COCOA RESEARCH INSTITUTE

Annual Report
1972-73

1975

COCOA RESEARCH INSTITUTE

Annual Report 1972-73

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*On study leave.

GENERAL REPORT

ADMINISTRATION

Staff matters

Scholarships

S. T. Ampofo was awarded a Commonwealth Scholarship to do his doctorate degree at the University College of North Wales. He left Ghana on 16th September, 1972. M. O. Abrokwa returned from Netherlands on 3rd August, 1972, where he did a two-year course in tropical agriculture under the Netherlands Fellowship Programme for Technical Co-operation.

Arrivals

The following joined the Institute on the dates against their names:

S. K. Firempong	—	21st August, 1972
L. A. O. Lamptey	—	1st September, 1972
N. A. K. Akotoye	—	16th October, 1972
Dr. P. L. White	—	7th November, 1972
M. R. Appiah	—	20th December, 1972
P. I. K. Boahene	—	18th January, 1973

Departures

Three members of the British Research Team left at the end of their contracts. They are D. F. Edwards on 19th May, 1972, D. A. Ll. Brown on 17th July, 1972 and Dr. H. A. C. Evans on 7th February, 1973.

G. E. A. Nuama who was on secondment to the Volta River Authority formally transferred to the Authority on 2nd January, 1973. A. K. Adri and B. D. Boateng resigned to continue their education at the University of Science and Technology, Kumasi. E. A. Amfo resigned on 1st December, 1972 to join the Cocoa Marketing Board. A. D. Mensah retired on 1st September, 1972. He joined the Institute on 1st September, 1938.

Promotions

M. Larbi-Addo and Edward Donkor were promoted to Senior Technical Officer Grade II. E. J. A. Ofori, E. N. Abbeo and M. O. Abrokwa were promoted to Senior Technical Officer Grade I. A. A. Buadu to Chief Technician; E. K. Tetteh to Chief Library Officer; N. K. Danquah to Senior Accounting Assistant, P. K. Amable to Stores Superintendent and Mark Owusu to Senior Works Superintendent.

Buildings and land

Both the new laboratory and library buildings were completed and moved into during the year.

The Afosu sub-station is now two years old. A further 23 acres near the town has been acquired to be developed into offices, workshops and residential area. Twenty-four thousand cedis was paid as compensation for crops and ₵19,000.00 for the land.

Conferences

Dr. T. Y. Kaufman attended the West African Cocoa Entomologists' Conference in Nigeria from 21st to 24th June, 1972. E. Owusu-Manu participated in the 14th International Congress of Entomology at Canberra from 22nd to 30th August, 1972. He also visited Papua and New Guinea. W. V. Hutcheon attended the Seminar on Environmental Measurements and Ecology at Itabuna from 12th to 24th June, 1972.

Change of administration

The Institute was absorbed into the Ghana Cocoa Marketing Board on 1st October, 1972 by the enactment of the National Redemption Council Decree No. 188.

Re-designation of Divisions

The Biochemistry section of the Chemistry Division was merged with Plant Physiology Division to form the Plant Physiology and Biochemistry Division on 2nd January, 1973. The Chemistry Division which now incorporates the Radioisotope Section is now the Soil Science Division.

PLANTATION MANAGEMENT

(E. MANU-BOAFO)

Land usage

Four new plots (B9, F6, J7 and K5) totalling 36.50 acres were developed during the year. Plots A15, A17, B6/7 and B8 totalling 10.20 acres were planted for virus trials. An extension of 4.40 acres to J × 1 was planted with coconut seedlings for the proposed "Coconut as Shade for Cocoa" Trial.

Firewood plantation of 5.00 acres was planted at the Catchment area with stumped seedlings of *Cassia Siamea*. It is proposed to extend this plot in future.

Weather and cropping

Total rainfall was 45.05 inches as compared with 69.04 inches for the previous year. Rainfall was evenly distributed over the first three months of the rainy season but very low for July, September and November. The weather was generally dry and hot, and the Beira which is the only source of drinking water dried out as early as December. Meteorological data for the period is shown in Table 1.

There was severe defoliation of cocoa and some died of drought. By the end of March most plants had not recovered from the effect of the drought and there were no signs of cropping by then.

The total crop was 94,663 lbs. dried cocoa. This was 34,483 lbs. or 36.42% more than the previous year. Table 2 shows the monthly yield for the past ten years.

Pests and diseases

There were occasional outbreaks of capsid damage particularly on young cocoa, but effective control was obtained by routine monthly application of insecticides.

Seasonal attacks by leaf-eaters were also controlled by spraying. *Bathycoelia* and other minor "pod insects" were present throughout the season but their attacks had an insignificant effect on the crop.

Because of the dry weather, only 12.6% loss was recorded for pod diseases. This was 6.1% lower than the figure for the previous year.

Cocoa crop forecast

Assessment is in the 5th year. Figures for the various plots are shown in Tables 3–5.

Cocoa nursery (Table 6)

Fifteen thousand, five hundred and sixty-eight seedlings were raised during the year.

TABLE 1

Meteorological data—Tafo. Figures for 1972 *with* 35-*year mean*

		Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Mean maximum shade temperature in °F	35-year mean	88.2	90.6	90.3	89.8	88.4	84.8	82.2	81.7	83.9	86.1	88.2	88.2
	1972	89.3	91.4	90.1	89.7	88.8	85.1	83.7	82.5	85.0	88.0	90.1	89.4
Mean minimum shade temperature in °F	35-year mean	68.2	69.8	70.6	70.9	71.0	71.0	70.6	69.8	70.8	70.9	70.2	69.6
	1972	68.2	69.7	70.0	70.8	71.9	70.8	72.0	70.4	71.4	72.1	71.4	70.2
Mean relative humidity (0900 G.M.T.)	35-year mean	85.9	83.0	81.6	80.6	81.8	84.9	86.0	86.0	85.2	83.3	81.0	84.0
	1972	86.4	83.7	81.7	80.3	84.9	84.1	86.6	86.6	86.0	94.3	81.6	85.2
Mean relative humidity (1500 G.M.T.)	35-year mean	56.2	53.7	58.0	62.7	67.5	74.5	74.3	73.2	72.1	70.6	65.2	61.4
	1972	58.5	55.9	61.5	65.4	69.0	76.8	76.5	73.2	73.7	73.8	63.8	63.2
Rainfall in inches	35-year mean	1.56	3.18	5.77	6.10	7.23	9.53	6.01	3.24	6.35	8.40	3.69	2.42
	1972	3.76	2.34	6.35	6.35	7.36	5.40	2.38	2.84	3.09	5.55	0.52	2.54
Number of wet days	35-year mean	4.2	7.0	12.3	11.5	14.5	19.3	15.3	13.9	17.5	18.5	10.7	6.2
	1972	3	11	12	14	19	19	15	14	15	19	8	7
Hours of sunshine*	30-year mean	198.2	178.9	194.2	193.9	185.3	118.4	85.1	78.9	93.5	160.3	200.4	206.9
	1972	221.5	209.3	199.4	205.4	209.1	143.5	93.1	108.0	115.6	183.0	212.1	170.4
Radiation in gr. cal/cm²/day	4-year mean	339.8	389.5	426.0	420.5	421.5	369.0	313.2	292.8	323.0	391.0	404.0	340.0
	1972	333	377	394	392	363	320	244	281	298	376	377	297

*Records used from complete calendar years only.

TABLE 1—*contd.*

Annual rainfall and sunshine 1938–72

	1938–58 *mean*	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	35-year *mean*
Rainfall in inches	62.73	68.13	77.27	52.68	62.00	80.07	58.24	80.09	63.16	52.94	87.32	58.63	46.35	69.23	48.48	63.49
	1939–58 *mean*															30-year *mean*
Sunshine in hours	1,852.4	1,849	1,880	1,814	1,858	1,941	1,816	*	*	*	*	2,138	2,186	2,224	2,070	1,894

*Records incomplete

Monthly rainfall, number of wet days, sunshine and radiation 1972–73 *season*

	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	Total
Rainfall in inches	6.35	7.36	5.40	2.38	2.84	3.09	5.55	0.52	2.54	0.62	2.92	5.92	45.49
Number of wet days	14	19	19	15	14	15	19	8	7	4	11	10	155
Sunshine in hours	205.4	209.1	143.5	93.1	108.0	115.6	183.0	212.1	170.4	201.9	182.2	137.1	1,961.4
Radiation in gr. cal/cm²/day	392	363	320	244	281	298	376	377	297	337	369	386	

TABLE 2

Monthly crop yield (dry beans) and corresponding acreage at Tafo for 1963–64 through 1972–73 seasons

Month	1963–64 lbs.	1963–64 %	1964–65 lbs.	1964–65 %	1965–66 lbs.	1965–66 %	1966–67 lbs.	1966–67 %	1967–68 lbs.	1967–68 %	1968–69 lbs.	1968–69 %	1969–70 lbs.	1969–70 %	1970–71 lbs.	1970–71 %	1971–72 lbs.	1971–72 %	1972–73 lbs.	1972–73 %
April	1,310	0.8	1,030	0.4	1,093	0.6	265	0.2	—	—	1,226	1.6	771	0.9	155	0.1	1,878	3.1	908	0.9
May	6,591	4.0	2,048	0.8	1,666	0.9	1,423	1.2	1,216	0.8	1,343	1.7	5,740	6.5	1,980	1.6	3,868	6.4	1,645	1.7
June	9,347	5.7	3,526	1.4	3,891	2.2	5,775	4.6	1,311	0.9	6,836	8.8	9,771	11.0	4,259	3.4	2,275	3.8	3,994	4.2
July	5,481	3.3	4,942	2.0	6,130	3.4	6,247	5.0	3,208	2.2	8,540	11.0	3,374	3.8	6,943	5.6	1,358	2.3	4,468	4.8
August	7,753	4.7	7,114	2.8	10,003	5.6	5,795	4.7	14,355	9.7	4,962	6.4	3,601	4.1	2,373	1.9	3,567	5.9	10,639	11.2
September	5,383	3.3	25,137	10.0	26,459	14.7	19,296	15.5	26,310	17.8	6,661	8.6	10,718	12.1	13,298	10.6	9,587	15.9	16,548	17.5
October	32,475	19.7	56,396	22.5	53,459	29.8	31,969	25.7	29,678	20.1	17,487	22.5	17,965	20.3	34,960	28.0	9,343	15.5	22,112	23.4
November	39,665	24.1	96,024	38.3	46,797	26.1	37,491	30.2	26,101	17.6	12,156	15.7	13,655	15.4	30,646	24.5	9,811	16.3	18,535	19.6
December	34,279	20.8	47,225	18.8	23,120	12.9	12,273	9.9	21,387	14.9	12,776	16.4	16,656	18.8	17,817	14.2	10,105	16.8	8,788	9.3
January	20,400	12.4	6,141	2.4	6,678	3.7	3,411	2.8	22,122	14.9	5,186	6.7	5,818	6.6	10,095	8.1	7,129	11.9	6,451	6.8
February	1,880	1.1	890	0.4	183	0.1	253	0.2	1,884	1.3	423	0.5	397	0.5	2,524	2.0	975	1.6	464	0.5
March	131	0.1	471	0.2	12	—	53	—	272	0.2	55	0.1	—	—	18	—	284	0.5	111	0.1
Total	164,697	—	250,944	—	179,491	—	124,251	—	147,844	—	77,651	—	88,466	—	125,068	—	60,180	—	94,663	—

	1963–64	1964–65	1965–66	1966–67	1967–68	1968–69	1969–70	1970–71	1971–72	1972–73
Acreage of bearing cocoa	401.87	396.87	362.91	298.00	266.62	213.19	273.77	246.67	221.2	203.00

TABLE 3

Cocoa crop forecast—1972–73

Plot P2 *Amelonado* (100 *sample trees*)—*planted* 1950 *at* 8 *ft.* × 8 *ft.*

	Cherelles												Mature								
	0″–1″				1″–3″				Over 3″				Healthy				Diseased				Total mature pods
Month	1969 70	1970 71	1971 72	1972 73	1969 70	1970 71	1971 72	1972 73	1969 70	1970 71	1971 72	1972 73	1969 70	1970 71	1971 72	1972 73	1969 70	1970 71	1971 72	1972 73	1972–73
1972																					
April	248	48	124	314	165	132	169	206	70	214	69	159	68	171	37	90	5	8	19	12	102
May	352	—	247	194	189	116	228	162	130	115	194	325	90	491	133	205	4	124	5	5	210
June	50	152	166	101	178	229	162	82	100	180	171	254	135	562	393	470	10	117	29	21	491
July	25	115	122	63	5	77	37	83	89	149	81	153	138	595	629	383	18	74	58	20	403
Aug.	17	81	108	36	11	50	83	54	109	70	72	72	340	811	242	240	47	56	20	53	293
Sept.	8	39	24	48	20	32	14	38	105	54	25	31	443	795	185	175	31	65	21	9	184
Oct.	16	22	11	4	45	20	6	17	120	23	17	57	200	294	194	131	3	20	10	11	142
Nov.	9	2	1	1	50	3	—	4	80	1	4	27	208	90	202	130	19	15	13	12	142
Dec.	24	—	—	—	54	1	—	4	75	5	—	—	129	56	152	59	29	7	6	1	60
1973																					
Jan.	109	—	—	—	58	—	6	—	65	2	—	1	112	30	38	2	11	1	5	4	6
Feb.	97	8	53	19	88	2	10	1	74	—	5	4	92	37	16	3	—	19	54	—	3
March	101	24	109	14	95	9	54	3	64	12	12	4	78	17	9	6	—	9	7	—	6
Total	1,056	491	965	794	958	671	769	654	1,089	825	650	1,087	2,033	3,949	2,230	1,894	117	515	247	148	2,042

TABLE 4

Cocoa crop forecast 1972–73

Plot P9 Amazon (100 *sample trees*)—*planted* 1957 *at* 12 *ft.* × 12 *ft.*

Month	Cherelles 0"–1" 1969–70	0"–1" 1970–71	0"–1" 1971–72	0"–1" 1972–73	1"–3" 1969–70	1"–3" 1970–71	1"–3" 1971–72	1"–3" 1972–73	Over 3" 1969–70	Over 3" 1970–71	Over 3" 1971–72	Over 3" 1972–73	Mature Healthy 1969–70	Healthy 1970–71	Healthy 1971–72	Healthy 1972–73	Diseased 1969–70	Diseased 1970–71	Diseased 1971–72	Diseased 1972–73	Total mature pods 1972–73
1972																					
April	3	10	161	226	9	93	66	121	38	347	29	86	156	357	149	17	1	3	5	6	23
May	5	69	181	341	7	53	216	215	39	118	204	305	160	563	207	74	—	80	8	5	79
June	10	107	219	251	5	99	205	180	39	225	217	340	161	994	472	268	3	87	26	21	289
July	7	96	119	207	8	64	99	220	47	142	91	478	170	918	638	304	—	93	18	31	335
Aug.	—	92	113	58	9	57	62	116	48	108	73	262	175	1,167	460	442	4	63	11	36	478
Sept.	—	64	37	31	3	56	41	63	53	72	50	115	168	1,289	449	617	13	67	53	40	657
Oct.	—	30	11	3	5	33	11	26	9	115	21	78	317	960	400	227	18	97	18	4	231
Nov.	18	16	3	4	—	9	9	6	—	9	13	18	324	231	204	54	2	17	3	2	56
Dec.	20	16	8	—	—	12	7	4	—	9	—	7	85	107	179	30	1	113	4	1	31
1973																					
Jan.	33	29	9	2	—	24	25	2	—	10	13	1	—	69	162	1	—	2	2	1	2
Feb.	38	34	23	15	5	21	8	6	—	15	3	3	—	201	18	1	—	5	22	—	1
March	35	21	41	66	11	23	23	13	13	5	6	10	—	159	7	2	—	9	5	—	2
Total	169	584	927	1,204	62	544	772	972	286	1,175	715	1,703	1,716	7,015	3,345	2,037	42	536	175	147	2,184

Table 5

Cocoa crop forecast 1972–73

Plot N7—Hybrid cocoa—(100 *sample trees) planted* 1952 *at* 8 *ft.* × 8 *ft.*

Month	Cherelles 0″–1″				Cherelles 1″–3″				Cherelles Over 3″				Mature Healthy				Mature Diseased				Total mature pods
	1969 70	1970 71	1971 72	1972 73	1969 70	1970 71	1971 72	1972 73	1969 70	1970 71	1971 72	1972 73	1969 70	1970 71	1971 72	1972 73	1969 70	1970 71	1971 72	1972 73	1972–73
1972																					
April	145	16	120	257	6	63	54	76	113	101	24	67	98	244	161	15	11	11	14	2	17
May	141	99	92	349	22	84	143	227	114	34	146	133	98	373	251	43	—	66	15	5	48
June	143	168	68	303	30	189	93	134	119	199	98	349	104	568	336	147	2	96	17	7	154
July	94	121	172	175	79	100	117	131	86	125	97	310	139	815	506	246	4	72	32	3	249
Aug.	75	83	95	117	96	54	49	107	102	123	44	200	148	951	378	388	3	59	29	12	400
Sept.	48	—	76	63	84	4	60	69	155	155	74	170	170	575	438	412	—	103	38	12	424
Oct.	35	6	38	14	73	20	31	31	78	42	43	66	163	696	557	357	9	37	21	4	361
Nov.	31	17	27	—	64	17	23	2	89	16	30	29	172	483	572	179	14	52	10	—	179
Dec.	39	24	9	—	68	17	5	—	105	17	12	—	125	250	287	76	27	17	11	—	76
1973																					
Jan.	18	34	36	2	62	28	9	2	93	21	3	1	144	109	72	6	8	4	6	5	11
Feb.	8	15	33	9	24	9	7	2	38	25	6	5	83	153	8	2	—	6	8	—	2
March	43	21	26	2	23	48	20	1	17	4	13	—	81	269	14	1	—	11	—	—	1
Total	820	624	792	1,291	631	633	611	782	1,109	862	590	1,330	1,525	5,490	3,580	1,872	78	534	201	50	1,922

Four thousand, three hundred and thirty-five seedlings of seven local tree species to be used as shade for cocoa were raised at the nursery. They are *Entandrophragma angolense*—34, *Discoglypremna*—184, *Albizzia Zygia*—174, *Combretedendron*—26, *Funtumia elastica*—1,894, *Erythrina*—285 and *Tetrapleura*—1,738. Two hundred and fifteen of these seedlings were used in the newly planted Amelonado plot, Z4, and 250 for Pathology plots.

TABLE 6

Cocoa nursery

Cocoa type	Seedlings from 1971–72	Seedlings raised 1972–73	Distribution		
			Planted	Experi-ments	Sold
T79/501 × T85/799	267	2,552	267	—	—
WAE 5	5,415	2,831	296	337	2,025
WBE 2	3,123	7,284	1,757	—	350
T12/16 × IMC60/131	3,437	—	152	—	800
Amelonado P30 × 5.84	3,056	2,901	1,478	616	—
Amelonado P.1	1,288	—	1,288	—	—
T60/887	17	—	17	—	—
Total	16,603	15,568	5,255	953	3,175

Fermentary (E. N. Abbeo)

During the period under review, 1,356,050 pods were received at the Fermentary. This figure shows an increase of 435,291 pods, i.e. 32.1% over the previous year's. Out of these, 1,628 pods were issued to the Research Divisions for experimental work and 138,497 pods, representing 10.2% of the total pods received, were discarded on breaking as unsuitable for fermentation. The remaining 1,215,925 pods gave 228,574 lbs. fermentable beans which yielded 94,663 lbs. of dry cocoa.

About 99.6% of the dry cocoa produced was dried mechanically after partial sundrying.

In all, the Fermentary carried out 177 fermentations: 162 stacks of trays and 15 heaps. Micro-fermentations, for the purpose of finding out conversion factors for some cocoa varieties, were also carried out for the Plant Breeding Division. On average, 12.8 pods gave 1 lb. dry cocoa and the conversion factor of wet to fermented dry cocoa was 41.4%.

Revenue

Sixteen thousand, eight hundred and eighty-nine cedis, five pesewas was realised from the sales of the following:

Cocoa	
Dry beans	₵15,930.43
Pods	55.85
Seedlings	79.37
Vegetables	394.97
Plantain	256.66
Corn	35.43
Oil palm fruits ..	122.34
Tuft grass	14.00

RESEARCH REPORTS

SUMMARY

Agronomy

Research work in the Shade–Spacing–Cultivar Experiment (D1–U1) at Bunso was continued, and decisions were taken on the main aspects of the statistical analyses. Severe defoliation occurred during the dry season, and the degree of defoliation in the various treatments was assessed. The study of the cocoa microclimate in K2–O1 and D1–U1 was continued. The third phase of cocoa establishment in the quarter-acre plots of the rehabilitation experiment was completed. Weed control accounted for the highest percentage of total labour input (22.6%) in the rehabilitation experiment.

Entomology

Monthly assessment of capsid populations on 25 farms in the Eastern Region showed a somewhat earlier peak this season than last although the number recorded over the year as a whole was comparable. At Akutuase, studies of the seasonal changes in spatial distribution continued and monthly parasite sampling was carried out at a number of sites.

Baygon, Entrofolan and Orthobux/Gammalin gave the best control of capsids in field trials of insecticides, Orthobux/Gammalin showing the lowest recovery rate followed by Baygon and Entrofolan.

The regular insect sampling on A11 which has now continued for three years is beginning to show up long term changes in species composition as the trees grow larger. On the same plot seasonal shifts in the distribution of mealybug colonies within the canopy have been noted.

Continuing studies of natural pollinators have revealed that not less than 50 species of Ceratopogonidae are to be found at Tafo and that these midges breed in large numbers within cocoa plantation although only a small proportion visit cocoa flowers.

New lines of research are concerned with the biology of Psyllids and of the biology and ecology of *Crematogaster clariventris* Mayr. which occurs as a dominant in certain cocoa situations.

Plant Pathology

As old cocoa is removed for new trials the problem of controlling swollen shoot disease decreases. There was again a reduction in the number of diseased trees (463) removed during the year.

Ten series of screening tests for resistance to virus infection were run but the very dry weather at the end of the year resulted in poor rates of infection in three of these. Both manual and vector transmission techniques were used. Eleven sets of data (six from 1971–72) were analysed on the Rothamsted Experimental Station computer.

The main project (in collaboration with Plant Breeding Division) is the selection of suitable male parents which can be substituted for the present Amelonado males in the hybrid seed gardens so as to produce hybrids resistant to virus infection instead of the present susceptible hybrids.

Six screening tests were devoted to examining prospective candidates in combinations with either T63/967 or T79/467 and some retesting of crosses to T85/799. This data was considered before selecting parents to go forward for field testing. Subsequently, a field resistance trial was planted (B7) at Tafo and a complementary progeny trial (11th P.T.A.) at Apedwa. Six male parents were crossed with T63/967 and thirteen male parents with T79/467 and various standard crosses were included for comparison.

A special examination was made of the Iquitos clones available because these appear to offer the best sources of resistance to swollen shoot virus among the material now at Tafo. IMC 76 was selected and this is going forward with another selected clone Nanay 34 for planting in a new generation of hybrid seed gardens. The land for this has been made available at Bunso by the Cocoa Production Unit and it (30 acres) will be planted up as budlings are produced. The screening for suitable male parents both in seedling tests and field trials will be completed by the time these seed gardens mature.

Plant Breeding Division are energetically collecting new cocoa types for inclusion in our screening tests. A first look at those now flowering was disappointing. The clones tested were predominantly Nanays but some new Parinaris, Iquitos, Scavina and Pounds were available. The range of variation in resistance did not extend beyond that demonstrated in earlier collected material at Tafo.

The narrow range of variation to resistance to virus infection which has been demonstrated may account for the difficulty found in demonstrating variation within populations in this resistance, but screening for this is being continued.

Although a capability to survive and yield well even when infected with virus, i.e. tolerance is not now considered a feasible method of combating swollen shoot disease, and earlier planted trial to examine tolerance is being continued and as a combined exercise the interaction of tree age at time of infection and tolerance will be studied. The older part of this trial (4 years) has started to produce a crop and vegetative growth has slowed.

With more experience in the joint CRIG/Cocoa Production Unit trials to assess latent infection at swollen shoot outbreaks it appears that mortality can be high especially in degraded soils with inadequate shade. Under such conditions regenerations of survivors is slow. The dispersed distribution of the latent infected trees emphasises the control problem and suggest that even with coppicing eradication is problematic.

A nationwide survey of black pod disease has got off to a slow start and it is hoped that more complete data from selected sites will be forthcoming.

The build up of black pod disease through the year is being studied using the cumulative percentage black pod incidence of the total year's crop as a parameter. In this way, seasonal, geographical, environmental and varietal effects on disease are being examined. The influence of fungicide application is also being studied.

Pods at different locations within a tree have different liabilities to infection as have fruits of different ages. For instance, the more numerous cherelles have a lower incidence than mature pods but these early infections may be significant in the epidemiology. The removal of infected pods every three days for four years has not eliminated cushions infections thus emphasizing the persistence of this source of inoculum.

On the basis of a pod analysis black pod infection from ant tent material is inversely related to rainfall although on a tree basis there is always a significant association with the presence of tent-building ants. Horizontal dispersal of inoculum was limited and not found beyond 2.5 m using radio-active tracers techniques, whereas vertical movement of material within a tree was measured up to 3.4 m. About 40 species of animals were found consistently carrying fungal inoculum and two of these which regularly visit pods (*Brachypeplus pilosellus* and *Chaetonerius latifemur*) were shown experimentally to be potential vectors to damaged pods.

Phytophthora can be more readily isolated from soils of productive cocoa farms than from abandoned farms or from forest reserves which suggests a build up during cultivation.

In using fungicides for controlling root and leaf infection in nursery beds phytotoxicity must be taken into account. Some fungicides inhibit germination while others affect growth of young seedlings. The fungicides Kocide 101 and Perecol were applied nine, six or five times; with both fungicides, nine and six applications significantly reduced infection compared with unsprayed plots but only Kocide did this with five sprays. Nevertheless, it was only profitable to spray six times a year. Large scale trials were continued with Kocide Burcop BBS and Copper Count–N again trying either nine, six or five applications.

In the hybrid cocoa of spray trial areas, high yielding hybrids had low black pod and low yielding cocoa high black pod. Most of the mature pod losses (94%) were from black pod. A consideration of the proportion of crop produced from July to September and the incidence of disease in that period did not provide an association between cropping patterns and annual disease incidence.

Further work on the *Phytophthora*/virus/water stress interactions showed that stem cankers were smaller in the wet season than in the dry. All the results indicate that the disruption of a tree's water supply by physical (e.g. drought) or biological (e.g. virus induced root necrosis) agencies will result in increased growth of *Phytophthora* cankers.

Mealy pod disease (*Trachysphera*) is more common in the Eastern Region than was thought. It is always associated with wounds but the type and age of a wound influences susceptibility. For instance, susceptibility decreases sharply after 24 hours.

Initial work on varietal differences in susceptibility and the virulence of different fungal isolates was impeded by the dry weather but clearly there are differences and these will be further investigated.

Nematode studies on a plot of land cleared from secondary bush planted with cocoa and kept clean weeded is regularly sampled and data is being accumulated on population changes.

The etiology of stem pitting is still uncertain. Graft inoculation tests particularly from roots of affected plants have been set up and the plants are under observation. A field trial is being prepared to compare the relative efficiencies of wounding and fungal or virus inoculation in inducing vascular pitting.

Physiology and Biochemistry

Experiments on cocoa by-products, methyl bromide residues and virus diseases are reported. In the first category the chemical properties which influence the quality of pectins have been determined for cocoa pod husk pectin as well as pectins extracted from pawpaw, lemon and apple. Cocoa pectin may be distinguished from the others by its high content of acetyl groups. The curing of cocoa beans by infiltration of the latter with chemicals was studied for its suitability for the collection of sugars in the bean pulp as a by-product. The quality of beans obtained by this process is discussed. In experiments on the utilization of cocoa pulp juice for wine making, clarification of the juice with pectinase prior to fermentation is considered necessary. Quantitative data on methyl bromide residues in fumigated cocoa beans are given. The amount of residual methyl bromide fell to low levels (particularly in the nibs) after aeration for 70 days.

In the study of the virus diseases of cocoa, the purification of cocoa necrosis virus (CNV) from cocoa leaves is described together with the electron microscopy of the virus. A modification of the method was also used to extract cocoa swollen shoot virus (CSSV) from cocoa leaves. Some physiological and biochemical effects of CSSV infection of cocoa on the host, namely, carbohydrate metabolism, photosynthesis, translocation and free amino acid levels, are described.

The water relations of cocoa was the main subject of study by the Physiology Section, as it is clear that nearly every important process in the tree is affected by the water status. Water potential continues to be the main criterion of internal stress but its main components—osmotic potential and turgor pressure potential—are also being taken into account, for it is clear that consideration of water potential alone gives an incomplete picture of what is happening in the tree. The measurement of osmotic potential with the bomb is described and the factors affecting the osmotic potential are discussed. Relative water content was not closely related to water potential and apparently cannot be used to obtain accurate information on water potential.

The changes in water potential over a drying cycle are described in detail for both seedlings and mature trees in the field. Some of the important factors affecting the development of stress in the field are considered. The 1972–73 dry season was very severe and afforded a good opportunity for studying the water relations in the field. The results of measurements taken in the dry season are discussed.

A start was made in defining the effect of stress on physiological processes such as leaf fall, stomatal movements, flowering, setting, cherelle wilt, flushing, leaf expansion and pod growth. Setting and flowering were particularly sensitive to stress. Results of the Bunsu irrigation trial are given, in which a marked response to both overhead and under-the-canopy watering was evident. It appears that stem contraction might be a very useful measurement for following the changes in water stress of field trees. Stem contraction can probably be calibrated against water potential.

The Scavinas and Nanays were shown to be able to tolerate full sunlight from an early age. The results of the polybag test correlate well with those of a small field establishment trial. Drought resistance is also considered to be highly desirable for establishment, and preliminary studies on testing for drought resistance in seedlings are mentioned.

An overall picture of the physiology of cocoa is given which should be useful in holding the various investigations together. Equipment for the measurement of photosynthetic rate has been assembled and is described.

Plant Breeding

The programme of plant introductions, aimed at extending the genetic variability of the breeding material, was continued. One consignment of 17 clones, mostly new selections of Nanays, was received from the quarantine at the Royal Botanic Gardens, Kew. Arrangements were made for the introduction of more clones from Trinidad and Mayaguez (Puerto Rico) and a number of these were successfully established at Kew. Plans were in hand to introduce Upper Amazon material collected from expeditions subsequent to Pound's.

Field establishment of the clones obtained in 1971–72 was good and few trees were lost despite the severe drought. With an increasing number of plants coming into flower, it was possible to use some of these clones both as male and as female parents in pollination programmes. There was regular harvesting of pods from natural sets, and a start was made in obtaining data on pod and bean characters of the selections.

All the established trials were maintained. Both the 8th and 9th Progeny trials showed an increase in crop, although that of the latter was comparatively low. The Amazon × Amelonado hybrids continued to yield better than the Amazon × Local Trinitario hybrids. The trial at Pankese suffered heavy pod losses, as a result of increased black pod incidence, and at Apedwa the reduction of shade had little effect on the yield. Uneven growth, as seen in the coefficient of variability of single tree circumference, of the Trial D14, was attributed to poor soil and unfavourable planting conditions. Missing trees were estimated to be 7.6%, and yields were low. The trial, however, permits some comparison between parents, with regard to yield and disease losses.

During the year the planting of hybrids within the block planting scheme was extended to five more stations in the Eastern Region and one in Ashanti. Seedling establishment at the different sites was very variable. High percentage deaths, particularly at Tinkong, were attributed to poor field conditions.

In an investigation on the effect of the frequency of harvests, in the Series V black pod resistance trial, some crosses gave lower rates of black pod infection at 2-weekly than in 4-weekly harvests; while others were unaffected by the time of harvest. New trials for comparing the field resistance of screened and unscreened seedlings to black pod disease were planted at Jamasi (Ashanti) and at Pankese (Eastern Region).

Artificial pod inoculation carried out on 3 to 5 month old pods of resistant and susceptible trees selected last year, showed that three-month-old pods were the most difficult to infect. Since the selected trees flowered at different periods, hand-pollinated pods of the same age were not available for testing at the same time. The reaction of the selections to inoculation were therefore not directly comparable. Furthermore, infection rates were low and could not be used to confirm resistance or susceptibility of the trees.

The results of black pod resistance screening showed higher percentages of resistant seedlings in crosses involving T79/501, Sca 6 and Y44 than occurred in seedlings of other parents. This confirmed the heritability of black pod resistance and susceptibility.

Investigations on natural pollinations and Cytogenetics of cocoa continued.

Soil Science

The sixteen acre Amazon shade and fertilizer trial on two of the four experimental blocks (Blocks I and IV) of plots K2–O1 are in progress. Shade effect is statistically significant ($P < 0.05$) with $S_0 = S_1 > S_2$. Fertilizer effect is not statistically significant even though yields on fertilized plots are much higher than the corresponding control plots. This is especially so for the S_0K_1 (No shade + 100 lbs. K_2O/acre) treatment. The main crop was 65% of the annual total. A 2^3Zn B, Fe factorial set of treatments randomised on the 3×3^3 NPK split plots (of K2–O1) were undertaken. Data for the first year treatment are yet to be analysed.

From the results of the various factorial trials, it looks as if the differences in response of Amazons and the Amelonado to the different times at which full dose or split doses of P or PK were applied reflect the variation in response of the two cocoa varieties to the triple superphosphate, muriate of potash or their combinations. Significant residual fertilizer effects tend to be associated more frequently and over longer period with P than with K while the annual application of PK combinations tend to be consistently significant over many sites.

There is a definite positive relationship between slope and cocoa yield on a soil catena. Soils on top slope far out yield those on lower slopes. Reports on trial on time and split of NPK fertilizers and the other factorial fertilizer trials on shaded cocoa at the Ministry of Agriculture Cocoa Stations and farmers' farms are included. The adverse effects from shortage of water on laboratory analyses were mentioned. Studies on soil organic phosphorus and phosphatase activity have been initiated.

AGRONOMY

COCOA ENVIRONMENT

Shade–Spacing–Cultivar Experiment, D1–U1 (E. E. N. A. Bonaparte and E. Bredu)

Treatments

In replicates 1 and 2, the final spacings for treatments F (8 × 6 ft.–8 × 12 ft.) and U (4 × 4 ft.–5.6 × 5.6 ft.–8 × 8 ft.–11.2 × 11.2 ft.) were achieved for all cultivars except Amelonado in May, 1972. Treatment F was thinned from 8 × 6 ft. to 8 × 12 ft. and treatment U from 8 × 8 ft. to 11.2 × 11.2 ft. In replicates 5 and 6, final spacings for treatments A (4 × 4 ft.–4 × 6 ft.) and C (4 × 4 ft.–5.6 × 5.6 ft.) were achieved for Amelonado. Thinning was carried out in two stages; the first in May, and the second in September 1972. Treatment B (4 × 3 ft.–4 × 6 ft.–8 × 6 ft.) was thinned to 4 × 6 ft. in the Amelonado plots in September, 1972. Treatments D (4 × 4 ft.–5.6 × 5.6 ft.–8 × 8 ft.) and T (4 × 3 ft.–4 × 6 ft.–8 × 8 ft.) were thinned on the Amelonado plots in September, 1972. Treatment D was thinned to 5.6 × 5.6 ft. and treatment T to 4 × 6 ft. Final spacing for treatments D and T were achieved for all cultivars except Amelonado in May 1972. Treatment D was thinned from 5.6 × 5.6 ft. to 8 × 8 ft., and treatment T from 4 × 6 ft. to 8 × 6 ft. In replicates 7 and 8, treatments B and T were thinned from 4 × 6 ft. to their final spacing of 8 × 6 ft. for all cultivars except Amelonado in May 1972.

Upkeep and maintenance

Shade reduction was effected in the densely shaded plots. This involved the poisoning of only the smaller trees in order to minimise or avoid subsequent damage to the cocoa trees. All shade trees in the unshaded plots of Replicates 5 and 6 were poisoned in January and February 1973.

Pests and diseases

No CSSV outbreak was observed during the year. Routine anticapsid spray of Baygon and Gammalin 20 was applied to all plots at recommended rates and periods. In replicates 2 and 3 incidence of white thread was observed on a number of trees in both shaded and unshaded plots.

Defoliation due to drought

The severe dry period between December and March resulted in moderate to severe defoliation of trees in several plots. Defoliation was most severe in the shaded plots of replicates 1, 2, 3, 6 and 7. In the worst plots (89, 90, 91 and 95) deaths ranged from 20 to 75%. The extent of defoliation was a reflection of soil type and the effect of the permanent shade trees. During the peak of the drought, in mid-January, the degree of defoliation was assessed on all plots. Scores were assigned on a 0–10 scale, where 10 referred to complete, and 0 to no defoliation. The scores were summed, for each cultivar, over spacing treatments in each replicate, and are summarised in Table 7.

TABLE 7

Degree of defoliation under shaded and unshaded conditions (mean and S.E. over replicate totals)

Cultivar	Shade	No shade
Amelonado (a)	31.1 ± 14.67	20.1 ± 13.85
Mixed Amazon (b)	26.9 ± 12.71	18.6 ± 14.01
Amazon x Amelonado (c)	29.3 ± 15.87	19.5 ± 12.84
Amazon x Local Hybrid (d)	23.1 ± 12.56	20.0 ± 15.35

Yields

The total crop produced in 1972–73 is shown in Table 8. The results of the experiment, in lb. dry cocoa per acre, according to treatments are being gradually compiled as results are received from the Statistics Department of East Malling Research Station.

TABLE 8

Shade–Spacing–Cultivar Experiment (Bunso D1–U1): crop, including plots and guard rows, 1972–73

Cultivar	Total pods	Pod rot	Im-mature ripe	Mammal damage	Other field losses	Discards at breaking	Actual usable pods
	Pod numbers in 100s						
a	538.7	38.7	54.8	6.7	6.5	23.4	406.7
b	1,467.0	180.2	186.3	74.9	28.4	47.1	950.2
c	1,532.1	177.5	194.6	33.8	27.8	57.0	1,041.4
d	1,117.9	207.1	125.8	31.4	11.2	39.6	702.7
	As percentage of total pods						
a	—	7.2	10.2	1.2	1.2	4.3	75.5
b	—	12.3	12.7	5.1	1.9	3.2	64.7
c	—	11.6	12.7	2.2	1.8	3.7	68.0
d	—	18.5	11.3	2.8	1.0	3.5	62.9

Cocoa microclimate (K2–O1, Tafo) (E. E. N. A. Bonaparte and J. Y. Mensah)

The study of the cocoa microclimate was continued in the Amazon Shade and Fertilizer Experiment (K2–O1) at Tafo, using Grant Temperature recorders and Lambrecht thermographs and hygrographs. In general, temperature maxima above the canopy were highest in the No Shade regime, and least in the Heavy Shade regime. Temperature fluctuations tended to be moderate under shaded conditions, and within the cocoa canopy. Seasonal variations were encountered, and are being studied in greater detail.

TABLE 9

Rehabilitation Trial (R5/V4): man-hours per acre per treatment, April 1972 to March 1973

Treatment		Quarter of year	Type of work* 1	2	3	4	5	7	8	10	11	12, 13&14	16	17	18	19	Total
Amelonado retained	No fertilizer	2nd	—	—	15.73	22.16	—	—	—	3.90	—	5.81	1.30	1.52	14.38	—	64.80
		3rd	—	—	8.34	18.08	—	—	1.38	3.95	—	24.15	2.22	3.20	6.99	3.50	71.81
		4th	—	—	—	10.51	—	—	1.44	3.03	—	35.95	1.84	2.05	6.22	15.55	76.59
		1st	—	—	—	6.33	—	—	—	2.46	—	—	1.09	2.60	8.89	11.28	32.65
	Fertilizer	2nd	—	—	18.71	26.75	—	—	—	3.73	—	5.51	1.30	1.52	14.38	—	71.90
		3rd	—	—	10.29	17.91	—	—	1.38	3.79	—	35.40	2.22	3.20	6.99	3.50	84.68
		4th	—	—	—	13.40	—	—	1.44	3.50	—	42.79	1.84	2.05	6.22	15.55	86.79
		1st	—	—	—	4.24	3.54	—	—	2.59	—	—	1.09	2.60	8.89	11.28	34.23
			—	—	53.07	119.38	3.54	—	5.64	26.95	—	149.61	12.90	18.74	72.96	60.66	523.45
Amelonado temporarily retained	No fertilizer	2nd	—	—	18.15	24.96	—	—	—	3.87	—	4.30	1.30	1.52	14.38	—	68.48
		3rd	—	—	10.21	15.64	—	—	1.38	3.71	—	22.94	2.22	3.20	6.99	3.50	69.79
		4th	—	—	—	12.56	—	—	1.44	2.87	—	30.31	1.84	2.05	6.22	15.55	72.84
		1st	—	—	—	4.64	6.21	—	—	2.57	—	—	1.09	2.60	8.89	11.28	37.28
	Fertilizer	2nd	—	—	10.93	25.06	—	—	—	3.61	—	4.40	1.30	1.52	14.38	—	61.20
		3rd	—	—	11.49	17.84	0.75	—	1.38	4.19	—	22.67	2.22	3.20	6.99	3.50	74.23
		4th	—	—	—	15.02	—	—	1.44	2.91	—	34.61	1.84	2.05	6.22	15.55	79.64
		1st	—	1.95	—	5.26	4.01	—	—	2.46	—	—	1.09	2.60	8.89	11.28	37.54
			—	1.95	50.78	120.98	10.97	—	5.64	26.19	—	119.23	12.90	18.74	72.96	60.66	501.00
Amelonado cleared	No fertilizer	2nd	—	—	16.53	19.23	—	—	—	3.67	—	3.43	1.30	1.52	14.38	—	60.06
		3rd	—	—	11.76	18.08	1.59	—	1.38	3.42	—	15.39	2.22	3.20	6.99	3.50	67.53
		4th	—	—	—	12.88	1.76	—	1.44	3.22	—	20.94	1.84	2.05	6.22	15.55	65.90
		1st	48.09	—	—	6.39	24.63	—	—	2.72	—	—	1.09	2.60	8.89	11.28	105.69
	Fertilizer	2nd	—	—	19.83	27.71	—	—	—	3.64	—	2.45	1.30	1.52	14.38	—	70.83
		3rd	—	—	10.30	15.62	—	—	1.38	3.87	—	9.43	2.22	3.20	6.99	3.50	56.51
		4th	—	—	—	21.67	—	—	1.44	3.21	—	13.73	1.84	2.05	6.22	15.55	65.71
		1st	48.61	—	—	7.75	39.76	—	—	2.66	—	—	1.09	2.60	8.89	11.28	122.64
			96.70	—	58.42	129.33	67.74	—	5.64	26.41	—	65.37	12.90	18.74	72.96	60.66	614.87
Mean per quarter per replicate		—	4.03		6.76	15.40	3.43	—	0.71	3.31	—	13.93	1.61	2.34	9.12	7.58	68.31
Percentage			5.9	0.1	9.9	22.6	5.0	—	1.0	4.9	—	20.4	2.4	3.4	13.3	11.1	100.0

*Type of work: 1. Felling: Uprooting cocoa trees. 2. Clearing. 3. Sowing cocoa: including lining and pegging. 4. Weed control. 5. Shade collection and planting. 7. Fertilizer application. 8. Mirid control. 10. Virus control. 11. Pruning. Removal of mistletoe. 12. Harvesting. 13. Splitting pods. 14. Transportation of wet beans. 16. Moving from plot to plot. 17. Awaiting further instructions. 18. Absent: sick. 19. Paid leave. (In 8, 16, 17, 18 and 19 the hours were allocated on a basis proportional to the acreage.)

REHABILITATION

Rehabilitation Trial (R5/V4) (E. E. N. A. Bonaparte and D. W. K. Toseafa)

Husbandry

The third phase of cocoa establishment in the quarter-acre plots was completed in June 1972 with seed from the Apedwa and Bunso seed gardens. Percentage germination was high, rodent damage was light, and the rather satisfactory initial growth was arrested by the very dry periods between November 1972 and February 1973. Defoliation was severe and extensive on several plots. A survey of a number of drought-damaged plants, carried out in January 1973, showed that the percentage of plants affected ranged from 1 to 40%. A survey of deaths in April 1973 confirmed earlier indications that the death toll would be high on several plots. The percentage of dead plants ranged from 37 to 88%, with a mean value of 63%. Vacancies were filled in June 1973. Thinning was effected in the 1970 and 1971 planting in July 1972 to one plant and two plants per picquet respectively.

Land preparation for the fourth and final planting was completed in March 1973. Cocoa was cleared where required, and temporary and permanent shade planted. *Gmelina arborea* and *Leucaena glauca* constituted a major weed menace in several plots. Several trees of these two species were poisoned during the year. All plots were inspected monthly for CSSV, and a total of 178 trees (diseased plus contacts) were cut out.

Shade reduction was effected in the densely shaded plots by the poisoning of the smaller trees, and the removal of temporary shade in the young cocoa where required. *Gliricidia* cuttings were planted where shade was considered inadequate.

Labour inputs

The input of labour for specific operations is summarised in Table 9. Weed control accounted for the highest percentage of total labour input (22.6%).

PLANT PATHOLOGY

COCOA SWOLLEN SHOOT DISEASE

Swollen shoot disease at CRIG (J. T. Legg)

Inspection and retreatment were continued on a monthly routine throughout the period. *Gliricidia* was planted as temporary shade at treated sites.

For the second year running there has been a substantial drop in the number of diseased trees. This is largely due to the removal of old cocoa and establishment of new trials which are as yet uninfected. The rehabilitation trial area R5, V4 was particularly bad with 115 diseased trees and 97 contacts removed.

A new outbreak (o/b no. 6) was discovered in Plot K2 where initially four trees were found and six more after coppicing. One new infection occurred in o/b 3 and two infections in O1 o/b 4. Thus in this shade and fertiliser trial, swollen shoot seems to be slightly more active than reported last year. Amazon material is less sensitive to virus infection than Amelonado and is likely to have more latent infection. This may tend to become apparent after certain sequences of environmental change thus leading to periodic flushes of symptom development.

RESISTANCE AND TOLERANCE

The screening of progenies in seedling tests (J. T. Legg and G. Lockwood)

The result from 15 series of tests are reported here: six were done in 1970/71 (VII and XI) but had not then been analysed and the remainder (XIV–XXIII) were completed this year. The data from last year's Series have now been analysed along with this year's except for XXI. The results from Series XIV, XX, XXII and XXIII were not analysed on account of low levels of infection. We are grateful to R. H. Wimble, O.D.A. Statistician at Rothamsted Experimental Station (U.K.) for doing the analyses for us.

In Series VII, XII and XIV, inoculation was done manually using the standard technique, while in the remainder nymphs of *Planococcoides njalensis* were used as described in *Rep. Cocoa Res. Inst., Ghana,* **1971–72,** 61. In Series IX, X, XIII and XV, four nymphs per bean were used throughout while in Series XI and XVI, the later runs were treated at the rate of five nymphs per bean, after early records indicated too low a rate of transmission from four nymphs per bean. Series XVII and XVIII were treated with five nymphs per bean throughout. Low rates of infection in Series XX-XXIII were attributed to exceptionally dry weather conditions affecting mealybug feeding behaviour. Series XIV failed because poor virus inoculum was used.

Results of 1970–71 experiments

Series VII. The main series was a comparison between various progenies of Nanay 34 and P30 including the generations P_1, P_2, F_1, F_2, and B_2

TABLE 10

Swollen shoot control 1972–73

Block		No. of trees removed: Diseased	No. of trees removed: Contact	No. of trees coppiced	Block		No. of trees removed: Diseased	No. of trees removed: Contact	No. of trees coppiced
A	a	31	6	24	L	a	0	0	0
	b	0	0	0		b	17	10	0
B	a		Virus Disease Trials		M	a	6	0	0
	b					b	16	13	0
C	a	4	0	5	N	a	27	0	7
	b	4	0	5		b		None	
D	a	23	0	22	O	a	2	0	5
	b	5	8	5		b			
E	a		Virus Disease Trials		P	a	60	7	0
	b					b	25	20	0
F	a	2	0	0	Q	a	0	0	0
	b	0	0	0		b	13	9	0
G	a	0	0	0	R	a	118	97	0
	b		None			b	0	0	0
H	a	0	0	0	T	a	0	0	0
	b	0	0	0		b	4	6	0
I	a		None		U	a	0	0	0
	b	13	11	0		b	0	0	0
J	a	0	None	0	V	a	8	8	0
	b	0	0	0		b	35	29	0
K	a	11	0	24	Z	a	0	0	0
	b	3	4	0		b	36	23	0
					Totals	a	292	118	87
						b	171	133	10
					All blocks	a + b	463	251	97

a = experimental cocoa
b = non-experimental cocoa

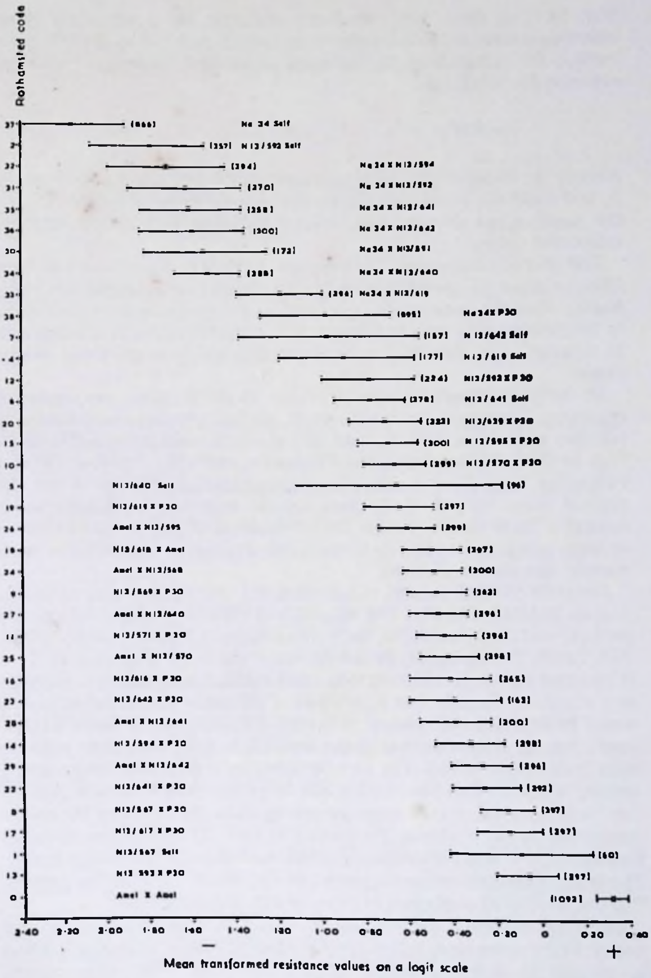

Fig. 1. Resistance rating series VII: progenies of Na34 and P30 Amelonado. N13 stands are Na34 × P30. (Nos. in parentheses are nos. of seeds treated.)

(Fig. 1). This series was inoculated manually but a subsidiary series including a representation of the crosses was inoculated by the mealybug method for comparison. In the main series the generations ranked as expected for resistance:

$$\text{Na34 } (P_1) > B_1 = F_1 = F_2 > B_2 > P_2 > (\text{P30})$$

Among the 19 parents in the B_2 one seedling (N13/592) was as good as the F_1 and itself was better than the F_1, comparable to the average of the B_1; this seedling has already been included in further pollinations for more exhaustive testing.

The genetic components for constant, additively and dominance were fitted to these six generations, only the additivety component was significant; when the same model was fitted to the symptom score data none of the components were significant. It is hoped that this experiment can be repeated to confirm the results, which then will be published in greater detail.

In the main experiment the 19 crosses in the B_2 were very similar in resistance, forming a continuous series, the better crosses were nearly as resistant as Na34 × P30 (F_1) and all were more resistant than P30 selfed (P_2). In the mealybug series, five P30 back crosses (B_2), Na34 × P30 and P30 selfed formed an overlapping series. Although P30 selfed was the poorest cross, several of the back crosses were not significantly more resistant. These results provide further evidence of poorer differentiation in tests using the mealybug inoculation techniques as compared with manual inoculation of virus.

Series IX. Tested a range of inter-Amazon crosses including as female parents T63/967, T63/971, T79/467 and T85/799 (the principal seed garden parents) and IMC47, IMC76, Na32 (from Nigeria), Na106, Na440, Na764, Pa7, Pa121, Pa150, Pa151, Pound 12, Sca 6 and Sca 9 (Fig. 2). IMC76 × ICS16 and Pa7 × ICS16 were tested and selfed Amelonado was included as a standard. Regular and high levels of infection were achieved and as would be expected this resulted in greater precision than in Series VI (last year's report). All the crosses except T63/971 × Sca 6 were more resistant than Amelonado selfed. The two Scavinas gave generally disappointing results, it seemed that Scavina 6 might be poorer than Scavina 9. Among the Nanays, none seemed more promising than the better of the earlier introduced Amazon clones. Parinaris 150 and 151 gave more resistance than Pa121, Pa7 was unfortunately not crossed onto the same tester parent. The better Parinaris were comparable to the Nanays as resistant parents. The test on IMC47 confirmed its promise as a resistance source.

The most resistant cross was IMC76 × ICS16, while Pa7 × ICS16 was one of the least resistant; ICS16 is a Trinidad Trinitario. Although caution is essential in assessing single tests, if resistance does occur among Trinitarios the scope for breeding will be widened.

Series X. This consisted of a range of T63/967 crosses which were under consideration as varieties for assessment in field trials (see p. 44). Twenty crosses of Amazons with T63/967 were included with T63/967 × Amel. Na33 × 34, Na34 selfed, Amelonado selfed, T85/799 × Amel. and T85/799 × T79/501 as standards (Fig. 3). In the tests, all the crosses except

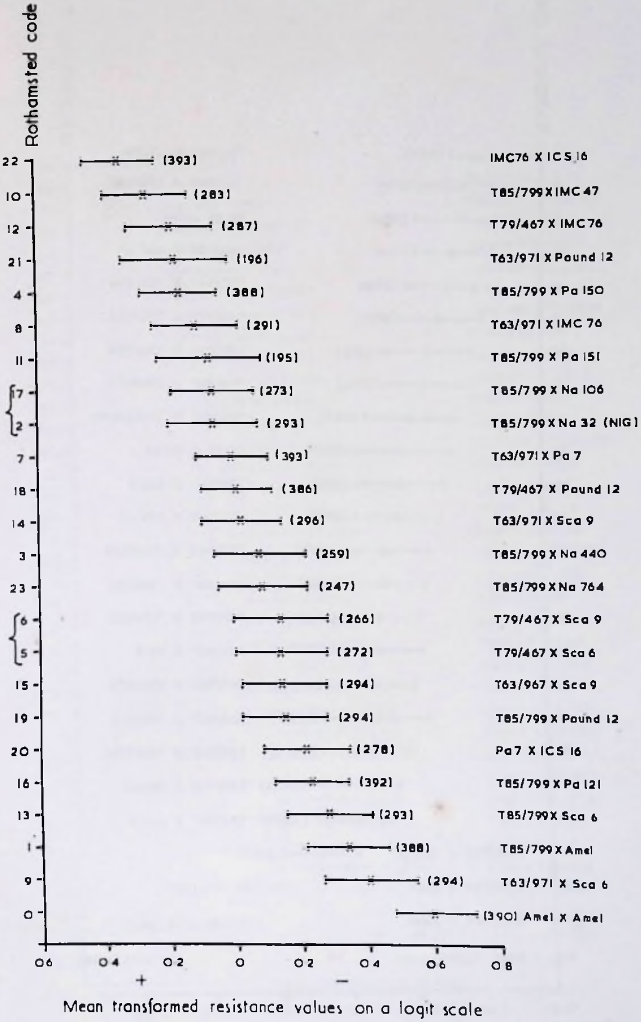

Fig. 2. Resistance rating series IX: inter-Amazon crosses including the principal seed garden parents. (Nos. in parentheses are nos. of seeds treated.)

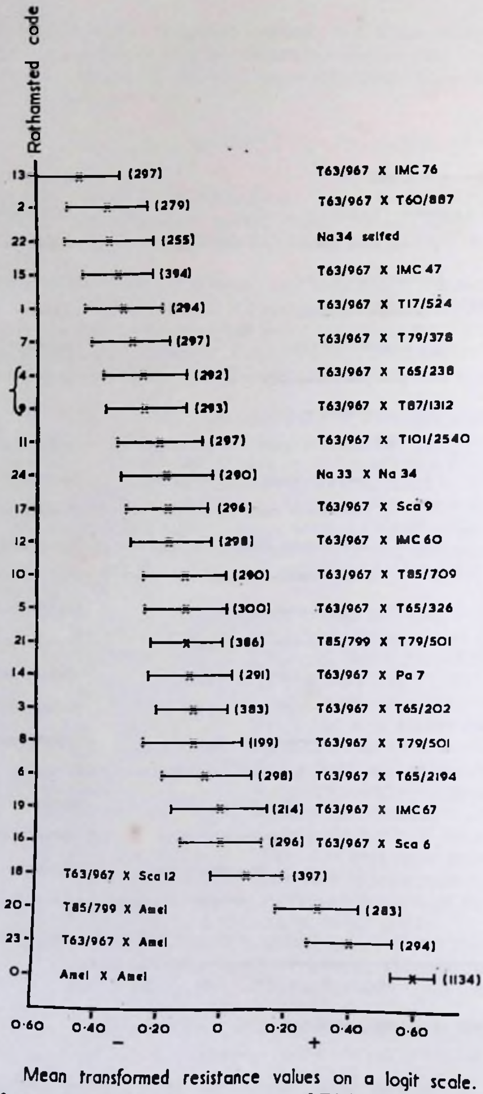

Fig. 3. Resistance rating series X: a range of T63/967 crosses. (Nos. in parentheses are nos. of seeds treated.)

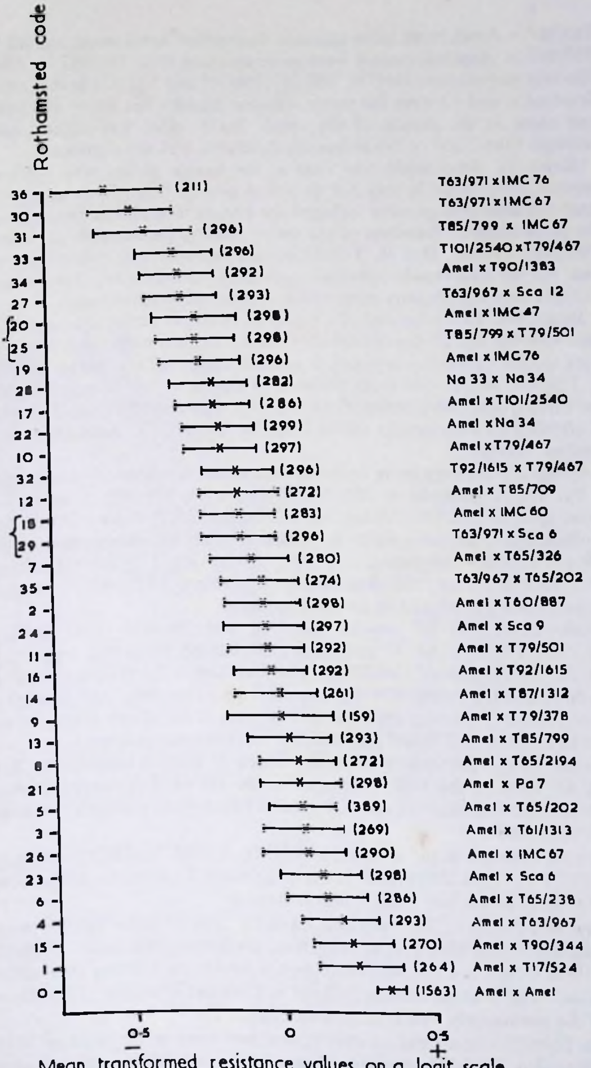

Fig. 4. Resistance rating series XI: male parents from series X and XII crossed to Amelonado. (Nos. in parentheses are nos. of seeds treated.)

T63/967 × Amel. were more resistant than selfed Amelonado and all the T63/967 × Amazon crosses were more resistant than T63/967 × Amel. The best parents were IMC76, T60/887, IMC47 and T17/524 in that order. Scavinas 6 and 12 were the worst Amazon parents but Sca 9 was better and came in the middle of the series. Na34 selfed was slightly more resistant than Na33 × Na34 but the difference was not significant.

Series XI. Amelonado was used as the female parent with the male parents from Series X and XII as pollen parents (Fig. 4). A number of inter-Amazon crosses were included for comparison and in general were the more resistant members of the series. Among the Amelonado crosses T90/1383, IMC47, IMC76, T101/2540 and Na34 (in that order) were the best. All the Amelonado hybrids except those with T63/967, T90/344 and T17/524 were significantly more resistant than selfed Amelonado.

Series XII. This consisted of a group of Amazon male parents crossed onto T79/467 and all the crosses were under consideration for field assessment as new varieties (see p. 44). Standards were Na33 × Na34, T85/799 × T79/501, two crosses from Series X (T63/967 × Sca 12 and T65/202) and three crosses from Series XI (Amel. × IMC60 and Pa7 and T85/799), in addition to Amelonado selfed (Fig. 5). T79/467 × Amelonado was omitted in error.

All the crosses were more resistant than selfed Amelonado, Amelonado × Pa7 and Amelonado × T85/799. In Series XI, T79/467 × Amel. was about equal to IMC60 × Amel. while in Series XII, IMC60 × Amel. was significantly more susceptible to infection than all except two of the T79/467 hybrids, suggesting that some of the new T79/467 hybrids are more resistant than the Amelonado equivalent (T79/467 × Amel.) presently being produced in the seed gardens.

Among the T79/467 crosses the best male parents were IMC67, T61/1313, T17/524, IMC47 and Nanay 34; among the worst were Sca 9, Sca 12, T85/799 and T101/2540. The two series X varieties were as susceptible as the poorer T79/467 crosses, but as they were also among the poorer Series X crosses they do not provide a satisfactory test of the relative abilities of T79/467 and T63/967 as resistance sources.

Series XIII. This included a wider range of parents than Series XII. (Fig. 6). Most of the T85/799 crosses in the 10th P.T.A. were included, together with a number of other progenies which were available when the tests were made.

The best crosses in the tests were T63/971 × IMC76, T9/21 × IMC76 and T9/21 × T101/2540 thus as in Series IX some Trinitario combinations were as good as the best inter-Amazon crosses.

Two new Nanays (106, 764) and Pound 8 crossed onto T85/799 were comparable to the 10th P.T.A. progenies, confirming the Series IX result that these clones are not markedly better resistance sources than older selections. The Scavina crosses differed in their performance; T63/971 × Sca 6 did particularly well in contrast to Series IX.

The T63/971 crosses did relatively well and were more resistant than the equivalent T85/799 crosses. However, it should be stressed that T63/971 × Sca 6 was the only cross in Series IX which was not significantly more resistant than selfed Amelonado and no firm conclusions about T63/971 can be reached at this time.

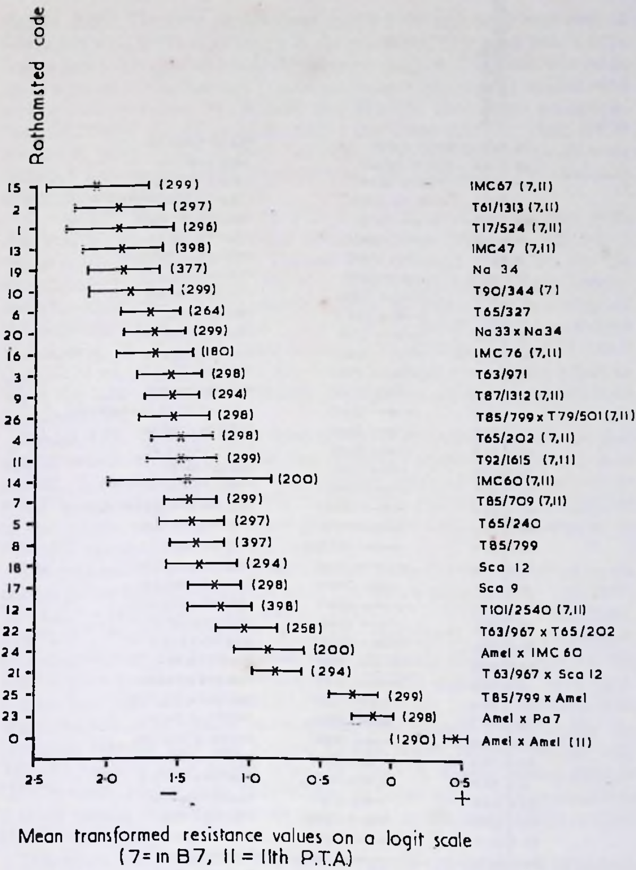

Fig. 5. Resistance rating series XII: a range of male parents crossed to T79/467 unless specified. (Nos. in parentheses are nos. of seeds treated.)

Results of 1972–73 experiments

During the year 10 series of inoculations were completed (Series XIV to XXIII). The results from Series XX, XXII and XXIII were not analysed statistically on account of low levels of infection.

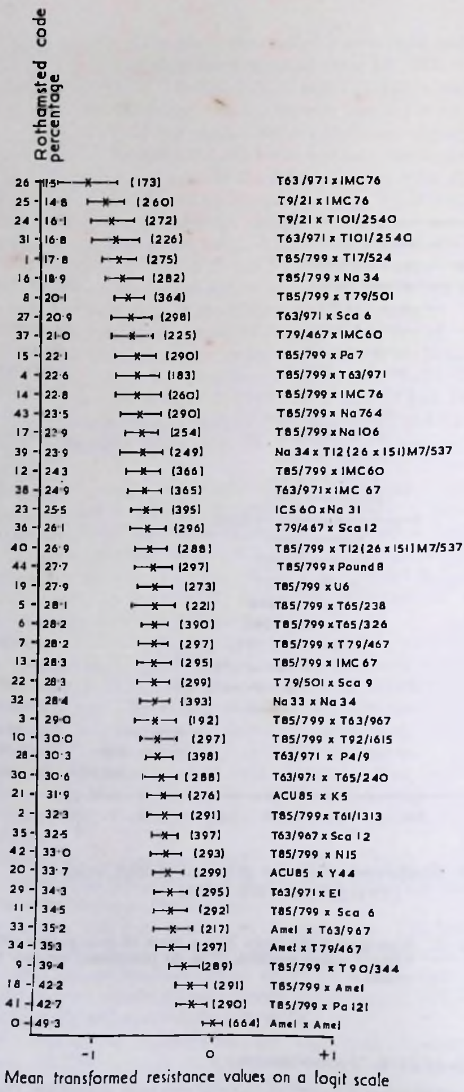

Fig. 6. Resistance rating series XIII: most of the T85/799 10th PTA crosses (*Rep. Cocoa Res. Inst., Ghana*, 1971–72, 68) with other selections (Nos. in parentheses are nos. of seeds treated.)

Series XIV. The virus preparations used for the first three runs were of low infectivity, levels of infection in the remaining four runs were a little higher and a few general conclusions can be reached. The series was made up of a group of Criollos and Trinitarios (mainly introduced) crossed onto one or both of Nanay 34 (N5/806) and T85/799. There were indications that GS29 and WA40 could be useful resistance sources, while UF29 seemed as poor as K5 (a local Trinitario) and Amelonado which were included for comparisons. Further tests on introduced non-Amazon selections are planned for 1973.

Series XV. This included 31 T90 and T101 seedlings crossed with Amelonado (Fig. 7) (17 of these crosses were in Series VI, last year's report p. 63). The parentage of T90 and T101 is (Na32 × IMC76) and the introduced clones Na32 and IMC76 (N8/122) were crossed onto Amelonado for comparison. As the identity of these parents cannot be confirmed the performance of the P_1 and P_2 compared to the F_1 should be judged with reserve. The P_1 and P_2 came in the middle of the group, IMC76 better than Na32 and the T90s and T101s formed a single overlapping group in which the better selections were only just significantly more resistant than the worst.

Series XVI. All the evidence from resistance screening test indicates that Iquitos selections are among the best resistance sources available to us at present. A direct comparison was therefore made of the four selections which were available IMC47, N8/112 (IMC60), IMC67, N8/122 (IMC76) to see which was best as these parents were under consideration as potential new seed garden parents (p. 45).

The four Iquitos clones were each crossed onto 12 other selections, some crosses failing through lack of flowers. The female parents were: T60/887*, T61/1328, T62/1596*, T65/326*, T72/1765*, T73/1438, T85/799*, T92/1614*, Na34 (N5/806)*, a Nanay (N8/131*), Pa7*, (N5/808)*, (* indicates that all four crosses were obtained) (Fig. 8). Among the Iquitos parents, the rates of infection of IMC76 and IMC47 were significantly less than that for IMC67. The results for the nine parents with which the full set of crosses was obtained were pooled. Unexpectedly, the two pure Nanays were the poorest parents while T60/887 did so well. T60/887 has not been tested often, in Series X it was second only to IMC76 when crossed onto T63/967 and in Series XI, with Amelonado as a tester parent, although poorer it was not significantly different from IMC76 × Amel.

This series is of particular interest as progenies can be pooled to provide large scale tests on particular parents. Considering only the nine females with which all four crosses were obtained, about 3,000 seed of each male were inoculated, leading to small within experiment errors; with the nine females, at least 1,150 beans of each were inoculated and again fairly small differences were detected.

Series XVII. The series was the resistance screening of a further group of T63/967 crosses which were under consideration for field planting (p. 44) good levels of infection were obtained (36.8 to 73.7%), (Fig. 9). The male parents were a group of Amazon selections which had done well in earlier tests along with the best selections of Ecuadorian origin from the screening Series I and II (*Rep. Cocoa Res. Inst., Ghana*, **1970–71,** 52). The

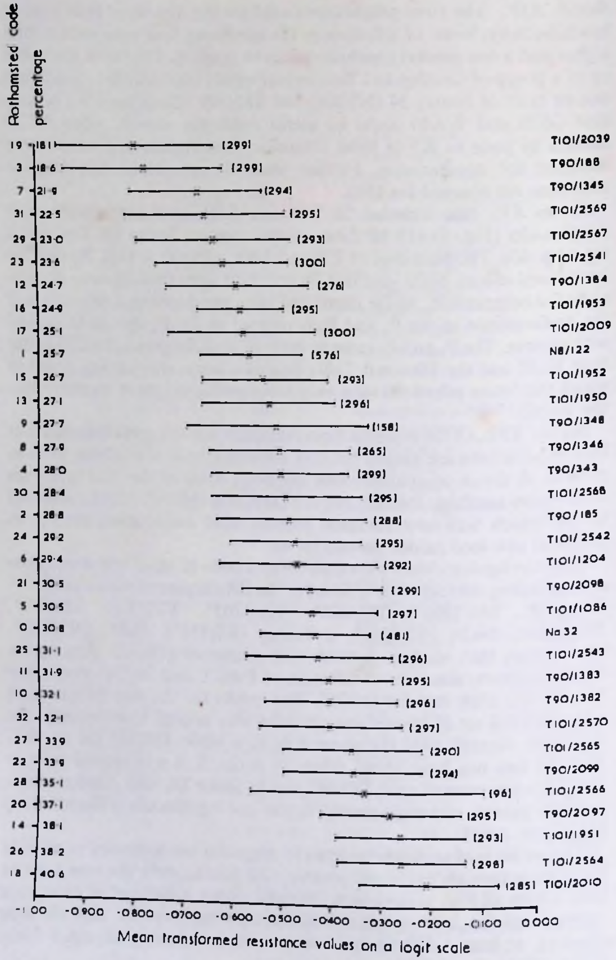

Fig. 7. Resistant rating series XV: T90 and T101 crosses with Amelonado. (Nos. in parentheses are nos. of seeds treated.)

existing seed garden hybrid (T63/967 × Amel.) was included for comparison and was significantly more susceptible than most of the T63/967 × Amazon crosses. Another seed garden hybrid (T85/799 × Amel.) was as susceptible as the T63/967 hybrid.

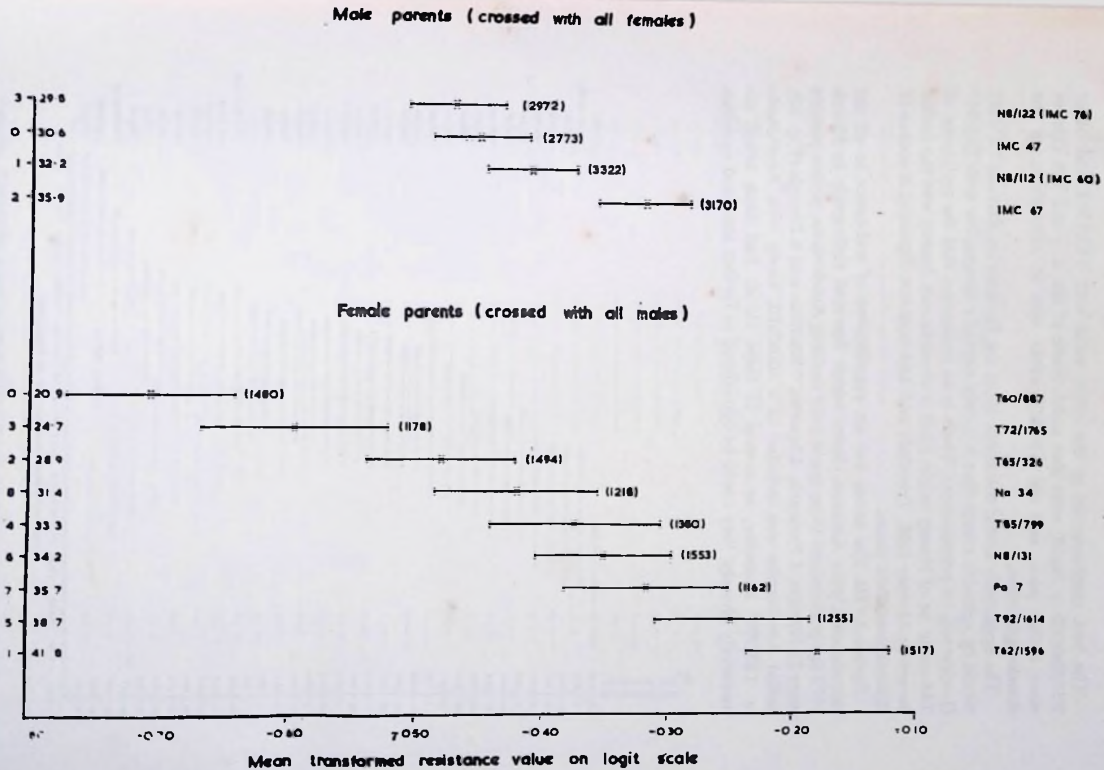

Fig. 8. Resistance rating series XVI: comparison of four Iquitos clones (Nos. in parentheses are nos. of seeds treated.)

The best combinations in the series were with T87/1312 and other T87(IMC60 × Na34) were also good. Some of the T55 and T56 crosses were rather poor and the T54/653 cross was as susceptible as the Amelonado cross.

The apparently useful resistance from the Ecuadorian derived T44/547 would be valuable except that it is only partially compatible with T63/967 (Lockwood, in preparation). There is an indication that the resistance of T44 could be of Nanay origin (that is an unknown Nanay was the pollen parent in Marper field, Trinidad) and T44 may not represent a source of different resistant genes.

Series XVIII. The series was an examination of resistance in all the introduced Upper Amazon clones which flowered sufficiently in March 1972 for pollinations to be made onto seedling Amelonado, pollen parents were 25 Nanays, 4 Parinaris, 4 Iquitos, 4 Scavinas and 6 Pounds (Fig. 10). Selfed Amelonado was included as a standard, along with Amelonado × T85/799. However, as several of these clones had been tested exhaustively already, they could be considered as further standard varieties.

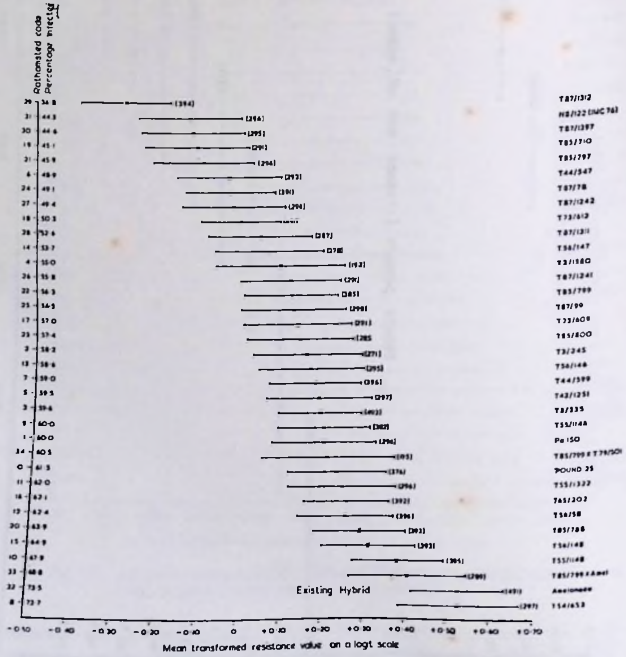

Fig. 9. Resistance rating series XVII: a further group of T63/967 crosses (Nos. in parentheses are nos. of seeds treated.)

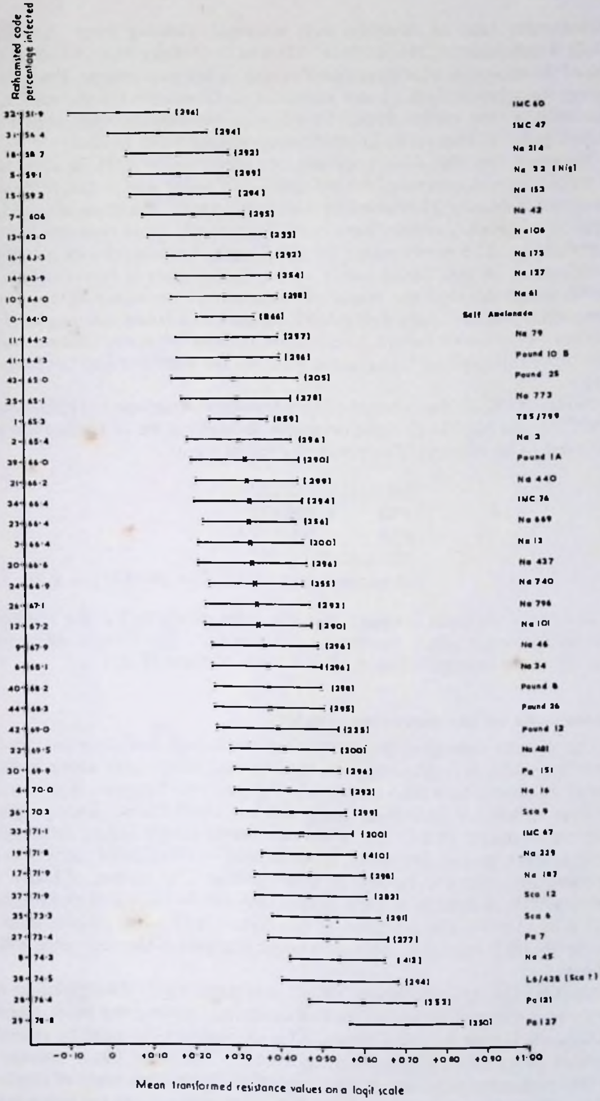

Fig. 10. Resistance rating series XVIII: a test of introduced Upper Amazon clones, all crossed to Amelonado. (Nos. in parentheses are nos. of seeds treated.)

Satisfactory rates of infection were obtained, ranging from 52 to 80%. Only Amelonado × IMC60 (N8/112) was doubtfully more resistant than selfed Amelonado, which ranked eleventh in the experiment. Possibly the heavy inoculation applied was sufficient to overcome the resistance, but similarly, in the earlier Series VI none of the hybrids were superior to Amelonado; in that series infection rates ranged from 19 to 43%.

However, on the four previous occasions when IMC76 crossed to Amelonado was compared with Amelonado selfed and in the three comparisons of Nanay 34 crossed to Amelonado with Amelonado selfed, the Iquitos and Nanay crosses have been significantly more resistant than the Amelonado. The performance of the Upper Amazon clones relative to Amelonado in this Series needs to be reinvestigated. Nevertheless, the Series indicated that the range of variation in resistance in the Upper Amazon collection does not extend beyond that found already at Tafo. As has been shown before, the Iquitos parents were the best sources of resistance followed by Nanays, the Pounds, the Scavinas and the Parinaris last.

Series XIX. This was based on three parents, Amelonado (P30), N8/122 (IMC76) and N8/131 (a clone originally thought to be an Iquitos but now believed to be Nanay). The progenies tested were:

N8/131 × N8/122
P30 × N8/122
P30 × N8/131
P30 selfed
36 progenies of (N8/122 × N8/131) × P30

The most resistant progeny was the inter-Amazon F_1, the remaining crosses formed a single overlapping group with Amelonado selfed significantly more susceptible than all but three of them (Fig. 11).

Comments on the screening results

The picture emerging from the virus resistance screening tests is that certain groups of selections, e.g. Iquitos and Nanay are more resistant under test conditions than others, e.g. Parinari and Scavina. However, the relative values for individual progenies are inconsistent. Two progenies may be separated in one test while another test may fail to differentiate them or even reverse the order. It seems that while most of the results are meaningful some are erroneous and confuse the picture. Clearly the sources of error must be located so that they can be identified and removed and thus increase the precision of the tests. Until more reliable data on susceptibility is available, detailed genetic analysis of the resistance will be difficult.

Attention is drawn to Series XVIII. It is particularly disappointing that we have not found better sources of resistance among the more recently introduced Upper Amazon clones. This emphasises the need to assemble a wider range of cocoa material in Ghana. The most likely sources of further resistance genes are other populations from the centre of origin of cocoa. These are not at present in Ghana but active steps are being taken to obtain them.

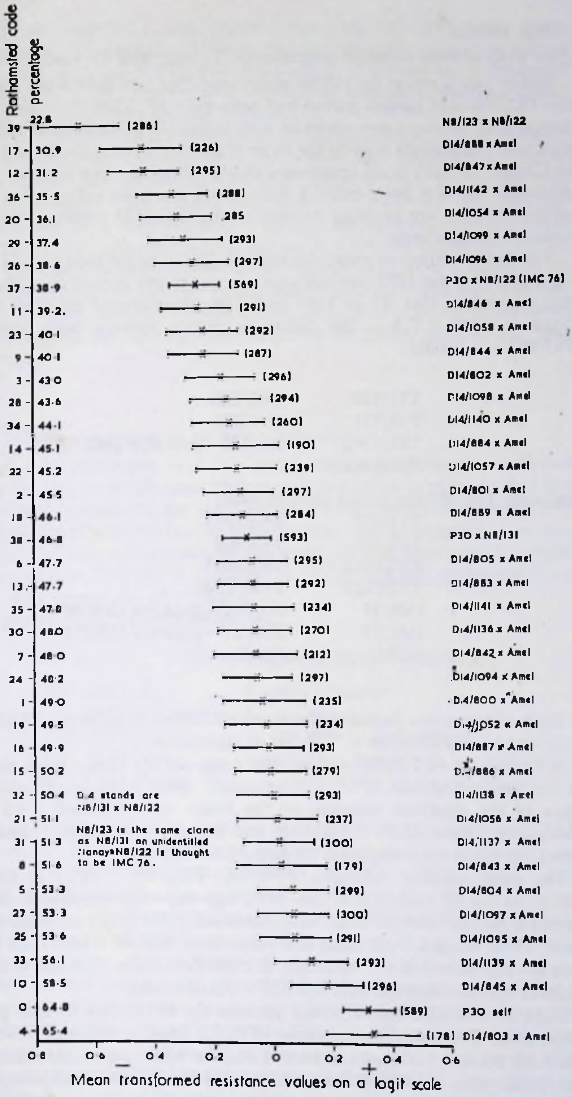

Fig. 11. Resistance rating series XIX: a study of crosses from Amelonado, N8/122 (IMC76), N8/131 (probably a Nanay) parents.

FIELD TRIALS

New trials of virus resistant progenies (J. T. Legg and G. Lockwood)

In last year's report (p. 68) we mentioned that two field trials based on the T85/799 seed garden parent had been planted. They form part of the programme to assess new varieties with resistance to swollen-shoot infection and which might replace the hybrids presently being issued to farmers in Ghana. In both trials temporary shade (plantain, tree cassava and/or *gliricidia*) has now been reduced and growth has been satisfactory. Some of the varieties are growing as well as the Series II varieties that were included as standards.

The field plantings of progenies with two more of the seed garden clones were made in June 1972 (see last year's report p. 68). A field resistance trial was planted in Plot B7 at Tafo and a complementary progeny trial at Apedwa (11th P.T.A.). The following pollen parents were used with T63/967 as a female:

T17/524	T65/238
T79/378	T79/501
T87/1312	N8/122—putative IMC76
Amelonado	

and with T79/467 the pollen parents were:

T17/524	T61/1313
T65/202	T85/709
T87/1312	T90/344*
T92/1615	T101/2540
IMC47	N8/112—putative IMC60
IMC67	N8/122—putative IMC76
Na34	Amelonado

Both of the trials included the two best Series II hybrids, T85/799 × Amelonado and T85/799 × T79/501 as standards.

A further set of T63/967 crosses was prepared for minor rains planting in September-October 1972. Unfortunately there were insufficient seed pods of the standard varieties so the trials were deferred until 1973. Pollinations were made in October and nursery preparations and virus screening had been completed by mid-April 1973.

The male parents T65/202, T79/378, T85/709, T87/1313, IMC47, IMC67 in the B7 and 11th P.T.A. plantings were not included in B5 and therefore had not been crossed with Amelonado for field resistance assessment. These crosses were made and planted in trial B6 where their resistance to virus infection will be tested. Standard varieties were the usual two Series II hybrids together with N8/122 × Amelonado.

Work to find alternative pollen parents for the Series II seed garden clones (*Rep. Cocoa Res. Inst., Ghana,* **1971–72,** 65–8) is now well advanced. Although no new varieties can be released for some years, agreement has been made with the Chief Cocoa Officer of the Cocoa Production Unit

*Not a test variety in 11th P.T.A. due to lack of space.

and with the Director, Cocoa Research Institute, that small stocks of the male parents under test should be produced to provide sufficiently mature trees at the time of release for the initial supply of flowers and of budwood for expansion of the clones. The clones will be planted at the three Cocoa Stations where the seed gardens are sited.

Looking further forward to an entirely new generation of virus resistant progenies, it is proposed that some six to eight new female clones should be selected for seed garden planting. The highest levels of resistance found so far have been in the Nanay and Iquitos populations. Among those Nanays which have been extensively tested none appear to be better than Na34. Series XVI reported here confirms that IMC76 is the best Iquitos parent available. Accordingly these two clones have been selected as the first female parents of the new generation of hybrids and a start has been made to develop 30 acres of each clone which will provide mature seed garden facilities by the time the screening of pollen parents has been completed.

Trials to assess sensitivity to virus infection

There is an indication that one factor affecting tolerance to infection may be the age at which trees become infected. This is to be studied in a series of trials containing the same progenies which are to be planted over a six year period and infected simultaneously. The investigation has been based on trial A13 as it is available but some of the remaining trials cannot include the cross T12/113 × (T62/891 × T62/977) E1/45 as the only trees of the male parent are very young.

The proposed series of trials will be:

Planted		Proposed age at infection	
A13	1969 May	6 years 2 months	
A17	1972 September	4 ,, 0 ,,	
E16	1973 June	2 ,, 0 ,,	(proposed)
B11	1974 June	1 year 0 ,,	(,,)
E18	1974 December	seed	(,,)

The A17 site was planted under thinned forest shade in September 1972 and land and seedlings have been prepared for planting E16 next year. In A17 one progeny was omitted because pollinations failed and a sibling of E1: C4/3/291 was used in error in another cross.

The outcome of the first phase of our resistance breeding programme will be the release of seed from the existing Series II seed garden female parents using new pollen parents probably of Upper Amazon origin. Although we are uncertain at this stage how to measure their reaction to infection, some information on the symptoms caused is needed to advise control units in the Cocoa Production Division. The resistance trials will give information on symptoms in young seedlings but to observe the effect on older trees, a new trial (A15) was planted in May 1972 with progenies of the female parents of the seed gardens, crossed to representatives of each of the main Amazon populations. The crosses included were:

	Female parents			
	T63/967	T63/971	T79/467	T85/799
T65/202			×	
T65/238	×	×		×
T101/2540	×	×	×	×
N8/122 (IMC76)	×	×	×	×
Pa 7	×	×		×
Sca 6	×	×	×	×
Na34			×	×
Amel.	×	×	×	

The usual two Series II hybrids were included as standards.

During the year, preparations were made for further plantings of T63/967 crosses and for the trials of T63/971. In addition the site was prepared for another time of infection trial.

Trials A13 and A14 (*Rep. Cocoa Res. Inst., Ghana*, **1968–69,** 27–28) (J. T. Legg)

Growth is now slowing down, probably due to inter-tree competition especially in the closely spaced resistance trial A14 and also with the onset of cropping (Table 11). The weak block 1 has now improved. The transformation of individual tree girths to log values gave a five fold reduction in coefficient of variation. The final values were from 3–5% except for T101/2540 × T9/21 which was 8–9%. The relative growth of the different progenies in the two trials is similar with a rank correlation coefficient of $r_s = 0.75$ (significant at 5% level).

TABLE 11

*Tree sizes and yields in Trials A*13 *and A*14 (*Planted* 1969)

	Log values of girths (Feb. 1973)		Yield as equivalent dry wt. (lbs.)/acre in A13
	A13	A14	
T12/116 × T62/977	2.3249	2.2364	524
Na34 (N5/807) × T12 (26 × 151) M7/537	2.3137	2.2608	427
85D/176A × T12 (26 × 151) M7/537	2.3060	2.2513	406
T85/799 × T12 (26 × 151) M7/537	2.2879	2.2306	477
T9/21 × T92/1704/9536	2.2763	2.2284	373
T12 (26 × 151) M7 (537 × IMC76) (N8/122)	2.2692	2.2240	336
T12/113 × T62 (891 × 977) E1/45	2.2687	2.2433	215
T63/967 × EIC4/3/291 (Series IIB)	2.2463	2.1961	295
T101/2540 × T9/21	2.1953	2.1525	156
LSD at P = 0.05	0.049	0.027	

The progeny T101/2540 × T9/21 is significantly poorer in growth than all the other progenies and has the lowest yield, whereas T12/116 × T62/977 remains the best for growth and yield. Some of the T12 (26 × 151) M7/537 crosses also continue to be promising in these respects.

The yields of the better crosses are promising but as yields from young trials are unreliable they will be considered more fully next year.

Joint CRIG/Cocoa Production Division coppicing trials to assess latent virus infection (J. T. Legg and L. A. O. Lamptey)

In addition to the 16 outbreaks reported on last year five more plots have been coppiced and plots have been accepted and are awaiting coppicing. Four plots have been returned to the farmers.

Mortality has been high (over 30% at five sites) in coppiced trees (Table 12) and with the greater liability for infected trees to die, this leads to an underestimation of infection. The effect may not be so marked where poor conditions have led to poor regeneration.

Exceptions are still being encountered to the expected appearance of disease symptoms shortly after regrowth starts following coppicing. For instance at Bunso 1 the first symptoms appeared seven months after coppicing, whereas at Seidi 1 symptoms have appeared throughout the 34 months since coppicing. It would be interesting to know whether infection is latent in coppiced trees for so long or whether new infections are occurring from nearby cocoa or alternative hosts.

All the treated farms have been revisited this year to assess regeneration. In each plot one hundred trees were randomly chosen and the vegetative growth and yield assessed. The regrowth was scored on a 1–5 scale with one for poor growth and five for very good. Five plots gave a good rating, seven were satisfactory and the remaining four were poor (Table 12). The poor performances were partly due to degraded soils and inadequate shade but also because of severe capsid damage although plots are scheduled for monthly spraying.

Ten of the plots have started flowering and eight were bearing fruit (the different periods of regrowth are shown in Table 12). It is intended that yield records will be continued on the more mature sites even after they have been returned to the farmers.

PHYTOPHTHORA STUDIES

EPIDEMIOLOGY

The importance of black pod in Ghana: Joint CRIG/Cocoa Division Project (J. T. Dakwa)

The nationwide survey to determine the incidence of black pod (*Rep. Cocoa Res. Inst., Ghana*, **1971–72,** 74) has been started. Ten one-acre plots were selected from each of the 137 districts of the Cocoa Division. Of the expected 137 districts only 51 made up of Eastern Region—19, Ashanti—12, Brong Ahafo—3, Volta Region—4, Western Region—10 and Central Region—3 have so far submitted completed harvesting records. A summary for the 442 acres involved is given in Table 13. The mean disease incidence was 20.7% of which 42.1% were completely destroyed. This represented a potential loss of 27,618.7 lbs. dry cocoa and an actual loss of 11,622.5 lbs. dry cocoa respectively. The Volta Region which has hitherto been regarded as an area of low disease incidence had both the highest disease incidence and disease loss. These are only one year's records and firm conclusions of the general situation should not be made yet.

Table 12

Performance of coppiced trees up to March 1974 at cocoa swollen shoot outbreaks

Farm	A Age (months) since coppicing	B Original no. of coppiced trees	C Dead	D No. of coppiced stumps showing diseased symptoms	E B−(C+D) symptom-less and presumed healthy	$\frac{C \times 100}{B}$ % of coppiced stump dead	$\frac{D \times 100}{B - C}$ % of coppiced stump infected	Growth mean score	Flowering	Fruiting
Kwakoko/Juansa AR	36	590	178	48	364	33.1	8.1	3.3	+	+
Magyida/Agogo AR	36	347	49	73	225	14.1	21.0	2.8	+	−
Sedi 1 AR	34	544	180	90	274	33.0	16.5	2.4	−	+
Nkroso ER	34	1,127	17	80	1,030	1.5	7.1	4.4	+	+
Nsutam 1 ER	33	901	365	40	496	40.5	4.4	3.1	+	+
Bawdua ER	33	585	57	46	482	9.7	7.9	2.4	−	−
Sedi 2 AR	33	593	181	72	340	30.5	12.1	2.9	−	+
Amanchia 1 AR	33	338	42	37	259	12.4	10.1	4.0	+	+
Amanchia 3 AR	32	481	84	21	376	17.5	4.4	2.5	−	−
Nsutam 2 ER	32	410	46	53	311	11.2	12.9	4.0	+	+
Mampong Anyinam ER	31	486	78	41	367	16.0	8.4	3.9	+	+
Amanchia 2 AR	31	388	83	27	278	21.4	6.9	2.5	+	−
Nsutam 3 ER	27	548	157	26	365	28.6	4.7	3.1	+	−
Nsutam 4 ER	21	447	50	115	282	11.2	25.7	3.1	−	−
Asafo ER	20	1,149	174	74	901	15.1	6.4	3.0	−	−
Bunso ER	20	620	39	9	572	6.3	1.5	4.0	+	−
Amanchia 4 AR	10	476	88	27	361	18.5	5.7	3.4	−	−
Amanchia 5 AR	10	500	69	4	427	13.9	0.8	3.0	−	−
Amanchia 6 AR	10	468	57	23	388	12.2	4.9	2.6	−	−
Amanchia 7 AR	10	455	36	15	404	7.9	3.3	3.0	−	−
Amanchia 8 AR	10	500	66	24	410	13.2	4.8	3.2	−	−

1 Growth performance was scored as 0 = very poor to 5 = good
2 Flowering and/or fruiting occurring = +, not occurring = −

TABLE 13

The incidence and severity of black pod disease in Ghana

Region	Acreage	Total pods	Disease incidence No. of pods	%	Diseased pods No. of pods	Destroyed %
Brong Ahafo	15	70,807	8,263	11.7	3,481	42.1
Volta	35	119,480	55,460	46.4	34,092	61.5
Central	28	64,513	10,337	16.0	3,183	30.8
Western	93	276,996	58,573	21.4	21,045	35.9
Ashanti	102	453,700	106,767	23.5	45,682	42.8
Eastern	169	613,328	92,024	15.0	31,986	34.8
Total	442	1,598,824	331,424	20.7	139,469	42.1

Black pod disease and the weather (J. T. Dakwa)

Investigations to study the effect of the weather on the outbreaks and development of black pod (*Rep. Cocoa Res. Inst., Ghana,* **1971–72,** 74) have continued and the data are being analysed.

Black pod disease progress curves (J. T. Dakwa)

The progress curves for black pod were drawn by plotting (a) the number of diseased pods at any harvest, (b) the number of diseased pods expressed as a percentage of total pods harvested on any occasion, (c) the cumulative total number of diseased pods at each harvest, and (d) the cumulative total number of pods expressed as a percentage of the total pods harvested in the crop year, against time (Fig. 12). The data were collected in 1968–69 season for the progeny coded D in the black pod resistance trial (*Rep. W. Afr. Cocoa Res. Inst.,* **1960–61,** 27–28). The total number of diseased pods at a picking, though demonstrating fluctuations between pickings, did not bring out clearly the nature of disease build up as indicated by the other three. The number of diseased pods expressed as a percentage of total pods harvested on any occasion indicated that between May and the end of June, disease built up sharply and dropped at almost the same rate about the second half of September. The curves based on cumulative data showed that the disease build up between May and late August was gradual; thereafter the increase in disease development was negligible. The cumulative total number of diseased pods was not related to yield and could not be used to estimate yield loss as disease curves are meant to do. The cumulative per cent data on the other hand fulfilled this important criterion and hence is preferred in the construction of black pod disease curves. It has been used to examine (a) the seasonal variation in disease development, (b) varietal and geographical differences in disease development and (c) the effects of fungicide application and shade on disease development. The details of this study will be published as a scientific paper.

Sources of primary field inoculum of *Phytophthora palmivora* in cocoa farms (A. Asare-Nyako)

Recording of black pod disease incidence continued as detailed in *Rep. Cocoa Res. Inst., Ghana,* **1969–70,** 65. The total number of pods produced

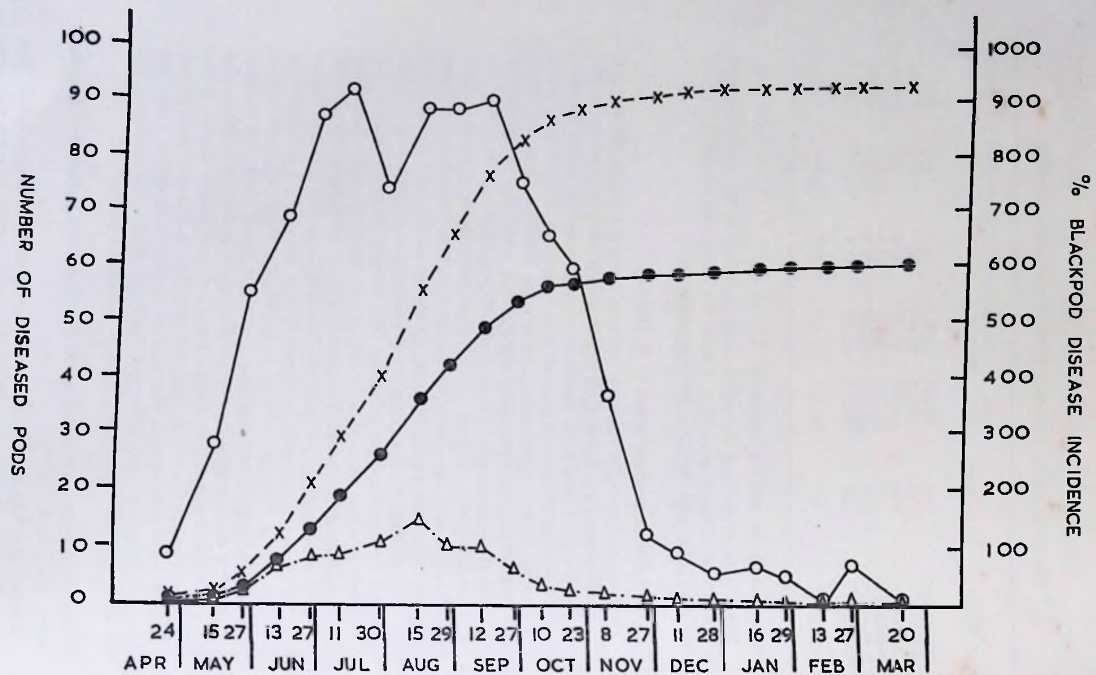

Fig. 12. Pattern of black pod development as indicated by actual number of diseased pods (△ — · — · — △), cumulative number of diseased pods (× — — — ×), per cent cumulative diseased pods (● ——— ●) and per cent actual diseased pods (○ ——— ○).

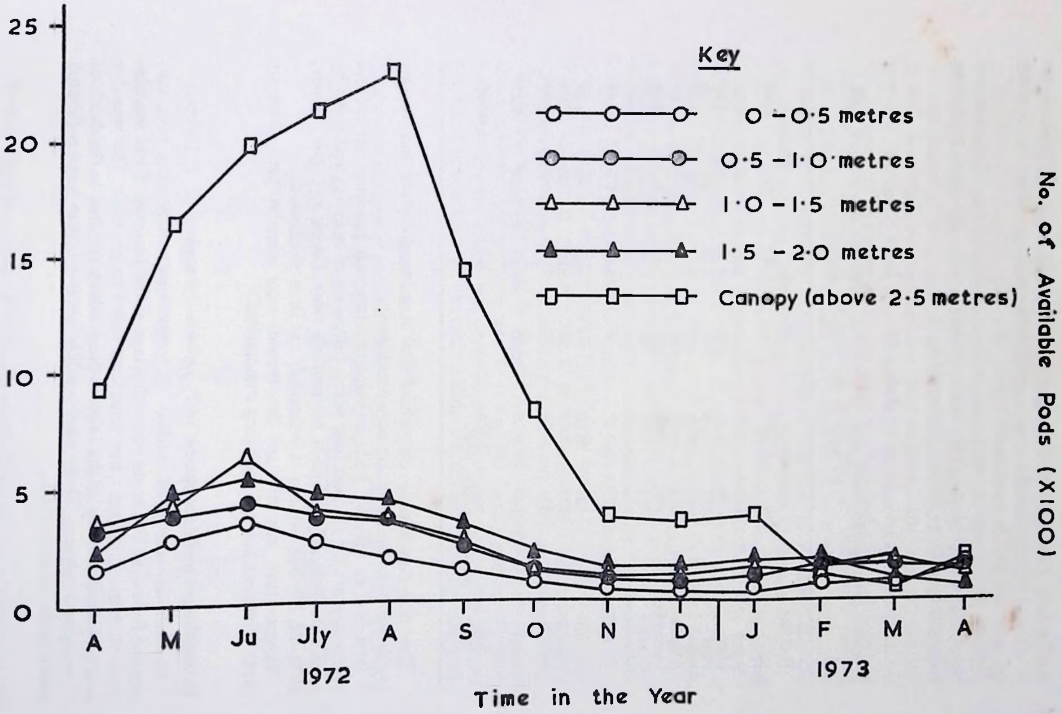

Fig. 13. Vertical distribution of available pods on 180 trees 1972–73 season.

by the trees gave a unimodal curve which reached a peak in June on the trunk and in August in the canopy; pod setting became evident in February on the trunk and in April in the canopy (Fig. 13).

Black pod incidence was lowest in cherelles followed by immature and mature pods (Table 14). However, cherelles were the most numerous followed by mature and immature pods.

TABLE 14

Monthly distribution black pods in cherelles, immature and mature pods on 180 *trees in the* 1972–73 *season*

Pod size	Cherelles		Immature		Mature	
	No.	%BP	No.	%BP	No.	%BP
1972						
April	2,152	0.42	190	0.00	26	0.00
May	3,354	0.57	388	3.35	331	1.82
June	3,812	0.16	383	5.22	601	2.16
July	3,238	0.22	469	5.12	1,029	3.60
August	1,611	0.55	445	3.37	1,420	4.44
September	1,403	0.78	232	3.45	1,547	6.08
October	464	0.00	94	3.19	1,102	3.45
November	189	0.00	59	1.69	553	5.24
December	348	0.00	6	16.67	177	1.69
1973						
January	504	0.00	20	0.00	93	3.23
February	653	0.15	22	0.00	34	0.00
March	452	0.00	22	0.00	45	0.00
Total	18,180	0.34	2,330	3.65	6,958	4.11
S.E. ±		± 0.079		± 1.324		± 0.593

%BP = percentage black pods.

The non-Amelonado outyielded the Amelonado plots but disease incidence was also higher on non-Amelonado.

Removal of infected pods at three-day intervals has been carried out on these plots for the past four years. Infections of cushions and stems by inoculum from infected pods are unlikely (*Rep. Cocoa Res. Inst., Ghana*, **1971–72,** 80) but cushion infection has not been eliminated.

Temperature, humidity and dew records were taken in three of the six plots. Figures obtained are being summarised.

Establishment and development of *P. palmivora* cankers (J. T. Dakwa)

Greenhouse and field studies. All greenhouse experiments were suspended following the acute water shortage at the Institute. Field inoculations were also stopped when infections failed to establish. This was due to the rapid drying up of the inocula plugs which resulted in the death of *P. palmivora* cultures. These studies will be resumed when hand pollinated cocoa pods are available.

Invertebrate vectors (H. C. Evans)

Ants (Formicidae). The experiment initiated to determine the importance of tent-building ant species in black pod epidemiology (*Rep. Cocoa Res. Inst., Ghana*, **1970–71**) was finalised at the end of October, 1972.

By plotting chi-squared measures of association against time, in order to compare black pod incidence with and without ants, the following conclusions were drawn. On the basis of a pod analysis it was found that the significance of black pods infected from ant tent material was inversely related to rainfall. At high rainfall these sources were of negligible importance; secondary spread by rain-splash, drip and contact accounted for the majority of infections. A tree analysis, however, revealed that the presence of tent-building ants could invariably be correlated with a significantly higher level of black pod infection ($P = 0.001$). Early rains, as during 1972, increased the significance and this may reflect the importance of ant-borne soil inoculum at the beginning of the season.

Horizontal spread of inoculum by tent-building ants was investigated using radioactive tracers. All hanging black pods and those left on the ground were removed from a block of trees colonised by *Crematogaster striatula*. Hand-painted P-32 black pods (*Rep. Cocoa Res. Inst., Ghana*, **1970–71**, 69–74) were placed in a small heap in the centre of the block. Material from ant tents at known distances from the P-32 source were routinely screened for presence of radioactivity after a three week interval. Tent radioactivity decreased with distance from the heap and none was detected on trees more than 2.5 m from the P-32 source (see Table 15). Trees at 1.0 and 1.5 m from the source had the highest P-32 counts and tents up to 3.4 m above ground level exhibited radioactivity. The evidence indicates that horizontal dispersal of inoculum by this ant is not extensive but endorses its role in vertical disease spread. Furthermore, the very low count rates obtained demonstrated that in this instance black pod tissues were not the main building material, but supplementary.

TABLE 15

Radioactive analysis of pod tents built by Crematogaster striatula *at varying distances from ^{32}P-labelled black pod heap*

Tree distance from ^{32}P source (m)	Height of pod tent (m)	Counts/100s*
1.0	0.5	41 ± 6.4
1.0	2.0	22 ± 4.5
1.5	1.0	32 ± 5.7
1.5	2.2	10 ± 2.9
1.5	3.4	8 ± 2.6
2.0	0.4	35 ± 5.9
2.5	0.6	22 ± 4.6
2.5	1.8	6 ± 2.4
2.5	2.7	5 ± 2.2

*After deduction of background count, mean of three readings. Two sigma confidence level.

Pod-feeding invertebrates. All the invertebrate groups of species which consistently carried viable inoculum of *P. palmivora* externally or internally, and which utilised black pods as a food source are listed in Table 16. I am

TABLE 16

Invertebrates found to carry viable Phytophthora *sporangia externally or internally and which regularly feed on hanging black pods*

Diptera

Neriidae
- *Chaetonerius latifemur* End.

Drosophilidae
- *Leucophenga* sp.
- *Zaprionus* sp.

Tephritidae
- *Acanthoneura fallacivena* End.

Lauxaniidae
- *Cestrotus* sp.

Lonchaeidae
- *Silba* sp.

Platystomatidae
- *Rivellia* sp.

Coleoptera

Nitidulidae
- *Brachypeplus pilosellus* Murr.
- *Axyra papillosa* M.

Staphylinidae
- *Oxytelus gabonesis* Ful.

Lagriidae
- *Derolagria* sp.

Curculionidae (Anthribidae)
- *Litocerus mocquerysi* Jordan
- *Litocerus* sp.
- *Araecerus* sp.

Lepidoptera*

Arctiidae
- 5 species

Cossidae
- 2 species

Geometridae
- 2 species

Noctuidae
- 2 species

Psychidae
- 1 species

Zygaenidae
- 1 species

Myriapoda
- *Spirobolus* sp.
- 4 unidentified species

Mollusca

Urocyclidae
- ? *Gymnarion* sp.
- 2 unidentified species

Veronicellidae
- *Veronicella* sp.
- ? *Macrochlamys indica* Godwin-Austen

Subulinidae
- ? *Homorus* sp.

Annelida

Acanthodrilidae
- *Dichogaster arboricola* Wasawa & Omodeo

*Larval stage.

indebted to the staff of the British Museum (Natural History) for many identifications.

An observational study of the behaviour of these potential invertebrate vectors revealed that several of them also regularly visit and feed on wounded, but otherwise healthy, pods. Furthermore, because of their relative abundance (*Rep. Cocoa Res. Inst., Ghana*, **1971–72**, 88–90) they were selected for an investigation of their transmission efficiencies. Tests were carried out in an isolated block of cocoa in which regular harvesting and removal of all black pods kept the incidence of natural infection at a very low level. Throughout the experiments hand-pollinated, green mature pods were used.

Brachypeplus pilosellus. This nitidulid beetle invades damaged pods usually via the wounds of insect pod borers (*Olethreutes* spp.) and various rodents; feeding on the internal mucilaginous tissues.

Pods were aseptically wounded with a cork borer and immediately sealed with sterile cotton-wool plugs. Beetles were carefully removed with fine forceps from black pods in the field and allowed to crawl through gauze into sterile conical flasks. By blowing air into the flasks it was possible to produce rapid flight movements and was aimed at simulating natural flight within the cocoa farm. Beetles were then either introduced directly into wounded pods (one/pod) or prior to this, immersed in 1% mercuric chloride for one minute and thoroughly washed in sterile water. After introduction of the beetles the pods were resealed; controls consisted of wounded sealed pods only. All pods were removed after 10 days and any lesions examined microscopically for pathogen identification. The results in Table 17 suggest that *Brachypeplus* is an important vector of *P. palmivora*, carrying inoculum both externally and internally. *Botryodiplodia* appears to be a common external contaminant and to a lesser extent *Trachysphaera*.

TABLE 17

Determination of external and internal transmission of fungal pod rot by Brachypeplus *beetles, using wounded pods in the field*

Treatment	*Phytophthora*	*Botryodiplodia*	*Trachysphaera*
Pods without beetles (control)	0/210 (0)	7/210 (3.3)	0/210 (0)
Pods with unsterilised beetles	57/230 (24.8)	90/230 (39.1)	12/230 (5.2)
Pods with surface-sterilised beetles	23/200 (11.5)	5/200 (2.5)	0/200 (0)

Figures are numbers of pods developing infection/numbers treated.
Figures in parentheses are % infection rates.

Chaetonerius latifemur. This long-legged fly, in addition to feeding on black pods, commonly visits mirid-damaged pods, notably damaged by *Helopeltis*. Sugary exudates usually occur around fresh mirid lesions and act as strong attractants for this dipteran. Drosophilidae have a strong predeliction for rodent-damaged pods and rarely feed around mirid lesions.

Experiment 1. Flies were collected from the immediate vicinity of trees bearing diseased pods, chloroformed and the mouthparts examined microscopically. Results (Table 18) showed that out of a total of 692 mouthparts 217 (31.4%) were contaminated with sporangia of *P. palmivora*. From a monthly examination there were definite seasonal differences in the proportion of flies carrying sporangia, and this may be directly related to the density of sporulation on the pod surface. Towards the end of September, conidia of *Trachysphaera* were also associated with the mouthparts, adhering particularly to the labial hairs.

TABLE 18

Monthly occurrence of Phytophthora *sporangia on the mouthparts of* Chaetonerius *flies collected from diseased cocoa trees*

	July	August	September	October	November
No. flies carrying *Phytophthora* sporangia/no. examined	61/138	54/140	41/144	39/150	22/120
Percentage contamination	44.2	38.6	25.0	26.0	18.3

Experiment 2. Pods were superficially wounded, using standard aseptic procedure, and enclosed in insect-proof cages. Single flies, newly collected from black pods, were introduced into half the cages and the remainder left as controls. After 10 days the pods were examined for signs of infection. Almost 23% of the pods with flies developed *Phytophthora* lesions, which initiated directly from the wounded areas (Table 19). The experiment was repeated using flies collected from mealy pods and from the high infection rate it would seem that the conspicuously spiny conidia of *Trachysphaera* are well adapted to insect dispersal.

TABLE 19

Transmission of fungal pods rots by Chaetonerius *flies, using superficially-wounded caged pods in the field*

Wounded caged pods (control)	2/100* (2.0)
Wounded caged pods +	
Flies collected from black pods	16/70 (22.9)
Flies collected from mealy pods	12/30 (40.0)

Figures are numbers of pods developing infection/numbers treated.
Figures in parentheses are % infection rates.

**Botryodiplodia.*

Soil activities of *P. palmivora* (J. T. Dakwa)

The isolation of *P. palmivora* from soils collected from cocoa farms, an abandoned cocoa farm and from a forest site (*Rep. Cocoa Res. Inst., Ghana*, **1971–72,** 80–84) has been concluded. At Pankese, the fungus was baited from 57.3% and 56.3% of all soil samples collected from R2 and area 117 respectively. It was similarly collected from 58.3% and 52.1% of the soils from Bunso Plots P1 and P2 respectively. The corresponding figures for Tafo were 33.3% (A6) and 50.0% (M4). At Obomeng, successful isolations were 47.9% for the black pod variety trial, 29.2% for the abandoned cocoa farm and only 19.8% for the forest reserve area. At all stations, isolations of the fungus between September 1971 and July 1972 was erratic, a period when the mean maximum ambient temperatures ranged from 30° to 32.5°C. The fungus was consistently and more frequently isolated at Bunso and Pankese than at Tafo and the Obomeng resistance trial plot. The number of soil samples out of a maximum of four from which the fungus was detected also followed the same pattern. These may be reflections on differences in agronomic practices at these stations. A detailed account of this work has been submitted for publication.

CHEMICAL CONTROL OF *PHYTOPHTHORA PALMIVORA*

Root infection and leaf blight in seedlings (A. Asare-Nyako)

Screening of fungicides for controlling *P. palmivora* was continued in attempts to find fungicides as efficient as or better than Kocide which was found in the previous tests to control root rot and seedling leaf blight caused by *P. palmivora* (Asare-Nyako *et al.*, *Ghana Jnl. Agric. Sci.*, **5**, 127–133). The chemicals tested and their respective basic concentrations were as given below:

Chemical	Weight or volume in 1.1 litres
Dithane C-90	11.4 g
BBS	11.4 g
Brestan	2.0 g
Burcop	14.3 g
Duter	2.0 g
Copper Count-N	42.2 g
Kocide	11.3 g
Aureofungin	0.3 g
Daconil	1.7 g
Captan Terrachlor	11.4 g
Bordeaux Mixture	18.2 g
Perecol	32.3 g

Where three concentrations were studied, half and twice the basic concentrations (concentrations C and A respectively) were also tested. The basic concentration was designated B. The methods of inoculation were as detailed in the previous annual report (*Rep. Cocoa Res. Inst., Ghana*, **1971–72,** 84-85) but beans were planted on raised nursery beds. Three tests were made using four replications.

In Tests 1 and 2 only peeled pregerminated seeds of the hybrid A62 × S27 known to be highly susceptible to *P. palmivora* infection was studied using three concentrations of each chemical.

Dithane C-90 Bordeaux Mixture and BBS did not reduce emergence. In the case of Kocide, Aureofungin, Duter and Perecol, emergence was reduced only at the highest concentrations studied. Copper Count–N, Captan Terrachlor and Duter reduced emergence at all the concentrations studied (Table 20).

TABLE 20

Percentage emerged seedlings 10 days after inoculating peeled pre-germinated seeds with 10 candidate fungicides

Fungicide	A		B		C		Mean	
	Test 1	Test 2	Test 1	Test 2	Test 1	Test 2	Test 1	Test 2
BBS	71.4	100.0	100.0	88.9	100.0	88.9	85.0	85.2
Copper Count-N	0.0	44.4	28.6	55.6	57.1	66.7	28.6	55.6
Bordeaux mixture	83.3	88.9	100.0	100.0	100.0	100.0	95.0	96.3
Dithane C-90	100.0	88.9	100.0	77.8	100.0	88.9	100.0	85.2
Duter	50.0	33.3	100.0	33.3	100.0	44.4	61.9	37.0
Brestan	0.0	11.1	0.0	44.4	0.0	55.6	0.0	37.0
Captan Terrachlor	14.3	66.7	28.6	77.8	57.1	66.7	33.3	70.4
Aureofungin	14.3	55.6	100.0	77.8	85.7	100.0	66.7	77.8
Kocide	42.9	77.8	71.4	77.8	85.7	100.0	66.7	85.2
Perecol	28.6	77.8	85.7	77.8	85.7	100.0	66.7	85.2
Control	100.0	94.4	100.0	94.4	100.0	94.4	100.0	94.4
Se ±	7.03	8.49	11.20	6.22	9.31	6.12	9.68	6.4

Concentrations of fungicides (A, B, C).

In Test 3, only concentration B was used. The efficacy of the fungicides in the control of *P. palmivora* inoculated as detailed in last year's annual report was tested alongside their toxicity on seedlings. The height, the number of leaves, the diameter of stem immediately below the cotyledons as well as the number of seedlings surviving were recorded 42 days after inoculation and planting (Table 21).

Of the seven fungicides which did not adversely affect germination, i.e. Kocide, Perecol, Duter, Burcop, Dithan C-90, Captan Terrachlor and Bordeaux Mixture, Duter was the only one which caused stunted growth. Thus although 80% survivals were recorded for Duter-treated seedlings as against 94.8% in untreated seedlings, the mean height of Duter-treated seedlings was 5.8 cm compared with 18.6 cm for untreated seedlings. Treatment with Brestan and copper Count–N resulted in significantly less surviving seedlings. BBS and Aureofungin reduced seedling survival but to a less extent.

A reduction from 94.8 to 21.3% in surviving seedlings was recorded on control plots after *P. palmivora* inoculation. There was, on the average, significantly less reduction in surviving seedlings when the fungicides were jointly inoculated with *P. palmivora*. BBS, Kocide and Perecol in that order of efficacy had the least reduction in stands.

A summary of correlation and regression analyses is given below:

	Correlation coefficient (r) Diameter	Surviving seedlings	No. of leaves
Height	0.5700**	0.7723**	0.8877**
Diameter	—	0.4318*	0.3984NS
Surviving seedlings	—	—	0.6287**

TABLE 21

Effect of 11 *candidate fungicides inoculated severally or jointly with* P. palmivora *on surviving seedlings, height, diameter and number of leaves produced* 42 *days after inoculation*

Chemical	Inoculum	Mean height in cm	Mean diameter in mm	% surviving seedlings	Mean no. of leaves
Kocide	−	17.8	3.8	100.0	3.2
	+	15.6	4.0	95.0	2.9
Perecol	−	17.7	3.9	100.0	3.2
	+	16.9	4.1	90.0	3.1
Brestan	−	5.6	4.5	15.0	0.0
	+	0.0	0.0	0.0	0.0
Duter	−	5.8	4.1	80.0	0.8
	+	0.0	0.0	0.0	0.0
Burcop	−	17.4	4.2	90.0	2.6
	+	13.5	4.0	40.0	1.6
Cu-Count-N	−	9.1	3.6	30.0	0.5
	+	3.5	4.0	10.0	0.0
Dithane c-90	−	18.4	4.6	90.0	4.2
	+	17.1	3.7	30.0	4.5
Captan Terrachlor	−	13.8	4.2	85.0	2.9
	+	9.1	4.8	25.0	1.0
BBS	−	14.2	4.1	40.0	2.6
	+	14.3	4.2	40.0	3.9
Bordeaux Mixture	−	15.3	4.1	80.0	4.9
	+	7.9	5.2	25.0	0.8
Aureofungin	−	15.4	3.7	40.0	3.6
	+	12.6	3.8	15.0	2.3
Control	−	18.6	4.0	94.8	3.6
	+	13.2	4.3	21.3	2.4
Mean		12.2	3.9	51.5	2.3
Se ±		1.17	0.25	7.26	0.32

Within the period of study, there was thus a significant correlation between surviving seedlings and stem diameter, height and number of leaves produced. There was no correlation between stem diameter and the number of leaves produced.

Chemical control of pod infection (A. Asare-Nyako)

Small scale field tests

A. The comparison of Kocide and Perecol sprayed at nine, six and five times in the year continued as detailed in the previous year's report. (*Rep. Cocoa Res. Inst., Ghana*, **1971–72,** 90–1). Figure 14 gives the distribution of black pods at three-weekly intervals in the 1971–72 and 1972–73 seasons for the various spraying schedules. The lowest disease incidence occurred with nine applications followed by six, five and no applications in that order of increasing incidence. There was no significant difference (P = 0.05) in disease incidence on plots given nine and six spray applications. Perecol-treated plots receiving five spray applications had about the same level of black pods as the control plots but there were significantly (P = 0.05) less infection on plots receiving five applications of Kocide compared

TABLE 22

Total Black Pod Incidence in mature pods in Plot N14 (1971–73)

No. of applica-tions	% Black pod in plots treated with Kocide			Perecol			Totals		
	1971–72	1972–73	Mean	1971–72	1972–73	Mean	1971–72	1972–73	Mean
9	20.1a	16.6a	18.4	17.7a	8.3a	13.0	18.9a	12.4a	15.7
6	17.9a	13.4a	15.7	19.2a	12.5a	15.9	18.5a	13.0a	15.8
5	15.8a	27.0b	26.4	50.8b	36.0b	43.4	38.3b	31.5b	34.9
0	77.3b	36.3c	56.8	77.3c	36.3b	56.8	77.3b	36.3b	56.8
Mean	35.3	23.3	29.3	41.3	23.3	32.3	38.2	23.3	30.8

Figures bearing similar letters are not significantly different at the 5% level according to Duncan's Multiple Range Test.

TABLE 23

Mature pods harvested on plots given nine, six, five and no spray applications of Kocide and Perecol, 1971–73

No. of applications	No. of pods harvested in plots treated with Kocide			Perecol			Totals		
	1971–72	1972–73	Total	1971–72	1972–73	Total	1971–72	1972–73	Total
9	2,527	2,875	5,402	2,396	2,937	5,333	4,923	5,812	10,735
6	2,265	2,753	5,018	2,928	2,993	5,921	5,193	5,746	10,939
5	2,220	2,416	4,636	1,587	1,910	3,497	3,807	4,326	8,133
0	1,250	1,675	2,925	1,250	1,675	2,925	2,500	3,350	5,850
Total	8,262	9,719	18,011	8,161	9,515	17,676	16,423	19,234	35,657
Mean	2,065.5	2,429.8	4,502.8	2,040.3	2,378.8	4,419.0	4,105.8	4,808.5	8,914.3

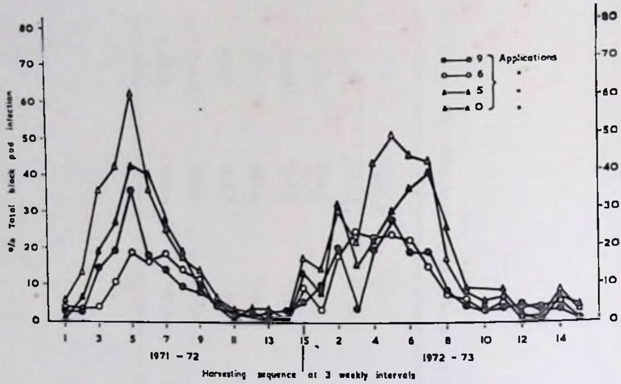

Fig. 14. Black pod incidence in plot N14 (1971–73).

with the control plots. Nine and six applications gave significantly less disease incidence (P = 0.05) than five applications or no spray (Tables 22 and 23) of both fungicides. Mature pod yields on unsprayed plots were about 63 % the mean yield on sprayed plots (Tables 22 and 23).

Considering the crop saved and the cost of spray applications (Table 24), it was profitable to spray six times in the year but not profitable to spray nine or five times.

Details of this study are being published elsewhere (*Ghana Jnl. Agric. Sci.*, **7**, in press).

B. Tests with eight candidate fungicides studied in the previous year (*Rep. Cocoa Res. Inst., Ghana*, **1971–72**, 91–2) were continued. On the whole, better control of the disease was obtained when spraying was done one day after harvesting than seven days later (Fig. 15). Fungicides found

TABLE 24

Comparison of crop and cash savings on applying Kocide at nine, six and five times in the year

Year	No. of applica-tions	Crop saved Dry weight (lbs.)	Crop saved Value ¢	Cost of application Labour ¢	Cost of application Sprayer ¢	Cost of application Chemi-cal ¢	Total ¢	Net cash savings on spraying ¢
1972–73	5	128	21.3	10	1.5	20	31.5	−10.2
	6	285	47.4	12	1.5	24	37.5	+9.9
	9	279	46.5	18	1.5	36	55.5	−9.0

− and + represent loss and gain respectively.
Figures are based on estimates for an acre.

promising included Kocide, Burcop, BBS and Copper Count–N. The last two will be further tested using Kocide as the standard.

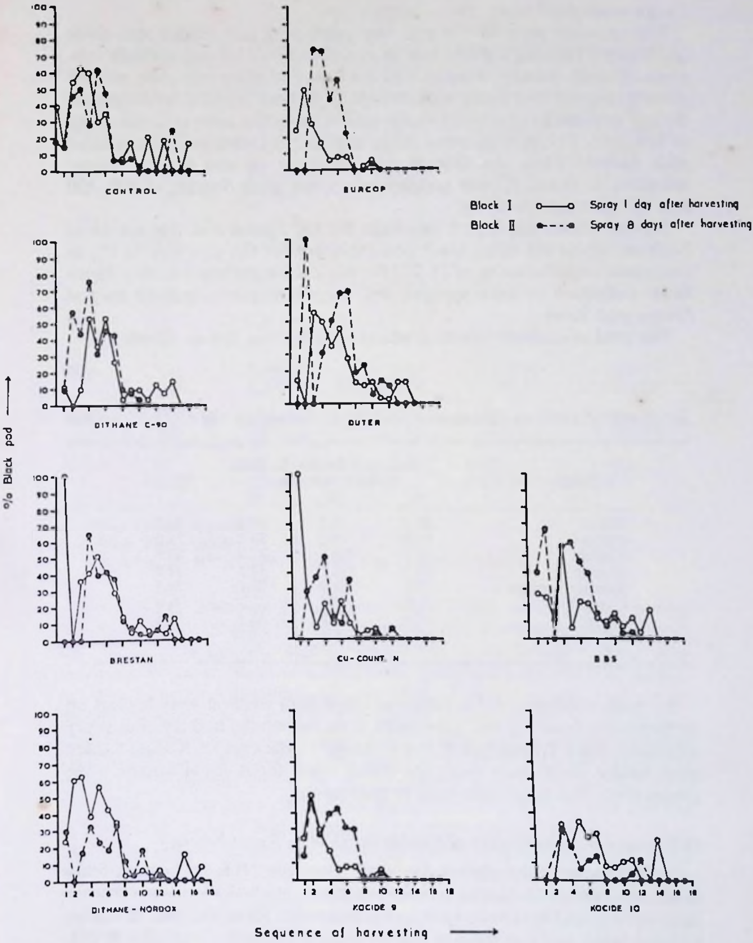

Fig. 15. Percentage black pod incidence following application of nine fungicides one day or eight days after harvesting.

Large scale field tests

The one-acre plots of the past two years were sub-divided into three (A, B and C) leaving a guard row of two plant-rows (40 cm) between sub-plots. Kocide, Burcop, Perecol and Bordeaux Mixture sub-plots marked A were sprayed nine times while sub-plots marked B and C were sprayed six and five times respectively in the season using the same concentrations as last year. The periods when spray applications were missed coincided with periods when the disease was naturally on the decline. Duter sub-plots A, B and C were sprayed nine times using dosages of 800, 400 and 160 g/acre respectively.

On the whole, black pod incidence for the season was low except at Pankese, where the mean black pod incidence for the year was 72.7% as compared with the mean of 21.7% for the eight experimental sites. Significant difference between sprayed and unsprayed plots occurred only at Goaso and Bieni.

The level of cushion infection was recorded at the Jamasi (Table 25).

TABLE 25

Summary of cushion infections recorded at Jamasi in the 1972–73 season

Fungicide	% cushion infection on plots given treatments			Mean
	A	B	C	
Duter	81.7	69.7	69.8	73.7
Perecol	87.9	76.6	70.2	78.2
Kocide	79.3	81.1	81.7	80.7
Burcop	83.7	78.2	57.1	73.0
Bordeaux mixture	77.5	73.0	72.1	74.2
Control	51.9	57.6	73.3	60.9
Mean	77.0	72.2	70.7	73.4
S.E. ±	5.23	3.43	3.24	2.79

Secondary infections, i.e. infection other than cushion were highest on unsprayed (control) plots. Treatment A on the whole, had less secondary infections than Treatments B and C except in the case of Kocide-treated plots where the disease incidence levels were about equal for the three treatments. This is an indication of persistence.

Differences in susceptibility of hybrids in N14 (A. Asare-Nyako)

In the course of the chemical control studies in N14, the susceptibility of the six hybrids to black pod was separately studied. Yield and disease incidence on the four control plots were recorded. There was, on the whole, a higher black pod incidence in mature than in immature pods (Table 26). Losses in immature pods were due mainly to precocious ripening (72%) while losses in mature pods were almost all due to black pod incidence (94%).

The differences in yield as well as in the black pod incidence between the various hybrids studied were significant (P = 0.05). Two high yielding hybrids (IIJ and IIE) had low black pod incidence and two low-yielding varieties (IID and IR) had high black pod incidence.

TABLE 26

Summary of mature pod yield and black pod incidence in plot N14 (1971–1973)

Hybrid	Pod size*	1971–72 Yield lbs./acre	1971–72 % black pod	1972–73 Yield lbs./acre	1972–73 % black pod
II J	I	4,333 (1)	22.9 (6)	4,405 (1)	15.4 (6)
	M	1,545 (1)	31.1 (5)	2,390 (1)	16.7 (6)
II D	I	1,553 (5)	32.2 (1)	1,616 (5)	27.3 (3)
	M	552 (6)	55.1 (1)	665 (5)	45.4 (1)
I R	I	1,404 (6)	28.5 (4)	1,153 (6)	24.8 (4)
	M	659 (5)	37.7 (4)	651 (6)	29.2 (4)
II C	I	2,561 (4)	29.8 (2)	1,716 (4)	31.4 (2)
	M	1,068 (4)	38.3 (3)	931 (4)	37.2 (2)
II A	I	2,740 (3)	29.7 (3)	2,179 (3)	31.8 (1)
	M	1,309 (2)	38.5 (2)	1,463 (3)	31.5 (3)
II E	I	2,823 (2)	23.6 (5)	2,282 (2)	19.4 (5)
	M	1,276 (3)	27.2 (6)	1,616 (2)	17.9 (5)
S.E.	I	±431.9	±15.2	±466.3	±26.8
	M	±159.4	±39.0	±275.3	±45.2

*I = Immature pods.
M = Mature pods.
Figures in brackets denote ranking along the vertical column.

The yield or cropping pattern for 1971–72 and 1972–73 seasons are summarised in Figure 16. With the exception of IID which had a unimodal distribution, the hybrids tended to have two peaks in yield. Black pod incidence however, showed a unimodal distribution in 1971–72 and a tendency towards a bimodal curve in 1972–73. IIA however, had a unimodal disease curve (Fig. 17). The period of high black pod incidence coincided with the period of high yield. The percentage black pod and yield in July to September is summarised in Table 27 for each hybrid for the 1971–73 seasons. There was no significant correlation between yield and black pod incidence in July to September. In 1971–72 IID was the hybrid which had the highest proportion of its annual crop in the July–September period. It also had the highest disease incidence. Hybrids IIJ and IIE which ranked third and sixth respectively considering the proportion of their annual crop realised between July and September ranked sixth and fifth respectively with respect to black pod incidence for the same period.

In the 1972–73 season, the hybrid with the highest proportion of its yield in July–September was IIJ (69%) followed by IID (63.2%). IIJ however had the least black pod percentage (20.5%) for the period while IID had the highest (57.3%). It is worth noting that there was a significant (P = 0.05 in 1971–72, P = 0.01 in 1972–73) correlation between black pod incidence in the July–September period and the annual incidence in both years. It could be inferred therefore that the differences in annual black

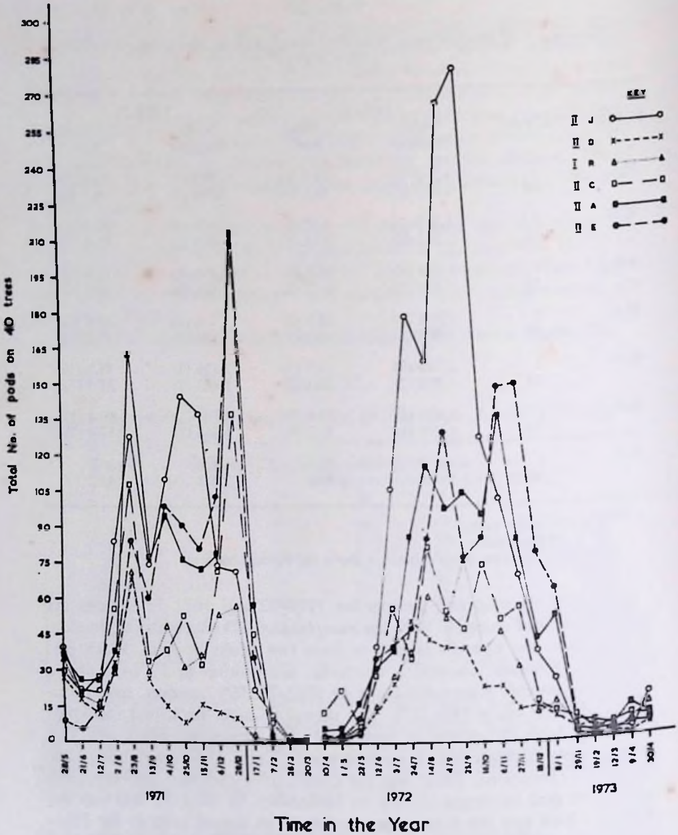

Fig. 16. Cropping patterns for six Hybrids in plot N14. Tafo (1971–72).

pod incidence could not be attributed to differences in cropping patterns in N14.

CSSV/*Phytophthora*/water stress inter-actions (H. C. Evans)

A field experiment complementary to one carried out in the 1971–72 dry season (*Rep. Cocoa Res. Inst., Ghana*, **1971–72**) was completed during the 1972 wet season (June–August). By using the same trees and inoculation procedure it was thus possible to compare canker growth in healthy and

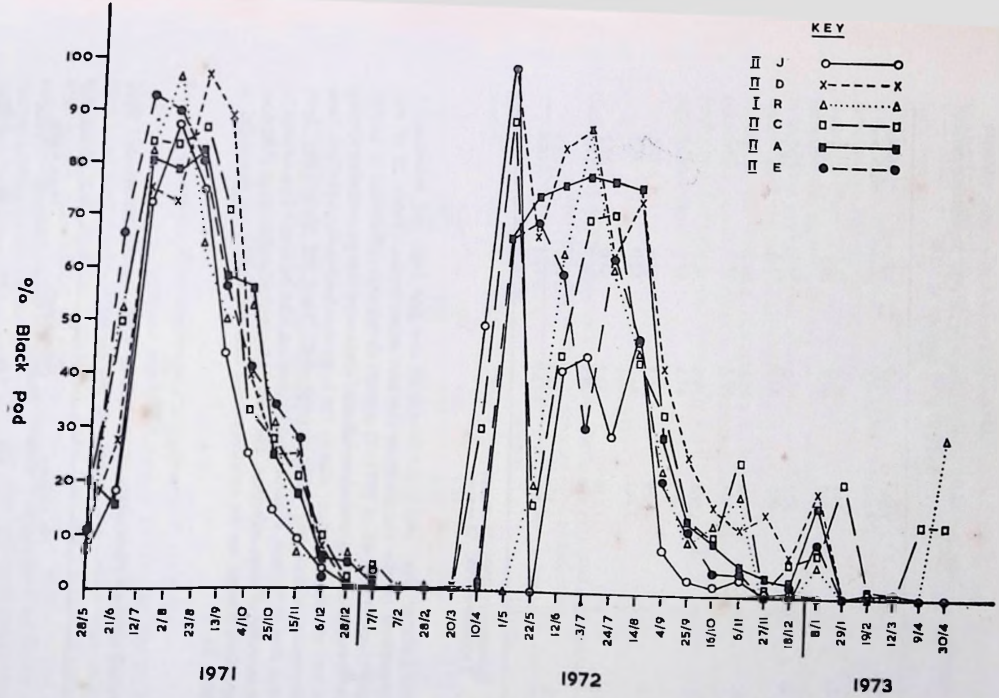

Fig. 17. Distribution of black pods in plot N14, Tafo (1971–73).

Table 27

Comparison of yield and black pod incidence in July to September periods for 1971–72 *and* 1972–73 *seasons in N*14

Variety	Year*	Yield lbs./acre	% crop in period	% black pod in period	% annual black pod
II J	1	1,545	45.0	58.3	31.1
	2	2,390	69.7	20.5	16.7
II D	1	552	62.4	83.3	55.1
	2	665	63.2	57.3	45.4
I R	1	659	45.3	66.2	37.2
	2	651	57.3	37.7	29.2
II C	1	1,068	39.6	76.2	38.3
	2	931	47.1	45.6	37.2
II A	1	1,309	41.3	70.2	38.5
	2	1,463	46.3	52.0	31.5
II E	1	1,276	35.1	64.0	27.2
	2	1,616	38.9	31.7	17.5
S.E.	1	±159.45	±12.1	±11.6	±12.3
	2	±275.3	±15.9	±17.5	±14.4

*1 represents 1971–72 season.
2 represents 1972–73 season.

virus-infected trees under conditions of low and high soil moisture. A comparison of the results from the two experiments (Table 28 of this report, and Table 48 of 1971–72 report) shows that differences in canker size between healthy and virus-infected trees were less pronounced during the wet season. However, due to the large standard errors involved these differences, within and between treatments, were not statistically significant and it became evident that trees must also be ranked according to the severity of virus infection. The tree canopies, as indicators of infection, were then scored on an arbitrary scale and the results are presented in Table 29.

Table 28

Growth (cm) of Phytophthora *cankers in healthy and virus-infected trees during the wet season*

	No. cankers		Mean length		Mean width	
	Healthy	Virus	Healthy	Virus	Healthy	Virus
Amelonado	60	55*	5.66	8.88	1.68	2.76
Amazon	165	165	4.76	6.93	1.57	2.28
Hybrid	155	150†	5.42	9.01	1.58	2.83

*One tree dead.
†General die-back on two trees.

Healthy trees with full canopies exhibited little differences in the rate of canker growth during the dry and wet seasons and varietal differences were also small. In general, canker size increased with the severity of virus infection and dry season cankers were significantly larger compared with those in the wet season, particularly on the Amazons. It is possible that the Amazon selection was less drought resistant than the other varieties. Amelonado and hybrid trees with severe virus infection had significantly bigger cankers ($P = 0.01–0.001$) than trees with either milder or no infection during both the dry and wet seasons. Even when soil moisture is high, it is probable that severe root necrosis is still a limiting factor in water uptake. All the results indicate that the disruption of a tree's water supply by physical (e.g. drought) or biological (e.g. virus induced root necrosis) agencies will result in increased growth of *Phytophthora* cankers. Prolonged disruption may eventually lead to die-back, ring-barking and subsequent death.

TABLE 29

Growth (cm) of Phytophthora *cankers during the dry and wet seasons on trees ranked according to severity of virus infection*

Canopy score*	Amelonado		Amazon		Hybrid	
	Dry	Wet	Dry	Wet	Dry	Wet
5	5.19†	5.66	7.01	5.23	5.71	5.42
4	6.91	6.24	8.80	6.04	9.19	7.43
3	9.50	7.72	11.01	6.24	9.40	6.87
2	14.36	9.50	11.66	8.51	10.97	9.23
1	8.38	9.21	16.12	10.54	10.70	10.83
0	19.34	12.03	—	—	22.50	24.03

5 = Healthy, full canopy
4 = Healthy but reduced canopy or mild infection
3 = Loss of leaves from upper branches, some die-back
1 = Less than quarter of the canopy remaining
0 = Severe infection, 30 leaves or less
*at end of final experiment
†mean length only

Mealypod disease—*Trachysphaera fructigena* (J. T. Dakwa)

A recent survey of mealypod disease (Dakwa, J. T.—*Pl. Dis. Reptr.*, **56**, 1011–1013) revealed that the disease is more common in Eastern Region than has hitherto been indicated. In this survey, the disease was always associated with wounds, particularly those caused by rodent damage. Microscopic examination of diseased pods showed a large number of viable spores which indicates that inoculum is not a limiting factor in disease development. Viable spores were also observed in drops of water collected from diseased pods. Pods that were directly in the way of the infested water drops were on the other hand free from the disease. Thus the limiting factor(s) must be associated with transmission and establishment of the disease. Experiments were therefore carried out to investigate establishment of *T. fructigena* in the field.

The type of wound on establishment and lesion development

Because mealypod is always associated with wounds, the effect of the type of wound on the establishment and lesion development on attached pods was investigated with an isolate T24, obtained at Tafo. Three types of wounds were investigated as follows:

(a) Holes were punched with no. 1 cork borer and immediately inoculated with a drop of a standardised conidial suspension from a pod culture.

(b) Six holes were made with a nail through the lid of a MaCartney bottle. The sharp-edged protrusions on the lid were used to make scratches on pods by gently drawing the lid over the pod surfaces. The resulting scratches were immediately inoculated with the conidial suspension as above.

(c) Ten pin holes were made with a mounted pin within an area on a pod defined by a MaCartney bottle lid. The pin holes were immediately inoculated with the conidial suspension as before. There were 30 pods per each treatment.

The results are summarised in Table 30. The establishment as well as lesion development was poor with the pin holes.

Although the disease established equally well with the scratches and plug holes, infection had established in 23 of the plug holes but only four of the scratch sites after 24 h; lesion development was faster from the plug holes. In all treatments, growth was faster laterally than longitudinally.

TABLE 30

Type of wound on establishment and lesion development of mealypod disease

Type of wound	Plug holes	Scratches	Pin holes
No. established	30/30	30/30	6/30
No. sporulating	29/30	27/30	4/6
Mean lesion length (mm)	100.2	93.1	62.8
Mean lesion width (mm)	182.1	143.3	81.6
Mean sporing length (mm)	73.4	67.0	41.0
Mean sporing width (mm)	133.0	104.6	50.5

Effect of wound age on establishment and lesion development

Holes were made on 240 green Amazon cocoa pods with no. 1 cork borer. Batches of thirty pods were inoculated immediately and subsequently at daily intervals for seven days, with a conidial suspension of isolate T24. Records were taken seven days after the inoculation. The

TABLE 31

The effect of age of wound on the establishment and lesion development of mealypod disease

Age of wounds (days):	0	1	2	3	4	5	6
No. established:	30/30	22/30	6/30	0/30	2/30	2/30	0/30
Mean lesion length (mm):	130.6	122.7	86.8	0.0	95.5	88.5	0.0
Mean lesion width (mm):	218.4	192.5	141.4	0.0	143.5	116.0	0.0

susceptibility of wounds declined sharply after 24 hours; only six of the thirty pods were infected in wounds that were two days old (Table 31). The development of lesions also followed the same pattern. Differences in lesion development after 24 hours were however not as large as those between wounds inoculated on the same day and those inoculated two days later.

***Varietal susceptibility of cocoa to isolates of* T. fructigena**

The susceptibility of cocoa varieties in the Obomeng (Mpraeso) black pod resistance trial (*Rep. W. Afr. Cocoa Res. Inst.*, **1960–61,** 28–29) was tested with isolates of the fungus collected from Anyinam (T18, T21), Begoro (T11, T14), Bunso (T1, T7, T8), Obomeng (T4) and Tafo (T23, T24) all in the Eastern Region of Ghana. The design of the trial is such that pods on one tree of each variety in a plot was inoculated with one isolate only. Some of the trees failed to produce pods and hence not all the varieties could be tested with all the isolates. Four of the eight blocks at Obomeng were used in this trial. Holes were punched with no. 1 cork borer and replaced with a similar plug of non-sporulating pod culture. Records were taken after five days. Due to the many missing data as a result of trees without pods, only general observations can be made on the results (Tables 32 and 33). In all varieties, lesions developed faster laterally than they did along the longitudinal axis of pods. Only J and W could be tested with all the fungus isolates; and W appeared to be more susceptible than J. Varieties T, G, M and L were among the most resistant, while F, N, K, W and H were among the most susceptible. Isolates T4, T14, T21 appeared to be mild in their attack while isolates T11 and T24 appeared to be virulent. The work will be repeated when pods are available to enable all varieties to be tested with all the fungus isolates.

The effect of fungicides on the establishment and development

The fungicides being currently screened against *P. palmivora* (*Rep. Cocoa Res. Inst., Ghana*, **1969–70,** 68–71) at CRIG were tested against the fungus. Holes were punched with no. 1 cork borer and immediately sprayed with the fungicides (Table 34) at concentrations that are being used against *P. palmivora* (*Rep. Cocoa Res. Inst., Ghana*, **1971–72,** 91–3). Controls were sprayed with water. The pods were then inoculated with isolate T24. In one set, a loop of dry conidial from pod cultures was stirred in the fungicides or the water within the punch holes; in another set, the holes were replaced with infected pod plug of same size; records were taken five days after treatment. There were ten replicates. Lesions appeared sooner on pods inoculated with spores than those inoculated with infected pod tissues. Less than 50% infections occurred on pods sprayed with copper Count-N, Burcop, Perecol and Bordeaux mixture with both inocula (Table 34). Cela and Duter also caused less than 50% infections when inoculated with tissue plugs. With both inocula, between 80 and 100% infections were recorded when pods were sprayed with Dithane and Dithane-Nordox. Infection was also high with Cela (conidial) and BBS Bordeaux (plug). All the controls were infected irrespective of the type of inoculum. The relative ineffectiveness of these fungicides were also reflected in the lengths and widths of both lesions and sporing zones. With conidia

TABLE 32

Mean lesion length (mm) five days after inoculation isolates of T. fructigena

Var. Code*	T1	T4	T7	T8	T11	T14	T18	T21	T23	T24	Mean	Order‡
A	54.3	50.0	60.0	58.5	59.0	57.3	—	42.2	50.2	41.0	52.5	8
B	36.0	41.7	55.0	50.0	57.0	54.0	60.0	—	—	63.0	52.1	7
C	48.5	58.5	—	58.7	66.0	64.5	54.0	57.0	49.8	55.0	56.9	14
D	50.0	—	53.0	52.8	—	—	61.0	—	—	—	54.2	13
E	59.5	52.5	60.0	60.0	—	49.0	—	43.5	—	—	54.1	12
F	55.7	63.3	62.0	60.0	—	58.0	48.0	—	—	69.0	59.4	15
G	34.0	32.0	—	60.0	34.0	57.8	—	47.4	45.0	56.0	45.8	2
H	64.0	53.0	—	65.0	105.0	74.0	—	—	51.5	60.7	67.6	19
J	55.0	50.3	55.3	50.5	40.0	54.0	72.0	45.0	44.0	52.0	51.8	6
K	72.0	—	—	72.0	—	56.0	50.0	69.0	58.0	57.0	62.0	17
L	52.0	—	50.5	67.0	41.0	51.5	50.9	25.0	—	69.0	50.9	5
M	47.0	48.8	41.3	—	55.0	44.3	46.3	35.0	44.7	52.6	46.1	3
N	69.0	56.3	60.8	—	49.2	54.0	80.0	—	62.0	—	61.6	16
P	56.2	52.3	46.0	49.3	67.0	—	36.0	56.0	65.0	—	53.5	11
R	53.3	49.2	—	52.8	61.5	—	67.8	31.0	51.1	54.5	52.7	9
S	64.0	18.0	53.5	40.4	60.0	47.5	46.3	—	—	66.0	49.5	4
T	—	56.0	57.0	47.5	44.0	29.8	47.0	40.0	24.0	49.7	43.9	1
V	—	54.0	—	50.8	—	53.7	—	48.0	58.5	—	53.0	10
W	84.0	67.9	64.0	58.8	79.0	45.1	62.7	38.0	60.5	64.0	62.4	18
Mean	56.2	50.9	55.3	56.1	58.4	53.2	55.8	44.4	51.1	57.8		
Order†	3	9	6	4	1	7	5	10	8	2		

— Not tested
* See *Rep. W. Afr. Cocoa Res. Inst.*, 1960–61, 28–29
† Order of decreasing virulence
‡ Order of increasing susceptibility

Table 33

Mean lesion width (mm) five days after inoculation
Isolates of T. fructigena

Var. Code*	T1	T4	T7	T8	T11	T14	T18	T21	T23	T24	Mean‡	Ranking‡
A	85.3	70.0	88.0	93.5	93.7	76.7	—	47.6	78.4	64.0	77.5	7
B	32.5	56.3	93.5	71.0	95.5	74.2	90.5	—	—	84.0	74.7	5
C	56.5	88.0	—	82.7	88.5	75.5	64.0	88.1	75.8	79.0	77.6	8
D	80.0	—	83.5	84.8	—	—	106.0	—	—	—	88.6	13
E	87.0	75.5	93.5	90.0	—	77.0	—	47.8	—	—	78.5	9
F	93.3	93.3	98.0	93.0	—	79.7	70.1	—	—	—	101.0	14
G	76.0	54.7	—	93.0	54.0	80.0	—	56.8	80.0	81.0	71.9	3
H	99.0	77.0	—	74.0	125.0	98.0	—	—	77.5	97.3	92.6	16
J	68.0	76.0	90.5	69.5	80.0	79.0	98.0	65.0	61.1	83.0	77.0	6
K	97.0	—	—	102.0	—	81.0	115.0	95.0	92.7	105.0	98.2	18
L	85.0	—	76.3	84.0	51.0	62.0	80.3	40.5	—	91.0	71.3	2
M	57.5	70.0	60.3	—	62.3	57.9	62.0	54.3	42.0	72.8	59.9	1
N	81.0	85.3	89.4	—	76.8	74.4	117.0	—	106.0	—	90.0	15
P	71.0	91.0	74.7	85.0	97.0	—	61.0	88.5	77.0	—	80.7	11
R	89.0	94.2	—	95.3	83.5	—	114.0	7.5	91.4	84.0	82.4	12
S	110.0	61.0	77.8	61.9	85.0	73.0	63.3	—	—	111.0	80.2	10
T	—	93.4	70.0	76.5	70.5	51.3	77.3	65.3	57.0	89.3	72.5	4
V	—	44.0	—	80.8	—	73.3	—	68.0	90.5	—	71.3	2
W	122.0	106.9	99.2	95.2	131.0	70.0	101.0	32.0	99.8	101.0	95.8	17
Mean	81.8	77.3	84.2	84.4	85.3	73.9	87.1	58.2	79.2	88.7		
Ranking†	6	8	5	4	3	9	2	10	7	1		

— Not tested
* See *Rep. W. Afr. Cocoa Res. Inst.*, 1960–61, 28–29
† Order of decreasing virulence
‡ Order of increasing susceptibility

Table 34

Effect of fungicides on the infectivity of T. fructigena

Fungicide	Kocide	BBS Bordeaux	Copper Count N	Burcop	Cela	Perecol	Bordeaux mixture	Duter	Brestan	Nordox	Dithane C90	Dithane-Nordox	Control	Type of inoculum
No. established*	5/10	6/10	1/10	1/10	9/10	1/10	1/10	8/10	6/10	5/10	10/10	10/10	10/10	Conidia
No. sporing†	4/5	4/6	1	1	9/9	1	4/4	8/8	6/6	5/5	8/10	10/10	10/10	Conidia
Mean lesion length (mm)	70.2	73.8	86.0	66.0	68.4	53.0	65.0	93.3	91.5	56.8	89.9	99.3	117.2	Conidia
Mean lesion width (mm)	113.6	130.2	118.0	102.0	102.6	121.0	91.3	136.1	126.9	82.5	137.7	132.2	203.7	Conidia
Mean sporing length (mm)	64.0	61.8	56.0	41.0	47.3	48.0	50.0	63.4	58.7	43.2	64.9	70.7	95.8	Conidia
Mean sporing width (mm)	85.5	115.3	89.0	89.0	84.0	76.0	62.3	86.4	100.8	76.4	108.8	98.2	159.7	Conidia
No. established	4/7	8/9	0/10	3/10	4/10	4/10	1/10	5/10	6/9	5/8	7/8	6/6	7/7	Infected pod tissue
No. sporing	3/4	8/8	0	2/3	4/4	4/4	1	5/5	6/6	4/5	7/7	6/6	7/7	Infected pod tissue
Mean lesion length (mm)	68.8	86.6	0	91.0	74.0	68.5	49.0	85.0	84.4	59.5	70.9	97.5	99.1	Infected pod tissue
Mean lesion width (mm)	119.5	121.9	0	116.0	120.0	108.0	92.0	108.5	126.5	93.8	97.9	122.8	179.9	Infected pod tissue
Mean sporing length (mm)	64.7	54.6	0	71.5	53.3	47.0	3.0	62.0	62.8	43.8	48.9	60.5	78.6	Infected pod tissue
Mean sporing width (mm)	84.3	76.4	0	97.5	89.3	91.0	67.0	79.0	98.0	71.8	69.3	80.7	119.9	Infected pod tissue

* No. of pods infected/No. of pods inoculated.
† No. of lesions sporulating out of the no. established.

as inoculum, all the parameters considered were higher in the control than with any fungicide. With pod tissue as inoculum however, lesion on pods sprayed with Dithane-Nordox, Brestan, Duter and BBS Bordeaux were nearly as long as in the controls.

The survival of* Trachyspaera *in infected pods

The survival of the fungus was investigated with isolates T4, T7, T13, T20, T22 and T24. Pods were inoculated in September 1972 with conidia and at monthly intervals the presence of the fungus was tested by baiting the fungus from squashed infected pods. All the isolates could be isolated four months after the inoculation. After this time, rodents disrupted the experiment by removing beans from most of the pods and sometimes detaching them. Further sampling was therefore suspended and the investigations will be resumed.

NEMATODE STUDIES

Extraction of nematodes from Plot A16 continued throughout the year at monthly intervals using a modification of Kobb's seiving and decanting method. The dominant nematode genus was *Paratylenchus. Xiphinema, Tylenchorhynchus, Rotylenchus, Helicotylenchus, Aphelenchoides, Tylenchus,* an unidentified Mermithoidea, *Longidorus, Cacopaurus* and *Atylenchus* were other genera encountered. There was significantly ($P = 0.01$) more nematodes in the upper 10 cm than the lower 10 cm of soil.

MISCELLANEOUS

Stem pitting disorder (J. T. Legg and Mrs. E. Phillips)

Grafts tests

By root chips. Root chips from affected trees at Bunso, Pankese and Obomeng were inserted into inverted T cuts on the trunks of Amelonado and Amazon test seedlings. The seedlings were pruned soon after inoculation and for every six months thereafter. They were fertilized weekly with 20 20 20 (N.P.K.) for six months. The rate of application is 5 ml per pot of seedling.

Most of the grafts established but died few days later. The seedlings however, have been retained in the greenhouse for observation.

Bench grafting. Small root pieces of about ¾ in. or less in diameter collected from pitted trees were grafted on to roots of healthy cocoa seedlings in the greenhouse using either saddle and whip or tongue graft techniques.

Seed boxes were filled with rooting medium (sand, fibre and soil mixed in equal proportion). The test seedlings were gently removed from polythene bags and the stem portion pruned. The affected root pieces were then grafted on to the roots of the test seedlings and they were arranged in the prepared seed boxes and covered with polythene sheet. Seedlings with successful grafts were transferred into polythene bags and they are being observed.

Manual inoculation

More herbaceous and ornamental plants were raised in pots for inoculation. Bark and wood pieces were macerated in buffer solution and used in inoculating the following plants:

Synedrella nodiflora Gaertn.
Sida rhombofolia Linn.
Amaranthus spinosus Linn.
Glycine soja
Cucumis sativus L.
Cajanus cajan Millsp.
Helianthus annus.

No virus symptons were observed.

Out-station experiments

The apparent spread of stem pitting has been under observation for three years at two outstations. It has been noticed recently that some trees previously recorded as affected appear symptomless. These trees were marked for further observation. Twelve and six newly pitted trees were recorded at Pankese and Bunso respectively during the period 1972–73.

Field trials

Some test plants which were retained in the nursery the previous year were planted in the alternative host plot (Plot M8). These comprised Amelonado seedlings and other forest plants namely *Ghyphaea brevis* (Spreng) Monachine, *Cola millenii*, K. Schum *Leptonychia pubescene*, Keay *Hildergadia barteri* (Mast.) Kosterm *Sterculia tragancantha* Lindl.

Plants in E8 received routine maintenance operations. No new symptoms were recorded.

A new trial (in collaboration with Dr. Asare-Nyako) has been planned to determine whether pitting is induced by (a) wounding, (b) fungus infection (*Phytophthora*) or (c) virus infection. The site (E17) was cleared, lined and pegged and *gliricidia* shade established. The seedlings have been planted in polythene bags and will be treated before planting into field sites.

ENTOMOLOGY

CAPSID STUDIES

Capsid population cycle and damage (E. Owusu-Manu and F. K. Manteaw)

Monthly capsid population assessment of the 25 × 1 acre farms in the Eastern Region continued. There was a gradual population build-up from June and the maximum was reached in October, two months earlier than last season (Figs. 18 and 19).

This may be due to early rains during the April–June wet season and unusual low rainfall thereafter.

The subsequent decline occurred very rapidly beginning in January so that in March the population was down to a level unusual for this time

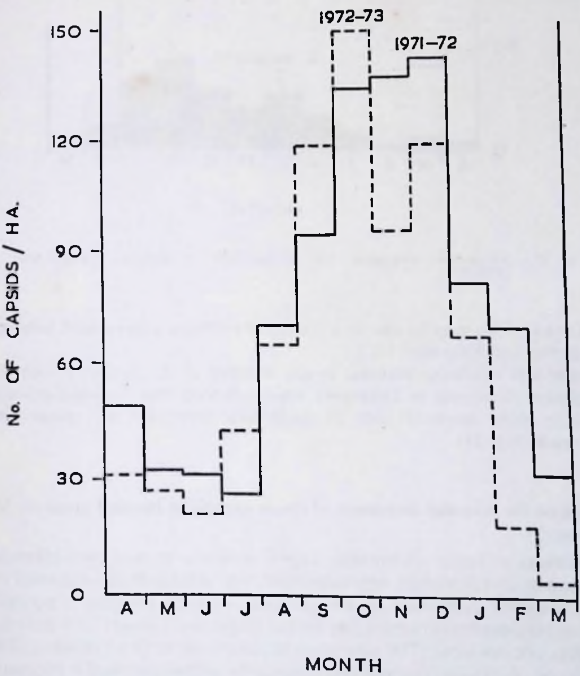

Fig. 18. Capsid population cycle, Eastern Region 1971–72 and 1972–73.

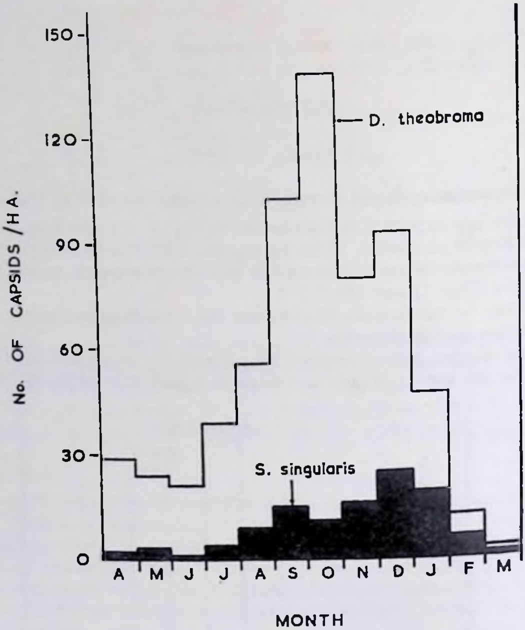

Fig. 19. *Sahlberella singularis* and *Distantiella theoborma* populations 1972–73.

of the year. This may be due to a drastic dry season experienced between November and February 1972.

There was a relative increase in the number of *S. singularis* with the population maximum in December which showed that *S. singularis* was relatively more successful than *D. theobroma* during the dry season and vice versa (Fig. 19).

Studies on the seasonal movement of cocoa capsids in infested areas (J. M. Somuah)

Observations based on monthly capsid assessments and spot-planning at Akutuase and Atukrom were continued. The Atukrom plots showed no traces of capsid infestation for nine months, possibly because of periodic insecticidal treatments carried out by the respective farmers. No data for the plots are available. The nine plots at Akutuase were all infested. The assessment of chupon, fan and pod damage by capsids showed a very high degree of chupon damage, 94% as against 6% for fan and pod damage.

TABLE 35

Data on monthly distribution of capsid—Akutuase site 1972–73

	Feb.		March		April		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.		Jan.		Feb.		March	
	Dt	Ss	Dt	Ss	Dt	Ss	Dt	Ss	Dt	Ss	Dt	Ss	Dt	Ss	Dt	Ss	Dt	Ss	Dt	Ss	Dt	Ss	Dt	Ss	Dt	Ss	Dt	Ss
1	351	6	247	17	101	1	18	—	58	—	39	—	20	—	205	—	30	—	76	—	88	—	123	—	20	—	1	—
2	330	10	34	1	14	2	38	—	37	1	16	—	4	—	197	—	119	—	56	—	174	—	172	—	6	—	4	—
3	302	18	103	8	122	21	46	—	41	—	9	—	11	—	64	—	16	—	44	—	38	—	35	—	7	—	—	—
4	222	2	38	1	55	1	92	—	197	—	164	1	329	—	226	—	259	—	168	—	452	1	551	—	154	—	13	2
5	85	7	30	4	31	8	32	10	7	—	—	—	3	—	40	—	28	—	21	—	68	—	62	—	7	—	—	—
6	310	14	21	3	60	2	71	—	49	—	—	—	6	35	112	—	39	—	112	—	265	—	189	—	61	—	—	—
7	43	79	10	26	3	—	3	—	—	—	—	—	3	17	81	5	—	4	10	—	38	—	78	—	29	—	—	—
8	70	39	6	8	22	15	17	8	—	5	6	22	6	13	61	36	34	125	80	23	124	69	120	354	15	41	2	4
9	40	103	5	18	—	4	—	—	—	—	—	3	17	—	27	19	25	78	6	9	29	10	121	128	30	91	4	4

TABLE 36

Infested trees with capsids damage on chupons, fans and pods

Month	Total no. of trees infested	Infested trees with damage on Chupons	Fans	Pods	% infested Chupons	Fans	Pods
1972							
February	777	761	—	16	97.9	—	2.1
March	291	271	16	4	93.1	5.5	1.4
April	219	205	10	4	93.6	4.6	1.8
May	122	119	3	—	97.5	2.5	—
June	145	141	4	—	97.2	2.8	—
July	97	92	4	1	94.9	4.1	1.0
August	136	131	2	3	96.3	1.5	2.2
September	309	280	7	22	90.6	2.3	7.1
October	224	187	11	26	83.5	4.9	11.6
November	208	197	3	8	94.7	1.4	3.9
December	359	347	7	5	96.7	1.9	1.4
1973							
January	464	432	30	2	93.1	6.5	0.4
February	181	165	12	4	91.2	6.6	2.2
March	20	18	—	2	90.0	—	10.0

Distantiella theobroma was the predominant species. The distribution and the fluctuations of the seasonal population of the two capsids are summarised in Fig. 20 and tables 35–38.

Capsids were mapped by locating every cocoa tree found with live capsids and/or fresh damage. Capsid infestations appeared to be more concentrated in the pocket areas in most months of the year. In the good canopied areas capsid incidence was very low and periodic. This invasion appeared to be consistent with the general high population of capsids. Intensive observations and mapping of capsids in the other plots are in progress.

TABLE 37

Distribution of capsids in pocket and good canopied areas

Month	Total	No. of trees infested Pocket areas	Good canopy	% infested Pocket areas	Good canopy
1972					
February	122	95	27	77.9	22.1
March	115	97	18	84.3	15.7
April	46	37	9	80.4	19.6
May	9	8	1	88.9	11.1
June	22	17	6	77.3	22.7
July	15	13	2	86.7	13.3
August	9	7	2	77.8	22.2
September	46	35	11	76.1	23.9
October	11	9	2	81.8	18.2
November	35	32	3	91.4	8.6
December	24	19	5	79.2	20.8
1973					
January	40	35	5	87.5	12.5
February	6	6	—	100.0	0
March	1	1	—	100.0	0

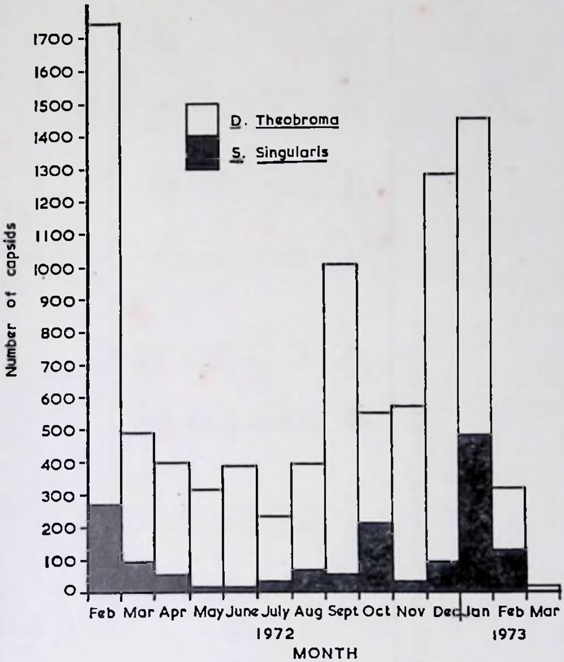

Fig. 20. Monthly distribution of cocoa capsids at Akutuase.

Parasitism of *Sahlbergella singularis* (N. K. Kumah)

Evaluation by dissection of *Sahlbergella singularis* to determine local and annual variations in the rates of parasitism was extended to the various cocoa growing Regions in March 1972. Monthly collection of material for dissection have been concentrated on large farms with capsid-pockets, and capsid infested trees were examined for *Sahlbergella* adults and nymphs. Monthly mean number, however, was calculated for 5th, 4th, 3rd and 2nd instar nymphs from pockets of the same farms.

Monthly evaluations, so far at Tafo, in Eastern Region, have provided some interesting information on host/parasite population fluctuations. Parasitism of 4th instar nymphs was constantly above 20% and reached 59% in December. Rates of parasitism of the other stages were fairly high but the higher rates of parasitism were consistently recorded in the 4th instar.

The peak rates of parasitism have been invariably recorded in months with rainfall below four inches. The highest number of the host in October and the least rainfall in November were followed in December by the

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TABLE 38

Parasitism of Sahlbergella singularis *at Tafo* 1972–73

Months	Adult		5th instar		4th instar		3rd instar		2nd instar		1st instar	
	Nos.	% para.	Nos.	% para.	Nos.	% para.	Nos.	% para.	Nos.	% para.	Nos.	% para.
March	12	—	18	11.1	46	30.4	36	22.5	6	33.3	—	—
April	6	—	24	25.0	34	29.4	38	10.5	10	—	5	—
May	14	—	16	12.5	40	27.5	20	15.0	13	7.7	7	—
June	11	—	58	13.8	36	22.2	34	17.6	22	9.1	12	—
July	32	18.8	36	16.7	18	44.4	12	16.6	8	—	—	—
August	28	14.3	50	28.0	24	41.7	22	18.2	14	—	—	—
September	20	15.0	43	18.6	35	28.6	34	11.8	16	—	—	—
October	12	16.7	62	38.7	118	22.1	38	15.8	28	7.1	4	—
November	18	11.1	74	16.2	44	27.3	46	30.4	10	—	—	—
December	34	5.9	102	7.8	74	59.5	12	33.3	12	25.0	—	—
January	12	8.3	24	16.7	48	33.3	16	37.5	6	—	—	—
February	16	—	13	15.4	14	35.7	5	20.0	2	—	—	—

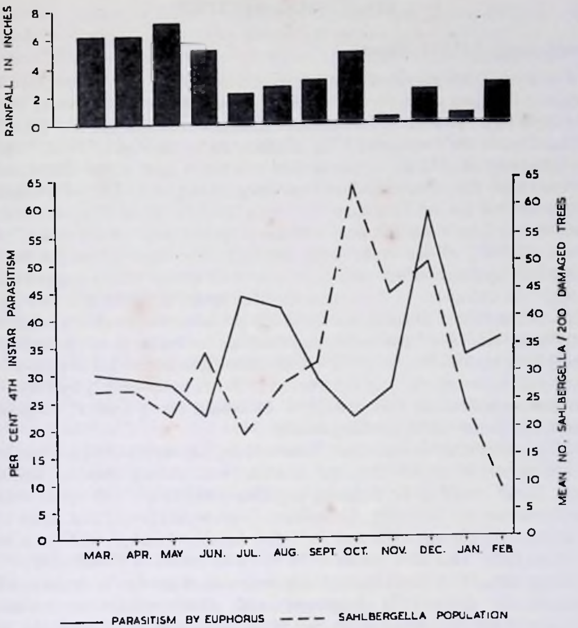

Fig. 21. Parasitism of *Sahlbergella singularis* by *Euphorus sahlbergella.*

highest rate of parasitism. It would seem to suggest that dry conditions favour searching efficiency of the parasite.

Although Cotterell (*Proc. 1st W. Afr. Agric. Conf. Ibadan, Nigeria*, 1927, 98–112) suggested that dry conditions are unfavourable for parasite breeding; and King's suggestion that lower rates of parasitism in November and December might have been due to dry conditions (*Rep. Cocoa Res. Inst., Ghana,* **1969–70,** 100–103) the highest rates of parasitism were generally recorded during drier months in the 1940s. Sufficient data, over the years, are needed to evaluate the relative importance of factors, such as hyper-parasite as well as dry conditions on rates of parasitism.

Determination of rates of parasitism at Asikuma, Akomadan and Akaa, in Central, Brong-Ahafo and Volta Regions, respectively gave results similar to those obtained at Tafo in the early months. Work was temporarily discontinued in August 1972, however, it is hoped that regular work will resume in May 1973.

Insect survey A11 (M. Bigger)

Records of the presence/absence of various insect species on A11 has continued. Three years records have now been taken and certain trends are apparent. *Planococcoides njalensis* which was found on less than 1% of the trees in 1970 occupied 17% of the trees by the end of 1972. During the latter part of 1972 the rate of spread was much accelerated. *Planococcus citri* has been the most abundant mealybug throughout. The infestation of this insect fell during February 1971 to a level of about 25% of trees on the plot but since there has been continual spread until by the end of 1972 about 55–60% of the trees were infested. The level of infestation is irregularly cyclical with a period of about 10 weeks which suggests that it might be entrained to the cocoa flushing cycle. Records are now being taken of the rate of flushing but have not yet been analysed. *Pseudococcus hargreavesi* has also been increasing from an initial level of about 5% to about 25% by the close of 1972. On the other hand, *Ferrisia virgata* which was found on nearly 40% of the trees in 1970 fell to below 5% by July 1971 and has remained at this low level. It would seem that *F. virgata* is essentially an insect of seedling cocoa.

Of the other coccids recorded, *Steatococcus* has maintained a mean level of infestation of about 15% but overlaid with a very marked seasonal cycle. There seems to be a strong negative correlation with mean weekly afternoon relative humidity. *Ceroplastes* (*Gascardia*) found at a mean level of about 25% during 1970 and 1971 fell steadily through 1972 to a level of about 10%. This also, seems to be more an insect of young cocoa.

Of the ants, the ground living *Camponotus* have gradually declined to be replaced by *Oecophylla longinoda* and *Macromischoides aculeatus*. *Oecophylla* has increased from less than 10 to about 25% of the trees infested and *Macromischoides* from 5 to about 20%. *Crematogaster castanea* has remained around 10%. At maturity it is likely that the trees will be dominated by an *Oecophylla–Macromischoides* complex.

Distribution of mealybugs within the canopy (M. Bigger)

Since April 1971, the position on the tree of every mealybug colony recorded on A11 has been noted. For this purpose the tree has been divided into 10 categories namely:

Canopy	leaves shoots branches pods
Trunk	bark pods
Chupons	leaves shoots bark pods

Numbers of colonies, adults and nymphs of each of the seven species of mealybug found were recorded.

So far, only one years' data has been analysed using the ICL 1900 computer at the Central Revenue Headquarters but a seasonal pattern is evident. The bulk of the mealybugs are concentrated in the canopy and canopy pods are uncommon so only the first three canopy categories, i.e. leaves, shoots and branches have been considered.

In April 1971, about 75% of *P. njalensis* colonies were to be found on older branches. As the year progressed the proportion on these branches gradually fell to about 15% with a corresponding rise in the proportion on young shoots. During January, February, and March, however, this trend was reversed and by March about 50% of colonies were on canopy branches. The somewhat lower proportion on canopy branches compared with the previous April can, in part, be attributed to an increase in the proportion on leaves where there was a fairly steady increase from about 15% to 30% through the year.

With *P. citri*, although the percentage on thicker branches fluctuated somewhat the trend line is fairly level. On the other hand the percentage on young shoots increased steadily from 20% to about 50% at the expense of the leaf population.

It would seem with both species that the young canopy shoots are the preferred feeding place and that with increase in density of the canopy and/or shade an increasing proportion are to be found on young shoots but that *P. njalensis* is more sensitive to low humidity conditions and tends to retreat towards the centre of the tree during dry periods.

Virus outbreak survey (M. Bigger)

The insect survey of swollen shoot outbreaks described in the previous report continues (*Rep. Cocoa Res. Inst., Ghana*, **1971–72**, 117). The results from 14 outbreaks, 10 on the Institute and four within farmers' cocoa in the Eastern Region have been analysed at Rothamsted Experimental Station by R. H. Wimble and a preliminary summary obtained.

Locations of the outbreaks were as follows:

1	Tafo	Q1	7 trees
2	Tafo	K1	17 trees
3	Tafo	N3	4 trees
4	Tafo	N4	6 trees
5	Tafo	C5	10 trees
6	Tafo	P1	11 trees
7	Tafo	M1	9 trees
8	Tafo	N7	5 trees
9	Tafo	A3	9 trees
10	Tafo	K2	13 trees
11	Nankese		21 trees
12	Asesewa		14 trees
13	Tete		20 trees
14	Kwahu Kwamang		20 trees

At each site the trees were first sprayed with pyrethrum and the insects knocked down collected on circular boards one square metre in surface area, one board being used for each tree to be sampled. This gave an estimate of active insects such as ants, spiders, mantids, leaf eating caterpillars and others. The trees were then cut down and examined carefully for coccids and other sedentary insects.

Planococcoides njalensis occurred at 11 of the 14 sites, *Planococcus citri* at nine and *Pseudococcus hargreavesi* at nine. At two sites only *P. njalensis* were found and at one only *Paraputo ritchei*. The remaining sites all had more than one species of mealybug. On a basis of mean number per tree *P. njalensis* was the most numerous followed by *P. citri* and then *P. hargreavesi* but owing to the highly aggregated distribution an arithmetic mean gives a distorted picture of the relative importance of the species (c.f. number of trees infested, Table 39).

A total of 61 ant species were recorded from knockdowns. The relative abundance of the five most frequently occurring species is shown in Table 39. The importance of *Crematogaster striatula* has declined in recent years over the Institute and it was only recorded on one of the 10 outbreaks. It will be noted, however, that this outbreak (no. 9) shows the highest mean density of *P. njalensis*. The remaining outbreaks on the Institute were dominated either by *Oecophylla longinoda* or by *Crematogaster clariventris*, *Macromischoides aculeatus* often being present as a co-dominant. On two of the four off-station outbreaks all three species were co-existing.

It has been suggested that by encouraging the spread of *Oecophylla* the spread of swollen shoot disease could be reduced. The presence of *Oecophylla* as a dominant on five out of 14 proven outbreaks does not lend support to this theory. Furthermore, *C. clariventris* thrives under similar conditions to *Oecophylla* and it is very probable that the two species are in competition. Replacement of *Oecophylla* by *C. clariventris* would not lead to much improvement in the situation.

At each outbreak the shade over the plot as a whole was assessed as None, Light, Medium, or Dense and for each tree the degree of individual shade was scored on a similar scale. Two of the plots were unshaded, the remainder lightly shaded. Of the 166 individual trees 131 had no direct overhead shade, 21 were lightly shaded and 14 had medium shade. The impression gained is that virus spread is likely to be greatest in open areas of lightly shaded plantations.

The presence of virus alternative host trees within 100 yards of each outbreak was also noted. Seven outbreaks had *Triplochiton* trees near them one a *Ceiba* and one a *Bombax*. Five outbreaks did not have an alternative host tree in the vicinity.

Association analysis (M. Bigger)

It was reported in the last annual report (*Rep. Cocoa Res. Inst., Ghana*, **1971–72**, 120) that cluster analysis of presence/absence of various insect species on H10 had revealed groupings which could be related to shade and to the condition of the cocoa canopy. This same data has now been re-run as a Canonical Variate analysis by K. Martin of East Malling Research Station. For this purpose the trees were divided into four groups according to whether or not they had shade directly above them and

Table 39

Mean number of ant and mealybug species from the virus outbreak survey

	Outbreak no. 1	2	3	4	5	6	7	8	9	10	11	12	13	14
Ants per square														
Oecophylla longinoda	55.4	0	0	125.8	2.3	23.3	0	1.0	0	0	0	1.0	46.4	14.8
Macromischoides aculeatus	0	48.0	77.6	0	11.0	0	1.0	2.0	0	32.5	1.1	15.7	32.6	24.6
Crematogaster striatula	0	0	0	0	0	0	0	0	25.8	0	60.1	0	2.0	0
Crematogaster clariventris	0	187.0	52.5	0	0	3.3	402.6	15.0	0	26.2	0	0	37.0	15.1
Crematogaster africana	0	0	0	0	0	0	0	0	0	0	0	111.8	0	0
Mealybugs per tree														
Planococoides njalensis	65.3	12.9	15.5	1.0	0.8	0	44.9	0	112.1	0.1	38.9	0	7.6	10.5
Planococcus citri	2.3	0.4	0	0	0.5	0	0	0.8	1.6	0.1	0	1.4	2.5	0.3
Pseudococcus hargreavesi	0	0.1	0	0.3	0	0	0	9.8	0.4	1.1	1.3	1.5	1.5	1.4
Paraputo ritchiei	0	0	0	0	0	1.1	0	0	0	0	0	0	0	0
Trees infested with mealybugs														
P. njalensis	7	6	2	1	1	0	5	0	8	1	19	0	3	11
P. citri	2	4	0	0	1	0	0	1	4	1	0	8	10	2
P. hargreavesi	0	2	0	2	0	0	0	1	4	1	2	8	9	13
P. ritchiei	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Total trees	7	17	4	6	10	11	9	5	9	13	21	14	20	20

whether their canopy was good (categories 2–3 in original data) or poor (categories 0–1):

Group 1: Poor canopy unshaded
Group 2: Poor canopy shaded
Group 3: Good canopy unshaded
Group 4: Good canopy shaded

Twenty-three insect species were used as variates. The effect of the analysis is to compare the four groups of trees in terms of the insect species which they bear along new axes termed the canonical variates. In the present instance there will be three canonical axes, one less than the number of groups. The set of weights which each insect contributes to the loading of each group on the Canonical Variates is known as a latent vector. There is one latent vector associated with each canonical variate. The first canonical variate accounts for the largest portion of the total variance, in this case 51% followed by the second (33%) and the third (16%).

If the analysis is discriminating between groups it would be expected that the loadings for individual trees when plotted out onto their respective axes would tend to cluster into distinct swarms according to the group to which they belong. In fact, there is considerable overlapping of the four groups so it would appear that it is not possible to distinguish between the environmental groups on the basis of the insect fauna as a whole. However, some useful information does emerge. The means of the four groups on the canonical variates are as follows:

	Canonical variate means		
	1	2	3
1. Poor canopy unshaded	0.5722	−0.1919	−0.4821
2. Poor canopy shaded	0.3323	0.3766	0.2673
3. Good canopy unshaded	−0.2013	−0.9090	0.3223
4. Good canopy shaded	−0.9531	0.2344	−0.1843

Canonical variate 1 is clearly an indication of canopy condition with good canopy at the negative end and poor canopy at the positive whilst C.V.2 compares unshaded trees with shaded. C.V.3 is more complex and does not order the groups according to either of these criteria.

As the actual positioning of the groups on the canonical axes depends on the insects present it is to be expected that insects which prefer good canopy will have high negative loadings on the first latent vector and that those which prefer unshaded conditions will have a high negative loading on the second latent vector. In Fig. 22 the loading of the various insects on the first two latent vectors have been plotted against each other.

It will be seen that canopy condition is a more important criterion than shade and indeed this is to be expected since the first canonical variate accounts for a much larger percentage of the total variance. It will also be noticed that although there is a fairly even spread of species along the first canonical axis there is a tendency towards unshaded conditions on the second axis. The two exceptions *C. striatula* and *Acantholepis sp.* are rare species occurring on only four and one tree respectively of the 271 samples. They have high loadings on both canonical variates simply because they are rare and so their between group variance is high. The same may also

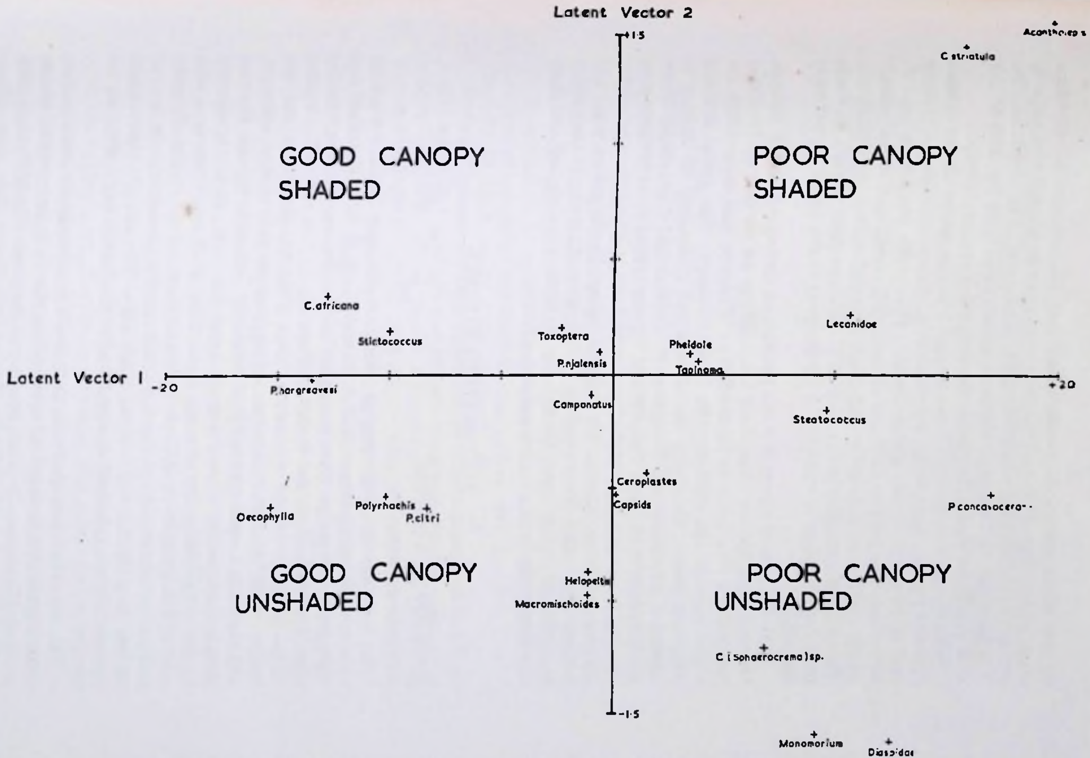

Fig. 22. Loadings of various insects on the first two latent vectors of Canonical Variate Analysis.

be true of Lecanidae, *P. concavocerarii* and *Monomorium* all of which occur on less than 10 trees. Thus the results must be treated with caution, and not too much reliance placed on the positioning of rarer species. This is a drawback to Canonical Variate analysis when used for data of this kind as it is designed to maximize the differences between groups.

With this proviso in mind it can be seen that the species can be divided into two groups, those which are sensitive to canopy condition and those that are not. The former group contains *Oecophylla*, *Polyrhachis* and *P. citri* which also tend to be found in unshaded conditions, *P. hargreavesi* which is not sensitive to shade and *C. africana* and *Stictococcus* which are. This is understandable in the case of *C. africana* since it nests in shade trees and so might be expected to be foraging in the cocoa immediately beneath.

With the second group, it is not possible to distinguish in this analysis between those species which have low loadings on the canopy condition axis because they occur in all conditions of canopy and those which are found only in intermediate type broken canopy. The group contains *Macromischoides*, *Helopeltis*, the capsids and *Ceroplastis* all tending to unshaded conditions and *Toxoptera*, *P. njalensis* and *Camponotus* which are not sensitive to shade. *Pheidole* and *Tapinoma* tend more towards poor canopy. It is the presence of this large central group of insects which makes the discrimination between the original canopy/shade groups poor and suggests that with a few exceptions the majority of cocoa pests are either insensitive to canopy condition or occur on broken canopy and that there is a general preference for unshaded conditions.

POLLINATION STUDIES

Pollination (T. Kaufmann)

Ceratopogonidae

In Tafo, the family Ceratopogonidae is represented by several genera (*Forcipomyia*, *Atrichopogon*, *Lasiohelea* and others yet to be identified) and no less than 50 species. These insects are neither rare nor occur only during the rainy season as stated by Billes (*Trop. Agric. Trin.*, **18,** 151–156) and Entwistle (*Rep. W. Afr. Cocoa Res. Inst.*, **1956–57,** 45–47). Instead, the midges breed in cocoa plantations throughout the year in large numbers, although only a small percentage of these ever visit cocoa flowers. Even so, their number on the flowers is much larger than that previously reported by Entwistle (*ibid.*). The monthly fluctuation of various Ceratopogonids visiting flowers is shown in Table 40; these figures are the results of regular collections carried out twice each week between 6.30 and 9.00 a.m. by two trained men in the Tafo Cocoa Plantation. The midges were caught between a glass tube and its stopper after the insects had settled on the flowers.

The most abundant species as individuals is *Forcipomyia squamipennis*. Cage experiments have proved conclusively that both sexes of this species pollinate (Kaufmann, in press) contrary to the statements of Dessart (*Bull. agric. Congo belge*, **52,** 525–540), Gerard (*Rep. Cocoa Res. Inst., Ghana*, **1963–65,** 46–47) and Soria (Ph.D. Thesis, Univ. Wis., 1970). Likewise, at

Table 40

Monthly fluctuation of Ceratopogonids visiting cocoa flowers in Tafo

	No. flowers examined	No. midges caught	No. midges/1,000 flowers
1972			
June	2,316	36	11.2
July	1,245	70	56.2
August	873	50	57.3
September	779	21	27.0
October	976	27	27.7
November	656	16	24.4
December	525	11	21.0
1973			
January	596	11	18.5
February	983	24	24.4
March	1,450	18	12.4
April	990	24	24.2
May	2,014	43	21.4
Total	13,403	351	335.7
Mean	1,117	29.7	28.0

least one species of *Atrichopogon* (of both sexes) fertilizes *Theobroma cacao* and it seems certain that this is not the only one of the 14 species of the genus occurring in Tafo to do so. Consequently, cocoa pollination by Ceratopogonidae is by no means limited to the females of certain *Forcipomyia* species as has been claimed (Billes, *ibid.* Sauders, *Can. J. Zool.*, **37,** 33–51; *Soetardi, Archf. Koffiecult.*, **17,** 1–31).

When one examines a large pollen cluster or an extensive smear left on a style by a Ceratopogonid, one gets the impression that the midge is an efficient pollinator. This impression is not quite correct. To understand this, it is essential to keep in mind that the midge's flower visits are by no means intended for pollination. This is apparent by the way the insect enters flowers indiscriminately; some flowers, for instance, have just opened with their staminodes still tightly closed around the pistil, while others have already been pollinated or even set. In the first case, effective pollination could still result; but in the second, pollen grains are obviously wasted. Between these two extremes, staminodes of the flowers assume various positions in regard to the pistil; if the staminodes lie more or less parallel to the pistil, pollen may be deposited on the style in a cluster or a smear, as the midge with pollen adhering to its dorsal bristles, crawls up the inner surface of a staminode toward its base, and in so doing brushes against the style, but if the staminodes splay wide apart from the pistil, then pollen will be rubbed off only at the base of the staminode and not on the style, since this is the only area narrow enough to come in contact with the midge's body (Kaufmann, in press). The ratio between effective and ineffective pollination is given in Table 41. As shown, almost 50% of the flowers visited by Ceratopogonids are ineffectively pollinated because they fly to "wrong" flowers.

The main attraction of the cocoa flower for Ceratopogonids seems to be the coloured parts: staminodes and petal guide lines both of which are

TABLE 41

Comparison between effective and ineffective pollination by Ceratopogonids in wild

	No. flowers examined	No. effectively pollinated*	No. ineffectively pollinated Staminode poll.†	Double poll.‡	Total
1972					
June	236	15	7	1	8
July	260	26	20	3	23
August	209	38	27	2	29
September	180	17	23	1	24
October	180	13	17	5	22
November	180	15	8	4	12
December	180	24	11	0	11
1973					
January	190	15	11	3	14
February	241	23	24	2	26
March	253	12	8	2	10
April	240	8	13	0	13
May	255	16	24	1	25
Total	2,604	222	193	24	217
Average	217	18.5	16.1	2	18.1

*Flowers with pollen cluster or smear on style or/and stigma.
†Flowers with pollen on staminode but not on style or/and stigma.
‡Flowers already effectively pollinated or set by other insects prior to Ceratopogonid visit.

dark reddish brown. Of the two, the midges prefer staminodes probably because they are vertically oriented in the flower, as Ceratopogonids, like many other insects, tend to fly to vertical objects rather than horizontal ones.

The great majority of the flowers visited by these insects have pollen on their staminodes (these include effectively pollinated flowers as well as those which bear pollen only on staminodes), but only 15–4% (depending on the species) carry pollen on the filaments of the stamens, for as in the case of style pollination described above, a midge would enter a petal hood following the guide lines, and as it emerges from the hood laden with pollen, it brushes against the filament resulting in "filament pollination" (Kaufmann, in press). In short, Ceratopogonids visit staminodes much more frequently than petal hoods. This results in a successively diminishing number of pollen grains left on the styles of flowers entered by a midge between one petal-hood visit and the next. As a result, some flowers are pollinated, and others are not. This phenomenon was evident in the cage experiments and there is strong indication that the same is true in nature. It is therefore not surprising that of all the effectively pollinated flowers (those with a minimum of 35 pollen per style) an average of only 22.0% (range: 7.9–58.7) in 1971 (sample size: 4,200 flowers), and 30.4% (range: 6.5–60.0) in 1972 (sample size: 2,613 flowers) were due to various Ceratopogonid species (Fig. 23). This gives quite a different picture from what was presented by Entwistle (*ibid.*) for it is evident that *Theobroma cacao* will still bear fruits in absence of Ceratopogonids. Indeed, cocoa pollina-

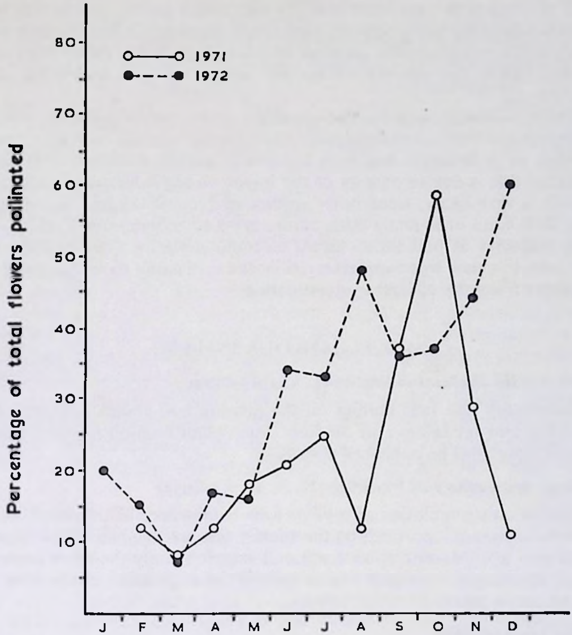

Fig. 23. Percentage of total effectively pollinated flowers which were pollinated by Ceratopogonidae.

tion is performed by different kinds of insects such as *Tyora tessmanni* (Kaufmann, *J. Kansas ent. Soc.*, **46,** 285–293), *Scaptodrosophila triangulifer* (de Mire, *4th Inter. Cocoa Res. Conf.*, 1972), Cecidomyiids (Kaufmann, in press), *Crematogaster* sp. (de Mire, *ibid.*; Posnette, *Trop. Agric. Trin.*, **19,** 188–191), *Toxoptera aurantii* (Billes, *ibid.*; Harland, *Ann. appl. Biol.*, **12,** 403–409; Posnette, *Trop. Agric. Trin.*, **19,** 12–16; Posnette, *Trop. Agric. Trin.*, **19,** 188–191; Stahel, *Verh. K. Akad. Wet.*, **25**), *Frankliniella parvula* (Billes, *ibid.*; Posnette, *Trop. Agric. Trin.*, **21,** 115–118).

Apidae: a new pollinator

In August 1972, a tiny Hymenopteron was seen flying from flower to flower gathering pollen in Tafo Cocoa Plantation. This individual was captured after visiting seven flowers, and was identified as a species of genus *Trigona* (Hymenoptera: Apidae), variously called sweat bees, stingless bees, or mopane bees. The second one was caught in September of the same year at the same site, but no more were observed until March 1973 when four more *Trigona* were taken. The tibial "pollen baskets" of each of these bees were literally white with cocoa pollen, and so was the ventral side of the body between meso- and metathoracic legs. Smaller but considerable number also adhered to other legs, head, thorax and abdomen. Thus the number of pollen carried by each individual was enormous.

Unlike Ceratopogonids, the stingless bees are apparently pollen gatherers and visit cocoa flowers for this purpose only. So far only a small number of individuals has been observed between 6.30 and 9.00 a.m. Whether this is due to paucity of the insect, wrong hours of observation (which is very likely, since other species of *Trigona* become active only after 8.00 a.m.) or to some other causes is yet to be determined. However their efficiency at pollination seems to compensate for their paucity. At any rate, this new hymenopteran pollinator surpassing *Ceratopogonids* in efficiency is worthy of further investigations.

MISCELLANEOUS INSECTS

Bathycoelia thalassina **studies** (E. Owusu-Manu)

Laboratory and field studies on the distribution, abundance, damage, parasites and predators and the insect/host plant relationship continued.

Full report will be published elsewhere.

Biology and ecology of Psyllidae (N. A. K. Akotoye)

Studies on a population of psyllids were commenced in December 1972. Two main lines of approach on the studies were undertaken. The first was the use of a UV-light trap to catch and sample mainly the adult populations; the second approach was to sample the population in the field on young cocoa plants by visual counts.

Light trap catches

The UV-light trap started running from December 1972. There were two types of Psyllids caught. Type A has oval wing tips while the second type, B has round tips. Each of these types has its green and brown forms denoting state of age. Greens are younger than the browns which are the most matured adults. For both the oval and round wing types of psyllids, the trap catches showed higher numbers for the brown form than the green for January. However, for December, February and March, the trend reversed so that there were more greens than browns. (See Table 42.) One conclusion to be drawn from the overall Psyllid population for the December–April period is that the population fluctuated in relation to the environmental conditions such as excessively high temperatures, low humidity and drought.

Field counting

Study plots were:

Shed A—potted cocoa seedlings 4–6 months old and 1½–3 ft. tall.
Shed B—potted cocoa plants 2–3 years old and 4–6 ft. tall.
Plot G9A and G9B—each 100 × 50 ft. (⅛ acre) of 3–4 years old.
Plot J6—100 × 50 ft. (⅛ acre) of 3–4 years old cocoa plants.
Plot G7—100 × 100 ft. (¼ acre) of 3–5 years old cocoa plants.

TABLE 42

Light trap catches of two forms of Psyllid, 1972–73

Months	Psyllid type A				Psyllid type B			
	Green		Brown		Green		Brown	
	Total	Average	Total	Average	Total	Average	Total	Average
December	117	9.0	114	8.7	87	6.7	76	5.7
January	121	6.4	246	12.9	1,014	53.4	1,766	92.9
February	195	12.2	138	8.7	114	7.1	53	3.3
March	1,949	92.7	1,212	57.7	160	7.6	71	3.3
April	294	24.5	396	33.0	14	1.2	14	1.2

The plots in the field were selected in such a way that they were spread over the square mile of the Institute's farm, to give a comparative estimate of Psyllid populations over the farm. Bi-monthly visual sampling was carried out on all of these test plots counting both nymphs and adults. From the results covering December to April, the Psyllid population was found to fluctuate in relation to availability of flush, humidity, drought stress, and high temperatures. In the early part of 1973 intermittent short droughts were experienced and consequently there was suppression of Psyllid numbers at these periods. Population sampling is still continuing.

Parasite incidence

Field collections of 4th and 5th instar nymphs were made and these dissected to look for possible parasites. Out of 200–300 nymphs dissected between January and March 1973, only four were found to be infested with one Hymenopteran larva per nymph.

It seems that parasitism is low at this time of the year, the result compares with what Lodos (*Rep. Cocoa Res. Inst., Ghana,* **1966–67**) found, i.e. 6–8 parasites for 500–700 psyllids examined.

Preference behaviour

Nymphs were examined to see if they show any preferential behaviour for the adaxial or abaxial surfaces of the flush-leaves. From Table 43, it seems that, there is preference shown for the abaxial side of the leaves.

One conclusion which can be drawn from this sort of preferential behaviour is that the Psyllids, especially the nymphs, were hiding away from direct sunlight and the consequent heating and desiccation effect which would prove disastrous to the nymphs.

TABLE 43

Number of Psyllids found on upper and lower leaf surfaces

Adaxial	Abaxial	No. leaves examined	χ^2	P
77	225	31	72.5	<0.001
146	267	51	35.6	<0.001

Biology and ecology of *Crematogaster clariventris* (S. Firempong)

Crematogaster clariventris Mayr (Hymenoptera Formicidae) is one of the dominant ant species of Ghana farms. Marchart and Leston (*Rep. Cocoa Res. Inst., Ghana*, **1967–68,** 63) mention it as one of the important predators of cocoa capsids and Evans (*Nature*, **232,** 346–7) has shown it to aid in the dissemination of black pod disease. However virtually nothing is known about the biology and ecology of this ant and an attempt has been made to study these.

Colony size

To determine colony size, a plot was selected and a plastic container with radioactive sugar attached to the nest (^{32}P; conc. 50 microcuries per ml). The area was monitored with a geiger counter after three days to find the size of the colony. Other methods used in addition were the acceptance–rejection test (which works on the theory that when ants of the same species meet and they belong to different colonies a fight ensues) and searching.

Each of these methods shows that the ant keeps extensive colonies: in one case the colony size occupying an area of 13,600 sq. ft.

It has also been found that the ants are polydomous.

Annual cycle

At monthly intervals, beginning from November 1972, nest populations were counted and the presence and number of the various castes noted. The method used involved bringing a nest to the laboratory and counting the number of the different castes.

Detachment of the nest from the nest trees was done early in the morning when few of the ants were active. Any ant that fell from the nest whilst it was being broken off was collected on a polythene sheet spread underneath the tree. In this way very few of the ants escaped. Numbers so far recorded indicate that nest populations are high, in the order of tens of thousands.

Activity pattern

The diurnal activity pattern has been determined twice, during periods of contrasting climatic conditions. One determination was made in November 1972 when there was rainfall and the other in February 1973 at a period of drought. Activity was recorded at hourly intervals 7.00 to 17.00 hours.

The method used involved watching a trail of the ant over a period of 5 minutes and recording the number of ants moving up and down past a point. There were 10 replicates of this.

Results, (Tables 44–51), show that as the day progresses the activity increases with a peak occurring from 12.00 hours to 14.00 hours and sometimes to 15.00 hours (e.g. as on 27–XI–72 when because of the hazy morning there was a delay in the break-through of the sun).

The activity, as the February determination shows, is not dependent on the hour of the day but on the interplay of temperature and humidity. The activity increases as the day wears on with the relative humidity decreasing and temperature increasing until a peak is reached at a temperature of

TABLE 44

Diurnal activity of Crematogaster clariventris: *27th November*, 1972

Time	1	2	3	4	5	6	7	8	9	10	Total	Average	Weather Wet bulb of	Weather Dry bulb of	RH %
7.00	No record														
8.00	49	77	43	72	95	276	183	66	261	12*	1,134	113.4	77*	80*	87
9.00	85	82	71	105	272	458	464	82	350	35	2,004	200.4			
10.00	48	92	67	188	225	346	292	61	100	110	1,529	152.9			
11.00	52	89	98	447	254	279	533	40	55	103	1,950	195.0	Hazy morning		
12.00	40	54	118	535	222	240	560	68	239	89	2,165	216.5			
13.00	224	267	335	575	348	439	287	94	128	203	2,900	290.0			
14.00	301	362	423	525	410	398	397	73	204	139	3,232	323.2			
15.00	407	355	297	582	489	562	387	70	129	161	3,439	343.9			
16.00	210	244	259	706	464	500	251	65	90	60	2,849	284.9			
17.00	299	350	264	439	287	316	377	51	116	60	2,559	255.9			
Total	1,715	1,972	1,975	4,174	3,066	3,814	3,731	670	1,672	972	23,761				

*Remarks: Trail was wet

7

TABLE 45

Diurnal activity of Crematogaster clariventris: *28th November*, 1972

Time	1	2	3	4	5	6	7	8	9	10	Total	Average	Weather Wet bulb of	Weather Dry bulb of	RH %
7.00	196	211	226	9	535	74	230	23	70	48	1,140	114.0			
8.00	278	301	401	96	324	296	351	194	96	23	2,360	236.0			
9.00	386	393	403	392	270	385	365	69	53	75	2,791	279.1	77	81	83
10.00	428	402	195	468	365	451	376	41	68	105	2,899	289.9			
11.00	478	388	209	407	323	347	305	52	86	165	2,760	276.0	Fair morning and afternoon		
12.00	498	398	415	574	411	539	231	94	131	216	3,507	350.7			
13.00	509	499	502	582	294	605	100	75	86	289	3,541	354.1			
14.00	532	511	586	629	259	559	—	43	175	207	3,501	389.0			
15.00	128	134	403	597	380	563	—	52	89	302	2,648	294.2			
16.00	112	208	339	590	341	490	239	52	92	119	2,582	258.2			
17.00	243	179	427	476	409	420	261	39	50	222	2,726	272.6			
Total	3,788	3,624	4,106	4,820	3,429	4,729	2,458	734	996	1,771	30,455				

TABLE 46

Diurnal activity of Crematogaster clariventris: 29*th November*, 1972

Time	1	2	3	4	5	6	7	8	9	10	Total	Average	Weather Wet bulb of	Dry bulb of	RH %
7.00	203	198	287	81	215	431	116	74	49	123	1,777	177.7			
8.00	249	230	295	125	256	429	125	60	35	128	1,932	193.2			
9.00	267	249	304	275	252	539	68	53	56	79	2,142	214.2	77	81	83
10.00	332	290	346	126	293	496	105	60	41	94	2,183	218.3			
11.00	355	311	410	134	256	363	93	97	25	121	2,165	216.5	Fair morning and afternoon		
12.00	409	384	472	454	229	371	153	129	72	293	2,966	296.6			
13.00	439	402	500	417	274	403	71*	57*	188*	128	2,879	287.9			
14.00	502	471	514	527	268	310	86	40	56	212	2,986	298.6			
15.00	302	134	461	302	276	343	105	77	59	144	2,203	220.3			
16.00	233	329	520	247	312	415	81	76	93	208	2,534	253.4			
17.00	228	288	386	268	321	449	197	41	40	250	2,468	246.8			
Total	3,539	3,286	4,495	2,956	2,952	4,549	1,200	764	714	1,780	26,235				

*Remarks: a very brief downpour occurred.

TABLE 47

Diurnal activity of Crematogaster clariventris: 30*th November*, 1972

Time	1	2	3	4	5	6	7	8	9	10	Total	Average	Weather Wet bulb of	Weather Dry bulb of	RH %
6.00	30	74	65	76	134	271	62	1	20	153	895	89.5			
7.00	206	195	200	58	197	374	73	30	48	93	1,474	147.4			
8.00	310	211	330	111	289	415	60	66	47	120	1,959	195.9	77	81	83
9.00	398	286	427	129	248	356	110	43	77	117	2,191	219.1			
10.00	488	370	495	139	255	344	417	51	47	131	2,737	273.7			
11.00	522	381	527	98	279	450	419	26	35	85	2,822	282.2	Hazy morning		
12.00	543	420	539	153	251	347	456	42	68	100	2,919	291.9	Rained in the afternoon		
13.00	577	472	584	428	280	310	151	43	85	Rain	2,930	325.6	then followed by a fair		
14.00					Rain								weather		
15.00	78	18	217	233	294	415	410*	40	5	47	1,757	175.7			
16.00	149	78	329	221	390	466	264*	24	91	44	2,056	205.6			
17.00	141	114	295	161	405	390	430*	4	93*	58	2,091	209.1			
Total	3,442	2,619	4,008	1,807	3,031	4,138	2,852	370	616	948	23,831				

*Remarks: Some of the ants left one of their trails and took to the trail on which work was being done.

TABLE 48

Diurnal activity of Crematogaster clariventris: *5th February*, 1973

Time	1	2	3	4	5	6	7	8	9	10	Total	Average	Temp (°C)	RH %
7.00	119	87	19	53	176	75	228	73	65	19	914	91.4	26.5	84.0
8.00	146	100	105	136	302	190	187	74	159	87	1,468	146.8	28.0	82.0
9.00	233	130	262	363	414	143	308	12	182	97	2,144	214.4	28.5	81.7
10.00	286	149	376	433	396	153	283	101	50	91	2,318	231.8	31.0	66.2
11.00	299	175	493	637	352	112	301	108	181	69	2,727	272.7	31.3	71.0
12.00	286	171	288	394	496	113	305	105	111	80	2,299	229.9	34.0	60.0
13.00	289	166	283	340	330	175	337	123	102	89	2,234	223.4	35.0	60.0
14.00	274	162	271	365	486	349	361	178	70	77	2,293	229.3	35.0	51.5
15.00	503	91	212	428	407	245	355	266	101	93	2,701	270.1	34.7	51.1
16.00	410	215	277	340	466	270	371	25	72	164	2,610	261.0	32.0	44.0
17.00	409	224	190	336	489	268	340	48	160	137	2,601	260.1	29.5	55.8
Total	3,254	1,670	2,776	3,775	4,314	2,093	3,376	1,113	1,523	1,003	24,897			

TABLE 49

Diurnal activity of Crematogaster clariventris: *6th February*, 1973

Time	1	2	3	4	5	6	7	8	9	10	Total	Average	Temp (°C)	RH (%)
7.00	109	65	49	52	257	82	138	122	47	60	982	98.2	26.0	84.3
8.00	132	76	73	150	308	130	224	61	123	74	1,351	135.1	27.7	83.0
9.00	200	99	94	174	494	132	265	92	161	133	1,844	184.4	19.60	73.3
10.00	223	109	106	180	546	180	444	52	285	47	2,172	217.2	35.3	68.1
11.00	261	98	144	236	440	210	543	49	312	51	2,344	234.4	34.0	54.7
12.00	250	94	148	240	306	240	147	140	124	98	1,787	178.7	34.0	53.0
13.00	244	96	114	227	284	230	133	137	118	88	1,671	167.1	36.0	52.0
14.00	221	91	98	493	298	160	122	164	214	77	1,938	193.8	36.0	46.0
15.00	557	109	162	497	389	361	325	20	237	124	2,781	278.1	36.0	48.0
16.00	463	226	284	637	504	402	371	20	154	92	3,153	315.3	34.0	49.8
17.00	515	98	131	426	457	374	418	12	96	78	2,605	260.5	34.0	53.5
Total	3,175	1,161	1,403	3,312	4,283	2,501	3,131	869	1,871	922	22,628			

TABLE 50

Diurnal activity of Crematogaster clariventris: *7th February*, 1973

Time	1	2	3	4	5	6	7	8	9	10	Total	Average	Temp (°C)	RH %
7.00	118	74	50	90	318	223	116	59	155	150	1,353	135.3	27.0	81.3
8.00	137	79	129	202	411	244	218	92	259	342	2,113	211.3	28.0	79.5
9.00	202	83	281	442	478	274	392	61	165	365	2,743	274.3	31.0	75.3
10.00	214	101	315	495	464	295	*	52	302	323	2,561	284.6	31.0	66.0
11.00	220	124	210	375	503	169	*	40	301	339	2,281	253.4	32.0	53.6
12.00	207	112	106	371	476	496	*	60	211	120	2,573	285.9	34.0	50.0
13.00	188	109	100	366	433	543	*	69	601	240	2,669	296.6	34.0	49.0
14.00	178	102	98	335	409	504	*	24	261	122	2,033	225.9	38.0	45.0
15.00	419	209	153	298	439	234	*	5	45	344	2,056	228.4	36.0	43.0
16.00	385	145	103	333	531	230	*	15	65	446	2,253	250.3	33.0	50.5
17.00	514	82	158	467	461	160	*	24	103	526	2,495	277.2	33.5	57.0
Total	2,782	1,220	1,703	3,774	4,833	3,372		521	2,468	3,317	23,990			

TABLE 51

Diurnal activity of Crematogaster clariventris: *8th February*, 1973

Time	1	2	3	4	5	6	7	8	9	10	Total	Average	Temp (°C)	RH %
7.00	108	59	70	182	354	121	*	236	130	267	1,527	169.7	25.0	81.0
8.00	115	63	159	445	412	187	*	352	158	296	2,187	243.0	28.0	80.5
9.00	199	67	221	469	469	207	*	59	172	325	2,188	243.1	30.3	69.0
10.00	229	75	217	470	314	248	*	45	134	313	2,045	227.0	30.8	66.0
11.00	238	106	198	472	235	136	*	50	313	231	1,979	219.9	32.5	58.0
12.00	235	102	164	463	425	220	*	148	414	546	2,717	301.9	35.0	55.0
13.00	221	99	113	455	398	649	*	182	448	453	3,018	335.3	35.8	54.0
14.00	208	72	160	498	425	672	*	242	364	474	3,115	346.1	36.0	53.0
15.00	540	100	172	480	424	114	*	57	75	414	2,376	264.0	35.3	51.5
16.00	517	158	168	416	454	304	*	42	142	561	2,712	301.3	32.0	57.0
17.00	———	———	———	———	Threats of rain	———	———	———	———	———				
Total	2,610	907	1,642	4,350	3,860	2,858		1,413	2,350	3,880				

34°C and provided the relative humidity does not fall below 49% a small increase in temperature can be tolerated.

Food items

The aim was to determine what food items are eaten by *C. clariventris*, and to see if there is any seasonal variation in food carried to their nest.

Four ant trails at different sites were selected and once every week for a period of one hour foragers carrying food items were intercepted and brought to the laboratory for their food items to be identified. The identification is still in progress. Even though a large percentage of the materials being carried are in small bits and are therefore difficult to identify, data collected so far indicate that the ants carry bits of bark, stem, leaves (for construction of their nest) and food items like psyllids, mosquitoes, leaf-hoppers, coccids, flies and other ants including their own species.

Ants and cocoa yield

To determine whether the presence of the ants affect the yield of cocoa a plot in K2–O1 has been selected. Experimental cocoa trees are those with nests on them and on which more than 150 ants can be seen in a minute. This experiment is to go on for a year.

INSECTICIDES

Insecticide screening (E. Owusu-Manu)

Four new compounds were screened for the control of *D. theobroma* by the cage spray method. A "cocktail" of these compounds and Gammalin were also included with Gammalin and Baygon as "base line" comparisons.

The results are shown in Table 52.

Actellic and Orthene, used alone or with Gammalin gave poor results both at 140 g and 280 g per hectare. Bioresmethrin and CA 71050 were also less toxic to capsids. Baygon and Ortho-Bux gave good results with Gammalin as they did when used alone.

Capsid field spraying trials (E. Owusu-Manu and F. K. Manteaw)

The two most promising insecticides, Entrofollan and Sevimol from a number of insecticides screened in 1971–72 were included in this year's trials. Other insecticides tested were Actellic, Actellic/Gammalin, Gammalin, Baygon and Ortho-Bux/Gammalin. The Gammalin and the Baygon were used for "baseline" comparisons. Untreated control was included (Table 53).

The trials were carried out in Brong Ahafo and Ashanti regions on seven sites as described earlier (*Rep. Cocoa Res. Inst., Ghana*, **1967–68**, 64–65). The plots were treated once a month from August to December except November. The T1 method of application was used for all the treatments.

The percentages of mortality are shown in Table 54.

Baygon, Entrofolan and Ortho-Bux/Gammalin gave the best control in reducing the capsid numbers. Sevimol, Actellic/Gammalin and Actellic

TABLE 52

Cage spray insecticide tests against D. theobroma

Compound	Formulation	Dosage g/ha	Mean 24 hour mortality
Bioresmethrin	20% EC	210 280	61.0 57.0
CA 71050	50% EC	280	57.0
*Pirimiphos methyl	Actellic 25% EC	140 280	39.0 82.0
*Ortho 12,420	Orthene, 75% EC	140 280	44.0 80.0
Gamma-BHC	Gammalin 20% EC	280 420	75.0 70.0
Arprocarb (Baygon)	Unden 20% EC	140	100.0
Ortho-5353	Bux 24% EC	140	96.0
Actellic + Gammalin	—	140 + 140	47.0
Orthene + Gammalin	—	140 + 140	65.0
Ortho-Bux + Gammalin	—	140 + 140	96.0
Baygon + Gammalin	—	140 + 140	100.0

*Organo-phosphorus compounds.

TABLE 53

Insecticides used in 1972–73 *Capsid Field Trials*

Treatment	Dosage g.a.i./ha	Method of application
Sevimol	280	T1
Actellic	280	T1
Etrofolan	280	T1
Gammalin (BHC)	280	G
Ortho-Bux/BHC	140 + 140	T1
Baygon	140	T1
Actellic/BHC	140 + 140	T1
Control	Untreated	—

were not significantly better than Gammalin although they showed significant improvement over the untreated control plots.

Results of capsid population recovery counts are shown in Table 55. There was a considerable population recovery in the succeeding months after each application but this was most marked with Actellic, Actellic/Gammalin and Sevimol. This may be due to their short persistence. Ortho-Bux/Gammalin compared equally well with Baygon and significantly better than Gammalin alone. Etrofolan was intermediate.

Table 54

Capsid field trials, % mortality—Mean values for seven reps. 1972–73

Treatment	August	September	October	December	Mean
Sevimol	82.0	86.6	64.9	74.6	77.0
Actellic	66.1	61.8	71.6	88.2	71.9
Etrofolan	84.4	96.5	96.9	97.2	93.8
Gammalin (BHC)	59.0	83.1	75.5	54.1	70.4
Ortho-Bux/BHC	97.9	82.5	85.6	100.0	91.5
Baygon	99.1	92.5	93.5	97.5	95.7
Actellic/BHC	88.1	68.9	74.6	77.9	77.4
Control	−13.1	−61.4	−28.5	−2.7	−26.4

Table 55

Capsid recovery count—Mean values for seven reps. 1972–73

Treatment	September	October	November	December	January	Cumulative total
Sevimol	78.0	45.6	61.4	81.7	44.4	311.1
Actellic	28.6	35.0	81.6	162.1	98.3	405.3
Etrofolan	58.6	26.6	38.9	70.9	23.0	218.0
Gammalin (BHC)	30.4	18.4	15.0	22.3	26.9	113.0
Ortho-Bux/BHC	24.4	3.9	4.0	32.9	6.7	71.9
Baygon	20.3	8.3	14.7	22.4	16.3	82.6
Actellic/BHC	89.9	39.6	51.6	85.9	33.9	300.9
Control	38.6	75.3	56.0	81.0	49.7	300.6

The mean capsid fresh damage per 100 trees (Table 56) shows a similar trend as the population recovery counts with Baygon, Ortho-Bux and Gammalin being significantly the best treatments. The untreated control plots were significantly better than Sevimol and Actellic.

Foliage assessment and degraded cocoa trees (Table 56) showed similar

Table 56

Capsid Spray Trial results: canopy assessment

Treatment	Capsid recovery cumulative for season	Mean fresh damage/100 trees	Percentage degraded trees (January)	Canopy improvement based on control
Sevimol	311.1	4.9	15.9	12
Actellic	405.3	3.8	25.1	4
Etrofolan	218.0	3.0	13.3	18
Gammalin	113.0	1.7	7.5	15
Ortho-Bux/Gammalin	71.9	1.9	4.6	24
Baygon	82.6	1.8	4.4	28
Actellic/Gammalin	300.9	3.1	20.9	8
Control	300.6	3.2	25.3	0

results as fresh damage count with Baygon, Ortho-Bux/Gammalin and Gammalin again being significantly the outstanding insecticides.

Ortho-Bux/Gammalin mixture compared equally well with Baygon both in capsid kill and population recovery as well as canopy regeneration. It was significantly better in capsid kill and recovery than Gammalin but equally effective in canopy regeneration.

Actellic, Actellic/Gammalin, Entrofolan and Sevimol were significantly less effective than Gammalin. However, Entrofolan was significantly more effective than the others. These treatments, showed improvement over the untreated control.

Visual observations made at the end of the season showed that the Ortho-Bux/Gammalin and the Baygon plots had no damage on the new growth with all the trees showing good recovery, although the canopy had not been closed yet.

The Gammalin and the Entrofolan plots showed signs of recovery but there were a few cocoa trees still with recent damage.

The Actellic, Actellic/Gammalin and the Sevimol plots showed no signs of recovery and seemed to be as damaged as the control plots.

Field spraying trials: second treatment (E. Owusu-Manu and F. K. Manteaw)

All the insecticides and the plots used in last year's field trial (*Rep. Cocoa Res. Inst., Ghana*, **1971–72**) were repeated this year. The insecticides are Ortho-Bux, Gammalin/Baygon, Carbamult and Gammalin. The experimental procedure has already been described (*Rep. Cocoa Res. Inst., Ghana*, **1971–72**). The plot meant for Entrofolan was used for Ortho-Bux instead; as such there were two Ortho-Bux treatments. Capsid counts were made between June and August before the second application began to find out the after-effect of these insecticides on the subsequent capsid population build-up.

All the insecticides gave very good kill of capsids (Table 57) except Gammalin which was significantly less effective. However, it showed improvement over the untreated control plots.

Capsid population build-up between June and August was less pronounced in the Carbamult and the control plots (Table 58) followed, in order of efficacy by Ortho-Bux (1), Gammalin, Ortho-Bux (2) and Gammalin/Baygon. This implies that the use of these chemicals might

TABLE 57

Second Capsid Spray Trial: percent mortality

Treatment	August	September	October	December	Mean
Ortho-Bux (1)	98.1	100.0	94.3	96.7	82.3
Gammalin/Baygon	100.0	100.0	100.0	100.0	100.0
Carbamult	100.0	100.0	100.0	100.0	100.0
Ortho-Bux (2)	97.8	100.0	96.7	100.0	91.1
Gammalin	95.5	72.6	72.2	93.3	84.4
Control	−16.7	41.9	−43.2	−40.0	−14.5

Table 58

Pre-treatment counts—1971–72 plots—2nd treatment 1972–73

Treatment	June	July	August	September	October	November	December	January	Cumula-tive season	Total June–Aug.	Sept.–Jan.
Ortho-Bux (1)	19.67	50.33	38.67	15.00	6.67	5.55	11.33	0.67	147.67	108.67	39.00
Gammalin/Baygon	73.67	47.67	85.33	20.67	2.33	2.00	16.33	1.33	249.33	206.67	42.66
Carbamult	48.00	5.67	7.00	10.33	4.33	19.33	13.33	7.00	114.99	60.67	54.32
Ortho-Bux (2)	121.67	51.33	74.33	31.33	3.33	13.33	11.67	3.67	310.66	247.33	63.33
Gammalin	32.33	30.33	78.33	55.00	12.67	25.00	27.33	9.33	270.32	140.99	129.33
Control	10.67	11.67	13.00	28.33	38.67	41.67	48.00	57.00	243.01	35.34	213.67

have killed all the predators and the parasites in the previous year causing such high capsid population build-up in the following year. Thus any cessation in the use of an insecticide may bring about an increase in the pest population.

However, after treating these plots, the capsid population recovery was significantly less on the two Ortho-Bux plots, Gammalin/Baygon and the Carbamult plots than on the Gammalin and the control plots. The Gammalin plots were also significantly less pronounced than the control plots.

Fresh capsid damage counts showed a similar trend of activity as the population recovery. Between June and August, Carbamult and the untreated plots had significantly the least number of freshly damaged trees. However, after treating the plots, the Gammalin and the control plots had significantly the highest counts (Table 59).

TABLE 59

Second Treatment Capsid Spraying Trials: canopy assessment

Treatment	Mean fresh damage/100 trees			Percentage degraded trees		Canopy improvement
	June-Aug.	Sept.-Jan.	Season	July '72	Jan. '73	1973 over 1971
Ortho-Bux (1)	2.6	1.0	1.8	18.7	7.0	24.0
Ortho-Bux (2)	1.7	0.7	1.2	23.3	2.7	46.0
Gammalin/Baygon	0.8	0.9	1.0	31.7	18.0	22.3
Carbamult	0.3	1.1	1.0	38.7	9.3	37.0
Gammalin	1.0	1.9	1.8	10.3	5.0	23.0
Control	0.0	2.1	1.5	44.0	23.0	11.7

Ortho-Bux (2) has been the most outstanding insecticide in canopy regeneration over the two seasons and Carbamult gave the best recovery. These were followed by Gammalin and then Ortho-Bux (1) and Gammalin/Baygon.

Capsid off-season spraying trial (E. Owusu-Manu and F. K. Manteaw)

Treatment of these plots started in February through to May at monthly intervals (*Rep. Cocoa Research Inst., Ghana*, **1971–72**, 135). Ortho-Bux (280 g a.i.), Gammalin/Baygon (140 g + 70 g a.i.), Carbamult (280 g a.i.) and Gammalin (280 g a.i.) were tried, using the T1 method of application.

All the insecticides gave good capsid control which was significantly better than the control plots (Table 60). During the spraying period, February–May, capsid population recovery was least in the Gammalin/Baygon plots. In the period after treatment, June to January, Gammalin/Baygon had the least population recovery rate. The other treatments compared favourably with the control, except the Carbamult plots which had significantly the highest number of capsids.

Similar observations were made in the capsid fresh damaged trees.

TABLE 60

Results of dry season, February–May, spraying trial, 1972

Treatment	Mean % kill	Capsid recovery cumulative		Mean fresh damage/ 100 trees	
		Feb.-May	June-Jan.	Feb.-May	June-Jan.
Carbamult	99.3	16.7	552.7	1.3	4.0
Gammalin	84.0	12.0	334.4	2.8	3.4
Gammalin/Baygon	100.0	3.0	201.4	0.0	3.1
Ortho-Bux	100.0	9.0	265.6	0.8	3.9
Control	−102.8	12.6	336.7	0.8	7.8

Although the population recovery in Baygon and Ortho-Bux plots was significantly lower than the control untreated plots, the populations were high enough to need a treatment. Applying the insecticides during the capsid off-season seems not to affect the population build-up during the capsid season, beginning from August.

Side effect of tested insecticides (E. Owusu-Manu)

The experimental procedure has been described in last year's report (*Rep. Cocoa Res. Inst., Ghana*, **1971–72,** 132). Four applications were made, beginning from February at monthly intervals, using T2 method. Counts were however, made until the end of November, 1972.

On predators

All the insecticides except Carbamult had some effect in reducing the population of ants during the four-month period of the application of the insecticides. However, the populations of these ants recovered to normal a month after the end of the treatment.

There was no adverse effect of any of the insecticides tested on the other predators.

On minor pests

Bathycoelia thalassina has been included here although it is now considered as a major pest. The population of *B. thalassina* started to build up in June, a month after the application of the insecticides on all the treated plots. There was no incidence of this pest on the control plots. It is likely that application of these insecticides might have killed all the parasites and the predators, giving rise to a high population of the pest.

No insecticide had effect on mealybugs. Nonetheless, after the treatment the mealybug population went up in the Gammalin and the Gammalin/ Baygon plots. These two insecticides, however, gave good control of *Helopeltis* sp. until October after which they lost their effectiveness. The carbamates had no after-effect on *Helopeltis* sp. and the population sometimes was more than that on the untreated control plots. Other minor pests were not adversely affected.

TABLE 61

The effect of different insecticides on flowers (F) that set (S) and on cherelles (C)

Month	Carbamult			Gammalin/Baygon			Gammalin			Ortho-Bux			Control		
	F	S	C	F	S	C	F	S	C	F	S	C	F	S	C
March	442	106	85	175	52	43	203	36	15	401	82	64	278	87	62
April	615	103	60	309	115	69	506	93	72	605	99	34	330	100	62
May	591	74	58	212	77	58	401	11	94	438	70	50	227	77	61
June	115	30	19	59	18	9	183	39	25	149	16	7	65	17	9
July	115	19	10	15	6	—	51	21	17	54	16	9	26	7	4
August	22	4	4	1	—	—	2	1	—	6	5	3	4	3	2

On pollination

The experimental set-up has been described (*Rep. Cocoa Res. Inst., Ghana*, **1971–72**). The results are summarized in Table 61.

Initially, all the insecticides seemed to have an adverse effect on the number of sets or pollinated flowers and no noticeable effect on the number of set flowers that dropped, nor the number of sets that became chelleres.

Further observations showed a slight decrease in the percentages of flowers that were pollinated on the carbamate plots, that is Carbamult and Ortho-Bux. There was no noticeable adverse effect of the other insecticides on the set flowers.

CRIG/Cocoa division joint trials (E. Owusu-Manu, F. K. Manteaw and Cocoa Division Staff)

Large scale field spraying trials

All treated plots used in the previous season, 1970–71, were repeated this season (*Rep. Cocoa Res. Inst., Ghana*, **1970–71**) except the Carbamult plots. These plots were not included because of the difficulty encountered in clearing an order for carbamult from the Tema Harbour.

The results are shown for percentage kill and capsid population recovery counts (Table 62). All the insecticides gave a significantly good kill. The capsid population build-up was fast in the following months in all the plots except Gammalin/Baygon plots but the build-up in December, two months after the application of the insecticides, was very high. Ortho-Bux was significantly the best in this respect

TABLE 62

CRIG/Cocoa Division Joint Trial—1972–73
Mean of 18 *Replicates*

Treatment	Capsids per acre				Cumula-	Mean
	August	September	October	December	tive total	% kill
Ortho-Bux	29.1	26.4	18.7	8.1	82.3	95.7
Gammalin/Baygon	10.4	8.5	6.4	27.3	52.6	88.6
Gammalin	6.9	22.6	13.7	33.6	76.7	82.0
Control	33.8	74.4	136.7	27.3	272.2	19.0

Capsid resistance survey

The survey nearly came to a stand-still, due to the low capsid population during the season. All the localities surveyed in Brong Ahafo and the Eastern regions had a certain degree of resistance which ranged between 5 and 68% with a mean of about 37% (Table 63). Resistance seems to be well established in all the cocoa growing regions of the country (*Rep. Cocoa Res. Inst., Ghana*, **1971–72**).

TABLE 63

Lindane resistant capsid survey results as at December 1972

Region	No. of localities surveyed	*Resistance category 1	2	3	% resistance Range	Mean
Brong Ahafo	6	—	—	6	10–68	37
Central	2	—	1	1	5–33	18
Eastern	4	—	—	4	25–67	37

*1. 100% susceptible.
2. 1–10% resistance.
3. 11–100% resistance.

Control of a cola pest (E. Owusu-Manu)

The Agronomy Division reported heavy stem borer damage on cola at Bunso, in the Attukrom block in July 1972. The insects were found to tunnel into branches and chupons of the cola tree, resulting in the death of the branch. With seedlings, the trunk was tunnelled, thus damaging the whole tree. The damage was relatively heavy in July.

Following the report, five branches were caged with wire-gauze nests to trap the adults for identification and the other plants were treated with 30% Azodrin 5 as stem paint.

Initial treatment was started in the middle of July and this was repeated two weeks later. A third treatment was given one month after the second treatment. One hundred percent control was achieved after the second treatment; the third was given to avoid re-infestation from outside.

Those branches that were already dead were cut back.

The adults were captured at the end of September. They were predominantly black with a yellow triangle anteriorly and a yellow crescent posteriorly. It was identified as *Phosphorus gabonator*.

PLANT BREEDING AND SELECTION

NEW INTRODUCTIONS

(G. Lockwood)

Only one consignment of 17 clones was received from the Royal Botanic Gardens, Kew, during the year. Some of the clones were repeats of ones which had failed to establish in 1971 (*Rep. Cocoa Res. Inst., Ghana,* **1971–72,** 141). New clones which were established were IMC 78, Pa 296, Na 443, Na 691, Na 752, Na 904 and Na 929 while Na 27, CC10 and 10P failed to establish.

The selections introduced last year (*Rep. Cocoa Res. Inst., Ghana,* **1971–72,** 141) were planted in the field and establishment was good. In the new introductions plot, increasing numbers of the older plants came into flower and were used as both male and female parents in a number of pollination programmes. The plot was harvested regularly and a start was made in obtaining data on the pod and bean characters of the various selections, although inevitably it will be several years before enough information is obtained on many of the clones. During the dry season the plot was protected by adequate shade and although many selections showed signs of acute water stress, few trees were lost.

In order to extend the range of breeding material at Tafo it has been arranged that a number of clones should be introduced to Ghana from Trinidad via intermediate quarantine at Kew. In 1972 a number of clones were successfully established at Kew including about 30 each from the Iquitos and Parinari populations, eight more Pounds, a Morona and five Scavinas. In addition nine clones were transferred to Kew from the U.S.D.A. plant introduction station at Mayaguez, Puerto Rico; these included seven more United Fruit Company clones. Most of these new clones should be available for transfer to Ghana by the end of 1973.

It is becoming increasingly apparent at Tafo that while the Pound material is of great value in cocoa breeding, the range of variability in some characters, particular resistance to swollen shoot disease, does not extend far beyond that seen in the selections tested already. Accordingly, during the year, preparatory work on introducing a wider range of material was begun, with particular emphasis on germplasm collected in the Upper Amazon by expeditions subsequent to Pound's. It is hoped that the first consignments of budwood will be sent from South America to Kew in the middle of 1973.

BREEDING TRIALS

8th and 9th progeny trials and off station series II trials (G. Lockwood)

Yield data from these trials are given in Table 64 and data on disease losses in Table 65.

Table 64

Actual yields in lbs. dry cocoa/acre from the 8th and 9th Progeny Trials and Series II Trials in 1972–73

Variety		8th P.T.A.	9th P.T.A.†	Apedwa	Asikuma	Oyoko	Pankese
WA1*		1,147					
WA2*		573					
WAE2		1,049					
WAE3		1,389					
WAE4		1,753					
WAE5	A	2,318			453		1,095
WAE11	H		678	706	546	1,629	992
WEA2	M		897	562			
WEA3	J		604	454	532	1,989	
WEA4			950				
WEB1	E		608		404	2,167	964
WEB2	N		355				
WEB3	L		594	421	261		
WBE2	B	917			439		474
WBE3	C	1,118		372		1,137	581
WBE4	D	1,425		602	597	1,231	756
WBE6	K		523	571		1,326	
WE2		574					
WE3		1,272					
WE4	G	925				1,037	761
WE6	F		655	704	374	1,550	938
WB2		802					
WB3		837					
TF1			483				
L.S.D. P = 0.05		—	—	—	—	—	—
C. of V. %		—	37.0	46.1	33.5	—	—

*Amelonado.
†Replicates 3–5 only.

For the 8th and 9th P.T.A.s the yields were estimated from the core plots using the pod values determined from individual harvests. In the case of the Apedwa and Asikuma trials the yields are also from core plots but pod values were estimated from the wet weights of cocoa recorded using the wet to dry conversion ratios determined at Tafo in the 1972–73 season. The pod values were estimated in the same way for the Oyoko and Pankese trials. The Oyoko yields are based on whole plots and the numbers of trees surviving until 1972, the Pankese yields similarly are from whole plots but are based on replicates 1–3 only.

In the 8th P.T.A. there was a sharp increase in the crop from all the varieties. The difference in yield between the two Amelonado selections (WA1 = unselected West African Amelonado and WA2 = P4/9:J11/4/5 selfed) continued to widen. It is unlikely that this is wholly a genetic effect as examination of the trial showed that because one plot of WA2 had been badly damaged by a falling shade tree and severely exposed, it contributed very little yield.

The varieties in the 8th P.T.A. continued to indicate that, because they are higher yielding, the Amazon × Amelonado hybrids (WAE) are to be preferred to the Amazon × Local Trinitario hybrids (WBE). The inter-Amazon hybrids in the 8th P.T.A. (WE) are poorer than either of the other

TABLE 65

Disease losses in 8th and 9th Progeny Trials and Series II Trials in 1972–73

Variety		8th P.T.A.	9th P.T.A.†	Apedwa	Asikuma	Oyoko	Pankese
WA1*		8.4					
WA2*		10.1					
WAE2		13.7					
WAE3		9.7					
WAE4		7.7					
WAE5	A	12.2			32.5		33.8
WAE11	H		17.2	21.4	24.1	12.7	30.7
WEA2	M		13.6	23.8			
WEA3	J		20.4	22.3	23.1	15.3	
WEA4			20.3				
WEB1	E		20.4		27.4	17.2	34.6
WEB2	N		26.1				
WEB3	L		30.5	31.1	37.5		
WBE2	B	13.1			29.8		25.6
WBE3	C	14.9		36.4		21.5	37.8
WBE4	D	14.3		20.3	31.0	18.1	32.0
WBE6	K		39.6	29.4		25.3	
WE2		9.9					
WE3		4.9					
WE4	G	9.0				16.8	28.0
WE6	F		9.5	14.1	26.2	10.3	17.8
WB2		9.3					
WB3		9.8					
TF1			31.4				
L.S.D.							
P = 0.05			13.5	9.6	—	—	—
C. of V. %			34.3	26.3	28.1	—	24.3

*Amelonado.
†Replicates 3–5 only.

Amazon types in the trial. However, all three WE progenies were derived by sibbing and the results should not be taken as indicative of Amazon crosses as a whole. Thus in the other five trials of the Series II hybrids, WE6 (F), an outcrossed Amazon, has given consistently good results.

The 9th P.T.A. also showed an increase in yield compared to 1971–72 but the level of yield continued to be disappointing. By comparison to the 8th P.T.A., the 9th P.T.A. yields have always been lower, although the varieties are comparable. As in the 8th P.T.A., the 9th P.T.A. Amelonado hybrids out-performed the Trinitario hybrids; the difference in disease losses being particularly wide. Once again F (WE6) was the variety with the lowest disease losses.

The Apedwa trial continued to be comparatively low yielding despite the shade reductions which were made last year (*Rep. Cocoa Res. Inst., Ghana*, **1971–72**, 147). However, it may be too soon for the shade reduction to have had an effect although some varieties did show a large increase in yield over 1971–72 (Table 66). From the analysis made last year (loc. cit.) it appeared that F was not greatly affected by the shade but that C, J, K and L were and that M benefited from comparatively little shade. As can be seen from the table there is no obvious relationship between the change in yields in the year of shade reduction and adjustment to the yields resulting from the use of shade as a covariate.

TABLE 66

Series II Trials at Apedwa

% change since 1971–72 in net yield (1971–72 = 100)							
C	D	F	H	J	K	L	M
+19.6	+14.2	+67.6	+25.0	+45.5	+101.1	+4.1	−0.1
% change predicted by covariance on the 1970–72 yields							
+21.8	−2.0	−7.5	−3.9	+11.2	+18.1	+6.3	−22.2

In last year's report (*Rep. Cocoa Res. Inst., Ghana*, **1971–72**, 147) an approximate comparison was made between the yield from the Series II trial at Apedwa and that from an adjacent Amelonado plot. The Senior Technical Officer in charge of the station has generously provided the Amelonado data again this year. The net yield over the whole Series II trial was 635 lbs./acre but on the Amelonado only 508 lbs./acre (the latter assumes a pod value of 12). However, whereas disease losses on the trial were 24.9%, on the Amelonado they were only 7.4%.

At Oyoko the yields were the highest in all of the Series II trials and variety E was particularly good. It must be stressed that the yields from this trial are approximations, firstly because parts of the trial have been destroyed following swollen-shoot infection and secondly because the yields are based on whole plots.

The Pankese trial was the only Series II trial in which the net yields were generally lower than in 1971–72. It is likely that the main reason for this was the sharp increase in the level of black pod in the trial.

D14 (G. Lockwood)

This trial was planted in 1965 as an additional test of some of the Series III, IV and V variety trials which were planted in 1963 (*Rep. Cocoa Res. Inst., Ghana*, **1962–63**, 47). The further plantings were considered necessary because it was intended that most of the plots of the Series IV varieties would be infected and the original Series IV trial was on poor land and so was not expected to develop into a long term experiment. In addition, all the 1963 trials were damaged by capsids during their early years.

Plots of 6 × 7 trees were chosen for D14 so that guarded cores could be separated in the later stages of the trial. (*J. hort. Sci.*, **40**, 317–9). Because there were many varieties and consequently plots, the replicates were large and so could not be very numerous. To improve the efficiency of the trial, the design adopted was a cubic lattice in duplicate. Twenty-three varieties were planted as whole plots and a further eight as split plots, the split plot varieties being:

IMC 60 × IMC 76 and IMC 60 × T17/524
Acu 85 × IMC 60 and W 41 × IMC 60
D 70 × IMC 60 and U 6 × IMC 60
K 5 × T85/799 and K 5 × T79/501

The spacing was eight feet square. (Glendinning, D. R. (1965), *Commencement of a new cycle of breeding*, 1962–63, *Series III, IV, V and VI. Selection of parents and first plantings: Proposed Technical Bulletin.*)

The trial site was cleared from swollen-shoot infected cocoa just before the experiment was planted so it was sparsely shaded. Furthermore, sandy patches of soil subject to seasonal waterlogging, capsid damage and drought in the latter part of 1966 and early 1967 (*Rep. Cocoa Res. Inst., Ghana*, **1966–67**, 76) and again in 1968 (*Rep. Cocoa Res. Inst., Ghana*, **1968–69**, 102) led to uneven growth and incomplete establishment.

From the foregoing it is clear that D14 is not a satisfactory experiment. However, some of the varieties in the trial and especially the inter-crosses of Amazon parents are of interest as they are of a type which may have field resistance to swollen-shoot disease. All of the information available from the trial has been summarised to permit assessment of the varieties, accepting that any conclusions are tentative.

The trial included a range of parents:

Local Trinitario clones: Acu 85, W41, K5, U6, D70

Inbred local Trinitario clone: E1 : C4/3/291

Amelonado clone: S84

Introduced Trinitario clone: T9/21, a Trinitario of Costa Rican origin which was introduced to Ghana via Trinidad. Cam 12b, a black pod resistant selection from the Cameroon.

Scavina 12 open pollinated: T12/62, T12/116

IMC 53 open pollinated: T17/524

Inter Nanay clones: T61/1313 (Na 33 × Na 32) and T62/977 (Na 33 × Na 34)

Na 32 × Pa 7 (T79/501)

IMC 60 × Na 34 (T85/799)

Introduced Iquitos clone: IMC 76

Introduced Nanay clone: IMC 60 (original identification was probably in error as this clone as more affinities with the Nanay than with the Iquitos population).

Alphabetical B36 is a seedling of T60/974 × T60/1051 and Alphabetical C34 a seedling of T60/974 × T60/1050. T60 itself is Pa 7 × Na 32.

The crosses made are shown in Tables 67 to 71 and were made in one direction only, the data have been entered into each table twice to facilitate comparison between parents. In the tables, no attempt was made at statistical analysis of the data on account of the large number of missing trees, 514 out of 6,804 or 7.55% in 1971. The yield figures (Table 67) are actual yields and were based on whole plots. For the years 1970–73 yields were calculated from the pod values estimated at each harvest but for the 1968–70 period, the dry weights were estimated using the wet weights actually recorded and the means of the conversion ratios obtained in 1970–73. The disease figures (Table 68) include all the pods recorded as diseased even if useable cocoa was obtained from them. The mean girths and single tree coefficients of variation for girth (Tables 69 and 70) were estimated from all the trees surviving until May 1971, except that any less than 10 cm. in circumference were omitted as they were probably replacements.

Table 67

D14. Net annual yields in pounds dry cocoa/acre 1968–73

1. *Crosses from Series IV*

	T9/21	T12/63	T12/116	T17/524	T61/1313	T62/977	IMC 60	IMC 76	E1: C4/3/291	W 41	Acu 85
T9/21				268	324		323	232			
T12/63									257		
T12/116						472					
T17/524	268					385	443	355	321	255	
T61/1313	324							251	219	152	
T62/977			472	385			255			168	
IMC 60	323			443		255		282	272	170	213
IMC 76	232			355	251		282		280	233	
E1:C4/3/291		257		321	219		272	280			
W 41				255	152	168	170	233			
Acu 85							213				

2. *Crosses from Series V*

	T79/501	T85/799	IMC 60	K 5	U 6	Cam 12b	D 70
T79/501				261			
T85/799				277		306	
IMC 60				192	253		83
K 5	261	277	192				
U 6			253				
Cam 12b		306					
D 70			83				

3. *Other crosses*

Alphabetical B36 × S84	290
Alphabetical C34 × S84	141
Selfed Amelonado	42

TABLE 68

D14. Proportion of diseased pods 1968–73

1. *Crosses from Series IV*

	T9/21	T12/63	T12/116	T17/524	T61/1313	T62/977	IMC 60	IMC 76	E1: C4/3/291	W 41	Acu 85
T9/21				14.0	8.4		14.4	13.8			
T12/63									11.2		
T12/116						12.1					
T17/524	14.0					9.0	15.7	7.9	11.3	11.7	
T61/1313	8.4							7.6	7.2	9.7	
T62/977			12.1	9.0			14.3			15.9	
IMC 60	14.4			15.7		14.3		10.4	14.8	13.4	8.0
IMC 76	13.8			7.9	7.6		10.4		10.6	15.6	
E1:C4/3/291		11.2		11.3	7.2		14.8	10.6			
W 41				11.7	9.7	15.9	13.4	15.6			
Acu 85							8.0				

2. *Crosses from Series V*

	T79/501	T85/799	IMC 60	K 5	U 6	Cam 12b	D 70
T79/501				10.2			
T85/799				9.0		8.2	
IMC 60				12.1	12.5		10.2
K 5	10.2	9.0	12.1				
U 6			12.5				
Cam 12b		8.2					
D 70			10.2				

3. *Other crosses*

Alphabetical B36 × S84	7.0
Alphabetical C34 × S84	8.8
Amelonado selfed	7.3

TABLE 69

D14. Mean circumferences in centimetres, May 1971

1. *Crosses from Series IV*

	T9/21	T12/63	T12/116	T17/524	T61/1313	T62/977	IMC 60	IMC 76	E1: C4/3/291	W 41	Acu 85
T9/21				27.9	31.1		31.7	28.6			
T12/63									28.9		
T12/116						30.9					
T17/524	27.9					28.0	30.8	25.9	25.4	28.1	
T61/1313	31.1							29.2	26.6	28.7	
T62/977			30.9	28.0			31.7			28.8	
IMC 60	31.7			30.8		31.7		30.3	28.4	29.9	27.5
IMC 76	28.6			25.9	29.2		30.3		25.4	28.8	
E1:C4/3/291		28.9		25.4	26.6		28.4	25.4			
W 41				28.1	28.7	28.8	29.9	28.8			
Acu 85							27.5				

2. *Crosses from Series V*

	T79/501	T85/799	IMC 60	K 5	U 6	Cam 12b	D 70
T79/501				27.7			
T85/799				27.9		28.6	
IMC 60				29.6	27.6		24.7
K 5	27.7	27.9	29.6				
U 6			27.6				
Cam 12b		28.6					
D 70			24.7				

3. *Other crosses*

Alphabetical B36 × S84	27.4
Alphabetical C34 × S84	28.1
Amelonado selfed	20.4

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Table 70

D14. Coefficients of variation (%) of single tree circumferences, May 1971

1. *Crosses from Series IV*

	T9/21	T12/63	T12/116	T17/524	T61/1313	T62/977	IMC 60	IMC 76	E1: C4/3/291	W 41	Acu 85
T9/21				28.8	23.0		22.9	28.6			
T12/63									18.4		
T12/116						19.1					
T17/524	28.8					20.8	24.8	23.7	22.3	21.2	
T61/1313	23.0							23.7	24.2	28.2	
T62/977			19.1	20.8			21.6			22.4	
IMC 60	22.9			24.8		21.6		23.4	20.3	21.8	32.1
IMC 76	28.6			23.7	23.7		23.4		21.7	21.6	
E1:C4/3/291		18.4		22.3	24.2		20.3	21.7			
W 41				21.2	28.2	22.4	21.8	21.6			
Acu 85							32.1				

2. *Crosses from Series V*

	T79/501	T85/799	IMC 60	K 5	U 6	Cam 12b	D 70
T79/501				28.1			
T85/799				22.9		24.2	
IMC 60				23.3	24.5		37.3
K 5	28.1	22.9	23.3				
U 6			24.5				
Cam 12b		24.2					
D 70			37.3				

3. *Other crosses*

Alphabetical B36 × S84	24.5
Alphabetical C34 × S84	21.1
Amelonado selfed	31.3

Four of the crosses in D14 were also included in another trial, D13, which was planted in 1963. The results from this trial up until March 1971 were discussed by Lockwood in *Rep. Cocoa Res. Inst., Ghana*, **1970–71,** 165. In the two trials results were:

	Yield		Disease	
	D13	D14	D13	D14
T61/1313 × W41	2nd lowest	4th lowest	2nd highest	12th lowest
IMC 60 × W41	5th lowest	5th lowest	Highest	8th highest
Alph. B36 × S84	6th highest	9th highest	2nd lowest	Lowest
Alph. C34 × S84	3rd highest	3rd lowest	Lowest	9th lowest

TABLE 71

*Summary of results from D*14 1968–73 (*Reduced from Tables* 67–70)

	Number of crosses	Mean yield	% diseased	Mean diameter	Coefficient of variation
Selfed Amelonado	1	42	7.3	20.4	31.3
Amazon × Amelonado (Series III)	2	215	7.6	27.8	22.8
Inter Amazon (Series IV)	7	349	11.0	29.5	22.4
Amazon × Trinitario (Series IV)	15	246	12.0	28.4	23.8
Amazon × Trinitario (Series V)	6	229	10.1	27.7	26.7

The comparison between the trials provides an indication of the reliability of the D14 results.

In the trial yields were uniformly low, some of the reasons for this were discussed at the beginning of this report. Low yields are common at all Plant Breeding trials planted at Tafo after 1962 and there is some speculation about this by Edwards in *Rep. Cocoa Res. Inst., Ghana*, **1971–72,** *160.*

The absolute levels of yield and disease losses of the varieties in the trial are not themselves very meaningful as an indicator of how the varieties would perform under farmer's management. A certain level of yield or disease losses would not be repeated on farms but it is believed the better varieties in trials would also be the better ones in farmer's use. There is reason to believe that the ranking the varieties at this age would agree with the ranking when the trial is more mature (Lockwood, in preparation). Because the best varieties in this trial for black pod are known to be comparable to the best Series II varieties, it is likely that most of the inter-Amazon crosses would have black pod losses comparable to the more average Series II varieties. The low levels of black pod in the trial do not mean that all the varieties are acceptable in this respect.

While the trial permits some comparison to be made between the parents, it must be stressed that comparisons are approximate.

Among the Trinitarios, T9/21 was a slightly better parent for yield than

W41 and E1:C4/3/291 but its progeny suffered approximately equal losses from pod diseases. It also seemed to be a better parent for yield than K5, U6 and D70.

T12/116 when crossed to T62/977 gave the highest yield in the trial with about average disease losses. It is unfortunate that other T12/116 crosses were not included so as to provide further comparisons.

The results from T17/524 indicated that it was one of the best parents for yield in the trial. Disease losses on its progeny varied widely and were particularly low when it was crossed to T62/977 and IMC 76.

Progenies of T61/1313 were not high yielding but as a group they were among those with lowest disease losses in the trial. T61/1313 is a Nanay; a population which is generally considered to be poor for disease losses at Tafo.

T62/977 gave variable results, on the whole it did not give particularly good progenies. Those of IMC 60 were comparable to those of the other pure Nanay parents (T61/1313 and T62/977) in yield. Of all the parents in trial, IMC 60 seemed to be the worst for disease losses.

IMC 76 progenies were of average yield and mostly were satisfactory for pod diseases. As this parent is thought to be one of the best sources of swollen-shoot resistance which have been found, the latter result is encouraging.

Block planting trials (J. D. Amponsah)

The planting of hybrids within the block planting scheme of the Cocoa Division of the Ministry of Agriculture (Cocoa Production Unit of C.M.B.) was reported by Edwards (*Rep. Cocoa Res. Inst., Ghana*, **1971–72,** 156). More trials were planted at Nkawkaw, Kibi, Asamankese, Kade, Domi and Effiduase Ashanti last year. The design of the plots remained unchanged.

TABLE 72

Block planting trial (extension), Tinkong
1971 *planting—state of plants at May* 1973

Ranking	Plot no.	Selection	No. of seedlings planted	No. dead	% dead	Seedlings remaining
1.	9	T79/467 × Sca 9	391	94	24.0	297
2.	11	(Pa7 × Amel) × N8/121	195	50	25.6	145
3.	8	T79/467 × Sca 9	139	39	28.1	100
4.	10	T63/967 × IMC76	406	135	33.3	297
5.	1	T79/467 × IMC76	361	159	44.0	202
6.	4	T85/799 × K5/353	361	183	50.7	178
7.	12	T63/967 × Sca 6	360	190	52.8	170
8.	16	Pa 7 × ICS16	247	135	54.7	112
9.	17	Pa 7 × ICS16	246	143	58.8	103
10.	3	T63/967 × Sca 6	361	220	60.9	141
11.	14	(Pa 7 × Amel) × N8/121	247	151	61.1	96
12.	15	(Pa 7 × Amel) × IMC67	247	155	62.8	92
13.	2	(IMC76 × Amel) × Amel	361	233	64.5	128
14.	13	(Pa 7 × Amel) × N8/121	247	160	64.8	87
15.	6	T63/967 × Pa 7	361	253	70.1	108
16.	7	T63/967 × Pa 7	149	117	78.5	32
17.	5	T79/467 × Sca 6	394	387	98.2	7

The establishment and growth of the seedlings at Nankese and Kofi Pare in the earlier plantings were good and bearing has started in some of the types. At Tinkong, Saamang and Adonkwanta, however, the establishment and growth were poor, largely due to poor soil and nurse shade conditions. The Tinkong trials suffered most. Table 72 shows the state of the seedlings in May 1973. The rates of death in the field are largely a reflection of the poor state of the field condition rather than differences among the varieties. Better establishment and growth of any type under the extreme adverse conditions as in plots 5 and 7 will surely be a good test of hardiness, and the types that failed under these conditions are probably unsuitable for planting under adverse or marginal conditions. More hardy seedlings have been planted in the worse sections of the plot at Tinkong. Large numbers of pods were produced for nursing to replace the dead seedlings in all the trial sites.

The effect of the drought on the Adonkwanta trial is shown in Table 73. The cross T85/799 × Amelonado which was planted later than the other was outstanding in establishment and vigour.

BLACK POD RESISTANCE TRIALS

New trials of screened and unscreened seedlings (J. D. Amponsah and A. Asare-Nyako)

The planting at Tafo of a six-acre trial for comparing the field resistance of cocoa seedlings screened for resistance to black pod infection and unscreened seedlings of the same types was reported last year (*Rep. Cocoa Res. Inst., Ghana*, **1971–72,** 154). Two similar trials, one at Pankese in the Eastern Region and the other at Jamasi in Ashanti, have been planted. A third one at Assin Foso in the Central Region could not be planted due to inadequate nurse shade condition.

Growth of seedlings in the Tafo trial, though initially retarded by the drought, has been good since the rains started. The screened and unscreened seedlings have given comparable growth, and the field deaths and diebacks are also comparable although there was a tendency of more deaths occurring in the unscreened seedlings. Table 74 shows the crosses, growth conditions and deaths after one year in the field.

The screened seedlings were those scored resistant using the new gauze house method of screening for black pod resistance (*Trop. Agric. Trin.*, **50,** 143–152).

Obomeng black pod resistance trial (J. D. Amponsah)

The plot serves as an important source of breeding material for the black pod resistance screening programme and other black pod studies. It is the only trial where bearing first generation progenies of some resistant selections can be found. This allows for the field study of these and also for the production and testing of later generations.

The drought, as in other trials at Tafo affected the development of pollinated flowers, and as a result insufficient pods were obtained for the proposed comparison of the resistance of the second generation inbred of selected F1 trees of Y44, the backcross to Y44, and also their crosses to a resistant type. The pollination programme is being repeated.

TABLE 73

Block planting trials, Adonkwanta, planted June 1971
State of seedlings after severe drought

	Parents			No. planted in field	Seedling condition after drought % Deaths	% Dieback	% Maintaining normal growth	Mean girth cm	Mean height cm
1.	T63/971	×	Amel	392	2.0	11.2	86.3	8.6	161.2
2.	*T85/799	×	Amel	392	2.8	6.6	90.6	8.3	162.4
3.	Amel	×	IMC 76	389	2.8	13.1	84.1	7.5	147.5
4.	Series II B			392	4.3	2.0	93.6	6.3	116.9
5.	T85/799	×	Pound 12	392	5.4	16.8	77.8	7.6	141.1
6.	T60/887	×	Amel	392	8.2	15.3	76.5	7.3	138.4
7.	Amel	×	IMC 47*	389	9.3	3.3	87.4	3.2	70.1
8.	Na 33	×	Amel	392	12.0	9.9	78.1	6.6	128.7
9.	*T85/799	×	T90/344	392	16.3	12.0	71.7	7.1	132.8
10.	*T85/799	×	T79/501	391	21.2	33.2	45.5	5.0	91.4
11.	Na 34	×	Amel	392	27.0	18.9	54.1	5.4	98.8
12.	T63/967	×	Amel	392	39.0	25.3	35.7	6.2	108.9
13.	T92/1615	×	Amel	389	40.1	11.1	48.8	5.8	103.6
14.	IMC 76	×	ICS 16*	392	40.3	4.8	54.8	2.7	49.3

*Planted in November 1971.

TABLE 74

Black pod resistance trial Plot T2. Early field performance

	Crosses			No. of seedlings planted in field		No. maintaining normal growth		Die-backs		Deaths and replacements	
				Inoc.	Uninoc.	Inoc.	Uninoc.	Inoc.	Uninoc.	Inoc	Uninoc.
1.	T79/501	×	Y44	50	50	45	42	3	1	2	7
2.	,,	×	P 30	50	50	47	47	0	2	3	1
3.	,,	×	Sca 12	50	50	45	46	4	1	1	3
4.	,,	×	Sca 6	50	50	47	50	1	0	2	0
5.	,,	×	K 5	50	50	48	45	0	2	2	3
6.	,,	×	T85/799	50	50	43	46	2	2	5	2
7.	,,	×	Pound 12	50	50	44	44	2	0	4	6
8.	,,	×	Na 32	50	50	46	44	3	3	1	3
9.	,,	×	GS 29	50	50	47	48	3	2	0	0
10.	,,	×	Sca 9	50	50	48	46	2	1	0	3
11.	,,	×	Lafi 7	50	50	48	49	1	1	1	0
12.	Y 44	×	T79/501	50	50	47	46	3	3	0	1
13.	,,	×	Pa 7/808	50	50	42	41	0	3	8	6
14.	,,	×	GS 29	50	50	41	43	3	2	6	5
15.	,,	×	Na 32	50	50	46	48	3	2	1	0
16.	K 5	×	Sca 6	50	50	47	45	2	1	1	4
17.	,,	×	Y 44	50	50	44	46	3	3	3	1
18.	,,	×	Pa 7/808	50	50	48	47	1	1	1	2
19.	,,	×	P 30	50	50	48	43	1	4	1	3
20.	,,	×	Na 32	50	50	44	46	3	3	3	1
21.	U 6	×	Y 44	50	50	47	44	2	3	1	3
22.	,,	×	K 5	50	50	42	47	5	3	3	2
23.	,,	×	Na 32	50	50	47	45	3	4	0	1
24.	W37/4	selfed		50	50	50	50	0	0	0	0
25.	W20/20	selfed		50	50	46	49	0	1	4	0
26.	Na 32	×	IMC 60	50	50	50	44	0	1	0	5
27.	,,	×	GS 29	50	50	50	47	0	2	0	1
			Grand Total	1,350	1,350	1,247	1,236	50	51	53	63
								3.7%	3.8%	3.9%	4.7%

Inoc.—refers to inoculated and screened.
Uninoc.—refers to uninoculated, unscreened.

Budwood was taken from the selected trees of the first generation inbred of Y44 at the Obomeng trial and propagated at Tafo. The budlings are growing satisfactorily in the nursery and a small plot carved out of an abandoned block of the black pod resistance trial in Plot F4 at Tafo has been prepared for planting in the next rains in June 1973. The selected trees and the number of budlings propagated are shown below:

Clone	No. budded	No. growing
W20/20	20	17
W19/20	20	18
W22/9	20	14
W25/42	20	14
W36/4	20	19
W37/4	20	17
W56/18	20	19

The Series V black pod resistance trial (J. D. Amponsah)

The two frequencies of harvesting, two and four weekly respectively in each half plot of the 18 treatments in the above trial started last year continued (*Rep. Cocoa Res. Inst., Ghana*, **1970–71,** 152). The results of the current year, and the combined results of the two-year period 1971–73 are shown in Table 75. The crosses are arranged in the order of the lowest to the highest losses to black pod in the two weekly harvests in the results of the current year.

The different crosses, as in the previous year, responded to the two frequencies of harvesting differently. About one half of the crosses appear to give lower rates of black pod infection at the two weekly harvest than in the four weekly. The others however, were either unaffected by the time of harvest, that is they gave similar infection rates at each frequency, or showed slightly lower rate at the longer interval of harvest.

As in the previous year D70 × T79/501 continues to give least infection. The cross Y44 × IMC 60, noted previously for low susceptibility, ranked low this year because the most resistant trees in that cross were selected for other breeding purposes, leaving only the susceptible trees. A number of the susceptible trees of D70 × T85/799 were also excluded for similar reasons. The assessments are therefore biased against Y44 × IMC 60 and in favour of D70 × IMC 60. In all, there was slightly higher rate of infection in the plot this year than last year.

BLACK POD RESISTANCE TESTS

Pod testing of "resistant" and "susceptible" trees in Plot F4 (J. D. Amponsah)

The selection for artificial pod inoculation of cocoa trees selected as resistant or susceptible based on natural infection was reported last year. The plan was to test three, four and five month old pods on the "resistant" and "susceptible" trees. Hand pollination were to be used to obtain pods of the same age. The testing could not be carried out as scheduled because most of the selected trees flowered at different periods and could not be pollinated at the same time to obtain pods of the same age. The few trees that flowered together and were hand pollinated lost most of these flowers

TABLE 75

Series V variety trial. Frequency of harvesting and black pod infection

Ranking	Parents	1972–73 Crop Year				Combined 1971–72 and 1972–73 yields			
		Two-weekly harvests		Four-weekly harvests		Two-weekly harvests		Four-weekly harvests	
		Total pods	% B.P.	Total pods	% B.P.	Total pods	% B.P.	Total pods	% B.P.
1.	D 70 × T79/501	550	2.4	516	8.3	860	2.4	851	7.6
2.	Cam 12b × Pa 7	862	6.7	692	10.55	1,595	7.4	1,136	12.1
3.	U 6 × T85/799	592	7.4	718	12.4	1,083	8.0	1,194	11.8
4.	Amelonado A	340	7.7	266	19.6	496	8.5	500	17.6
5.	" B	335	8.1	379	8.7	573	12.0	512	8.4
6.	K 5 × T85/799	437	8.2	455	16.9	725	7.9	857	12.6
7.	S 27 × T85/799	371	8.6	284	14.4	720	8.9	570	14.0
8.	U 6 × T79/501	644	8.7	580	6.0	1,192	7.3	1,155	7.3
9.	U 6 × Pa 7	991	8.9	690	18.0	1,749	8.3	1,057	14.8
10.	D 70 × Pa 7	490	9.0	530	9.4	985	9.2	1,034	8.4
11.	Cam 12b × T85/799	484	10.7	394	8.6	767	11.1	649	9.6
12.	K 5 × T79/501	689	11.3	634	12.0	1,061	9.3	1,211	10.3
13.	K 5 × Pa 7	407	13.5	592	10.5	879	8.7	1,087	8.9
14.	D 70 × T85/799	543	15.2	373	16.1	754	11.8	584	17.3
15.	U 6 × IMC 60	728	15.5	495	14.5	1,452	13.4	1,050	11.9
16.	Y 44 × IMC 60	757	17.6	746	20.8	1,403	16.6	1,450	17.2
17.	D 70 × IMC 60	528	20.3	1,729	18.2	812	16.3	1,130	19.9
18.	K 5 × IMC 60	517	27.7	452	18.8	1,056	22.8	874	18.1
	Grand total	10,175	10.6	19,525	13.6	18,162	10.7	16,901	12.6

due to adverse weather conditions. Table 76 shows the results of trees that had pods for testing as they became available. The reactions to inoculation of the selected trees shown are not directly comparable as inoculations were done at different periods. The infection rates were too low in all the tests, and could not be used to confirm or refute the resistant or susceptible status of the trees. It was evident however that three months old pods were more difficult to infect than older ones.

Black pod resistance screening programme (J. D. Amponsah and A. Asare-Nyako)

Varietal differences in black pod susceptibility

Using the new glass house method for screening cocoa seedlings (*Theobroma cacao* L.) for resistance to black pod infection described by Amponsah and Asare-Nyako (*Trop. Agric. Trin.*, **50**, 143) pre-germinated seeds of the progenies of selected cocoa types were tested. Table 77 shows the results.

In all the crosses resistant and susceptible seedlings occurred, but the proportions of these in the different parents varied. In the sets of crosses shown, higher proportions of resistant seedlings occurred in crosses involving T79/501, Sca 6 and Y44 irrespective of whether they occurred as female or male parents. The three types are well known as resistant types in the field. On the other hand crosses involving Na 32 and N8/131 gave lower proportions of resistant seedlings. The two parents are known to be susceptible in the field. These results agree with earlier results, and confirm the heritability of black pod resistance and susceptibility and also varietal differences in susceptibility.

POLLINATION STUDIES

Natural pollination studies in the Albino Plot (J. D. Amponsah)

The natural pollination studies in the Albino Plot (*Rep. Cocoa Res. Inst., Ghana*, **1969–70**, 146; **1970–71**, 161) were continued. The rates of cross pollinations resulting from pollen outside the 104 ft. × 104 ft. plot area, selfing and crossing resulting from pollen in the plot area only, and mixed pollinations for each month of the year were recorded. The results are shown in Table 78. All the pod categories occurred in all the months in which pods were harvested as in the previous years. As observed last year the highest rate of outcrossing occurred in pods ripening in December. High rates were also recorded in June and in November. The rates of out-crossing category *a* and selfing category *c*, were not associated with the quantity of pods harvested. High and low rates of both categories occurred irrespective of the number of pods harvested, suggesting that the habit of the pollinating insects is probably not dictated by the available number of flowers. Mixed pollinations which also occurred as in the other categories are probably a common occurrence in natural pollination.

Of the 1,395 pods harvested 24.9% were outcrossed, 9.2 mixed pollinations, 60.4% selfing and intercrossing within the plot area and 5.5% unclassified pods. The high percentage of pods resulting from self-pollinations and inter-crossing between the trees in the 104 ft. × 104 ft.

TABLE 76

Artificial pod inoculation of selected trees in F4

Cross	Stand no.	Field reaction	No. inoculated	Age group (in months) of pods inoculated 3	4	5	No. infected 3	4	5
(Y 44 × IMC 60)	F4/114	R	4	—	3	1	—	0	1
,,	F4/896	R	3	—	—	3	—	—	1
,,	F4/336	R	2	—	—	2	—	—	0
	Total		9	—	3	6	—	0	2
,,	F4/54	S	1	—	1	—	—	1	—
,,	F4/642	S	1	—	—	1	—	—	0
,,	F4/832	S	7	3	—	4	0	—	2
,,	F4/894	S	1	—	—	1	—	—	0
,,	F4/1613	S	1	—	—	1	—	—	1
,,	F4/1673	S	1	—	—	1	—	—	0
	Total		12	3	1	8	0	1	3
D 70 × T85/799	F4/90	R	4	3	1	—	0	0	2
,,	F4/771	R	7	—	—	7	—	—	2
,,	F4/897	R	4	—	1	3	—	1	0
,,	F4/1810	R	2	—	—	2	—	—	1
	Total		17	—	4	13	—	1	3
,,	F4/27	S	3	2	—	1	0	—	0
,,	F4/29	S	6	—	6	—	—	1	—
,,	F4/30	S	7	—	4	3	—	0	1
,,	F4/279	S	1	—	—	1	—	—	0
,,	F4/837	S	9	8	—	1	0	—	0
	Total		60	10	18	32	0	3	7

R = Resistant }
S = Susceptible } all based on natural infection.

TABLE 77

Reaction of pre-germinated cocoa seeds to inoculation with P. palmivora
Differential susceptibility to infection by different types of cocoa

Cross	Known field reaction	No. inoculated	No. uninoculated	Percentage emerged after 10 days Inoc.	Percentage emerged after 10 days Cont.	Percentage healthy after 10 weeks Inoc.	Percentage healthy after 10 weeks Cont.	Percentage susceptible	No. of tests
Y 44 × Sca 6	R × R	260	28	65.0	100	56.2	100	43.8	3
,, × T79/501	R × R	256	59	53.5	100	50.4	100	49.6	3
,, Selfed	R	742	176	60.9	92.0	39.1	95.5	59.9	9
,, × GS 29	R × S	400	80	49.0	98.8	36.8	98.8	63.2	4
,, × T85/799	R × Int.	220	60	56.4	100	34.5	100	65.5	3
,, × N8/131	R × S	400	86	44.3	94.2	26.3	88.4	73.7	5
,, × Na 32	R × S	314	57	32.8	98.2	24.5	100	75.5	3
N8/131 × Na 32	S × S	259	49	17.8	95.1	9.6	100	90.4	3
Sca 6 × Y 44	R × R	340	70	77.4	100	68.2	100	31.8	4
,, × T79/501	R × R	360	67	64.2	98.5	52.2	100	47.8	4
,, × GS 29	R × S	300	60	60.3	100	47.7	100	52.3	3
,, × Na 32	R × S	280	59	45.0	100	41.4	100	58.6	3
,, × IMC 60	R × S	340	80	43.2	100	39.4	100	60.6	4
,, × T85/799	R × Int.	200	40	56.5	100	36.5	100	63.5	2
Na 32 × N8/131	S × S	467	104	29.6	94.2	15.8	96.2	84.8	6
U 6 × Sca 6	Int. × R	280	60	34.3	100	42.1	100	57.9	3
,, × T79/501	,, × R	980	160	45.5	99.4	33.3	98.8	66.7	8
,, × Y 44	,, × R	1,540	320	43.8	98.8	31.9	99.4	68.1	15
,, × N8/131	,, × S	1,159	200	44.8	97.0	31.2	95.5	68.8	10
,, × T85/799	,, × Int.	1,398	229	41.7	97.4	27.5	97.8	72.5	12
,, × Na 32	,, × S	977	205	28.9	95.6	20.9	98.0	79.1	11
K 5 × T79/501	Int. × R	340	70	63.8	98.6	61.8	100	38.2	4
,, × Y 44	,, × R	200	26	63.5	84.6	56.0	96.2	44.0	2
,, × Sca 6	,, × R	760	157	55.4	98.7	47.1	100	52.9	8
,, × Amel	,, × Int.	318	68	35.8	98.5	32.1	98.5	67.9	4
,, × Na 32	,, × S	560	140	40.2	92.9	31.1	92.9	68.9	6
,, × T85/799	,, × Int.	300	68	39.3	85.3	27.3	94.1	72.7	4

R = Resistant
S = Susceptible
Int. = Intermediate.

TABLE 78

Rates of outcrossing and selfing in different months of the year in the Albino Plot

Month	Total pods harvested	Pod categories % a	% b	% c	% d
April–May	Nil	—	—	—	—
June	40	35.0	2.5	52.5	10.0
July	70	5.7	7.1	82.9	4.3
August	212	22.6	5.2	72.2	0.0
September	291	12.0	8.2	78.0	1.7
October	377	28.4	11.4	53.1	7.2
November	70	35.7	10.0	51.4	2.9
December	239	36.0	10.5	42.7	10.9
January	96	29.2	13.5	46.9	10.4
February–May	Nil	—	—	—	—
Grand Total	1,395	24.9	9.2	60.4	5.5

a = Pods developed from flower naturally pollinated with pollen from outside the 104 ft. × 104 ft. Albino Plot area.
b = Pods resulting from flowers naturally pollinated with mixed internal and external pollen.
c = Pods resulting from selfing and crossing between trees within the Albino Plot area only.
d = Bad pods that could not be scored for pollination.

plot area (category *c* pods) points to the possible loss in yield that could occur if self and cross-incompatible cocoa are inadvertently grown together, as has occurred in some farms in a South American country (Soria, personal communication).

Rates of flower setting, cherelle wilt and pod maturity in naturally pollinated flowers (J. D. Amponsah)

The observations in natural pollination, flower setting, wilting and pod maturity reported last year were continued (*Rep. Cocoa Res. Inst., Ghana*, **1970–71,** 162). Sixty-eight trees compared with 29 last year were selected for observation. The flower buds on the tree trunk were labelled daily as they opened and were observed for natural pollination, setting and wilting, and also for maturity and harvesting. (Flowers were considered naturally pollinated and set when they remained 10 days after the opening of the bud.) The number of flowers observed for each month starting from April 1972 to March 1973 were noted. Table 79 shows the results. No flowers were available from August to December. The highest number of flowers was recorded in May, but the highest percentage of setting and also of wilting occurred in July as in the previous year. In spite of the high percentage wilting the highest percentage of pod maturity also occurred in July. This month appears to be the most favourable for flower setting and subsequent growth to maturity in the albino plot. Allowing five months for the time of pollination of a flower to maturity and ripening, the higher rates of setting in June and July (Table 79) are probably associated with higher rates of outcrossing as was observed in the pods harvested in November and December in Table 78.

TABLE 79

Rates of flower setting, cherelle wilt and pod maturity in naturally pollinated flowers

Month	No. of flowers labelled	% Setting	% Wilting	% Maturing
April	1,413	9.2	4.6	4.6
May	1,684	11.7	7.5	3.4
June	679	11.5	9.0	2.1
July	190	20.5	14.7	5.8
August	Nil	—	—	—
September	Nil	—	—	—
October	Nil	—	—	—
November	Nil	—	—	—
December	Nil	—	—	—
January	118	5.1	3.4	1.7
February	150	4.7	4.7	0.0
March	780	1.7	0.3	1.4
Grand total	5,014	9.2	5.8	3.2

Number of trees observed = 68.

The lowest rate of flower setting and also wilting occurred in March. This happened in August last year. All flowers that set in February wilted, due probably to adverse weather conditions.

Of the 5,014 flowers labelled in the crop year 9.2% setting and 5.8% wilting were recorded leaving only 3.2% of the flowers to mature into ripening. A similar proportion (3.7%) matured last year.

CYTOGENETICS

(V. A. MARTINSON)

Cytology

T. cacao (diploid)

Meiosis in cocoa was re-examined with particular attention to chromosome behaviour at metaphase I, in order to obtain some insight into the recombination potential. Flower buds were collected from clones of Upper Amazon (T85/799), Criollo (T28) and Amelonado (TF 6) origin. No obvious differences were observed in the chromosome morphology of the three clones. Chromosome configuration at the early stages of meiosis were not clear, but at metaphase I, there were means of 8.6, 8.5 and 8.4 bivalents per cell in T85/799, T28 and TF 6 respectively (Table 80). The univalents were between two and four per cell and were frequently juxtaposed.

T. cacao (established artificial polyploids)

Established polyploids in Plot N6 were studied. The size of flower and pollen were used initially as an indication of polyploidy, but tetraploidy was subsequently established in some stands by means of chromosome counts in mitotic cells. Meiotic metaphase in two selected stands (78 and

150) showed a relatively high frequency of bivalents as in Table 81. Although the mean percentage fertility assessed from aceto-carmine stainability test was between 71.6 and 76.1, germinability on agar was much less (Table 82).

Colchicine-treated interspecific hybrids

Hybrids of *T. cacao* × *T. grandiflora* treated with colchicine grew very slowly. Squashes from young leaves collected from three treated seedlings had only cells with 20 chromosomes. Preparations from leaves from a fourth seedling had some large cells with 40 chromosomes among 20-chromosome cells. Sections are being prepared to study the distribution of these cells.

TABLE 80

Chromosome association in PMC of cocoa (2×)

Selection	No. of PMC	Configuration per cell Univalents	Bivalents	Chiasmata
T85/799	20	2.70	8.65	9.35
TF 6	12	3.17	8.41	9.08
T28	21	3.05	8.48	9.00

TABLE 81

Chromosome association in PMC of artificial (Co) polyploids

Stand no.	No. of PMC	Univalents	Configuration per cell Bivalents	Trivalents	Quadrivalents
78	21	2.19	10.24	2.10	2.76
150	20	2.65	7.00	2.65	3.85

TABLE 82

Pollen fertility in tetraploid (Co) cocoa compared with diploid cocoa

Material	Range of diameter in microns	Stainability Total count	% stained	Germinability Total count	% germinated
Stand 78 (4×)	8–28	4,800	71.6	2,500	64.0
Stand 150 (4×)	12–24	5,760	76.1	3,400	38.9
Amelonado (2×)	16	3,620	97.4	2,500	89.7

Crossing experiments with established tetraploid

The development of auto-tetraploid crops in which seed is required at harvest is not often successful because of reduced fertility. However, Dogget (*Heredity*, **19**, 403–417) showed that fertility could be improved by intercrossing autotetraploids selected both for their chromosome behaviour at meiosis and for their seed set. The established tetraploids in Plot N6 were studied for their value in breeding.

Tetraploid stands with pollen stainability of more than 50% were selfed and inter-crossed. Record was made of percentage fruit set, recovered ripe pods, bean number per pod, and the ploidy of the seedlings raised. It was not possible to trace the diploid parents of the tetraploids used, but the selected stands seemed to be of Upper Amazon origin.

It appeared from the observations that some crosses were more successful in one direction than the other. For example, while the cross of stand 78 × stand 150 resulted in 6% set, the reciprocal cross gave as much as 42% set in pollinations done during the same period. Although the mean number of beans per pod in the crosses between these raw tetraploids was only between 20.5 and 38.5, germination was never below 77% (Table 83).

TABLE 83

Seed set in tetraploid (Co) cocoa

	Ovule no.		Pollinations			Bean no.	
	Ovaries counted	Mean and S.E.	No. of pol-linated flowers	% set	% ripe	Pods counted	Mean and S.E.
Stand 78 (4×)	100	48.71 ± 2.80	199	11.5	5.0	10	24.7 ± 4.90
Stand 150 (4×)	100	41.79 ± 1.81	105	19.1	12.3	13	20.5 ± 5.12
Amelonado (2×)	100	42.00 ± 0.76	110	73.6	51.8	20	38.5 ± 4.30

Chromosome counts made so far showed that all C_1 seedlings satisfactorily raised from crosses between 4× parents were tetraploid.

A total of 216 pollinations on a diploid branch of stand 71, with pollen from the tetraploid stand 78 resulted in only 20% set and 11% ripe pods. Of the 420 beans extracted from the harvested pods only 12 germinated and these were found to be triploids.

Embryology

Seed development in diploid cacao

Seed formation is primarily dependent on successful fertilisation and embryo development. It is established that unpollinated cocoa flowers may remain on the tree for about two days (*Rep. W. Afr. Cacao Res. Inst.*,

1956–57, 64) and that a proportion of these may set fruit (Entwistle, H. M., *Rep. W. Afr. Cocoa Res. Inst.*, **1956–57,** 45). It is also reported that the number of ovules fertilised is limited to the number of pollen applied to the pistil (Cope, F. W., *Heredity*, **17,** 157). The probable effect of the age of the pollen and ovule on the proportion of maturing seed in an ovary was therefore examined.

Observations were made on the three cocoa selections TF 6 (an Amelonado), T79/501 (an Upper Amazon) and U6 (a local Trinitario), from May until August, in 1972. Stainability and germinability tests showed that pollen collected from flowers on the second day of opening had only slightly lower fertility than that collected from freshly open flowers. However in pollinations with a male parent compatible with all three clones, there was a marked difference between the percentage setting from pollinations of freshly-open flowers and those of one-day-old flowers. Results to date indicate that the clone U6 gives better sets from delayed pollinations than the other clones (Table 84). Variation in the number of beans in pods developed from these pollinations is being studied.

TABLE 84

Pollen and ovule viability in freshly open and one-day-old flowers

Clones	Days after* bud opening	Pollen % stainability		Pollen % germinability		% set	
		0	1	0	1	0	1
Amelonado TF 6		97.4	96.0	89.7	89.0	71.1	1.0
Upper Amazon T79/501		98.2	96.5	98.5	87.6	68.4	1.0
Local Trinitario U 6		97.8	96.9	98.1	93.3	79.4	22.5

*Days after bud opening 0 = freshly open flowers.
1 = one-day-old flowers.

PHYSIOLOGY AND BIOCHEMISTRY

BIOCHEMISTRY SECTION

(D. ADOMAKO)

COCOA-PRODUCTS AND BY-PRODUCTS RESEARCH

Cocoa pod husk pectin

The determination of the chemical properties of pectin preparations from cocoa husk was continued. A comparative study of pectins from some other Ghanaian fruits which may be used for commercial pectin manufacture, namely, pawpaw and lemon (peel) has been made. Peeled mature, unripe *Carica papaya* pulp (common Ghanaian variety grown on the Institute premises) and the peel of mature unripe lemon (Crops Research Inst., Bunso) were used. The chemical properties of the various pectins are shown in Table 85.

Yield. The yield of dry pectin from three different cocoa types ranged from 6.0 to 11.8% (Table 85). The value for the T63/967 (Amazon) cocoa husk is in agreement with the published data for Amazon cocoa husks (*Rep. Cocoa Res. Inst., Ghana,* **1970–71**). The yield from pawpaw is comparable to that of Amelonado cocoa husk.

Acetyl content. As shown in a previous report (*Rep. Cocoa Res. Inst., Ghana,* **1971–72**) cocoa pectin resembles sugar beet pectin in its high acetyl content (5.2–5.6%) and is markedly different from pawpaw, lemon and apple pectins (less than 0.5%).

Methoxyl content. Like beet pectin, cocoa husk pectin is of the low-methoxyl type. The values of 5.5 and 2.4% for pawpaw and purified BDH 250-grade apple pectins, respectively, also characterise these preparations as the low-methoxyl types. In contrast, lemon pectin showed a high methoxyl content.

In 1965 the Tropical Products Institute (TPI), London, extracted and analysed pectins from the pod husks of several different cocoa varieties (Criollo, Amelonado and Trinitario) sent from Tafo. The TPI results (unpublished) showed high methoxyl contents (7.9–10.1%) for the pectin preparations. The discrepancy between those results and the present ones may be attributed to failure to correct for the presence of acetyl groups in cocoa pod husk pectin (see *Rep. Cocoa Res. Inst., Ghana,* **1971–72**). It is noteworthy that the uncorrected methoxyl contents (Table 85) fall within the range of the TPI values quoted above.

Degree of esterification. The 60–76% degree of esterification characterises cocoa pod husk pectin as a slow-set type. The values reported by TPI for the pectins from the cocoa types described above ranged from 46 to 62%, the majority being 54–56%. The corresponding anhydrouronic acid (AUA) contents calculated in the usual manner (R. L. Whistler, ed.,

TABLE 85

Methoxyl, acetyl, and AUA contents of cocoa, pawpaw and lemon pectins

Source	Yield (% dry wt)	Protein N*	Ash*	Anhydrouronic acid‡	O-acetyl content†	O-methoxyl content†	Degree of (methyl) esterification
Cocoa husk:							
T90/3 × Amelonado	6.0	0.9	14.2	36.2	5.2	4.9 (8.7)	76.3
Amelonado	9.0	1.0	14.2	33.2	5.4	4.1 (8.0)	70.5
T63/967 (Amazon)	11.8	0.7	11.4	34.5	5.6	3.6 (7.6)	60.0
Pawpaw	6.9	0.3	10.1	68.5	0.5	5.5 (5.8)	45.6
Lemon	10.1	0.4	3.6	71.0	0.2	10.3 (10.3)	82.9
Purified apple pectin‡	—	0.2	0.0	65.5	0.0	2.4	20.8

*As % (w/w) dry pectin.
†As % (w/w) dry pectin on moisture and ash free basis.
The O-methoxyl contents are corrected for the presence of O-acetyl groups; the figures in brackets are the uncorrected values.
‡Purified from B.D.H. 250-grade apple pectin.

Methods in carbohydrate chemistry, **5**, 189) range from 95.5–99.5%. Apart from being above the theoretical values, the crude nature of the pectin preparations (prepared as alcohol insoluble solids) makes such high AUA values unlikely.

General quality. The jelly-forming ability of a pectin preparation is influenced by many factors, e.g. molecular weight, and degree of polymerisation; the chemical properties described here give little direct information on the suitability of the preparations for jelly making. The presence of acetyl groups is believed not to affect jelly formation adversely. As a follow-up to the present findings the jelly grades of various cocoa pod husk pectin preparations will be determined.

The peel of lemons is generally considered as an excellent source of commercial pectin. The degree of esterification and methoxyl content of the sample described here suggests that this variety would be a suitable source material for the preparation of conventional pectin-acid-sugar jellies.

Utilisation of cocoa pulp juice

One of the possible commercial outlets for cocoa pulp juice (a waste product during cocoa fermentation) is wine manufacture. The possibility of utilising the juice for this purpose is being studied. There are inherent problems to be overcome in this field, e.g. the collection of large quantities of the fresh juice under the present system of cocoa processing in Ghana. The juice is mucilaginous and viscous. With the special perforated-bottom cylindrical vessel available at the Institute it takes about 24 hours to collect about 4.5 litres of juice when the cylinder is packed to capacity with 100 lbs. fresh cocoa beans. As practically all the cocoa in Ghana is fermented by the heap method it is impossible to collect on a large scale fresh juice oozing from the heaped beans. It is worth mentioning that sugars are progressively broken down from the start of fermentation and the juice that runs out of the fermented heap about 36 hrs. after the start of fermentation consists of a mixture of alcohols and organic acids, and is therefore useless for the present purpose.

Carbohydrate composition of 'fresh' pulp juice. The free neutral sugars in the juice collected over a period of 24 hr. consisted mainly of glucose, fructose and sucrose, with trace amounts of two unidentified pentoses. The sucrose content was variable, being present in trace amounts in most of the batches of pulp juice. This may be attributed to microbial activity. The total fermentable free sugar content (as glucose) ranged from 9.0–10.0% for two samples of Amazon cocoa pulp juice and 11% for that of another cocoa variety (T63).

Conditions of fermentation. The natural pH of the juice varied between 4.3 and 4.7. Commercial sucrose was added to 10% where necessary. The juice was sterilised by boiling for 15 minutes and allowed to cool before being seeded with yeast. Commercial baker's yeast was used initially but this was replaced by brewer's yeast. Yeast was added at 6.25 gm/litre. Fermentation was carried out in three-litre plastic bottles. Fermentation periods of up to three weeks have so far been tried.

Clarification with pectinase. The presence of mucilage in the juice makes it viscous and cloudy. The cloudiness and viscosity persist even after fermentation. Treatment with pectinase for 5–6 hr. at room temperature and removal of precipitated material by low speed centrifugation prior to fermentation gave much clearer products. In addition, this treatment improved the taste of the final product by removing some bitter principles. It is expected also that it will prevent contamination with methanol usually formed by the action of yeast pectin (methyl-) esterase on pectic substances.

The final products will be subjected to chemical analysis.

Chemical curing (or non-microbial fermentation) of cocoa

A new technique involving vacuum-infiltration of fresh beans for 2 hr. with solutions containing pectinase, amino acids and salts, short-curing the pulp-free beans at 45–50°C for different periods of time at about 100% humidity, followed by sun-drying for three days and finally at 60°C for 24 hr. is being studied. The method is essentially as described by A. Purr and A. Helfenberger (*Gordian*, **71**, 298–306).

The technique has several advantages over the traditional method of curing (fermenting) cocoa beans for the market, e.g.

(1) Good quality dry beans can be prepared in 4 to 5 days.

(2) The waste products, such as pulp juice can be harnessed for large-scale manufacture of by-products.

Table 86 gives some experimental details and the grading of several batches of cocoa beans (mixed variety) processed as described above. Commercial assessment was by Mr. M. B. Adigun of the Institute's fermentary. As shown in Table 86, most of the products obtained meet the requirements for Grade I commercial cocoa, except that the very well cured beans tend to have brittle shells. Experiments are being made to determine the optimum conditions for the production of good quality cocoa beans.

Short-curing at 44–46° for 48 hr. gave the best quality beans. Such beans usually showed external moulding but the final drying at 60° seemed to destroy the mould. Short-curing at 50° for shorter periods will be adopted in future experiments. The best products will be tested for their suitability for chocolate manufacture.

CRIG-IAEA research contract on methyl bromide residues in fumigated cocoa

In Ghana, methyl bromide (at a dosage of 24 oz./1,000 cu. ft.) is used for large-scale fumigation of stored cocoa beans prior to export. The purpose of this IAEA Research Contract is to determine the nutritional and toxicological significance of methyl bromide residues in cocoa beans fumigated under conditions similar to the large-scale application in Ghana. The practical details were summarised in *Rep. Cocoa Res. Inst., Ghana*, **1971–72.**

The amounts of free volatile and bound methyl bromide persisting in the nibs, shells and whole cocoa beans aired over a period of 10 weeks are shown in Table 87. The results may be summarised as follows:

(1) The methyl bromide residues declined during the period of aeration to about 60% of the levels found after 1st day of aeration; total methyl bromide residues fell to about 7 and 12 ppm respectively in roasted and unroasted nibs after 10 weeks aeration.

TABLE 86

Assessment of cocoa beans prepared by vacuum infiltration with chemicals and "short-cured" at 44°C

Period of fermentation	Colour assessment			Commercial grading					
	BR (%)	PP (%)	DP (%)	SL (%)	Mould	Weevil	Germ	Flat	Grade
(A) pH of infiltration solution, 4.0									
24 hr.	35	65	Nil	Nil	Nil	Nil	Nil	Nil	I
36 hr.	35	65	"	"	"	"	"	"	I
48 hr.	90	10	"	"	"	"	"	"	I
(B) pH of infiltration solution, 5.3									
24 hr.	40	60	"	"	"	"	"	"	I
36 hr.	60	40	"	"	"	"	"	"	I
48 hr.	95	5	"	"	"	"	"	"	I

Infiltration solution: 2 litres of 0.2M sodium acetate solution containing 0.15% glycine, 0.05% asparagine, 0.1% glutamic acid, and 0.1% pectinase adjusted to pH 4 or 5.3. Vacuum-infiltrated beans were short cured at 44°C at 90–95% R.H. and samples withdrawn after 24, 36 and 48 hr. Beans from 10 pods were processed in each of experiments A and B. BR—brown; PP—pale purple; DP—deep purple; SL—slate; Germ—germinated.

TABLE 87

Volatile (Toluene-soluble) and Bound CH_3Br residues in unroasted cocoa beans, and in the nibs and shells of roasted and unroasted beans (ppm as CH_3Br)

Fractions/Samples	Storage/aeration time (days) 1	44	51	76	126
	(a) Whole beans or nibs				
Volatile (toluene-soluble) CH_3Br residues:					
Whole beans, UR	1.3	1.2	1.2	0.9	—
Nibs, UR	1.1	0.8	0.6	0.5	—
Nibs, R	2.9	3.0	3.0	2.7	—
Bound CH_3Br residues:					
Whole beans, UR	59.3	—	40.8	36.3	37.0
Nibs, UR	24.1	—	12.6	11.2	6.8
Nibs, R	6.7	—	6.1	4.6	3.7
Total (volatile + bound) CH_3Br residues:					
Whole beans, UR	60.6	—	42.0	37.2	—
Nibs, UR	25.2	—	13.2	11.7	—
Nibs, R	9.6	—	9.1	7.3	—
	(b) Shells				
Volatile (toluene-soluble) CH_3Br residues:					
UR	3.6	2.1	2.1	0.7	—
R	6.0	4.6	5.6	3.3	—
Bound CH_3Br residues:					
UR	357.0	—	293.5	220.0	199.0
R	305.0	—	278.5	192.0	140.0
Total (volatile + bound) CH_3Br residues:					
UR	360.6	—	295.6	220.7	—
R	311.0	—	284.1	195.3	—

The figures are mean values for duplicate samples analysed.
The shells in (b) belong to the corresponding nibs analysed in (a).
UR, unroasted; R, roasted.

(2) With the exception of roasted nibs residual methyl bromide occurs mainly in the bound form. In unroasted beans the shells contain 0.7–1.1% of the total residue in the free volatile form, whilst in the corresponding nibs about 3.9% of the residues occur in the free form.

(3) Bound methyl bromide concentration is 45 and 20 times higher in the shells than in the nibs of roasted and unroasted beans respectively.

(4) A striking effect of roasting is the occurrence in roasted nibs of about 30% of the CH_3Br residues mostly in the free form. Free CH_3Br forms 30–59% of the total residual methyl bromide in the roasted nibs, compared to the value of 16.5–27% in the unroasted nibs. Free CH_3Br concentration is higher in roasted than in unroasted shells whilst the bound CH_3Br concentration is higher in unroasted shells than in roasted shells.

The evidence suggests that during roasting bound methyl bromide is converted into free methyl bromide. It is possible that the residues occur mostly as adsorbed undecomposed methyl bromide some of which is desorbed during roasting. Methyl bromide is soluble in fats and oils and this property probably retards the rate of desorption. More recent work has shown that most of the free methyl bromide in the toluene extracts can be removed together with toluene by vacuum distillation at 80°C leaving relatively little ^{14}C activity in the lipid fraction. As the measurements are based on ^{14}C activity it is possible that the residues occur in the form of simple volatile ^{14}C-labelled methylated compounds instead of free undecomposed CH_3Br. Further experiments are being done to resolve these possibilities.

VIRUS RESEARCH

Purification of cocoa necrosis virus (CNV) from cocoa leaves (D. Adomako and G. K. Owusu)

Preliminary work on this was reported in the *Rep. Cocoa Res. Inst., Ghana*, **1971–72**. An improved isolation procedure which gives good recovery of virus and highly infective preparations has now been worked out. The preparation of crude virus extracts and precipitation of virus with polyethylene glycol were as described previously (*Rep. Cocoa Res. Inst., Ghana*, **1971–72**). PEG-precipitated virus was purified by differential centrifugation. Clarification of crude extracts by incubation with 0.2% (w/v) pectinase at 25° for 20 hr. prior to precipitation with PEG gave cleaner preparations (after one or two cycles of differential centrifugation) than preparations made without the pectinase treatment. Without this treatment usually 3 to 4 cycles of differential centrifugation were required, with some mucilage still persisting in the preparations. The incubation with pectinase appeared to cause some loss of infective virus; but the loss was compensated for by effective removal of inhibitors, which enhanced infectivity. The effective removal of mucilage by incubation with pectinase also made possible further purification of the virus by gel filtration.

As with sephadex gel filtration (*Rep. Cocoa Res. Inst., Ghana*, **1971–72**) filtration of virus through 4% agarose (Sepharose 4B) enhanced the infectivity of CNV when the source material consisted largely of leaves at the less advanced stage of necrosis. The infectivity of one such preparation was increased about 10-fold, with 100% infection at a dilution of 10^{-4}. This effect is attributed to removal of inhibitors.

Preparations made by the above procedure, when examined by the electron microscope, contained numerous isometric particles, 25–28 nm diameter, often seen in aggregates (Figs. 24 and 25). The preparations were examined in the Korle Bu Medical School HU-11E-1 Electron microscope by Mr. A. J. K. Gbewonwo.

Isolation of Cocoa Swollen Shoot Virus (CSSV) by polyethylene glycol precipitation and Celite 545 column chromatography (D. Adomako)

A modification of the procedure described previously by D. Adomako and G. K. Owusu (*Rep. Cocoa Res. Inst., Ghana*, **1971–72**) for purifying cocoa necrosis virus has been applied to the isolation of CSSV from cocoa leaves. Crude virus preparations were made essentially as described above. Virus was precipitated with 6% PEG in the presence of 0.4M NaCl and successively eluted with decreasing concentrations of PEG solutions containing 0.2M NaCl, 5mM β-mercaptoethanol and 5mM EDTA (pH 6.5).

CSSV was found to differ from CNV as follows:

1. Precipitation with PEG-NaCl instead of PEG alone did not cause loss of infectivity as observed with CNV.
2. CSSV was eluted mainly in the 5% and 3% PEG fractions whilst CNV was eluted in the 1% and 0% PEG fractions.
3. Unlike CNV, where chromatography on Celite caused loss of infectivity, about 6-fold purification was achieved by the chromatography of CSSV preparations on Celite.

This isolation procedure gives clear virus preparations, and will be useful for the preparation of purified virus suspensions for serological work.

Carbohydrate metabolism in healthy and CSSV-infected cocoa plants (D. Adomako and W. V. Hutcheon)

It was reported (*Rep. Cocoa Res. Inst., Ghana*, **1971–72**) that carbohydrates accumulate in the leaves and stems of CSSV-infected cocoa plants. As this could result from defective translocation to the root system, radio-tracer experiments were carried out to determine the efficiency of translocation of photosynthates to the roots. ^{14}C activity per unit leaf area was higher in roots of infected plants than in those of healthy plants. This indicates that translocation may be even more efficient in infected than in healthy plants. Leaf chorosis in infected plants was estimated, on the average, to cover about 60% of the leaf area. In spite of this, the infected plants, on leaf area basis, had a greater amount of photosynthates than the healthy plants (Table 88). This is supported by the fact that infected plants show a higher diurnal turnover of carbohydrates in their leaves than healthy plants (*Rep. Cocoa Res. Inst., Ghana*, **1971–72**). It has been established also that infected plants have a higher rate of respiration than healthy plants, labelled photosynthates being catabolised at a faster rate in infected than in healthy plants. The following conclusions may be made from the above results:

1. Photosynthesis appears to be stimulated in infected plants, particularly in the healthy parts of the leaves.
2. A greater proportion of photosynthates is presumably not available for the synthesis of host cellular material but enter into other metabolic routes, e.g. virus synthesis, host defence reactions. Also, synthesis of host RNA and protein may be inhibited by the virus infection.
3. The above factors may be considered to be responsible for the stunted growth of infected plants.
4. It is generally known that a direct relationship exists between translocation efficiency and photosynthetic efficiency (see *Plant Physiol.*, **52**, 412–415). The apparent higher rate of translocation in infected plants may be partly responsible for the observed stimulation of photosynthesis in infected plants.

Similar effects have been reported for other host-virus systems (*Virology*, **27**, 243–252; **48**, 255–258 and **55**, 426–438). It is believed that the high

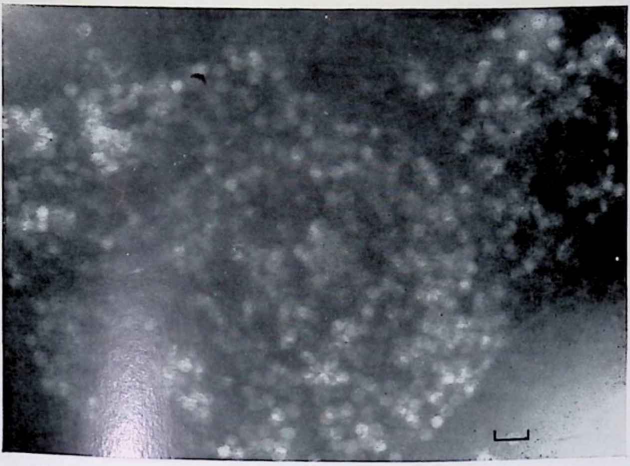

Fig. 24. Electron micrograph showing a large aggregate of CNV particles. The preparation was made (from 20.6 gm infected leaves) by clarification of sap with pectinase and 2 cycles of differential centrifugation. The bar represents 100 nm.

Fig. 25. CNV particles in a less dense area of the same preparation as Fig. 24. Arrow shows one of the few small particles (11–12 nm diameter) found in this preparation.

TABLE 88

^{14}C activities in 80% ethanol fractions of the tap roots of 10-month-old healthy and infected plants 24 h after feeding $^{14}CO_2$

Parameter	Plants fed $^{14}CO_2$ for 2½ hr.				Plants fed $^{14}CO_2$ for 1 hr.			
	Healthy		Infected		Healthy		Infected	
	1	2	3	4	5	6	7	8
Total activity in root:								
10^{-3} cpm/cm² leaf area	1.0	1.2	3.0	2.9	0.8	0.7	2.3	1.5
10^{-3} cpm/g dry wt.	880	1,295	1,420	1,135	518	570	458	345
10^{-3} cpm/g dry wt. × cm² leaf area	0.2	0.3	1.0	0.9	0.2	0.2	0.6	0.4
% ^{14}C activity due to free sugars	33.4	44	24.4	8.4	43	53	51	23.2

% ^{14}C activity due to soluble sugars = activity (cpm/g dry wt.) in the free (80% ethanol soluble) sugar fractions expressed as % of the total ^{14}C concentration (cpm/g dry wt.). Parameters involving activity/cm² leaf are based on the total leaf areas for each plant. No corrections have been made for leaf chorosis in infected plants.

turnover of carbohydrates in infected tissues is associated with high rate of photosynthesis.

Details of this work will be reported in *Physiologia Plantarum*, **30.** Work on photosynthesis in healthy and CSSV-infected cocoa is being pursued.

Studies on the mechanical transmission of CSSV (D. Adomako and G. K. Owusu)

The inability to infect pre-germinated cocoa beans or seedlings mechanically with CSSV (*Rep. Cocoa Res. Inst., Ghana*, **1967–68** and **1971–72**) was investigated further using the mealybug inoculation method, i.e. infecting pre-germinated beans with viruliferous mealybugs. With 10 mealybugs per bean 96–100% infections were got with beans germinated for three to seven days, and with control ungerminated beans. It seems unlikely from this that the difficulty experienced with the manual inoculation method is due to a build-up of virus inhibitors in germinated beans. The difficulty may be due to morphological and physiological changes which accompany the process of germination and render the cells unsuitable for establishment and proliferation of virus. Details of this work together with a study of the kinetics of symptom development in cocoa seedlings inoculated mechanically with CSSV at the bean stage will be reported in *Ghana Jnl. Agric. Sci.*, **7.**

Free amino acid levels in healthy and CSSV-infected Amelonado cocoa plants (D. Adomako)

Whole stems of nine six-month-old healthy and nine CSSV (1A)-infected plants of the same age were extracted individually and analysed for free nitrogenous compounds. The infected plants (inoculated with virus as beans) and the healthy plants were raised in sand-nutrient culture.

The stems were extracted with 80% ethanol and the alcohol evaporated at 45° under reduced pressure. The residues were made up to 20–25 ml with water and filtered. Aliquots were analysed for protein N by the micro-Kjeldhal method.

On dry weight basis, the protein N contents of extracts of healthy and infected stems, respectively, were 1.3% (SE = $\pm$ 0.17) and 1.08% (SEE = $\pm$ 0.13). Variance ratio test (P = 0.05) showed that the difference between the values for healthy and infected plants was not significant.

PHYSIOLOGY SECTION

(W. V. Hutcheon)

General aspects of the physiology programme

Much research has been done on the physiology of cocoa over the past four decades but there has been little attempt to integrate the various pieces of information into a complete picture showing how the tree functions and outlining the processes which are important in determining the yielding capacity. One of the main objectives is thus to build up an overall picture of the physiology of the tree, showing the main processes and the internal and external factors which affect these processes. This information is basic to any scientific attempt to increase yield, whether by breeding, improved agronomy, or management. Further uses of this kind of information would be in assessing the suitability of new areas for cocoa planting, and in predicting the behaviour and yielding capacity of existing field cocoa. Looking much further ahead, it should be possible to build a quantitative model (simulator) which would enable us to predict the performance and behaviour of cocoa given details of the weather/environmental conditions. This could be regarded as being the ultimate goal of physiological research, for to be able to model growth and development we need to understand on a quantitative basis every important process in the tree. While recognising that it will not be possible to build a quantitative physiological model for many years or even decades, we believe that working in this general direction is a very useful approach to the study of the physiology of cocoa; it encourages the investigator to look at the tree as a whole and to view the processes in relation to each other. It also highlights the gaps in our knowledge.

As a starting point we may construct a simple qualitative model, showing the way in which dry matter is produced, lost by respiration and assimilated into new plant tissue. The approximate flow of dry matter in a 15-year-old Amelonado tree over an annual cycle is shown in Fig. 26. Some parts (particularly the respiratory losses) are estimates based on published data for other trees. The important processes which contribute to yield are shown together with the main external and internal factors which appear to affect them. A picture of this type makes it easy to see where the "losses" occur and points to ways by which the efficiency of the tree could be improved.

Over the next few years it is hoped that many of the relationships shown in the diagram can be put on a quantitative basis. It is clear that water status affects almost every important process—photosynthetic rate, translocation, many aspects of metabolism including respiration, flower production, setting, cherelle wilt, all aspects of growth, leaf production and retention etc. Considerable emphasis has thus been placed on the study of plant water relations in the current year. Plans are also being made for a detailed study of photosynthesis and carbohydrate metabolism in the near future. Data on the most important aspects of reproductive and vegetative growth continue to be taken on a routine basis to aid our understanding of the factors which affect flower production, flushing, cherelle wilt, cambial growth etc. Particular emphasis is being given to the factors affecting leaf production, expansion and retention for it is clear that the leaf area is a vital, if it is not the most important, factor determining the productivity and yielding capacity of cocoa.

THE WATER RELATIONS OF COCOA

The components of total water potential (Ψw)

The use of the pressure chamber for the measurement of xylem sap tension was described previously. With most species the xylem sap tension is nearly equal to the total water potential. It has not been possible to check this for cocoa with a thermocouple psychrometer, but sap tensions of non-transpiring plants growing in nutrient culture with known osmotic potential (using PEG 4000 as the osmotic substrate) are close to expected values. Henceforth, tension measurements will be called water potentials.

Water potential has come to be the most widely accepted criterion of plant moisture stress and is particularly relevant to the study of water movement through the soil/plant/atmosphere system, as water moves along a water potential gradient. While some physiological processes appear to be related to water potential, others are more closely related to some component of water potential. Growth processes involving cell enlargement are controlled by the turgor pressure potential while metabolic processes occurring in the cytoplasm appear to be related to the osmotic potential. Before we can generalise about the role of water in plant growth and development, it is necessary to examine the individual components of water potential

The state of water in plant tissue in equilibrium is described in terms of the following equation:

$$-\Psi_W = +\Psi_p - \Psi_s - \Psi_m - \Psi_g$$

where the subscripts p, s, m and g refer to the effects of pressure (turgor), solutes (osmotic), matrix and gravity respectively, the sign showing the normal condition of each potential relative to that of free water.

Gravitational potential

This is of little importance in a tree the size of cocoa. Theoretically there should be a difference of about 0.7 bars between the top and bottom of a 7 m tall tree, and measurements made on suitable trees in the early morning show this to be approximately the case. The gravitational component in a normal canopy is therefore negligible and will be discounted in future discussion.

Matric potential

The water potential of soil is normally made up largely of matric potential and to a much lesser extent of the solute component, which is significant only in a saline or very dry soil. Plant tissue also has large areas of surface which could give rise to a matric potential. The matric potential of cocoa leaves was therefore measured with the pressure chamber. The theory behind the method is discussed by Boyer (*Plant Physiol.*, **42**, 213) though later workers have questioned exactly what the technique measures. Tissue is frozen and slowly thawed and the balancing pressure is determined in the same way as for a fresh shoot. By collecting and weighing expressed sap, the balancing pressure (matric potential) at various water contents can be measured. Balancing pressure is not so easy to assess as with fresh tissue as there is more bubbling and the liquid tends to appear several seconds after a pressure had been set. However, it was clearly very low within the range of water contents encountered in the field—less than −1.0 bars down to c60% water content and usually in the −0.3 to 0.5 bar range. We can therefore assume that the matric potential of cocoa leaves is also negligible and that the water potential consists almost entirely of osmotic and pressure components.

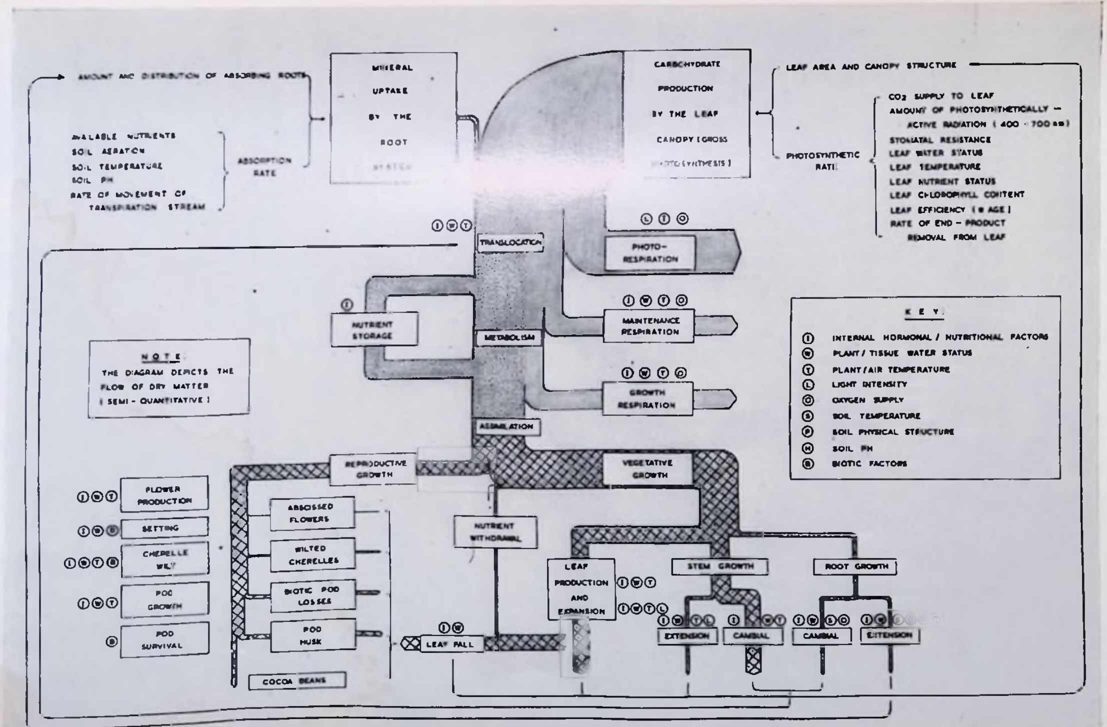

Fig. 26 The main physiological processes determining the yield of cocoa.

Osmotic potential, turgor pressure potential

The use of the pressure chamber to determine the osmotic potential of a leaf or shoot is described in Scholander's original paper and the technique has subsequently been used on a number of species. After determining the initial sap tension the pressure is raised by a further 5–10 bars and held for 1–2 minutes to express the sap—which is carefully collected and weighed to 1 mg. or better. The preferred capsules for sap collection are cylinders of tin foil 60 mm long and 5 mm diameter lined with a cylinder of filter paper to absorb the sap as it is pushed out. One end is closed from the start and the other is folded tight immediately after the sap has been collected to prevent loss before weighing. The pressure is then lowered and the new balancing pressure determined. This procedure is repeated about five times to give a set of seven balancing pressures and a weight of sap for the last six. The aim is to get the last six balancing pressures spaced at 4 bar intervals in the 15–35 bar range.

The reciprocal of sap tension is then plotted against cumulative sap collected to give a curve (Fig. 27) which falls rapidly initially as turgor is lost and then becomes linear when turgor is zero. When there is no turgor the osmotic pressure of the leaf sap is balanced by the pressure in the bomb. The linear part of the curve is then extrapolated back to 100% water content to give the original osmotic potential. The difference between the osmotic potential and the water potential gives the turgor pressure potential. Usually the last three to four points form a fairly straight line to give a good assessment of the osmotic potential. Though each osmotic potential determination takes about 30 minutes, the technique appears to be quite satisfactory.

Variation in the osmotic potential

From the measurements taken over the past eight months the following trends are evident.

Most values of osmotic potential of cocoa fall in the range −16 to −24 bars with a high proportion between −18 and −21 bars. For seedlings growing in the greenhouse there seems to be little diurnal change in osmotic potential. Leaves sampled every 30 minutes from 7.00 hrs. to 17.00 hrs. had a range of about 1 bar, being −19.2 bars in the early morning and falling to −20.2 bars at mid-day. This fall is due to a combination of solute concentration by dehydration and of sugar production by photosynthesis during the sunny part of the day. As conditions were not conducive to high photosynthetic rates, these values may not be typical of field cocoa. The mid-day fall in osmotic potential for unshaded field cocoa is expected to be considerably greater and will be reported at a later date.

No consistent difference in osmotic potential between different leaf ages has yet been shown. When a cocoa plant is subjected to water stress the old basal leaves wilt first. It was thought possible that this might be due to the older leaves having a higher osmotic potential and therefore losing turgor at higher water potentials than younger leaves. Whilst most results so far have been in this direction, the difference seems to be small.

The osmotic potentials of healthy and CSSV infected leaves have been

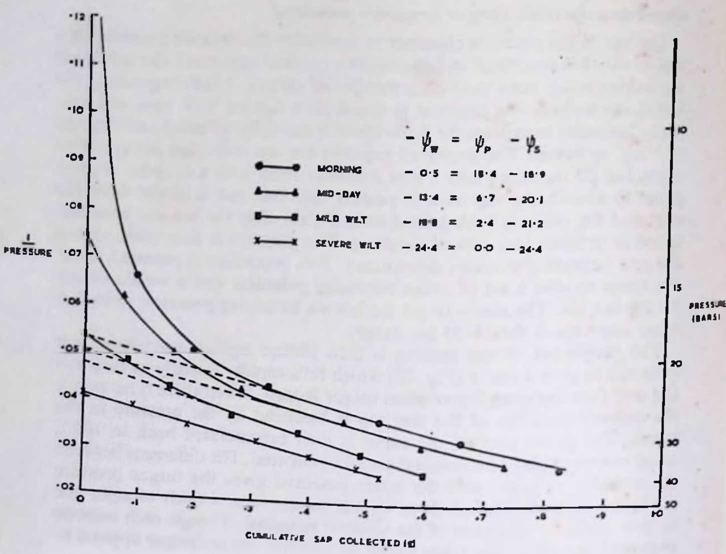

Fig. 27. Determination of osmotic potential.

compared on several occasions. In every case the virus infected leaves have had a lower osmotic potential than healthy leaves, the differences being 0.5 to 4 bars. This fits in well with another study in which the utilisation of carbohydrate was shown to be reduced by virus infection resulting in carbohydrate accumulation in the leaf. As some of the substances which accumulate would have osmotic activity, it is no surprise that virus infection lowers the osmotic potential. Virus infected plants have been observed to be more resistant to drought than corresponding healthy seedlings. It would be interesting to find out if this is attributable to the lower osmotic potential or if it is simply due to the smaller size of infected plants.

A comparison of the osmotic potentials of plants under various major nutrient regimes gave somewhat inconclusive results though it appeared that the osmotic potential of leaves receiving the high nutrient level was lower than those receiving one-tenth or one-quarter of the normal concentration.

It is clear that plants gradually exposed to moisture stress lower their osmotic potential. This is not due to the concentration of solutes by dehydration but seems to involve a build-up of osmotically active substances in the leaf. Perhaps it is the result of a greater reduction in assimilation of new tissue than in photosynthesis and nutrient uptake by water stress. Mature trees subjected to artificial drought (polythene sheets to exclude rain water) lowered their osmotic potential from −20 to −24 bars over six months. Several other trees and seedlings with a history of periodic drought have been found with osmotic potentials in the region of −24 bars.

There is no doubt that the osmotic potential of field cocoa varies seasonally but measurements have not yet been done over a sufficiently long period to show the pattern. The osmotic potential fell during the last dry season as growth slowed down. The osmotic potential is expected to rise after flushing at the end of the dry season. Thereafter it will presumably vary according to how photosynthesis, nutrient uptake, utilisation of nutrients for growth, organic transformations etc. bring about changes in the amount of osmotically active substances in the leaf. Routine measurements are in progress to establish the seasonal pattern.

Much attention will be given to the osmotic and pressure components of the total water potential in future for consideration of water potential alone leads to a highly incomplete picture.

The relationship between water potential and relative water content

Relative Water Content (RWC) is not so easy to determine as water potential but because the pressure chamber is not particularly mobile, RWC is a more convenient technique where a number of trees some distance from each other have to be measured at about the same time. However, unless there is a close relationship between RWC and water potential, RWC measurements are of limited use. RWC and water potential were therefore determined on a uniform batch of young plants over a drying cycle. For RWC determination six discs each of 25 mm diameter were punched from the leaf lamina and floated on distilled water for three hours in an illuminated incubator.

When over 100 pairs of values were plotted it was clear that there was not a particularly close association between the two. A general trend, however, was apparent and the following corresponding values of water potential (in bars) and RWC (%) can be given as an approximation: −1, 94.0; −4, 93.4; −8, 91.7; −12, 90.0; −16, 87.4; −20, 82.9; −24, 76.2. RWC is therefore not a sensitive indicator of water stress in the range normally encountered in the field, for a small fall in RWC corresponds to a substantial fall in water potential. RWC is a much more sensitive indicator of stress at water potentials below −16 bars and over this part of the curve, the relationship appears to be much closer.

The scatter of points at high values of RWC appeared to be due, in part, to a difference in the relationship when there was diurnal water stress compared with general drying out. The RWC corresponding to a temporary day-time water potential of say −10 bars seems to be higher than that corresponding to −10 bars under conditions of dry soil. Even allowing for this, however, there is still much unexplained variability.

Differences in the relationship appear to exist for different types of tissue—e.g. thick field leaves compared with thin greenhouse leaves. Unless most of the variability can be accounted for and removed, RWC does not seem to be a convenient way of obtaining data on water potential. It is possible, of course, that RWC may be a useful criterion of water stress which correlates well with plant response. However, it is unlikely to be a better criterion than water potential and its components.

Changes in the water potential of seedlings during a drying cycle

Nine-month-old seedlings in sand culture were well watered and allowed to dry out over a three week period. Water potential was determined at appropriate times as frequently as the number of leaves on the plants would allow. The diurnal pattern of internal water stress at various stages in the drying cycle is shown in Fig. 28.

When the soil or sand is wet (high water potential) the overnight plant water potential is nearly always higher than −0.6 bars. (The value 1–2 bars mentioned in the previous report was the tension at 7.00 hrs. and not the true minimum tension.) During the day the fall in water potential depends on the difference between the rate of water uptake and water loss. During bright sunshine, the water potential falls to −12 bars or lower and no known way of increasing the supply can overcome this. However, when the supply of water to the roots is good, absorption can catch up very quickly and reduce the level of stress in a very short time; hence during the passing of a cloud water potential can rise from −13 bars to −4 bars in a matter of minutes. Under these conditions, water potential changes as fast as transpiration rate. In the late afternoon, recovery is rapid and water potential reaches the baseline very soon after sunset.

As the soil dries and its water potential falls so does the baseline of plant water potential (e.g. day 6 in Fig. 28). The reduced rate of water absorption also leads to a faster build-up of stress in the early morning, much slower recovery during a cloudy period, slower recovery in the afternoon and a gradual equilibration with the soil water potential during the night. Night-time stress is therefore increased, and day-time stress is more prolonged, more severe, and more sustained.

As the soil dries out further these changes become more pronounced. Eventually the level of stress is reached during the day which induces stomatal closure. The stomata of the seedlings used closed at a water potential of about −15 bars, a value that was quite constant from plant to plant. During the early stages of drying (e.g. days 8–10) the stomata closed for a short time about mid-day. As the soil dried further, the critical level of water stress was reached earlier in the morning and stomata were closed for the greater part of the day. During the middle part of the drying cycle the minimum water potential therefore tended to stabilise at about −15 bars. As the soil water potential fell to about −5 bars the stomata were open for only a short time during the early morning. By the time the basal water potential had fallen to −14 bars stomatal closure was permanent or very nearly so. There was some evidence that previous exposure to water stress increases the sensitivity of stomata—i.e. lower levels of stress induce stomatal closure at the end of

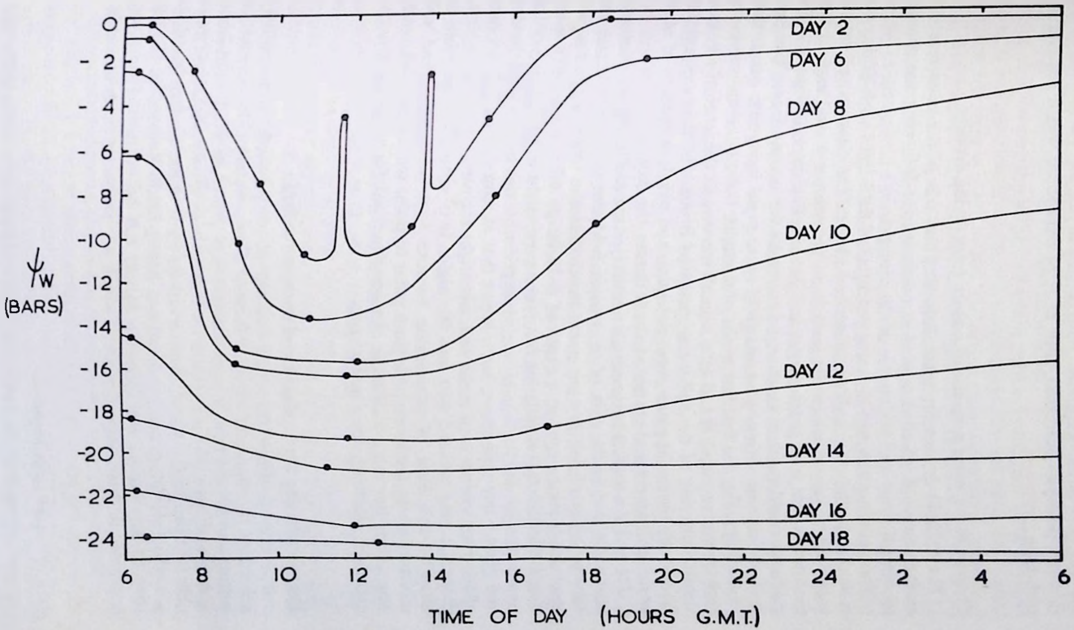

Fig. 28. Changes in plant water stress as soil dries out

the cycle than at the beginning. With further drying out the diurnal change in water potential decreased until at -24 bars there was a gradual fall with time.

Changes in the water potential of mature trees during drought

The 1972–73 dry season in the Tafo area was one of the most severe of recent years and afforded a good opportunity for following the changes in internal stress over the course of the drought.

The pattern of change in water potential of field trees with drying out is similar to that for seedlings described above. The changes, of course, occur over a very much longer period, as the volume of soil explored by the root system is so much larger and deeper. The days in Figure 28 for seedlings could perhaps be changed to weeks for mature trees. The final part of the cycle seems to be relatively more rapid in mature cocoa than in seedlings. For the first few weeks of drought, there is no change in the early morning potential and only a small increase in the level of day-time stress. Lowering of the soil water potential brings about corresponding falls in the overnight plant water potential, and the development of more prolonged, severe and sustained stress during the day.

The soil in a bucket containing a relatively large seedling dries relatively uniformly, but in the case of the mature field tree this is not so, as the surface layers of soil dry out much faster than the lower horizons. Soil moisture tensionmeters at a depth of 6–12 in. go off the scale (0.8 bars) long before the tree is suffering from severe overnight stress. Drying of the upper layer of soil leads to slower absorption by the tree during the day and greater day time stress, but it seems that as long as a significant part of the root system is in moist soil, overnight recovery can be complete, though it may proceed well into the night. It is virtually impossible to quantify this kind of relationship because root penetration and soil moisture status are so variable from point to point within the root zone. The effect, however, is that the changes described for a seedling occur extremely gradually for a mature tree.

Factors affecting the development of stress in the field

The rate at which the cycle outlined above proceeds varies widely according to plant and external factors. From watering to permanent wilting can be less than a week for seedlings grown in small containers and can be more than six months for mature trees growing under favourable field conditions. Based on observations made in the Eastern (particularly the Tafo-Bunsu area), Ashanti and Brong-Ahafo Regions during the 1972–73 dry season, the following factors can be mentioned as being important in determining the rate at which internal water stress develops.

Rate of water consumption

It scarcely needs to be stated that the rate of build-up of stress is strongly related to the evapo-transpiration rate. Severe harmattan conditions can bring about a change in plant water status in a few days which would take place over a few weeks in dull humid weather.

Less obvious and the subject of much debate in the past is the effect of shade. It is a question of whether the competition for soil moisture exerted by the shade trees is more or less important than the reduced water consumption by the cocoa which the overhead shade brings about. Over the early part of the cycle (i.e. until the maximum daily water potential of the cocoa just starts to fall below the baseline) there is no doubt that shade improves the day-time water status of the cocoa by 5 bars or so. Shade can be beneficial or harmful to the progress of the cycle depending on soil factors and on the characteristics of the shade tree root system.

In general, overhead shade slowed down the development of stress and shaded trees had a better canopy than the exposed cocoa. This was observed on a number of occasions and on some the difference was quite convincing. Provided the soil is fairly deep, it seems that the reduced transpiration caused by the shade trees more than compensates for the water they consume. This would be especially true if the shade tree exploits a deeper part of the soil horizon than the cocoa.

On two occasions only was the reverse situation noticed. By the end of the dry season the cocoa round the base of the shade tree was near permanent wilting (minimum tension c16 bars) while surrounding cocoa was just starting to develop overnight stress (1–2 bars). In both situations, the soil was shallow because of underlying rock and the shade tree provided little protection because of its height and isolation. There was therefore virtually no compensation for the competition for soil moisture. In both cases the tree was *Triplochiton* which is well known to be competitive with cocoa.

Moisture supply

Both plant and soil factors affect the supply of water to the plant and strongly affect the rate at which internal stress develops. The age of the tree over the first 5–10 years is obviously important, stress generally building up faster in young than in well established trees. There is evidence, however, that 2–3 year old trees are more susceptible to drought than seedlings in their first year. Presumably this would be related to variation in the root/leaf ratio. At Tafo, four-year-old trees reached 1.5 bars overnight tension about four weeks earlier than mature trees growing in the surrounding plots. Such effects are almost certainly attributable to differences in the volume and depth of soil being exploited by the root system, which in turn are related to the size of the trees. Information is needed on the changes in root/leaf ratio and in root distribution with ageing for a better understanding of these relationships.

In mature field cocoa, there was clear evidence of an association between tree size and the rate at which stress developed. Late in the dry season the larger trees in an Amelonado plot at Bunsu had an early morning tension very close to the 0.5 bar baseline while most of the trees had a minimum tension in the 1–5 bar range. The larger trees were still flowering but the trees under stress were not. It was particularly noticeable that the trees round the edge of the plot were larger, had lower tensions and were in much better condition than the interior trees. These perimeter trees would be expected to have a relatively large root system because of the extra photosynthesis possible from the additional light they receive and foliage they develop. The very large female-sterile trees were also slow to develop internal stress. It should be emphasised that these relationships were apparent under conditions of fairly deep soil. Where the volume of soil is restricted (e.g. by underlying rock or a high water table) it seems likely that large trees would deplete the available water relatively fast.

The depth and water-retaining properties of the soil are the other important factors affecting the development of stress. Within an area as small as 50 m square, there is enormous variability in the rate of build-up of stress, due to differences in the depth or water retaining properties of the soil. One patch of cocoa can be near permanent wilting while trees several meters away are still able to recover full turgidity at night. The root system can be shallow either because of shallow soil or because of a high water table during the wet part of the year. Hence trees in valley bottoms often develop stress rapidly during a dry spell, as do trees on rocky outcrops. Some patches of stressed cocoa on the Institute appeared to be associated with sandy soil. The Amazon shade and fertiliser trial (K2–O1) is on a fairly heavy clay soil and the trees have not yet suffered much stress, the minimum tension still being less than 1 bar. Under favourable soil conditions cocoa can come through a 4–5 month drought without developing significant internal stress.

From the great variability in water stress apparent in trees only a few meters apart, it is clear that the study of water relations of cocoa has to be focused on the tree itself rather than on rainfall, evaporation, soil moisture, etc. which are removed to a greater or lesser extent from the plant moisture status. Relating plant moisture status to soil moisture deficit (S.M.D.) is a formidable task because account must be taken of factors such as soil texture, soil depth, root penetration, etc. most of which are extremely difficult to describe quantitatively. For most purposes, the S.M.D. and similar approaches seem to have little to recommend them when the required information can be obtained by a simple direct measurement.

Xylem sap tensions developed during the 1972–73 dry season

In this section we may summarise the main conclusions drawn from well over 2,000 xylem sap tension measurements made at all times of the day in various plots at Tafo and Bunsu, during January–March, 1973.

The highest "living" tensions (i.e. tension in trees which still look fairly healthy and are able to recover) were found in four-year-old trees in Plot G7 at Tafo. Tensions built up progressively in these trees till maximum tensions on 8th March, 1973 were 22–25 bars for many of the trees. By this time the soil was quite dry and there were severe Harmattan conditions in the afternoon. Early morning tensions in the most severely affected trees were 10–13 bars; this rose to 23 bars by mid-day and by mid-afternoon had reached 25 bars. By 8.00 p.m. this had fallen to 18–19 bars and by early morning had returned to 12–13 bars. The trees least affected by the drought had a minimum tension of 4–5 bars and a maximum tension of 17–18 bars. These trees reached their maximum level of stress by 1.00 p.m. and overnight recovery was much faster.

Even the worst affected trees in this plot were not showing particularly severe visual symptoms of stress. At 25 bars there was fairly severe wilting but turgidity recovered fairly well overnight. Even the stomata were open till about 10.00 a.m. when about 20 bars of stress had built up. Stomatal closure occurred at about 20 bars—an unusually high value. It is probable that the osmotic potential of these trees was very low as neither stomatal closure nor wilting occurred till very high levels of stress had built up. After several measurements had been made, it was possible to predict the tension in trees from their state of turgidity—severe wilting indicated over 22 bars, mild wilt about 20 bars and unwilted less than 18 bars.

The 14-year-old trees in K2–O1 provided a contrast. Even in mid-March tensions were low—only slightly higher than those expected under wet soil conditions. Few tensions in excess of 16 bars were recorded even under the most severe Harmattan conditions, and in most cases 13–15 bars were the maximum. The minimum tension had scarcely left the baseline. It was particularly noticeable that stomata closed at low stress levels in these trees—11–13 bars. Many trees maintained open stomata throughout the dry season. Most continued flowering and there will be some mid-crop. The very good condition of these trees appeared to be due to the heavy clay soil in which they were rooted.

Trees in Plot N7 closed their stomata at even lower tensions—sometimes 11–12 bars. Tensions found in these trees were much lower than would be expected from the appearance of the trees. Possibly the osmotic potential of the trees was high and even mild stress had adverse effects on turgidity and leaf retention.

An Amelonado plot at Bunsu provided some interesting figures. On 8th February, 1973 it was found that the tension could be accurately predicted from the appearance of the trees. Trees with a sparse canopy (one flush remaining) had a minimum tension of 4–5 bars. Trees with an average canopy had a tension of about 3 bars and trees with a good canopy 1.5–2.0 bars. Very few of the trees were flowering but any one that was had a minimum tension of well under 1 bar. Trees which were flowering usually were bearing a few young cherelles which would give some mid-crop. It was mainly perimeter and large trees which were flowering and fruiting. Maximum tensions in these trees were 14–16 bars and most of the badly affected trees had closed stomata by late morning.

Trees in the large seed garden at Bunsu came through the drought extremely well. Tensions were little higher than normal and the trees continued flowering and maintained a good canopy. Even the stomata were usually open. The only effect of the drought was to cause a high proportion (over 80%) of pollinated flowers to wilter off in the first few days.

Trees with a shallow root system due either to shallow soil or a high water table, suffered severe stress early in the season. A low-lying plot in the Asiakwa Block of D1–U1 was killed out by the end of January. Trees on rocky outcrops in the seed garden suffered the same fate. These trees were in a very serious state at levels of stress which were considered to be fairly mild. Some trees were permanently wilted and dying off at tensions as low as 14 bars. The reason for 14 bars being lethal to these trees while having little adverse effect on the G7 trees is not clear—it may involve osmotic potential or possibly the speed at which stress develops.

Seed garden trees with a heavy crop of pods were particularly badly affected by the drought. They had tensions about 3 bars higher than nearby uncropped trees and had a rather sparse canopy. The explanation of this is not clear but may involve root growth or a difference in osmotic potential.

Evidence of differences in the drought resistance of different genotypes was continually being searched for but with little success. The only convincing example was a plot at Bunsu labelled as Owuram. These trees maintained a very good canopy and flowered and set some cherelles during the height of the drought. Though the plot was well shaded it appeared to be a varietal difference, for Amelonado trees on two sides were suffering fairly severe defoliation. A plot of male trees in the same block also maintained lower tensions than the surrounding trees.

For a given set of trees it is possible to predict tension from visual appearance. However, it is clear that trees in different plots may have different tensions at a particular stage of deterioration. The probable significance of osmotic potential in explaining these differences was not realised at the time so measurements of osmotic potential will be taken in future.

The effect of water stress on physiological processes

Some progress has been made in defining the effect of stress on various growth and developmental processes. The following estimates are based on limited data and will need checking under a wider range of conditions.

Stomatal closure generally occurs in seedlings when the tension reaches 14–16 bars. Stomatal closure of field trees seems to be much more variable but again 15 bars seems average. Towards the end of the dry season the stomata of some trees in G7 did not close till tensions of nearly 20 bars had been reached, while stomata of mature trees in K2–O1 sometimes were closed at stress levels as low as 12–13 bars. It is probable that stomata close at a definite value of turgor pressure potential rather than water potential—perhaps when there are 4–5 bars of turgor left. Future studies will therefore take account of the turgor pressure potential.

Leaf fall is one of the first visible signs of water stress but it has not been possible to define precisely the level of stress needed to induce it. Yellowing of the basal leaves occurred about a week after overnight recovery of tension slowed down and day time tension reached 15–16 bars. It is not clear whether exposure to a short period of severe stress above some critical threshold level (e.g. during a very severe Harmattan afternoon) is the stimulus, or whether leaf fall results from a more gradual accumulation of some abscission-inducing agent in the plant as a result of more gradual exposure to stress. Leaf fall during the later stages of drought appears to be the result of accumulated rather than critical stress. The relationship is not simple, for susceptibility to abscission increases with leaf age. Only the very oldest leaves (third flush and older) fall in the first peak during a drought. As stress increases, progressively younger leaves absciss until only the youngest flush remains at permanent wilting. Usually the youngest group of leaves (the last flush) wither rather than absciss even when stress develops gradually. Seedlings which develop stress rapidly usually do not drop their basal leaves until they are re-watered. It appears, then, that abscission is an active process which also depends on internal stress being below a certain level.

Visible wilting is first apparent when there are only 2–3 bars of turgor left—i.e. tension is normally 16–18 bars. Wilting thus occurs only at mid-day over the early part of the cycle and then becomes permanent as the soil water potential approaches −16 bars. When tension exceeds 20 bars wilting is very severe. Again there will probably be a closer relationship between wilting and turgor pressure potential for the same trees which maintained open stomata till nearly 20 bars of tension had built up also maintained turgidity till very high levels of stress had developed.

Flowering seems to become sparse fairly soon after the maximum potential falls below the −0.5 bar baseline. Trees with a minimum tension in stress of 1.5 bars are almost always out of flower. After release from stress, many floriferous trees produce an abundance of flowers ("crazy flowering") in the following 3–4 weeks. It is not clear if the flower buds simply accumulate during the period of inhibition or whether water stress promotes flower bud initiation. The latter, however, appears to be the case.

Setting appears to be very sensitive to water stress and is greatly reduced by tensions which are not inhibitory for flowering. During the 1972–73 dry season, the majority of seed garden trees continued flowering but hand pollinations made on these trees met with low levels of success. The pollinated flowers often wiltered off within five days—usually in the first two days. This is being called failure to set though it could also be regarded as being very early cherelle wilt. It is possible that the high temperatures or low humidities associated with the Harmattan are unfavourable for setting but the little evidence available at present points at water stress as being the influential factor.

Cherelle wilt is clearly induced by water stress but it has not yet been possible to define the relationship precisely. However, it is clear that it is much less sensitive to stress than flowering and setting. Cherelles seemed to be able to survive at minimum daily tensions as high as 3–4 bars.

Flushing is inhibited by water stress though the critical level, if it exists, has yet to be established. It appears to be low—of the same order as the tension inhibiting flowering. Thus during the dry season flowering and flushing often occur simultaneously as both are inhibited by stress and stimulated by release from stress.

Expansion of leaves and growth of pods is clearly strongly dependent on turgor but the exact relationship has yet to be established. Leaves and pods expanding during drought are much reduced in size. Though there were a number of flushes during the 1972–73 dry season, the leaves produced were small and the leaf area remained low.

The control of water potential with an osmotic substrate

The ability to control the level of plant water stress would aid the study of water relations considerably, especially in drawing up relationships between water stress and processes such as growth etc. The most effective way of controlling the plant water potential is to regulate the water potential of the rooting medium by lowering the osmotic potential. Polyethylene glycol (PEG 4000) was therefore tested on cocoa seedlings growing in aerated nutrient culture.

In the range of 0–12 bars there was good agreement between the osmotic potential of the nutrient solution and the plant water potential under non-transpiring conditions over the first few days. During the second week, however, the tension had increased and there were signs of absorption of the chemical. Leaves developed a dark coloration and showed characteristic patterns of damaged and normal tissue. While PEG 4000 may well be useful for short-term experiments (up to 7–10 days) absorption and toxicity apparently rule it out for long term studies.

Amelonado irrigation trial at Bunsu

Due to the severity of the 1972–73 dry season, there was a marked response to irrigation. From January 1973 onwards, the unirrigated trees suffered from fairly severe stress though two rainstorms during the dry season each gave relief for about a week. The minimum overnight tension in many of these trees reached 4–5 bars by the end of a dry spell though the maximum tensions seemed to be controlled effectively by stomatal closure and few values in excess of 17 bars were recorded. The canopy became quite sparse as a result of stress-induced leaf fall and many of the worst affected trees had little more than the youngest flush remaining by the end of the drought. The levels of internal stress were sufficiently severe to inhibit flowering for much of the early part of 1973 though there were bursts of flowering after each heavy shower of rain. There was virtually no trunk growth from early February onwards.

Both under-the-canopy and overhead sprinkler irrigation were effective in maintaining minimum daily tensions well below 1 bar. The trees receiving overhead irrigation have had a rather thin canopy almost from the beginning but there were no signs of excessive leaf fall during the dry season and the canopy remained in approximately the same condition throughout. Maximum tensions in these trees were considerable (13–15 bars) in spite of wetting of the foliage four times during the sunny part of the day. Stress builds up rapidly with drying of the foliage and frequent watering would be necessary to remove stress completely. Flowering occurred throughout the season and was especially heavy during the normal dry season. There was a period of reduced flowering during the cool period August–October, but flowers were available in considerable amounts throughout the year. Trunk growth continued through the dry season but at a much reduced rate compared with May–June.

Trees receiving under-the-canopy irrigation to maintain the soil moisture tension in the top 30 cm below 10 cm. Hg did not develop overnight stress and remained in very good condition throughout the dry season. The canopy was well developed and flowering was heavy throughout the dry season. Trunk growth continued but again at reduced rates compared with May–June.

It is clear that 20-year-old Amelonado trees can be induced to flower throughout the year provided the inhibiting effects of competition from pods and water stress are removed. The cause of reduced trunk growth on irrigated trees during November–March is not yet clear. From the evidence available to date it seems that under-the-canopy is preferable to overhead irrigation. The earlier expectations that removal of stress by mist or frequent sprinkling might improve performance have not been fulfilled. Moss growth on the trunks also seems to be a problem with the overhead application and on trees with pods there would be the black pod problem. Provided the soil water potential is maintained at high levels (above -0.5 bars) it seems that the level of stress which inhibits flowering and setting, and induces leaf fall will not normally build up.

Future studies on the irrigation of cocoa will therefore be concerned with testing whether soil watering is really effective in maintaining internal plant stress below the levels which adversely affect growth and development, even under severe Harmattan conditions. The application of these findings would clearly be in the irrigation of seed gardens in the drier areas of the cocoa region. The Bunsu trial will continue in its present state and the numerical results will be given in a subsequent report.

Stem contraction as an indicator of moisture stress

A basic understanding of water movement and the development of stress comes only through a study of the changes in water potential and its components. However, an indicator of moisture stress (which might be calibrated against water potential) more amenable to measurement on a routine basis would be very useful for following seasonal changes in water status, and for showing when irrigation was necessary. Further studies have therefore been made on stem contractions and their relation to water potential. Stem contraction is not the only physical indicator of water stress but it is probably easiest to use routinely.

The diurnal change in stem diameter is almost entirely due to contraction and expansion of the phloem. This was shown by comparing the change in diameter of the whole stem with that of the xylem core using a micrometer-screw gauge (removal of two discs of bark gives access to the xylem core). As tension develops in the conducting xylem a water potential gradient is established between the xylem and phloem which results in withdrawal of water from the phloem. The resulting loss in turgor causes contraction of the phloem. As water movement into and out of the phloem is a very slow process, there is always a lag of a few hours between a change in xylem tension and phloem turgor. Xylem tension starts to build up by 7.30 in the morning but the stem usually shows little contraction till 9.00–10.00 a.m. In the afternoon, the xylem tension of well watered plants is at or near its minimum by sunset but stem expansion proceeds well into the evening. Tensions are near their maximum at mid-day but stem contraction proceeds till about 3.00 p.m.

The change in diameter of a 2-year old tree as the soil dries out is shown in Fig. 29 along with the corresponding daily maximum and minimum

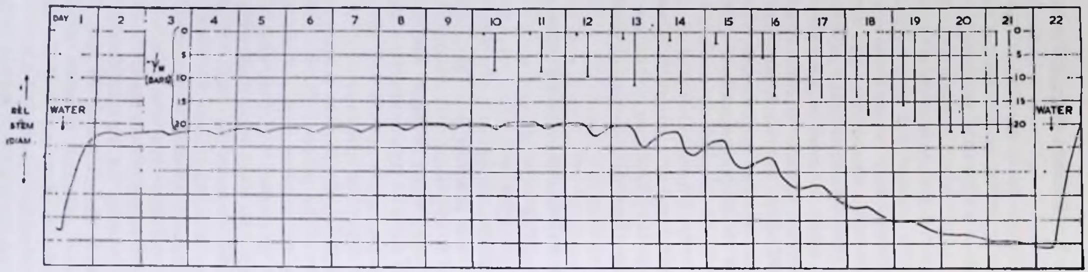

Fig. 29. The changes in stem diameter and water potential over a drying cycle.

water potentials. The polystyrene block device described in *Rep. Cocoa Res. Inst., Ghana,* **1970–71** was used to monitor the changes in stem diameter. This technique is found to be quite satisfactory under greenhouse conditions, though it is necessary to make a small correction for temperature as a small part of expansion during the hottest part of the day is caused by temperature effects on the block. When the soil is wet (days 2–5 in Fig. 29) day-time contraction is minimal and recovery takes place fairly quickly in the early evening. With drying of the soil in part of the root zone, water uptake becomes slower resulting in larger day-time contractions and slower but still complete overnight recovery (days 6–10). In the early morning of day 12, however, recovery of turgidity is incomplete and the water potential also falls below the −0.4 bar baseline. Further drying of the soil over days 13–16 results in larger day-time contractions and a progressive reduction in the overall diameter. Over this period, maximum water potential falls from about −2 bars to −6 bars. There is little overnight recovery on days 17 and 18 in the case of either diameter or water potential. By day 20 there is virtually no diurnal change because of severe wilting and stomatal closure. Watering on day 22 induced a rapid recovery in both diameter and water potential.

Hence stem contraction may well be useful in following, on a semi-quantitative basis, the seasonal changes in stress of selected trees in the field. The measurement has the advantages of being insensitive to fluctuations in evaporation rate and of giving an integrated value for the whole tree. Xylem sap tension often changes rapidly during the day and varies from point to point in the same tree, and is therefore not so suitable a basis for following seasonal changes. Information on stem contraction merely supplements and in no way replaces measurements of water potential.

The polystyrene block is not particularly suited for use in field conditions as it is easily upset by wind and heavy rain. A measuring device suitable for field use therefore needs to be developed. At present the type of dendrometer used extensively by Daubenmire for following cambial activity seems most promising for spot measurements. Day-time contractions can readily be detected with this instrument even when the soil is wet. Progress with these studies will be reported when more data are available.

THE ESTABLISHMENT ABILITY OF DIFFERENT PROGENIES

"Establishment ability" is regarded as being the ability of young plants to survive and grow well even under adverse field conditions. Exposure and soil moisture stress are the two main causes of poor early growth and seedling mortality. Though they often occur together in the field, tolerance of exposure and drought resistance are two distinct characteristics physiologically and are being treated as such in the tests being conducted. A degree of general early vigour is also clearly necessary for good establishment ability.

Reaction to exposure

The early results of tests conducted on seedlings in large polybags were mentioned in the previous report. While it is easy to see if plants can tolerate exposure at an early age it is not so easy to express the results numerically. Plants were harvested, measured and weighed at the age of 11 months—after being exposed for eight months—and linear and second-power quadratic curves of plant measurement against light intensity (% full daylight) were fitted for each cross. As the data are being prepared for publication in detail, only total dry weight will be considered here; other measurements follow a similar pattern.

The turning point of the quadratic curve, the 95% confidence limits attached to it, and the goodness-of-fit are given in Table 89. With many varieties the quadratic curve fitted well and the turning point was estimated with fair precision. As the actual points are usually not distributed symmetrically about the turning point (they fall off more steeply at high light intensity) the turning point given is usually an underestimate of the true optimal light intensity and the confidence limits are wider than they should be. The figures should therefore be taken as being comparative rather than absolute. As stated previously the Scavinas (especially Sca 6) and the Nanays (especially Na 33) came out on top with the two types of Amelonado right at the bottom. The ranking of the varieties by this method is similar to that obtained by visual assessment.

As a check on how the results of this test compare with field establishment, 15 of the varieties were planted in a small field trial in Plot H16. This was planted in June 1971, the design being four randomised blocks each split for shade and no shade with seedlings planted in 20-tree plots at 4 ft. × 2 ft. Growth of the exposed plants over the first year is also given in Table 89 and the ratio of the size of the exposed plants to that of the shaded plants. Because the shade plots had to be small, all plants received some protection and the two treatments could more correctly be designated shaded and having side protection.

The general ranking given in Table 89 is a weighted average of the four individual ratings. It can be seen that the rankings for tolerance of exposure in the polybag test, growth in exposed field conditions and the ratio of exposed to shaded in the field agree fairly well. The best eight progenies come out top or nearly so in all three rankings. Vigour of the plants grown under 50% of full sunlight in polybags did not agree with the other rankings though differences in vigour were small, with the exception of the extremes—Na 33 × Sca 6 and the two types of Amelonado.

It therefore appears that under the conditions of these tests, the polybag method gives an acceptable assessment of the field establishment ability in semi-exposed conditions. The 1971–72 dry season was rather mild and survival was very good. It remains to be seen if Scavina and Nanay crosses establish well under drought conditions. At Tinkong and some other block plantings where there was severe drought early in 1973, crosses expected to establish well suffered heavy losses. The study of establishment ability is therefore being extended to include drought resistance as this is at least as important as the ability of seedlings to withstand exposure.

The testing of varieties for their reaction to exposure is being continued in a modified form which will allow a greater throughput of progenies. Instead of growing plants under a wide range of light intensities, only two—exposed and well shaded—are to be used. A large batch of

Table 89

The reaction of different varieties to exposure

Variety	General ranking	Response to light—polybag test: % variance accounted for	turning point (% sunlight)	95% confidence limits		Ranking	Vigour under shade—polybag test: D.W (g)	Ranking	Growth under exposed field conditions: diam (cm)	Ranking	Exposed/Shaded Ratio	in field Ranking
Na 33 × Sca 6	1	52.2	47.5	42.5	51.3	5	1,100	1	2.27	1	1.09	3
T12/25 × Sca 6	2	No turning point—linear only				1	514	16	2.27	2	1.05	6
A 36 × Sca 6	3	No turning point—linear only				2	539	9	1.96	4	1.08	4
Na 32 × TF 20	4	18.6	57.9	50.1	69.9	3	524	13				
T63/971 × TF 20	5	48.8	43.3	35.3	48.4	8	561	5	1.96	5	1.21	1
Na 31 × Na 32	6	45.6	45.7	38.9	50.4	6	552	7	1.89	6	1.12	2
Na 33 × Pound 12	7	9.6	49.5	26.1	61.2	4	405	22	2.08	3	1.06	5
Pa 7 × Pa 35	8	85.4	39.5	35.8	42.4	12	702	2				
T16/613 × IMC 76	9	59.0	41.2	33.7	46.0	9	527	11				
T86/982 × T86/1599	10	57.1	44.7	39.1	48.7	7	554	6	1.79	8	1.04	8
Na 31 × IMC 60	11	64.1	40.3	33.2	44.9	10	445	18				
Pa 7 × TF 20	12	76.3	38.3	32.3	42.4	15	641	3	1.76	10	0.96	12
T12/113 × Sca 9	13	57.6	39.1	29.5	44.7	13	519	14	1.87	7	1.05	7
T79/501 × T85/799	14	56.3	37.8	26.3	44.0	17	547	8				
ICS 98 × UF 650	15	81.7	37.9	33.2	41.4	16	429	20				
ICS 60 × ICS 45	16	80.9	39.7	35.3	43.0	11	634	4	1.37	13	0.80	15
T85/799 × S 84	17	77.8	33.6	25.3	38.9	20	521	15				
T16/613 × S 84	18	86.4	37.4	33.0	40.7	18	536	10	1.73	11	0.97	11
TF 20 × IMC 76	19	54.8	33.1	14.8	41.2	22	525	12				
T86/896 × Pa 7	20	79.6	38.5	33.3	42.2	14	340	23	1.69	12	1.04	9
T17/1130 × IMC 76	21	52.2	34.3	16.4	42.3	19	434	19	1.79	9	0.96	13
T12/149 × T12/25	22	45.2	33.5	8.1	42.7	21	498	17	1.37	14	1.03	10
D 26 × Pa 35	23	75.4	33.0	23.3	38.8	23	421	21				
TF 6 selfed	24	88.1	10.7	−13.6	22.7	24	318	25	1.24	15	0.91	14
Amelonado (WAA)	25	85.4	2.1	−43.2	19.1	25	326	24				

Amelonado crosses was planned for testing in the coming year but the effects of drought on the parent trees reduced the number of crosses to about 70.

Drought resistance

It appears from preliminary observations and general considerations that drought resistance in young cocoa plants could take two forms: the seedling may use the water available in its root zone thriftily and delay the build-up of harmful or lethal levels of internal stress. Differences in the rate of water consumption between different types or progenies are known to exist in many crop plants—both herbaceous and woody. Economy of water use is often associated with efficient stomatal control of transpiration—particularly stomatal closure at relatively low levels of internal moisture stress. Alternatively the seedling may be able to avoid stress by virtue of its having a relatively deep root system and being able to exploit the deeper, moist layers of soil. A high ratio of absorbing root to transpiring leaf surface should lead to delayed build-up of stress. Both mechanisms come under the heading of *avoidance* of build-up of internal stress. While it is possible that differences in *tolerance* of stress exist, they seem unlikely to be of much importance because the final stages of dessication occur rapidly.

Bearing these principles in mind, the first step was to develop a reliable technique for testing the drought resistance of different crosses under somewhat artificial conditions, as natural drought at Tafo is rather irregular and unpredictable. It is envisaged that the reaction to drought of seedlings about six months old grown in fairly large polybags would be studied over a single drying cycle in the greenhouse. The work done to date has done little except highlight the possible pitfalls in this apparently very simple test. The size of the plant and the bag must be chosen carefully so that there is very little or no restriction of root growth. If the seedling is too big for the bag the plants simply die off in the order of size—largest first. Even when the polybag appears to be of adequate size there appears to be a tendency for the most vigorous plants to die off first. Care must obviously be taken to standardise the amount and texture of the soil, the precautions to minimise direct evaporation from the soil and the environmental conditions during drying out. The last condition is not easily attained if many crosses are being tested simultaneously. A fairly slow drying cycle seems preferable to rapid dessication.

Now that the preliminary difficulties are thought to have been overcome, it is hoped that some tests can be carried out in the coming year.

THE MEASUREMENT OF PHOTOSYNTHETIC RATE AND THE FACTORS AFFECTING IT

Figure 26 shows that photosynthesis (the product of average rate and leaf area) is an important, if not the most important, factor affecting the productivity of cocoa. Though leaf area probably varies more than the photosynthetic rate, it is obviously important to study variation in the photosynthetic rate. Apart from some early work by Lemée this aspect of cocoa physiology has been completely neglected. There is little accurate data on net assimilation rate (NAR) from growth analysis.

Both of the two principal methods of measuring instantaneous photosynthetic rate have shortcomings. Following CO_2 exchange with an IRGA is most widely used but control of the leaf chamber environment is difficult under sunny field conditions and the technique is generally used in the laboratory. The uptake of radioactive CO_2 is a simple technique which is gaining in popularity. Its advantages are simplicity and the fact that it measures photosynthesis of the leaf in its natural situation. The main disadvantages of the technique are that it is destructive and that it measures a rate which is close to gross rather than net photosynthesis. However, this seems to be the appropriate technique for our purpose and conditions, so the necessary equipment has been assembled and is now ready for use. The design is based on that described by Turner and Incoll (*J. appl. Ecol.*, **8**, 581–591). I am grateful to Dr. P. Jarvis and his group at Aberdeen University who assembled the central control unit (timing and gas flow rate) and made the perspex gas-feeding head. Soluene TM–100 (Packard) is to be used initially as the solubiliser and counting will be in a normal liquid scintillation system.

Though the infiltration technique gives a useful semi-quantitative assessment of stomatal opening, information on diffusive resistance is necessary for a real understanding of water loss and CO_2 uptake. Hence an aspirated diffusion porometer has been obtained and it should prove to be of great value in the study of both water relations and photosynthesis. The instrument used is described by Turner and Parlange (*Plant Physiol.*, **46**, 175–177).

Photosynthetically active radiation (PAR) in the 400–700 nm band is to be measured with the Lambda quantum sensor as this instrument has a spectral response very close to the ideal quantum response. For the measurement of leaf temperature, an infra-red radiometer has been used in the past but the technique is rather cumbersome and we anticipate going back to a thermocouple or very fine thermistor.

All the necessary equipment for the measurement of PAR, stomatal resistance, water potential, leaf temperature is now at hand and data on photosynthetic rate in relation to some of the main factors regulating it shown in Fig. 26 should be available by next year.

SOIL SCIENCE

SOIL FERTILITY, SHADE AND COCOA NUTRITION FIELD EXPERIMENTS

(Y. Ahenkorah, M. R. Appiah and G. S. Akrofi)

Amazon shade and fertilizer experiment (K2–O1) (Blocks I and IV)

The summary of yield results of the Amazon shade × fertilizer trial is presented in Table 90. It should be pointed out that as a result of the minor elements application, yield was calculated on the basis of the trees (average of 11 trees per sub-plot) which received only the major elements. Yield data prior to the 1968–69 crop year were presented in the previous annual reports.

Like the 1971–72 season, the main fertilizer effect is not significant but the main shade effect is, however, significant ($P < 0.05$) with $S_0 = S_1 > S_2$. This shade effect appears more pronounced than that of last season. The mean yield from each shade regime is over one and a half times greater than the corresponding yield value of the 1971–72 season. Neither shade nor fertilizer effect was significant during the minor crop season (April–August). The effect from the increase in fertilizer dose on Blocks I and IV (*Rep. Cocoa Res. Inst., Ghana*, **1971–72**) is as usual not expected to be detected within the same season. The main crop was 65% of the annual total. The high incidence of *Heliopeltis spp.* damage to cherelles reported last season on this plot was not observed for this period.

Even though the fertilizer effect is not statistically significant, it is clear from Table 91 that the fertilizers were better utilized under the No shade (S_0) conditions and that the no shade with potash (K), especially S_0K_1, appears slightly better than the rest. Consistent with previous trends, the average effect of the combined shade removal and fertilizer treatment is superior to either the shade removal or the fertilizer effect.

Minor elements application in Blocks I and IV of K2–O1

Further to the reports on boron deficiency (Asomaning and Kwakwa, *Ghana Jnl. Sci.*, **7**, 126–129) and zinc deficiency symptoms (Ahenkorah, *Ghana Jnl. Agric. Sci.*, **2**, 3–6) with the Amazon cocoa, the proposed 2^3Zn, B, Fe factorial set of treatments were randomised on the K2–O1 split plots (*Rep. Cocoa Res. Inst., Ghana*, **1967–68**, 112). Borax and chelated zinc and iron fertilizers were used. Zinc was applied at the rate of 63.7 lb. Na_2 Zn EDTA/acre (14.2% Zn) and iron at the rate of 86 lb. Na_2 Fe EDTA/acre (10% Fe). These rates are equivalent to 25 lb./acre of fertilizer zinc sulphate (36.2% Zn) and ferrous sulphate (34.4% Fe) respectively. Boron was also applied at the rate of 10 lb. borax per acre. These minor elements were broadcast between 26th May and 21st June, 1972.

The complete statistical analyses of the first year data to determine the

TABLE 90

Mean yield (lb. dry cocoa per acre) from Amazon shade and fertilizer experiment, K2–O1*

	1968–69			1969–70			1970–71			1971–72			1972–73		
	S_0	S_1	S_2	S_0	S_1	S_2	S_0	S_1	S_2	S_0	S_1	S_2	S_0	S_1	S_2
Without N	1,371	1,029	1,112	1,672	1,477	1,794	1,452	1,146	891	592	544	417	924	989	676
With N_1	1,409	1,021	1,120	1,648	1,397	1,869	1,648	1,001	862	676	468	388	1,041	988	559
With N_2	1,600	1,042	1,133	1,715	1,424	1,937	1,662	954	903	743	489	408	1,110	935	652
Without P	1,375	964	975	1,556	1,330	1,671	1,516	942	801	602	418	344	946	954	528
With P_1	1,482	1,048	1,173	1,747	1,492	1,954	1,600	1,071	913	726	518	460	1,074	997	677
With P_2	1,523	1,081	1,219	1,732	1,476	1,975	1,646	1,088	941	683	567	410	1,055	961	682
Without K	1,321	1,016	1,064	1,571	1,400	1,728	1,457	967	840	558	537	371	866	988	541
With K_1	1,540	1,065	1,169	1,691	1,451	1,901	1,710	1,125	875	751	482	416	1,110	1,055	614
With K_2	1,520	1,011	1,133	1,772	1,447	1,970	1,595	1,008	940	702	483	427	1,098	869	732
Mean	1,460	1,031	1,122	1,678	1,433	1,867	1,587	1,034	885	670	501	405	1,025	971	629
Main shade effect	Not significant			Not significant			Not significant			Sig. $P < 0.05$			Sig. $P < 0.05$		
Main fertilizer effect	Sig. $P < 0.001$			Sig. P. < 0.01			Sig. $P < 0.05$			Not significant			Not significant		

*Potential yield based on conversion of 12 pods = 1 lb. dry cocoa.
S_0 = No shade.
S_1 = *T. ivorensis* shade trees at 56½ ft. × 56½ ft.
S_2 = *T. ivorensis* shade trees at 40 ft. × 40 ft.

TABLE 91

Percentage yield increase or decrease from Amazon Shade and Fertilizer Experiment K2–O1 following shade removal and addition of fertilizer

Shade regime	Rates of N: 0	Rates of N: N_1	Rates of N: N_2	Rates of P: 0	Rates of P: P_1	Rates of P: P_2	Rates of K: 0	Rates of K: K_1	Rates of K: K_2
				Shade removal effect 1968–69					
S_0	28.1	31.7	47.2	41.9	33.5	32.4	27.0	37.9	41.8
S_1	33.2	38.0	53.6	42.6	41.4	40.9	30.0	44.6	50.3
S_2	23.3	25.8	41.2	41.0	26.3	24.9	24.2	31.7	34.2
				Fertilizer effect					
S_0	—	−2.8	16.7	—	8.0	10.8	—	16.6	15.1
S_1	—	−0.8	1.3	—	9.0	12.1	—	4.8	−0.5
S_2	—	0.7	1.9	—	20.3	25.0	—	9.8	6.5
				Combined shade removal and fertilizer effect					
S_0	128.1	131.7	147.1	141.9	133.5	132.5	127.0	137.9	141.7
S_1	96.1	95.3	95.3	99.4	94.4	94.0	97.7	95.3	141.7
S_2	103.9	104.7	104.7	100.6	105.6	106.0	102.3	104.7	105.7
				Shade removal effect 1969–70					
S_0	22.0	9.2	20.2	3.7	1.3	0.3	0.4	0.9	3.7
S_1	13.2	18.0	20.4	17.0	17.1	17.3	12.2	16.5	22.5
S_2	7.3	13.4	12.9	7.4	11.8	14.0	10.0	12.4	11.2
				Fertilizer effect					
S_0	—	−1.5	2.6	—	12.3	11.3	—	0.8	12.8
S_1	—	−0.6	0.4	—	12.2	11.0	—	0.4	0.3
S_2	—	0.4	0.8	—	16.9	18.2	—	10.0	14.0
				Combined shade removal and fertilizer effect					
S_0	102.2	100.9	102.0	103.7	101.3	100.3	100.4	100.9	103.7
S_1	90.4	85.5	84.8	88.7	86.6	85.5	89.5	86.6	84.7
S_2	109.8	114.4	115.2	111.3	111.4	114.5	110.5	113.4	115.3
				Shade removal effect 1970–71					
S_0	42.6	76.9	42.1	73.9	61.3	62.3	61.2	70.9	63.7
S_1	26.7	64.6	74.3	61.0	49.4	51.3	50.7	52.0	58.2
S_2	63.0	91.3	84.1	89.1	75.3	74.9	73.4	95.4	69.7

				Fertilizer effect					
S_0	—	10.0	10.0	—	10.0	10.0	—	20.0	10.0
S_1	—	−10.0	−20.0	—	10.0	20.0	—	20.0	40.0
S_2	—	−30.0	10.0	—	10.0	20.0	—	40.0	10.0
				Combined shade removal and fertilizer effect					
S_0	142.6	176.9	179.0	173.9	161.3	162.3	161.2	171.0	163.7
S_1	112.5	107.5	179.0	108.1	108.0	107.2	107.0	112.5	103.5
S_2	87.5	92.5	97.3	91.9	92.0	92.8	93.0	87.5	96.5
				Shade removal effect 1971–72					
S_0	23.2	57.8	65.2	58.0	48.6	40.0	22.8	67.4	54.4
S_1	88.6	44.2	51.9	44.1	40.3	20.6	38.4	55.8	45.5
S_2	42.0	74.1	82.0	75.0	57.0	66.8	50.3	80.8	64.4
				Fertilizer effect					
S_0	—	10.0	30.0	—	20.0	10.0	—	30.0	30.0
S_1	—	−10.0	−10.0	—	20.2	30.0	—	10.0	−10.0
S_2	—	−10.0	−10.0	—	30.0	20.0	—	10.0	20.0
				Combined shade removal and fertilizer effect					
S_0	123.2	157.8	165.6	158.0	148.6	140.0	122.8	167.4	154.4
S_1	113.2	109.3	109.0	109.7	105.8	116.1	118.2	107.4	106.1
S_2	86.8	90.6	90.9	90.3	94.1	83.9	81.7	92.6	93.4
				Shade removal effect 1972–73					
S_0	11.0	35.0	40.0	28.0	28.0	28.0	13.0	33.0	37.0
S_1	−6.7	5.4	18.7	−0.8	7.7	9.7	−12.3	5.2	26.3
S_2	36.6	86.1	70.1	79.2	58.5	54.6	60.1	80.9	49.9
				Fertilizer effect					
S_0	—	12.7	20.2	—	13.5	11.6	—	28.2	26.7
S_1	—	−0.1	−5.5	—	4.6	0.8	—	6.8	−12.0
S_2	—	−17.3	−3.5	—	28.4	29.3	—	13.4	35.3
				Combined shade removal and fertilizer effect					
S_0	111.0	135.0	140.0	128.0	128.0	128.0	113.0	133.0	137.0
S_1	118.8	127.7	117.8	128.8	119.1	117.0	129.2	126.5	108.5
S_2	81.2	72.3	82.2	71.2	80.9	83.0	70.8	73.6	91.5

effects of the minor elements were not ready at the time of writing this report.

Blocks II and III

Analysis of the yield for experimental Blocks II and III, the unfertilized portion of the K2–O1 (see *Rep. Cocoa Res. Inst., Ghana*, **1971–72**, 212), indicates that the residual fertilizer effect is not significant. It was highly significant ($P < 0.01$) for the 1971–72 season. Because of the unusual weather conditions especially the extreme dryness at the station, it is intended to hold on a little longer before the introduction of the new design. Experience from other trials (see last paragraph of the discussion on the 4A × 2B factorial trials in this report) and previous experiments (*Rep. Cocoa Res. Inst., Ghana*, **1968–69**, 83) indicated that residual PK fertilizer effect on mature cocoa could last for about three seasons with a steady yearly decline in the significant levels of the fertilizer treatment.

Time and split of NPK application

These trials are sited at Akaa (4-acre Amelonado plot) and Pankese (Amazon plot 1124) cocoa stations. The details of the experiment have been reported (*Rep. Cocoa Res. Inst., Ghana*, **1966–67**, 102). For a second time at Akaa the response to the application of the 90 lb. P_2O_5/acre is significant ($P < 0.05$) regardless of whether the P was applied once in May (P_1), split applied in May and July (P_2) or one third each applied in May, July and September (P_3) of the same year. By way of summary, P_1, P_2, $P_3 > P_0$; $P_1 > P_3$ both at the 1% level; $P_1 > P_2$ at 5% level and $P_2 = P_3$. Similarly the P response was significantly better than either N, K or any of the fifteen NK combinations. Unlike the last crop season (*Rep. Cocoa Res. Inst., Ghana*, **1971–72**) the highly significant response to P at Pankese, did not repeat. However, a high but statistically non-significant yield was recorded from the split treatment (P_2K_2), that is the half dose each of the combined PK (90 lb. P_2O_5 and 75 lb. K_2O per acre) applied in May and July.

It looks as if the differences in response of the Amazons and the Amelonado to the different times at which the full dose or split doses of P or PK were applied could reflect the variation in response of the two varieties to the triple superphosphate, muriate of potash or their combinations. Furthermore the differences in the soils from Pankese and Akaa with respect to the effect of the addition of P on the availability of K are worth considering in the final interpretation of the results of the fertilizer trials in these areas. It was observed for Akaa that the addition of P has a tendency to influence the availability of K uptake (*Soil Sci.*, **100**, 127–135). Presently, however, it is still regarded premature to make definite observations from this two-year-old trial.

Time and rate of NPK application

The trial is located at Asikuma cocoa station (Plot 2055). None of the treatments is statistically significant probably because of the earliness of the experiment. However, for this season, yield for the various treatments averaged 60.7% (range 56–62%) of the corresponding yield for the 1971–72 season. This drop could be due partly to the unusual dry weather conditions.

Factorial fertilizer trials on shaded cocoa at cocoa stations and farmers' farms

Tables 92 and 93 summarise the type of experimental design, cocoa variety, respective sites and yield results of the above trials. In the older trials, Table 92, none of the treatments is significant. Like the last two seasons, the apparent low yields tend to be associated with the plots not treated with K. Individual yields from such plots are generally consistently lower than the corresponding mean yield from the respective site. There is practically no difference in yield in the Amazons whether Mg is applied or not. With the exception of Bunso 1006, where this year's yield dropped 32% lower than the previous year, there is, at the remaining sites, not much difference in yield between the current and previous season from the various factorial set of treatments. An average increase of 10% and 3% at Akaa and Pankese and a decrease of 7% at Bieni respectively were obtained over the 1971–72 crop.

TABLE 92

*Factorial Fertilizer Experiments on shaded Amazon mean yield**
(lb. dry cocoa/acre) for 1972–73 season

Design / Plot treatment	2^3NPK Bunso 1006	3^2KMg Akaa 3009	3^2KMg Pankese 1116	2^2Kmg Biene 2025
Without N	485	—	—	—
With N	456	—	—	—
Without P	451	—	—	—
With P	489	—	—	—
Without K	444	889	886	1,345
With K_1	497	940	901	1,505
With K_2	—	972	966	—
Without Mg	—	957	926	1,415
With Mg_1	—	904	865	1,433
With Mg_2	—	940	961	—
Mean SE ±	470 ± 43	934 ± 83	917 ± 53	1,424 ± 83

*Potential yield based on conversion of 12 pods = 1 lb. dry cocoa.

Under the 4A × 2B factorial trials, Table 93, it would be incorrect, because of the age differences, to compare directly the yields from the control plots of the two cocoa varieties. Except at Bechem 4097 where P (60 lb. P_2O_5/acre) is highly significant ($P < 0.001$), no other significant fertilizer treatment was obtained at the remaining sites, yet in almost every case all the fertilized plots tended to yield higher than their control plots. However, at Pankese 1117, a rather anomalous situation was observed because the nil plot out-yielded all the treated plots. Yield from the nil plots of experimental blocks II and III were found to be unusually high even though the analysis of variance did not indicate any significant block differences.

TABLE 93

Mean yield (lb. dry cocoa per acre) of the 4A × 2B factorial trials on shaded Amelonado × Amazon*, 1972–73

Site treatment	Bechem L1/R	Akaa Block G	Amelonado Asikuma Block G	Pankese Plot 29	Bunsu Area 28	Mabang-Brosankro
(−)	447	158	490	509	555	808
K	615	179	527	534	628	941
P_1	592	170	550	592	544	1,038
P_2	613	251	423	594	644	1,370
P_3	533	224	370	509	653	1,239
KP_1	776	274	594	484	630	817
KP_2	606	263	631	578	672	1,497
KP_3	674	185	538	528	697	1,049
Mean SE ±	607 ± 79.2	213 ± 36.5	515 ± 49.0	541 ± 42.2	627 ± 53.9	1,094 ± 95.5
Site treatment	**Bechem 4097**	**Akaa 3010**	**Amazon Asikuma 22**	**Pankese 1117**	**Bunsu 1045**	**CRIG D12**
(−)	436	411	513	591	409	664
P	592	595	548	488	471	882
K_1	440	442	527	468	540	624
K_2	497	540	548	482	489	735
K_3	533	524	459	555	419	719
PK_1	567	585	579	525	389	762
PK_2	540	549	602	523	483	773
PK_3	744	595	582	474	500	785
Mean ± SE	544 ± 50.9	530 ± 81.6	544 ± 56.1	513 ± 39.9	462 ± 42.6	743 ± 72.7

*Potential yield figures have been adjusted by the analysis of covariance using 2 years as pre-treatment data to adjust 1972–73 yield.

The analysis of covariance performed with the results from CRIG D12 and using the two-year pretreatment data indicated a significant covariance regression ($P < 0.05$) but a break down of the various treatments showed no significant level. This seems to suggest that probably the covariant factor was affecting the previous yield in the same way as the current yield. In other words, after allowing for the covariant effect no other treatment effect was significant. In a case like this, the interpretation of the data becomes difficult; therefore the raw data (unadjusted values) were used in the analysis of variance. None of the treatments was found to be significant, thus confirming the observation that there were no treatment differences when the covariant effect was taken out.

In an attempt to obtain some information on the relative merits of the annual application and the residual effects of the various fertilizer levels, half portion of all the individual plots (under the 4A × 2B factorial trial) have not been fertilized for the past four years. However, each of the remaining portion (also containing 12 or 13 trees) is fertilized annually. So far at the Akaa 3010, Bechem 4097, Asikuma Block G and Mabang-Brosankro plots the significant residual effects have been associated more frequently and over longer period with P than with K while the annual applications of PK combinations have been found to be consistently significant (with the probability varying between $P < 0.05$ and $P < 0.01$).

Trials within the Eastern Region cocoa rehabilitation area

A second year recording for the pretreatment yield data is in progress on the selected sites (*Rep. Cocoa Res. Inst., Ghana*, **1971–72**, 219). A split plot design of Time and Rate of NPK fertilizer application would be adopted.

Soil catena and cocoa yield relationship—Plot M3

A five-acre plot, M3, at Tafo was selected for the above study. The area was planted to the Amelonado cocoa in 1947 at 8 ft. × 8 ft. spacing and spans across four distinct soil series. From the top to the bottom slope, the catena consists of the Wacri, Nankese, Asafo and Akwadum series.

Profile description of the soil series

Wacri soil series

Found on well-drained portions of undulations and differs from the Koforidua series by having hornblende granodiorite parent material; pH 7.4 to 7.0.

0–2 inches	Dark brown, humic crumbly sandy loam.
2–9 inches	Dark brown to reddish-brown, structureless, less humic clayey sandy loam.
9–24 inches	Reddish brown sandy kaolinitic clay with frequent quartz gravel and soft ironstone concretions not exceeding two inch diameter. Present also are easily decomposed boulders of hard pan and unfoliated rocks.
24–48 inches	Red brown sandy kaolinitic clay without iron concretion but with incomplete weathered remnants of the parent material.
48–60+ inches	Sandy kaolinitic clay, mottled red, containing partially weathered minerals like biotite, fragments of decomposing parent material and disintegrated ferromagnesian and quartz materials. Some slightly weathered rocks occur in this zone which probably merge into unaltered rock at greater depth.

Nankese series

This consists of soils of the middle slope. Profile is similar to Wacri series but yellow-brown in colour with the decomposing rock comparatively near to the surface. The brown coloration, instead of the red, is presumably due to the closer proximity of the water table to the surface and hence less perfect under-drainage. pH 6.5–5.6.

0–2 inches	Dark grey humic loamy sand.
2–12 inches	Pale brownish grey sand.
12–40 inches	Yellow brown clayey sand with abundant ironstone concretions, quartz gravel and stones and some manganese dioxide (?) concretions.

40–60+ inches	Brownish yellow to pale yellow mottled gritty sandy clay with partially decomposed hornblende or biotite granodiorite parent material.

Asafo series

Soils in this series are partly from transported hill-wash material and partly from *in situ* weathering of the underlying rock. pH 6.0–5.0.

0–2 inches	Grey-brown humic crumbly sandy loam.
2–40 inches	Pale, yellow-brown sand.
Below 60 inches	Gritty clay mottled yellow and grey grading into disintegrated and partially decomposed rock.

Notes

The top layer, of two to about five feet, of such profiles consists of transported material washed down from the higher elevations of the catena; frequently a thin quartz gravel material separates this upper zone from the *in situ* decomposing parent material. Ironstone concretions found in Wacri and Nankese series are typically absent although the brownish (hydrated ferric oxide) and blackish (manganese dioxide) spots and patches may occur in the sand transported material, and these may present semi-hard concretionary centres. Sometimes layers, together with the gravel zone may be cemented with hydrated iron oxides.

Akwadum series

Valley bottom soils found besides small drainage channels. They consist of grey sandy poorly drained material; pH 5.0–4.5.

0–3 inches	Grey or brownish-grey sandy loam.
3–36 inches	Grey or pale yellowish-grey sand, medium to coarse texture, mottled rusty brown.
Below 36 inches	Clayey, disintegrated and decomposing rock, grey or greenish-grey colour, mottled rusty brown and speckled with whitish kaolinitic clay and sand materials and frequently containing unweathered boulders of the parent material.

Notes

The layers to a depth of about three to five feet consist of transported material, partly hill-wash and partly stream alluvium. A layer of quartz lies between the transported material and the decomposing bed rock. Like the Asafo series of the lower slope soils, seepage ironstone may develop in the sandy upper layers.

Soil suitability classes for cocoa and their cocoa productivity

Detail profile description (given above) and results of the chemical analyses of soils from the series fit four of the six representative soil suitability classes for cocoa described by Adu and Mensah-Ansah (*3rd Int. Cocoa Res. Conference. Accra*, **1969**, 56–64). The Wacri series, occurring on the top slope forms a deep (over 8 feet) sedentary soil, fits the Class I, very good cocoa soil; Nankese satisfies Class III, moderately good cocoa soil; Asafo fits Class V, fair cocoa soil and Akwadum is Class VI, very poor cocoa soil. The corresponding yields of the Amelonado cocoa, for the 1970–73 cropping seasons, from the above four soil series on the catena in plot M3 are summarised in Table 94.

TABLE 94

Cocoa yield from soil series on a catena in plot M3 over three years

Year	Soil series			
	Wacri	Nankese	Asafo	Akwadum
	lb. dry cocoa/acre			
1970–71	753	528	315	299
1971–72	806	338	281	283
1972–73	857	219	301	203
Mean	812	359	302	264

The three-year mean yield of the mature Amelonado cocoa on the Wacri series is more than twice the yield from the adjacent Nankese series downslope. The yield, as is obvious from the table, decreases with both the depth of the profile and the variation in the water table of the various soil series.

Shade × Variety × Fertilizer Trial Block G7

Girth measurements of all the immature trees were taken for uniformity analysis. Growth has been very vigorous among the hybrid series and some individual trees have begun bearing. Thinning of some of the trees to obtain the desired spacing would be undertaken after receipt of the statistical advice. Growth performance of the Amelonado is, as expected, very slow. Routine plantation practices are in progress. Details of this trial which was planted in May 1970, were reported (*Rep. Cocoa Res. Inst., Ghana*, **1968–69**, 92–93).

Cocoa root activity studies using radioisotope P-32

The work on this contract with the International Atomic Energy Agency (*Rep. Cocoa Res. Inst., Ghana*, **1969–70**, 173 and **1971–72**, 219) is now completed. Results of the statistical analysis on the main trial are in progress. Meanwhile summary of the findings on all the preliminary experiments is reported (*IAEA Research Contracts*, 13*th Annual Report*, p. 63–64). The final report will be presented.

LABORATORY WORK

Soil and leaf analysis: as diagnostic technique for cocoa nutrition studies

All the laboratory work involving chemical analyses had to be suspended for some time because of shortage of water. Work on cocoa leaf analysis to provide the standard curves for the nutrient elements (*Rep. Cocoa Res.*

Inst., Ghana, **1971–72**, 219) is being continued. The objective is to use foliar analysis, supplemented with soil analysis, as a diagnostic tool in determining the nutritional status of cocoa.

Studies on soil organic phosphorus and phosphatase activities have been initiated.

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BALANCE SHEET AS AT 30TH SEPTEMBER, 1972

	₵	₵
Fund Accounts		
Development Fund Account	2,322,745.48	
Less: Development Expenditure—Schedule 2	2,322,745.48	
Balance		—
Recurrent Grant		
Unspent balance, Schedule 2		712,377.27
WACRI Account		
Amount due to liquidator		—
Sundry Liability		
Superannuation Account	32,639.75	
Sundry Creditors	81,409.28	
General Account—Crown Agents	545,319.80	
Investment Fund	3,033,646.35	
Head Office Current Account	55,447.25	
Accrued Charges and Provisions, Schedule 3	16,230.14	
Endowment Fund	—	
Inter-Institute Accounts	2,198.28	
		3,766,890.85
Total of Capital Funds and Liabilities		₵4,479,268.12
Represented by:		₵
Investments, Schedule 4		17,285.60
Fixed deposits, Schedule 5		3,105,000.00
Sundry assets, Schedule 6		1,356,982.52
		₵4,479,268.12

We have examined the Balance Sheet as at 30th September, 1972 and the annexed accounts of the Cocoa Research Institute of the Council for Scientific and Industrial Research in respect of the period of 15 months to 30th September, 1972.

In our opinion, and to the best of our knowledge and belief, the Balance Sheet and the Income and Expenditure Account are in accordance with the books of account as appears from our examination of the books of the Institute.

The Balance Sheet and the Income and Expenditure Account, in our opinion, reflect respectively the state of affairs and the operation results of the Institute.

R. S. AMEGASHIE & CO.
CHARTERED ACCOUNTANTS.

Accra,
2nd July, 1973.

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.. .. Herbicide trial. Amazon hybrid cocoa planted

D .. in 1968.

Planted in 1970 for shade trial.

D .. .. Herbicide trial—Hybrid cocoa planted in

.. 1968.

D Weed control studies.

D .. .. Part of original Old Station cocoa. Seedling

D .. establishment trials.

E(.. Cocoa Rehabilitation experiment.

F‹ .. ..

F:

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Growth regular trial.

L(.. .. Tolerance of exposure (planted in 1970).

.. .. Amazon 3 shade × (3K × 3P × 3K), planted

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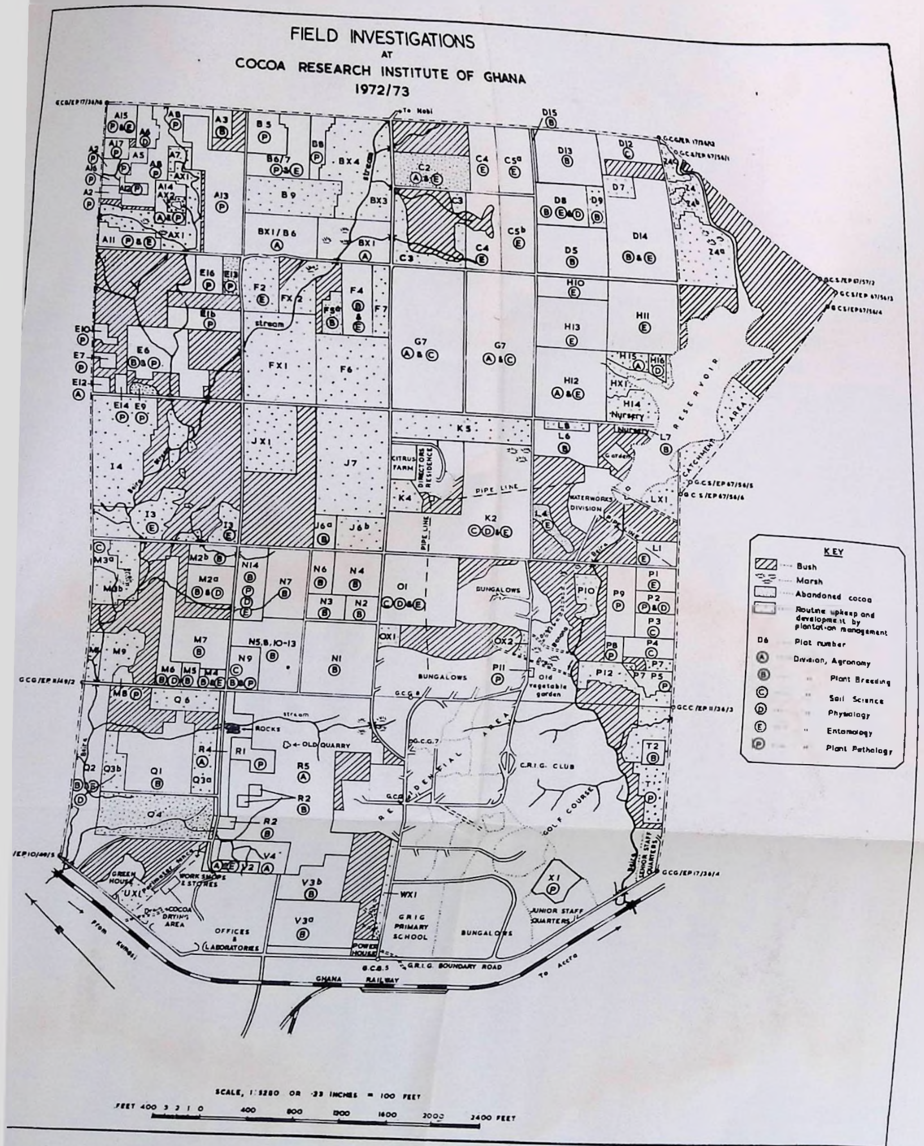
M



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