several species of these. A study of the breeding habits of the insect has established the importance of a thick layer of undisturbed mulch on the floor of the plantation. The numbers of Forcipomyia captured in traps is shown in the Table 5. . These results emphasize the importance of the mulch layer as this is where the largest numbers of insects were found during the winter months. In summer, the largest numbers were found in rotted cacao pods. Pieces of banana pseudostem could serve as supplementary breeding places for the insect. The maintenance of a thick mulch and the uniform distribution of opened cacao pods through the plantation would seem to be highly desirable measures to assure, and perhaps to improve, pollination.

Table 5 . Numbers of *Forcipomyia* spp. captured in traps in three farms in the Quevedo area, 1978.

Treatment	Months											
	M	A	M	J	J	A	S	O	N	D	J	F
Cacao Pods 20 cm. height	24	27	25	50	21	205	172	143	202	51	108	17
Cacao pods 30 cm. depth	19	4	32	73	77	330	230	209	307	80	191	18
Bancna pseudostem 20 cm. height	16	11	20	4	13	14	5	8	6	8	47	6
Banana pselidostem 30 cm. depth	19	13	50	33	54	10	4	12	40	44	72	8
Mulch	103	192	101	53	9	7	4	17	10	14	190	101

C. Programa de Café - Cacao (Plant Breeding and Horticulture)

1. Selection and Breeding

This department is carrying on extensive trials of selections and hybrids at Pichilingue for the evaluation of yield and resistance to disease, especially Witches' Broom. The yields obtained are so low as to render the information of little use in evaluating the material (100 - 200 or as high as 500 kg/ha), since it is evident that the trees have not been given a fair chance to demonstrate their capability. The incidence of Witches' Broom and Monilia is rather uniformly high. Whether these trials are suffering from being located on a bad site, La Isla, or from early mismanagement, the situation should be corrected and the material perhaps moved to some other location. New collections are being made from the Trinitario-Nacional population of the litoral in an attempt to upgrade quality by the incorporation of Cacao Nacional bean characteristics.

Although trials at Pichilingue are giving poor yields, some of the same material planted elsewhere is performing well. A trial of hybrids and one of clonal cacao at Vinces are showing quite good yields; a top yield of about 1000 kg/ha. for clones and 1500 kg/ha for hybrids. These plots are irrigated and this is very likely an important factor contributing to good yield. Disease incidence is heavy in both trials, although there seems to be variation among trees in Witches' Broom incidence in the trial of hybrids. Table 6 shows the yields produced by the trial of hybrids over a ten year period.

2. Crop Concentration to Avoid Disease

Interesting results have been obtained from the use of hand-pollination and ring-banding in an attempt to concentrate the setting of fruit at a time when pod infections would be least se

Table 6 . Yield of dry cacao per hectare from the trial of 8 hybrids on Hda. La Delia, Vinces

Tratamientos	Quintales per Hectare										$\bar{X}$	% árboles muertos/72
	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978		
ICS- 6 x SCA- 6	1.44	27.70	38.83	36.76	28.60	23.84	37.76	21.23	24.05	46.17	28.59	11.11
EET-19 x SCA- 6	0.56	10.48	20.49	21.38	19.76	17.73	37.18	29.42	33.95	48.34	23.93	13.89
EET-62 x SCA- 6	1.07	11.62	21.64	20.64	16.74	17.74	28.38	21.26	25.96	38.30	20.34	8.33
SCA- 6 x EET-62	0.80	11.63	21.57	23.84	18.27	17.04	24.09	19.43	22.84	46.00	20.55	9.72
ICS- 6 x SCA-12	1.84	15.31	20.50	22.00	15.80	12.86	22.10	25.67	20.89	31.77	18.87	8.33
SCA- 6 x IMC-67	1.81	13.46	15.17	18.50	16.49	18.02	28.75	22.09	21.03	38.14	19.35	13.89
EET-96 x SCA- 6	0.48	10.03	18.38	12.85	13.02	9.91	22.10	17.43	20.90	32.89	15.80	16.67
EET-95 x Sil- 1	0.60	10.09	14.89	16.31	14.54	12.28	19.78	15.12	13.14	36.16	15.29	5.56
C.V. (%)			46.00	25.00	29.00	30.00	35.58	46.45	42.01	28.37		

vere. Pollination and ring-banding were done during the period June-August, planning for harvest during December-January. As can be seen in Table 7, a substantial increase in the yield of dry beans per hectare was achieved by these treatments. It is generally conceded, however, that ring-banding is not a practice that could be generally recommended to the farmer and that hand-pollination alone would be recommended, even though ring-banding seemed to result in a further increase in yield.

The results of a cost study on hand-pollination plus fertilizer versus traditional practice is given in Table 8. Hand-pollination plus fertilizer shows a substantial profit. The data also demonstrate very clearly that an effective spray treatment against pod infections would very probably have shown a further substantial profit.

3. Ecosystem Analysis

Several studies are in progress dealing with light, temperature and moisture relations within the cacao plantation. Because of the prolonged dry season, moisture conservation and irrigation appear to be needed. The maintenance of a thick layer of undisturbed organic mulch on the floor of the plantation seems an obvious necessity to reduce moisture loss and to avoid excessively high soil temperatures, as well as to improve soil condition and the utilization of phosphorous.

The effect of climate on the cycles of flowering and vegetative flushing of several types of cacao are being studied as are the numerous effects on the plantation of shade trees. The effects of all these factors on disease incidence will be studied in cooperation with the pathology department.

Table 7. Numbers of healthy and diseased pods, pod value, and yields of cacao hand-pollinated and ring banded, Quevedo area[1/] [2/].

Farm	Treatment	Nº Pods Healthy	Nº Pods Diseased	Pod[3/] Value	Kgs/Dry Beans/ha
Digna Maria	Po	870	34	7.64	302.98
	Po+Cs	1761	27	7.97	555.22
	T	151	12	10.15	39.09
Santa Rosa	Po	415	8	11.12	129.83
	Po+Cs	824	26	10.83	192.32
	T	87	5	10.18	20.16
Alvarez	Po	460	11	9.75	130.50
	Po+Cs	375	1	10.80	108.11
	T	88	8	10.91	21.81

Po-hand-pollination; Cs-ring-banded; T-control.

1/ Harvest November, 1978 - february, 1979

2/ 150 trees per treatment

3/ No. pods needed to produce one pund of dry cacao.

Table 8. Diseased and healthy pods, yield, man-days of labor, amount of fertilizer, and operating costs of trial carried out at San José farm converted to per hectare basis[1].

Treatment	Healthy Pods	Diseased Pods	Pod Value.	Dry cacao per ha[2]	Man-days of labor[3]				Fertilizer[4] (lbs)	Total Costs	Profit
					Harvest	Cleaning	Hand Pollination	Fertilizing			
T1	13,858	21,420	8.12	17.06	62.18	4.45	8.90	3.34	890	S/. 9,363.92	S/. 34,992.08
To	5,586	11,838	12.55	4.45	44.16	4.45				3,888.80	7,681.20
Profit between treatments											S/. 27,310.88

1/ Agricultural year Sept. 77-August 78

2/ At S/. 2,600 per qq.

3/ At S/. 80.00 per man-day

4/ 536.50 gr/plant of 12-24 plus sulfato of amonia

Studies on the root distribution of the cacao tree together with comparisons of high cutting, ground level cutting, and chemical control of weeds have resulted in a discrediting of the traditional practice of "limpieza raz al suelo" which involves a literal scraping of the soil surface in the weed cutting operation and a piling up of all this material, together with the organic matter, if any, scraped from the soil surface, in a windrow between the rows of trees. The large number of feeder roots close to the surface which may be directly damaged by the machete or indirectly by the removal of organic matter and soil in the process, not to mention the tendency of such an uncovered surface to overheat, dry out and become like concrete, prompts the abandonment of this practice in favor of one which does not disturb the layer of organic matter on the soil surface (see Table 9).

Similarly, the traditional practice of applying fertilizer in a band around the tree has been shown to damage the feeder roots and should be replaced by broadcasting down the row (see Table 9).

D. Soils and Fertilizers

The soils and fertilizers department has no research projects on cacao at the present time.. A bulletin was published in 1972, Boletín Técnico Nº 6, Fertilización Química de Café y Cacao en el Litoral Ecuatoriano, summarizing results and making recommendations. INIAP operates a soil test laboratory at the Boliche Experiment Station, to which cacao farmers, or any other farmers, may send soil samples for analysis and fertilizer recommendations.

New research on cacao is contemplated for the near future to include the following:

1. Fertilizer requirements of cacao subject to hand-pollination.
2. Evaluation of the efficiency of various cultural practices on cacao.
3. Fertilizer requirements of cacao and coffee nurseries.

Table 9 . Survival of feeder roots of cacao following certain cultural practices and methods of fertilizer placement[1/].

Treatment	Locations	
a. Weed control	Pichilingue	Quevedo
T1 Use of herbicide	84.85b	87.09a[3/]
T2 High cutting[2/]	89.88a	89.90a
T3 Low cutting[2/]	84.03b	82.98b
To Control	84.88b	81.72b
b. Fertilizer placement		
T1 Circle around tree	83.36b	83.09b
T2 Broadcast	89.51a	90.62a
To Control	84.09b	83.54b

1/ Annual Report, Pichilingue 1976-77

2/ Machete

3/ Averages with same letter do not differ statistically.

E. Weed Control

Favorable results have been obtained in the chemical control of weeds in cacao and a bulletin was published in 1978 entitled Controle las Malezas en Cacao.

New work is going forward on the control of epiphytic plants, "hierba de pajarito", members of the Laranthaceae, which affect cacao. Indications are that these pests may be killed by injections of certain herbicides without affecting the host.

III. CACAO EXTENSION

A. Programa Nacional del Cacao

Extension work in cacao is carried out by the Programa Nacional del Cacao (National Cacao Program). The Technical personnel of this organization consists of 34 Ingenieros Agrónomos and two Economists. In addition there are eleven administrative personnel at the Guayaquil headquarters and six stationed in the zones. The organization of the Programa is shown in Chart 1.

To carry out its extension activities, the Programa has extension officers stationed in the towns throughout the cacao producing areas, as shown in Chart 1. In addition to the normal work of advising farmers, these extension officers also have the responsability to assist farmers in making loan applications, preparing work and investment plans for loans, and the supervision of loans. The Programa also has regulatory functions, including that of establishing the minimum price for cacao in Guayaquil, based on the New York market price (see Table 10), and to verify that exported cacao conforms to the grade specified. The Programa is also preparing the terms of reference for a feasibility study for a project to rehabilitate and renovate Ecuador's cacao and is cooperating with the Commission for the Development of the Guayas River Basin in a study of the zonification of cacao. A study is also being made of cacao fermentation and drying in Los Ríos, Guayas, and El Oro provinces.

The Programa has held a seminar for cacao farmers each month since October, 1977 and considers this an extremely important feature of the extension program. The seminars are rotated from area to area and each is attended by more than 100 farmers. A radio program for cacao farmers is being presented at 5:00 a.m. and this is to be expanded to several stations.

CHART 1

ORGANIGRAMA ESTRUCTURAL DEL PROGRAMA NACIONAL DEL CACAO 1979

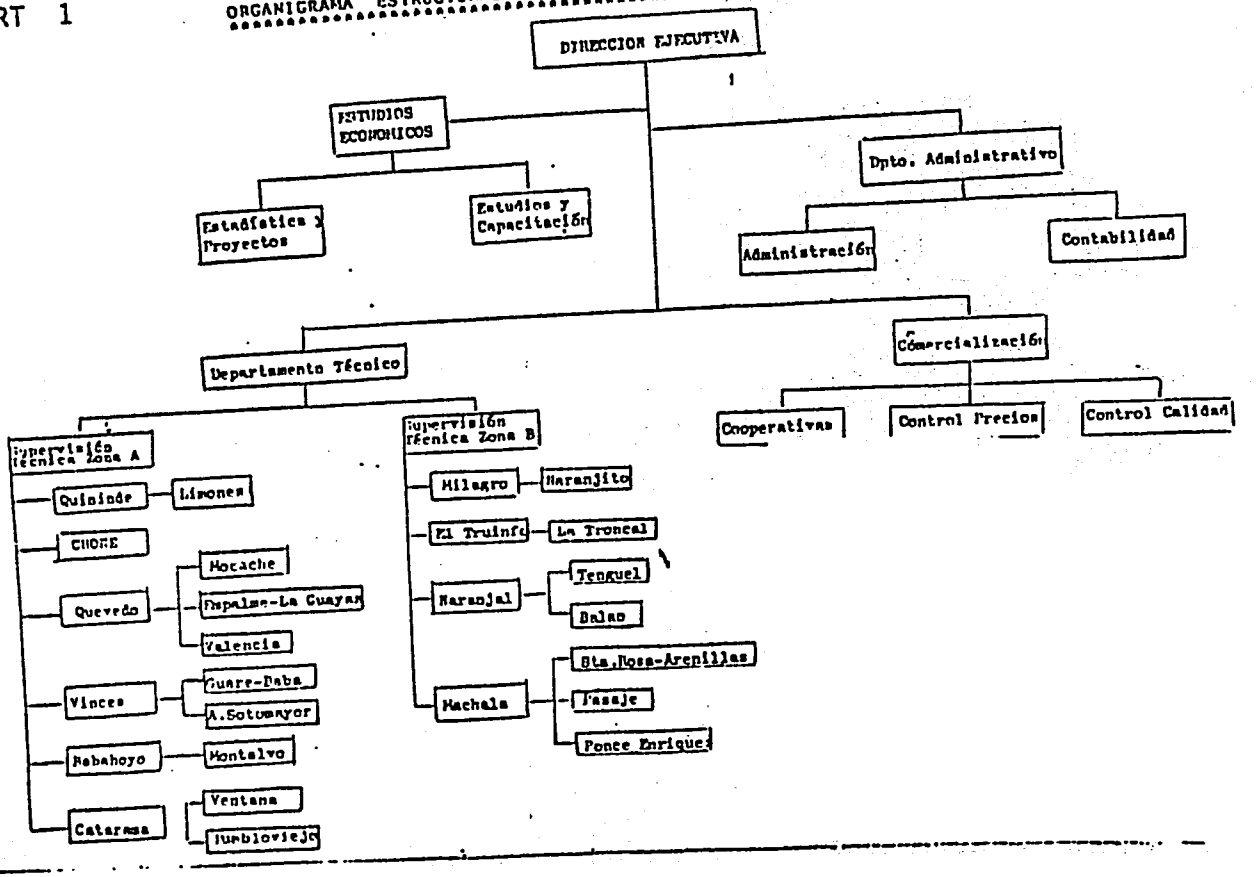


Table 10 . Prices paid for cacao in Guayaquil and New York, 20 days averages, per quintal.

		Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1976	Gquil. S/.	1292	1350	1362	1392	1560	1828	1808	1858	2136	2264	2312	2394
	N.Y. $	75.52	76.56	79.40	77.63	90.84	100.36	96.36	106.56	117.71	132.80	152.63	152.16
1977	Gquil. S/.	2940	3268	3088	3021	3320	3984	3985	3533	3710	3422	3687	2849
	N.Y. $	169.81	182.18	197.35	167.00	176.00	207.82	217.58	197.72	195.00	176.44	181.90	158.16
1978	Gquil. S/	2361	2241	2557	2714	2469	2345	2481	2636	2950	3115	3166	3082
	N.Y. $	139.68	137.07	161.07	157.76	144.06	139.28	146.86	154.25	162.49	179.67	180.53	176.00

The training of agents is done by in-service instruction, on-the-job training, and courses and seminars given for extension agents by the research personnel at Pichilingue. The need is felt for more extensive participation by Pichilingue in the training of agents.

The Programa is in process of establishing a series of demonstration plots on cacao farms throughout the litoral. A "package" of new practices is needed and this will have to come from Pichilingue, in order to be able to include the very latest recommendations. Close cooperation between Pichilingue and the Programa in this demonstration activity would be most desirable as well as beneficial to both organizations.

There has been some criticism of the Programa to the effect that, in matters having to do with recommendations to farmers, it has had a tendency to develop an independent policy instead of working closely with the research people at Pichilingue. An instance of this is the recommendation by the Programa in favor of the planting of clonal cacao (rooted cuttings), a practice opposed by Pichilingue. This sort of problem is unfortunate and it is hoped that a more harmonious working arrangement is developing. The climate at present is very favorable for the development of a close cooperation among the Programa, Procacao and Pichilingue.

Basically, the information delivered by the extension service to farmers must come from the research service and it must carry the endorsement of the research service. Therefore, the content of all training courses given to extension agents must be in accord with the recommendations of the research people. Similarly, all field days and seminars for farmers must be based on research recommendations and should never include recommendatios contradictory to research findings.

An extremely useful device to assure that all hands are playing the game according to the same rules is to have regional field trials and demonstrations conducted jointly by extension and research personnel; technical mitters to be handled by the research people and public relations, organization of meetings, etc., by their extension counterparts.

Procacao

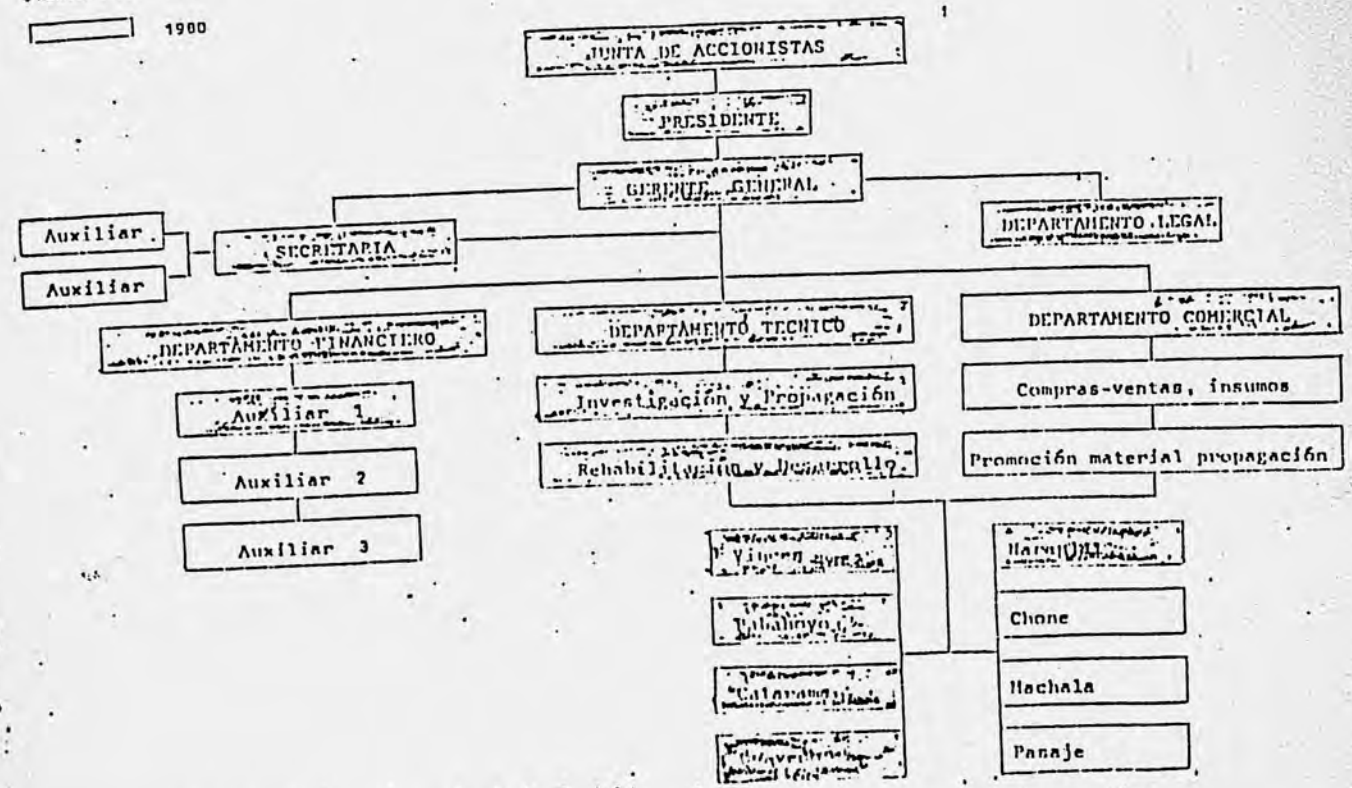
Procacao is a new organization financed by the cacao processing industry of Ecuador. Funding is provided by ASEICA (Asociación Ecuatoriana de Industrias de Cacao) which includes most of the companies engaged in the processing of cacao beans in the country.

The purpose of Procacao is to promote an increase in the production of cacao, both by improving the yield per hectare on existing farms and by the establishment of new plantings, and to improve the quality of the crop. Procacao is, therefore, an extension and promotion organization with essentially the same purpose as the Programa Nacional del Cacao. The interesting feature of Procacao is, however, that it is financed by the local chocolate industry, demonstrating for the first time a substantial interest on its part to do anything to improve production or to assist the farmers.

The organization of Procacao is shown in Chart 2. It is seen to be similar in structure to the Programa Nacional, though smaller. As part of its program, Procacao plans to produce extension bulletins and some are already in preparation. It will advise and assist farmers to obtain loans and its Commercial Department contemplates the purchase of agricultural inputs such as fertilizers and fungicides for resale to farmers at low prices.

CHART 2 PROCACAO

ORGANIGRAMA



The program of Procacao can complement that of the Programa Nacional and close cooperation between the two organizations would be in the best interests of the cacao farmer and the industry. It is hoped that a close and cordial relationship can be maintained between these extension organizations and Pichilingue.

IV. MARKETING

Recent years have seen a sharp increase in the number of firms engaged in the elaboration of semiprocessed cacao products such as chocolate liquor, cocoa butter and cocoa powder for export rather than the exportation of the dried beans. The majority of Ecuador's cacao is now handled in this way and the quantity of cacao beans exported as such is steadily declining. Table 11 shows the relative amounts being exported as beans and as semiprocessed chocolate. There is also a small amount of fully processed chocolate marketed within the country.

There are seven companies (Table 12) engaged in the exportation of cacao beans and 13 which export semiprocessed chocolate products (Table 13). Some companies perform both functions but under different names.

The grinding capacity of the industry, including material used internally as well as exported, is far greater than needed to handle the cacao crop. Grinding capacity is given in Table 14. If the figure of 22.6 metric tons per hour is multiplied by 250 work days per year, times 3 eight-hour shifts, the annual grinding capacity is seen to be 135,600 metric tons. This would require almost twice the amount of cacao beans now being produced.

The semiprocessing industry has been made very attractive to investors. While a 25% ad valorem tax is levied on exported cacao beans, the semiprocessed material being exported is not taxed. In addition, the semiprocessing industry received a 15% subsidy until 1977 when this was reduced to 5%. The 5% subsidy continues at the present time.

Table 11. Exportations of Cacao from Ecuador[1/].

	Metric tons
Cacao beans	15,576
Semiprocessed chocolate	57,619
Total	73,195[2/]

1/ Based on figures from Programa Nacional del Cacao. Departamento Comercialización, agricultural year 1977-78.

2/ Cacao beans in storage not included. Also some processed material. This would raise total to about 75,000 metric tons.

Table 12. Exporters of Dried Cacao Beans from Ecuador[1/].

Prodexport

Productos de Exportación Café-Cacao C.A.

Marchán Internacional S.A.

Santa Fé Cia Ltda.

La Merced Cia Ltda.

Prodec

Productos Ecuatorianas Co. Ltda.

Compañía Agrícola Pechichal S.A.

Corporación de Exportadores Independientes del Ecuador

1/ Information from Programa Nacional del Cacao, Departamento Comercialización.

Table 13 . Exporters of Semiprocessed cacao products from Ecuador[1/].

Edeca S.A.
Cafiesa
Exportadora Salcedo (Salco)
Incacao
Inedeca
Cacaos del Ecuador Saci
Colcacao
Expelca
Elaborados Colombo Ecuatoriano
Caesa
Ritec
FGH
Manacoa

1/ Information from Programa Nacional del Cacao, Departamento Comercialización.

Table 14. Grinding capacity of Ecuadorean Cacao Industry 1/

Company	Metric tons per hour
La Universal	15
Inedeca	21
Salco	23
Procoa	10
Cafiesa	20
Incacao	20
Ere	10
Cacaos del Ecuador	20
Manacoa	10
Prodelca	10
Colcacao	10
Expelca	10
Caesa	25
Ritec	12
FGH	10
Total	226

1/ Information from Programa Nacional del Cacao, Departamento Comercialización.

A. The Quantity of Cacao Available

The industry is obviously concerned to find itself with such a large underutilized grinding capacity. For this reason it is interested in the improvement of yields and the establishment of new plantations. The improvement of yield is not an unreasonable goal. A fairly effective control of Monilia Pod Rot plus a few improvements in farm management could more than double the yield now obtained from the average cacao farm and this could provide the beans needed to supply the grinding capacity of the industry.

An association has been formed among eleven or twelve of the exporters of semiprocessed chocolate. This organization, the Asociación Ecuatoriana de Industrias de Cacao (ASEICA), has financed the establishment of Procacao, the industry's own extension organization, dedicated to the improvement of yield and quality and the expansion of the area planted to cacao. Because it includes such a large proportion of the industry, and seems to be growing, ASEICA has been called a cartel or monopoly by some.

B. The Question of Quality

In addition to its concern about the total amount of cacao being produced, the industry also worries about quality. The best that can be said about the quality of much of the cacao being brought into Guayaquil is that it isn't very good and should have received a good deal more work before leaving the farm. Good quality cacao is still to be found and exporters of beans to some of the very demanding buyers of Europe, who refuse to buy semiprocessed chocolate, are still able to locate good quality well fermented beans, but it is increasingly difficult.

The components of quality in cacao, aside from genetic makeup, include the degree of fermentation, size and weight of the bean (which are affected by the degree of ripeness), freedom from dirt and rubbish, freedom from moldy and insect-damaged beans, and moisture content. There has been a steady deterioration of quality, attibutable partly to the genetic makeup of the trees as well as to the manner in which the beans are handled after harvest.

The genetic problem is one not easily solved and will require a prolonged effort. The original cacao population of Ecuador consisted of the variety known as Cacao Nacional. This population was genetically uniform and the beans were large, plump, and of a very pale lavender color. The advent of Witches' Broom disease, to which Cacao Nacional is very susceptible, caused a trend towards the importation of Trinitario cacao and, later, the planting of hybrids containing Forastero genes. These admixtures have resulted in a serious decline in the amount of true Cacao Nacional.

Trinitario cacao, referred to in Ecuador as "Venezolano", is of good quality so that the country can still maintain a reputation for quality based on Trinitario. This is especially true if the Trinitario contains some Nacional. The best long-term expectation may be that a population may be developed containing Trinitario and Nacional genes, of high quality and more tolerant to Witches' Broom than pure Cacao Nacional.

The technique of fermentation has complicated the problem of quality in Ecuador. The amount of time required to achieve a satisfactory degree of fermentation varies directly with the amount of anthocyanin pigment in the bean. Thus, Cacao Nacional achieves a very effective fermentation in just 2-3 days in windrows on a bamboo patio. This is

the traditional method for fermenting Cacao Nacional and the production of Arriba Superior Summer Plantation Selected with 85% or more well fermented beans (see Table 15) presented no real problem. Trinitario cacao, however, having much darker beans, has traditionally been subjected to 5-7 days of fermentation in deep boxes with much stirring and shovelling. Forastero cacao, being darkest of all, is even more of a problem. Naturally, when the Ecuadorean farmers proceeded to ferment Trinitario cacao by the traditional Cacao Nacional method, the results were less than satisfactory.

Improved transportation and a reduction in the size of cacao plantations seem also to have contributed to a worsening in quality. Formerly, when the only method of transportation was by river launch, a cacao farmer would send a shipment of beans to his agent in Guayaquil by launch. The agent would then sell the cacao to an exporter. The quality of the shipment would be uniform, the reputation of the grower known, and high quality would be almost taken for granted. Farmers developed pride in the quality of their product.

Now, however, the situation is different. Middlemen in trucks traverse the roads in the cacao producing areas, buying up small lots of beans from small farmers, regardless of quality, with or without fermentation, and regardless of moisture content.

The price is docked for moisture content, of course. These lots of cacao are mixed and quantities of diseased and damaged beans may even be added to build up volume. Cacao, by this process, may pass through the hands of several middlemen before it reaches the manufacturer or exporter in Guayaquil. Under such a system there can be no pride of origin since the indentity of any particular lot of cacao is lost in being mixed with others by the middlemen. Since no premium price is paid for quality, there is no incentive to change and it is doubtful that a change could be effected in the face of the middlemen's activities.

Table 15. Asociacion Nacional de [illegible]

de Cacao ecuatoriano para Europa (Europ[illegible] Standard of qualities for Ecuadorean cocoa).

	A.S.S.P.S.	S.S.S.	A.S.S.	S.E.S.	A.S.E.	A.S.N.S.	A.S.N.
Cien pepas, pesan m/m (gramos) (Weight per hundred beans) (grammes)	135-140	130-135	120-125	120-125	105-110	120-125	110-115
Buena fermentación rojo-café (Cutting Brown fermented)	75%	65%	60%	35%	20%	50%	42%
Buena fermentación, ligeramente morado o gris-café (Slightly Violet-Gray/Brown fermented)	10%	10%	5%	15%	15%	10%	10%
Total buena fermentación (Total fermented beans)	85%	75%	65%	50%	35%	60%	52%
Morado (Violet)	10%	15%	20%	30%	25%	25%	25%
Pastoso-Pizarroso (Slaty)	5%	9%	12%	18%	30%	13%	18%
Defectuosos, mohosos o con insectos (Defective beans)	—	1%	3%	2%	10%	2%	5%

N. B. Los porcentajes arriba indicados son "aproximados" (Above percentages are "approximative").

Feb. 1962

SIGNIFICADO DE LA NOMENCLATURA DE LOS STANDARDS

A.S.S.P.S. = Arriba Superior Summer Plantation Selected

S.S.S. = Superior Summer Selected

A.S.S. = Arriba Superior Summer

S.E.S. = Superior Epoca Selected

A.S.E. = Arriba Superior Epoca

A.S.N.S. = Arriba Superior Navidad Selected

A.S.N. = Arriba Superior Navidad

The Programa Nacional del Cacao is preparing a project for the establishment of receiving centers for cacao to which the farmer would deliver his cacao instead of selling it to a passing middleman. The objective is to encourage the improvement of quality through better fermentation and drying and to eliminate, or at least reduce, some of the abuses caused by the middlemen.

V. FOREIGN ASSISTANCE

The cacao industry of Ecuador has received assistance from various donor agencies, including the Agency for International Development and its predecessor agencies, over a period of many years. Some of the more recent instances of foreign assistance are noted below.

A. Relation with Trinidad

INIAP had a working relationship with Trinidad during the period 1972-1975 for explorations in the search for new genetic material. This arrangement was financed in part by the American Cocoa Research Institute.

B. Relation with Brazil

INIAP has a mutual arrangement with CEPLAC, the cacao development organization in Bahia, Brazil, for the exchange of information, training of personnel and the conduct of expeditions in search of new genetic material.

C. Chocolate Manufacturers' Alliance, Great Britain

An arrangement is in the final stages of negotiation with the Chocolate Manufacturers' Alliance for aid in the financing of expeditions in the Amazon Valley in search of new genetic material. CEPLAC will be cooperating in this activity and Trinidad may be interested in participating.

D. U.S. Agency for International Development

AID loan 518-L-033 for agricultural diversification included funds for loans to farmers for annual oil crops and cacao. The bulk of the financing was for annual oil crops. This loan has been rolled over,

however, and numerous loans have been made to cacao farmers. These loans are being supervised by the Programa Nacional del Cacao.

E. British Ministry of Overseas Development

A team from the British Ministry of Overseas Development has been lending valuable assistance during the past four years, primarily in the areas of horticulture and plant physiology and the establishment of a physiology laboratory. The MOD now proposes to assist INIAP's future cacao research with the following technical personnel[1/].

One soil microbiologist to study the soil rhizosphere with regard to possible root disease problems as well as problems arising from traditional malpractice in fertilizer placement.

Two physiologists for ecosystem analysis, to study water stress, light, and nutritional problems of the cacao tree.

One agronomist to work on the problems of shade adjustment, fertilizer application, micronutrients, weed control, spacing, etc.

Two associate research officers, to assist the above.

One extension specialist, to assist in organizing the delivery of information to the farmers.

1/ A report on some aspects of cocoa research in Ecuador with recommendations for both short and longer term policies aimed at increasing production and developing the industry. J. T. Legg, J. B. D. Robinson and K. J. Trehorne. MOD, London, January 1979.

VI. RECOMENDATIONS

A. Organization and Management

1. Personnel Systems

Cristicism is heard among INIAP staff that the personnel system of the organization operates against the retention of the better trained, older and more experienced personnel.

This is because a ceiling is imposed to promotion and salary increases for personnel who do not assume administrative responsibility. Under such circumstances, and since the number of management positions is limited, a research worker not fortunate enough to move into one of the few posts in management can look forward to a restricted professional future. This would be especially frustrating to those research officers who are not interested in entering management and who would prefer to continue in their professional specialties.

INIAP management contends, however, that it is not the policy of the Institute to make promotion in grade and salary contingent upon the assumption of administrative responsibility and that some scientists are now actually receiving higher salaries than the directors of the experiment stations where they are employed.

Because of its importance to personnel relations and to the efficiency of the Institute, this complaint should be investigated and measures should be taken to correct whatever injustices may exist.

2. Cacao Department

The assorted cacao research personnel, at present scattered through several departments at Pichilingue, should be organized as a single Cacao Department. This commodity orientation has worked well for oil palm research and may, perhaps, be recommendable for all the major commodities. This type of organization will permit full time dedication to cacao research and better coordination of effort as well as esprit de corps.

3. Coordination of Research and Extension

A committee should be named, consisting of the Director of the Programa Nacional del Cacao, the Manager of Procacao and the Head of the Cacao Department of Pichilingue, to coordinate cacao extension and information activities. Additional personnel could be invited to participate as needed. This committee should meet on a regularly scheduled basis, possibly every six weeks, to consider the release of new information, to plan extension and information campaigns, to evaluate and determine action to be taken to solve new problems, and to plan training activities for extension agents.

Recommendations made to farmers must be based upon the results of research and no recommendation should be made without the approval of Pichilingue. A committee such as that suggested here should provide the coordination necessary to avoid the dissemination of misinformation and should also provide immediate access of the Cacao Department to new problems arising in the field.

B. Research

1 Control of Witches' Broom Disease

Witches' Broom disease, caused by Crinipellis perniciosa, is still the great unsolved problem of cacao. The evolution of new races of Cr. perniciosa, to which the Scavina and other material selected for resistance are highly susceptible, brings out the need for a shifting of emphasis and priorities in cacao research. It is obvious that varietal resistance to Witches' Broom is not the panacea that it once appeared to be. If we assume that the Scavina lines are resistant to Race I of Cr. perniciosa but were demolished by Race II, we have also to assume that any new material found to be resistant to Races I and II would eventually succumb to Race III.

Great confidence should not, therefore, be placed in resistance as a control for Witches' Broom. It is always desirable, of course, to have as high a level of resistance or tolerance as possible and the search for superior genetic material, in disease resistance or tolerance, yield, quality and vigor should continue. Emphasis in disease control research should, however, be shifted to a search for a method of controlling the disease in the field, and this should receive the highest priority (see Sect. VII). This is, of course, a long term goal. For the short term, Pichilingue already has a number of recommendations of management practices which will enable the farmer to live with the disease and still obtain a fairly good harvest.

The work in progress using spray oil emulsions to inhibit sporophore formation should be expanded to include various fungicidal chemicals in the emulsions. Application techniques

should also be investigated, including high, low, and medium volume spraying methods.

2. Estimation of the effect on the cacao tree of vegetative Witches' Brooms

The vegetative witches' broom formed as a result of infection with Cr. perniciosa represents a loss to the cacao tree which is not easy to estimate. An approximation may be made, however, if one were to obtain an average figure for the dry weight and number of leaves of a normal new shoot. This would represent the normal photosynthetic area and tissue lost to the plant in the formation of a broom. An average dry weight of broom would provide the total tissue and energy lost. The difference between the two would represent the extra energy expended by the tree to form the broom. The amounts of water, carbohydrates and minerals utilized can be calculated.

In addition, it would be interesting to determine if the cacao tree derives even transitory benefit from the photosynthesis carried out by the witches' broom during its short life or if this is all used in the growth of the broom.

3. Possibility of Separating the Original Scavina-resistant Race of Cr. perniciosa

Seedling trees of Scavina origin were observed on a farm near the city of Esmeraldas which showed little or no Witches' Broom infection although surrounded by ICS and EET clones heavily infected with the disease. This suggests that only the original race of Cr. perniciosa, to which the Scavina selections were resistant, exists on this rather isolated farm. The collection and maintenance of this isolate of the fungus could prove to be valuable for possible future research.

4. Control of Monilia and Other Pod Rots

Work on the field control of pod rots should be intensified. It is evident (see Sect. II-A-1) that certain fungicides effect a substantial reduction in losses to pod rots - even having some effect on Witches' Broom. Losses still remain high, however, and further work is required in the evaluation of chemicals, perhaps the inclusion of more than one chemical in a spray, dosages, application techniques and equipment.

5. Exploration in Search of New Genetic Material

While genetic resistance as a means of controlling Witches' Broom must be deemphasized, the collection of cacao germ plasm should continue. In this activity, resistance to Witches' Broom should be only one of several characters being sought, the others including seed color size and shape, pod value, yield potential, vigor, season of bearing. The Amazon basin is the center of origin of cacao and doubtless still contains much valuable material which should be collected and established at experiment stations. INIAP contemplates the use of its new Napo Station for this purpose.

Since the Amazon region is rapidly being opened to colonization and tourism, the collection of this material should be speeded as much as possible before it is destroyed.

6. Selection of Superior Planting Material

The large collection of clones at Pichilingue, collected over a period of many years from all parts of the country, should be reexamined with the objective of selecting self-pollinated material or certain hybrids which are better than average in disease tolerance yield potential and quality. Such selections could then be used as the basis for populations of seedlings to be released to farmers.

There should be sufficient information at Pichilingue, accumulated over the years, to identify such superior material which can be utilized directly as seedling progeny of clones or certain hybrids. Starting from such a base of existing information and already available parent stocks, the multiplication of material for release should be accomplished in a relatively short time.

Simultaneously, farmers should be advised to plant seedlings derived from outstanding trees identified on their own plantations. These should be examined by extension and/or research people and the basis for making the selection determined. Yield potential, quality and vigor as well as above average disease tolerance should be included in the selection criteria. Any tree of known or suspected Ceratocystis-susceptible ancestry should, of course, be avoided.

7. Irrigation

Available evidence indicates that cacao planted anywhere on the Ecuadorean litoral-except the rainiest areas will, or should, benefit from irrigation during the dry season. There is a dearth of research information on irrigation of cacao and, in view of the interest in "zonification", which implies a shift of the crop to drier areas, research on the irrigation of cacao becomes of great importance. There will be increasing demand for information on the quantity and timing of water applications, salinity problems, types of irrigation systems, etc. Pichilingue should establish irrigation trials on farms distributed so as to cover a range of dry season drought conditions. A comparison of the effect of surface vs. overhead irrigation on the incidence of diseases would be interesting and useful.

8. Fertilizer Trials and Soil Test Laboratory

Fertilizer trials should also be conducted on farms which span a range of climatic conditions. It would be useful for these to be carried out in conjuction with irrigation trials. The purpose should be to enable the farmer to obtain an economical and realistic fertilizer recommendation when he sends soil samples to the soil test laboratory at Boliche.

It appears that relatively few cacao farmers are aware of the existence of the soil test laboratory at Boliche and even fewer - make use of it. An advertising campaign, making use of radio, television, leaflets and farmers' meetings should be mounted to inform the cacao farmer (and others as well) that this service is available.

It has been demonstrated that the application of fertilizer in a ring around the tree is harmful (see Sect. II-C-3). Application techniques should be investigated, including foliage sprays and injection into the soil. The timing of applications and application equipment also require study.

C. Extension

1. Planting Material

In the absence of planting material highly resistant to Witches' Broom, the policy of living with the disease and using the best available planting material must be adopted. Selected seedlings recommended by Pichilingue should be used. Also, farmers should be advised to use seedlings derived from superior trees on their own property. Such selections should be carefully reviewed and the bases for making the selection determined. Yield potential, quality, vigor and above average disease tolerance should be among the selection criteria.

The planting of clonal cacao should not be recommended. The establishment of a plantation with this material is much more costly than if seedlings are used. Also, past experience with clonal cacao in Ecuador has demonstrated the vulnerability of such genetically uniform stands to attack by diseases to which they happen to be susceptible.

The use of seedling cacao, plus management practices recommended by Pichilingue which are calculated to make it possible to obtain reasonably good yields in spite of disease, should be recommended to farmers as the best possible proceedure until the disease problem has been solved.

2. Demonstration Plots and "Package of Practices"

The demonstration plots now being organized by the Programa Nacional del Cacao should include a complete "package of practices" based on the latest available research information. The following is a suggested set of practices which may be recommended to farmers as well as used in a program of demonstrations:

a) Establish a population of 1100-1300 trees per hectare, using selected seedlings as recommended by Pichilingue.

b) Eliminate entirely the pruning of cacao trees, except for the removal of chupones and damaged branches.

c) Eliminate, or drastically reduce, shade over the cacao plantation.

d) Encourage the closing of the canopy of cacao trees (see items a and b above) and fill in gaps in the stand. This will reduce or eliminate the cost of weed control and will result in the formation of a thick mulch of organic matter on the ground. This is important for the protection of roots, conservation of moisture, impro

vement of the soil and provides breeding places for the midges responsible for pollination (see Sects. II-B and II-C-3).

e) Use fertilizer in amounts and analyses determined by soil analyses performed by the Soil Test Laboratory at Boliche. Apply the fertilizer on the basis of kgs/ha. rather than gms/tree and broadcast down the row rather than in a band around each tree (see Sect. II-C-3).

f) Eliminate weed competition by herbicide spraying. In a plantation with closed canopy the need for this should shortly be reduced to occasional spot spraying.

g) Practice hand pollination combined with fungicide spraying in accordance with Pichilingue recommendations (see Sect. II-A-2).

h) Harvest at short intervals, preferably 7-10 days. Harvest mature pods only in order to improve quality and reduce losses to disease. Remove diseased pods from the trees as part of the harvest operation and leave these on the ground.

i) Open the pods immediately after harvesting and leave them on the ground at the point where harvested, removing only the seeds from the plantation. Do not concentrate pods at collection points for opening. The pods add to the organic matter and nutrient content of the soil as well as providing important breeding places for the midges responsable for pollination. For these reasons they should remain distributed throughout the plantation (see Sects. II-B and II-C-3).

j) Ferment Trinitario (Venezolano) cacao four days in perforated, 4-inch Rohan trays.

3. Fermentation

Poor fermentation technique, or the failure to ferment at all, have contributed to the decline in the quality of Ecuadorean cacao. Since Ecuadorean cacao is now predominantly Trinitario, it should be fermented in a manner suitable to Trinitario cacao. What Cacao Nacional remains may be given the traditional Nacional treatment, but that is inadequate for Trinitario cacao (see Sect. IV-B).

The simplest way to ferment Trinitario cacao is four days in 4-inch Rohan trays. The trays have spaces of about 1/4 in between the bottom slats and augur holes spaced along all sides to promote aeration. The trays are filled, stacked, insulated with a tray of sawdust top and bottom, draped with burlap to prevent chilling at night and left for four days. A few trials should result in a refinement of the proceedure which will produce an excellent fermentation consistently under local conditions.

The Programa Nacional del Cacao is developing a project for the establishment of cacao receiving stations in the various zones. This will have to be combined with a campaign to promote better fermentation and drying and the use of Rohan trays could be a critical element of such a campaign.

4. The Provision of Necessary Inputs

Procacao plans to use its Departamento Comercial to purchase fungicides, fertilizers and other inputs in quantity for resale to farmers. Such activity needs, of course, to be closely coordinated with the Cacao Department at Pichilingue as well as with the Programa Nacional del Cacao.

Similarly, in order for the Programa Nacional del Cacao to mount a fermentation campaign based on the use of Rohan trays, large numbers of these trays will be required. The Departamento Comercial of Procacao could contract for the construction of these in quantity and sell them to farmers at close to cost price as a device for promoting their use.

VII. SUGGESTED AREA FOR PARTICIPATION BY AID, POSSIBLY ASSISTED BY OTHER DONORS

Although the staff of the Pichilingue Experiment Station includes a number of competent and dedicated research personnel, the problems affecting cacao in Ecuador are too numerous and too complicated to be effectively handled without outside assistance.

The present as well as proposed British programs are concentrated on the horticulture of the cacao tree and not on Witches' Broom or other major disease problems. There would, therefore, be no conflict whatever between the British effort and a U. S. sponsored project to solve the problem of Witches' Broom. In fact, the two activities would complement each other and provide a well-rounded total endeavor.

Witches' Broom, caused by the fungus Crinipellis perniciosa, is the most serious disease of cacao. Its range includes Ecuador, Peru, the Amazon valley of Brazil, Surinam, Guyana, Colombia, Venezuela, Trinidad and Tobago, Granada and, of course, it may be expected to appear in other countries without warning.

Black Pod, caused by Phytophthora palmivora, is usually described as the most serious disease of cacao because, in addition to being very destructive, it is the most widespread. Monilia Pod Rot, caused by Monilia roreri, is an equally destructive disease, and more severe than Black Pod under Ecuadorean conditions, but is limited in its distribution to a range slightly less ample than that of Witches' Broom. Monilia was found for the first time in Costa Rica in 1978, however, thus indicating its tendency to continue to spread. Black Pod and Monilia can both be controlled by spraying with fungicides, but for Witches' Broom in Ecuador there is no known control at present.

The Witches' Broom fungus attacks the rapidly growing meristematic tissues of the new vegetative shoots, fruit cushions and pods. In addition,

therefore, to the pods which are destroyed by direct attack, there is a further, severe reduction in productivity caused by the fruit cushion infections and the loss of leaves and shoots resulting from the production of useless brooms. These latter effects are difficult to measure. Since merismatic tissues in rapid expansion are difficult to protect with fungicidal sprays, this approach has not been notably successful and virtually all efforts to control Witches' Broom have been directed towards the development of resistant varieties. Selection and breeding directed towards this end have been carried on over a period of many years in Ecuador and Trinidad with very encouraging results. After a promising start, however, the resistant varieties ceased to be resistant in Ecuador, apparently because of the appearance of a new strain of the pathogen. The resistant varieties continue to be resistant in other countries but there is no assurance that the same thing won't happen abroad as happened in Ecuador as a result of a new local strain of the fungus or one imported from Ecuador.

Because of the severity of Witches' Broom in Ecuador, INIAP's Tropical Experiment Station, Pichilingue, has been designated as a center for research on this disease by the Interamerican Committee on Cacao Diseases. A research project of the sort required to solve the problem of Witches' Broom is, however, much more than INIAP could undertake with existing resources and personnel. Rather than to continue with the piecemeal approach which has prevailed until now, it would seem more efficient to mount a research program designed to study the basic physiology of the disease with the objective thus to detect those points in the life cycles of the pathogen and host at which control measures may be most effectively applied.

The best approach would seem to be a combined effort between INIAP and a U.S. university. The University of Florida is suggested as a likely candidate because, in addition to having competence and good repute in the fields required, it also has had considerable Latin American experience, including

previous contact with Witches' Broom. At least three Ecuadorean graduate students have worked at Gainesville on thesis problems related to Witches' Broom.

A. Scope of Work

It is contemplated that certain phases of the work would be carried out in Florida and others in Ecuador. Provision would be made for travel of Florida personnel to Ecuador for periods of time consistent with the nature of the work and for the stationing of Florida graduate students in Ecuador and the sending of Ecuadorean graduate students to Florida. The suggested scope of the project is as follows:

1. Studies on the physiology of Witches' Broom of cacao and Crinipellis perniciosa.

The study of the causes of the initiation of the growth of the witches' broom, its rapid expansion, followed by its sudden death, has not been undertaken and should prove a fruitful field for study by plant physiologists. An understanding of these phenomena could provide guidance towards the discovery of a control for the disease, possibly based on the timely interruption of a process vital to the formation of the broom.

This study would have to be accompanied by a similar investigation designed to examine the problem from the point of view of the fungus; factors favorable or unfavorable to its penetration of the host and the establishment of the host - parasite relationship, its activities within the green broom, its survival in a dormant state in the dead broom, and its revival and sporulation upon the advent of the rains. The understanding of this entire process should disclose possibilities for the interruption of the cycle and the control of the disease in the field.

These studies should also result in a solution to the problem of producing sporophores of the fungus on artificial culture media, something not thus far accomplished but important for the testing of plants for resistance to specific strains of the fungus.

2. The identification of races or strains of Crinipellis perniciosa and their pathogenicity for cacao and related species of Theobroma[1/]

Collections of Crinipellis perniciosa on dead brooms would have to be made in Trinidad, Colombia, Brazil and other countries as well as in several locations in Ecuador in order to accumulate as many races as possible. Inoculation studies would be conducted on several clones of cacao, such as the Scavina and Silecia clones and others formerly resistant in Ecuador, as well as numbered clones of Cacao Nacional, Criollo, Trinitario and Forastero cacao and related species of Theobroma.

These studies may provide information on;

a. A means of identifying and distinguishing among strains or races of C. perniciosa on the basis of differential pathogenicity.

b. The mechanism of resistance of cacao to C. perniciosa

Because of the risk involved in bringing new races of the fungus into a cacao-producing country, the work involving races of C. perniciosa, except for their collection, would have to be done under laboratory and greenhouse conditions in Florida and a target of these investigations might be the establishment in Florida of a international center for the testing of cacao germ plasm for resistance to races of C. perniciosa.

3. The field control of Witches' Broom, Monilia Pod Rot and Black Pod.

This area of investigation would include the field testing of cultural practices and chemical applications for the control of the three diseases with the objective of developing the most effective and economical set of recommendations. This would involve the field testing of fungicides and spray equipment, the development of spraying techniques, and the evolution of spray application schedules based on climatic conditions and cultural practices designed to avoid infection, i.e. crop concentration by hand-pollination.

Promising leads developed during the physiological investigations referred to under point 1 of this program would be subjected to field testing under this part of the program.

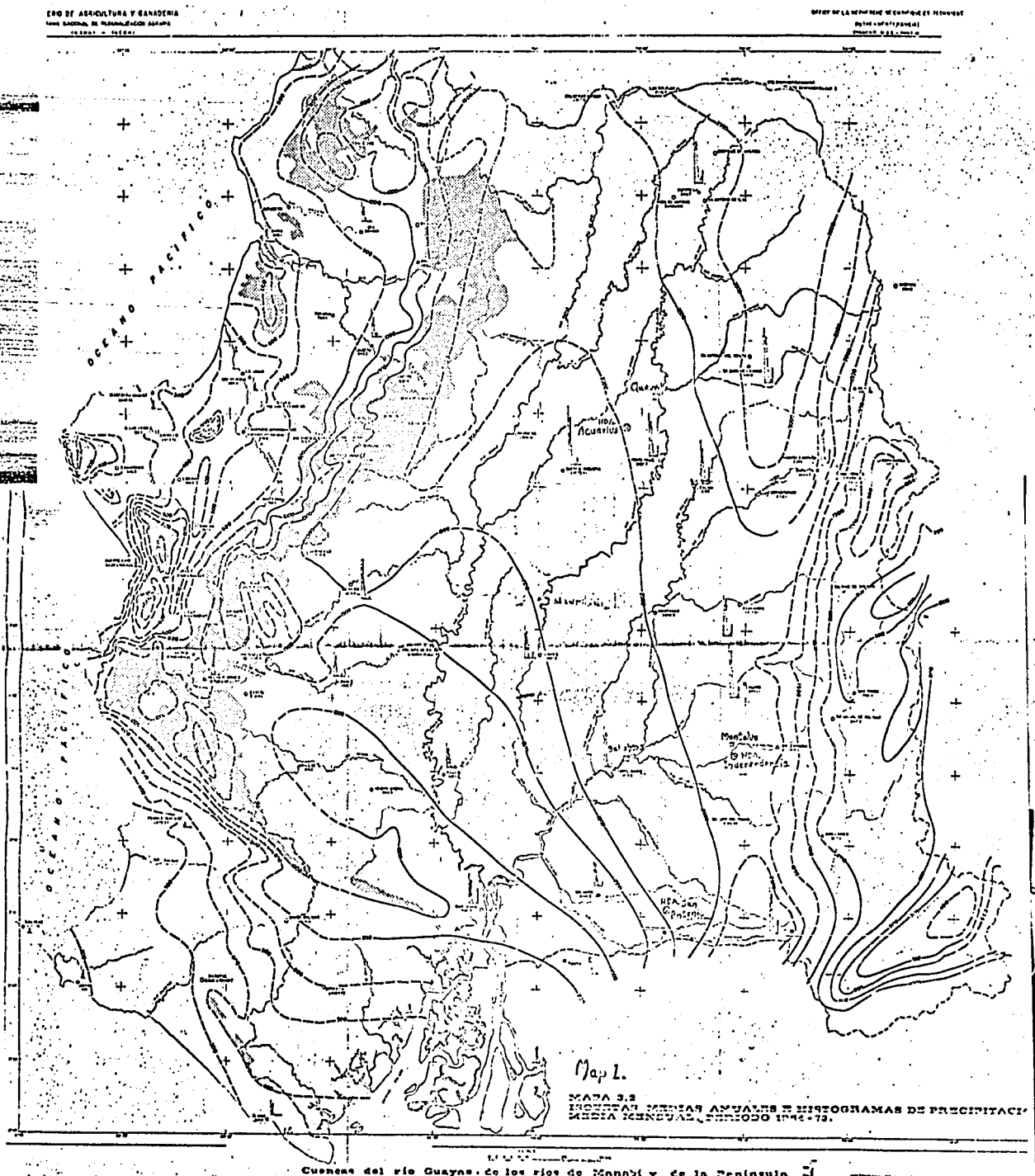
In addition, this aspect of the research would have to include epidemiological and climatological studies and the consideration of the possibility of shifting cacao production to drier areas which appear to be less severely affected by these diseases than are the more traditional cacao zones. This would imply the need for irrigation to offset a prolonged dry season.

B. Foreign Personnel Required

The following requirements in technical personnel from a U. S. university are anticipated:

1. One plant physiologist-biochemist - Witches' Broom physiology
2. One fungus physiologist-biochemist- physiology of C. perniciosa
3. One plant pathologist - mechanism of resistance and races of the fungus
4. One plant pathologist - field control of diseases

This personnel would consist of experienced staff of the university. In addition, several U. S. graduate students would work, both in Florida and Ecuador, on various phases of the research and Ecuadorean students and staff would receive graduate training both in Ecuador and in Florida.



MAPA 3.3
ISOYETAS MEDIAS ANUALES E HIETOGRAMAS DE PRECIPITACI
MEDIA MENSUAL, PERIODO 1946-73.

REDUCCION DEL ORIGINAL 50%