

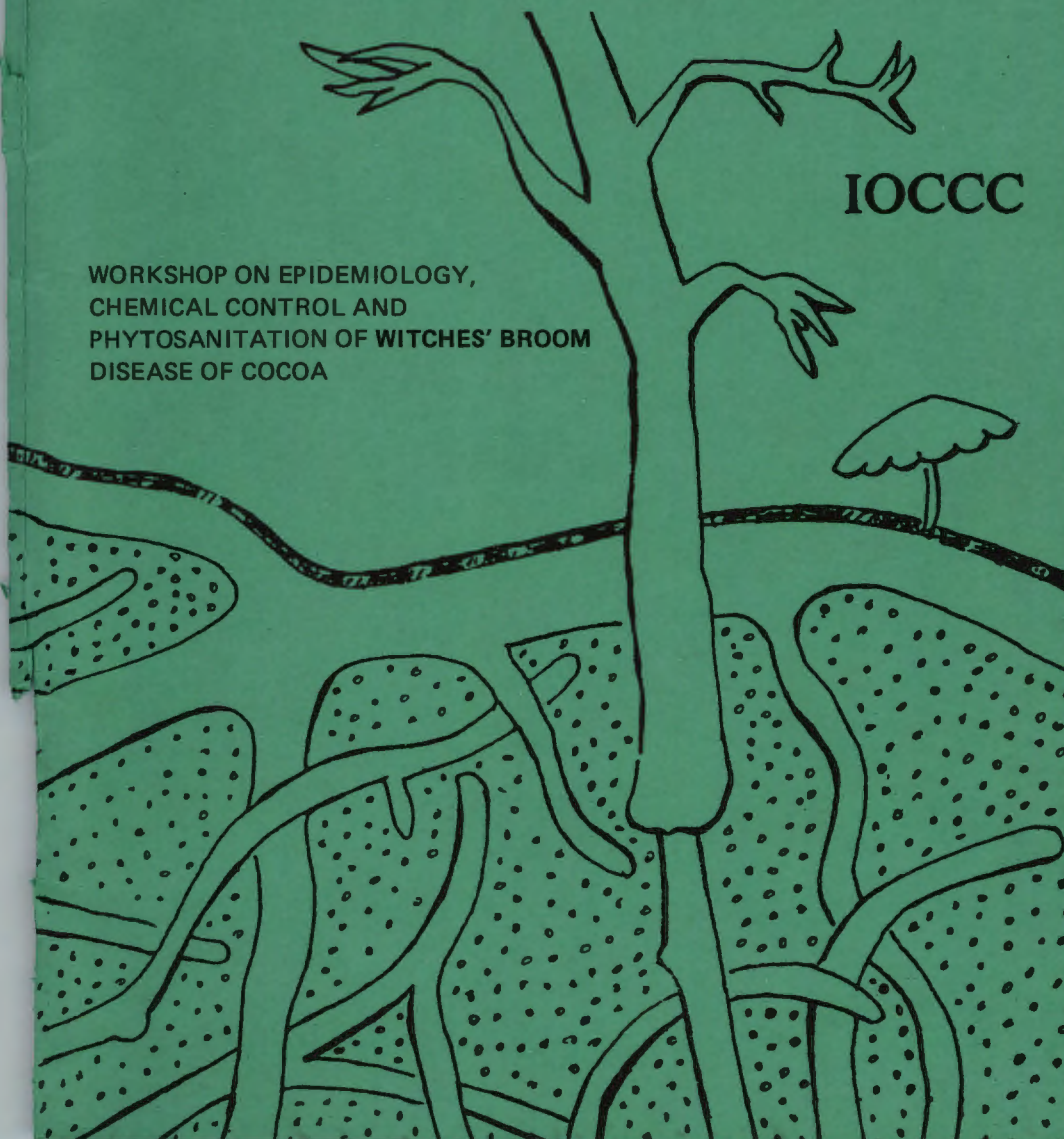
MANAGING WITCHES' BROOM DISEASE OF COCOA

REPORT OF 7th WORKSHOP
OF INTERNATIONAL WITCHES' BROOM PROJECT

12 – 18th April 1991, Warwick, UK

IOCCC

WORKSHOP ON EPIDEMIOLOGY,
CHEMICAL CONTROL AND
PHYTOSANITATION OF WITCHES' BROOM
DISEASE OF COCOA



INTERNATIONAL WITCHES BROOM PROJECT

(IWBP)

IWBP is an international project funded by chocolate manufacturers in Europe and North America with a number of International Agencies and with the governments of 6 cocoa producing countries. It is conducting fundamental research at a total of 21 centres in Europe, Latin America and the United States aimed at a reduction of the devastation caused by Witches' Broom disease of cocoa due to the pathogen *Crinipellis perniciosa* (Stahel) Singer.

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REPORT OF THE 7TH IWBP WORKSHOP

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UK

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1. INTRODUCTION TO IWBP

Almost one-third of the world supply of cocoa is produced in the Americas but in many countries maximum production is severely curtailed by Witches' Broom (WB) disease. It now occurs in Brazil, in the Upper Amazon region and also in the traditional area of cocoa cultivation in the State of Bahia, in Bolivia, Colombia, Ecuador, Grenada, Guyana, St Lucia, Panama, Peru, Surinam, Trinidad and Venezuela. In the Brazilian Amazon, pod losses have reached 95 per cent on occasions, and almost all infected pods are a total economic loss. Moreover, there is NO assurance that its absence from cocoa producing countries outside the Americas will continue. On 24th May 1989, witches' broom disease was identified near Urucuca in the State of Bahia, Brazil. This was a new outbreak and was discovered some 2,000 kilometres from the nearest known previous infection. CEPLAC made a most strenuous attempt to eradicate infected material from that location by cutting down and burning all infected trees and surrounding cocoa within a distance of 300 metres from diseased trees. In August 1989, another focus of infection was found in Urucuca about 2.5 kilometres from the area from which all cocoa material had been eradicated. Unfortunately, on 26th October 1989 a further series of outbreaks were discovered about 123 kilometres south of Urucuca and distributed across an area of some 25 kilometres. The area involved was obviously too large to make eradication a viable option and so regular frequent pruning on a fortnightly basis has been implemented. On 26th March 1990 another outbreak was discovered near Ibirapitanga about 43 kilometres to the north of Urucuca and many other outbreaks have been discovered subsequently.

The pathogen (*Crinipellis perniciosa*) causes overdevelopment of cocoa meristematic tissues leading to hypertrophied and proliferated growth, to give the characteristics Witches' Brooms (Escoba de Bruja/Vassoura-de-Bruja/Balai de Sorciere). It also infects many pods. Infected pods fail to ripen and the beans either become liquified or adhere to the pod husk and are commercially valueless.

These features made a co-ordinated, multi-centre, multi-national research program on the disease a top priority and so a project proposal was formulated in the early 1980's by scientists in countries where the disease is important. In view of these serious threats, the International Office of Cocoa, Chocolate and Sugar Confectionery (IOCCC) with some other international donor agencies agreed in 1985 to fund a US\$700,000 multi-national project initially over a period of 5 years from 1st July 1985. The objective of the project is "to develop an economic management system to control Witches' Broom disease of cocoa in a number of cocoa growing environments". The Project has been recently extended to June 1992, by which time the findings should be published as a Monograph (in English and Spanish recording the scientific findings), as a series of extension leaflets (recording the recommendations for control for the farmers affected by the disease) and in due course as a number of specific papers in a variety of journals.

It is appropriate to record the very generous assistance to IWBP from the Governments of the participating countries in Latin America and the Caribbean where IWBP sites are in operation. Significant assistance in terms of facilities, transport and personnel are being provided by the Governments of Brazil (CEPLAC), Colombia (ICA), Ecuador (INIAP), Grenada (GCA), Trinidad (CRU) and Venezuela (FONAIAP). This assistance is very much appreciated and without it the Project could not operate. Direct financial assistance from the

Science and Technology for Development Fund (STD) of the European Community through DGXII, from UK Overseas Development Administration and indirectly from the Canadian International Development Association (CIDA) is also greatly appreciated and is acknowledged with gratitude.

In early July 1985 participants in IWBP met at Pichilingue, Ecuador, for the 1st IWBP Workshop to formulate the direction of the research programme on the epidemiology of *Crinipellis pernicioso* and the decisions of this were published in October 1985 in the 'Report of the 1st IWBP Workshop'. The collection of data in these experiments to investigate the disease epidemiology are now completed at all ten sites in six countries and at one site where the disease is not present.

It was considered important to start to consider the evaluation of candidate chemicals for disease control and a preliminary discussion was held at the 2nd IWBP Workshop held in Wageningen, Holland in October 1985. The discussion was published in the 'Report of the 2nd IWBP Workshop'.

The 3rd IWBP Workshop was held at Granja Luker, owned by Chocolateria Luker and situated near Manizales in Colombia from 7-12th July 1987. The experimental Protocol for the 'Comparative Epidemiology Experiment' (agreed in July 1985) was carefully and extensively reviewed at this Workshop and amended as necessary. An experimental Protocol for recording climate data at two sites where Witches' Broom disease is absent was also developed and data recording at one of these sites started in mid-1987.

The objective and philosophy for phytosanitation studies within IWBP were discussed and the experimental Protocol for the 'Comparative Phytosanitation Experiment' was established and guidelines for conduct of Inoculum and/or Gradient Experiments and for Chemical Evaluations were drawn up at the 4th IWBP Workshop held in Belem, Brazil from 11-17th September 1987.

The 5th IWBP Workshop was held at the spectacular Asa Wright Nature Centre, Arima, Trinidad from 3-10th November 1988. During the course of this Workshop the results at that time available from the epidemiology, inoculum and gradient experiments were carefully reviewed. Suggested methods of data management and presentation were discussed and some Guidelines were produced. The experimental protocol for the 'Comparative Phytosanitation Experiment' was reviewed and some minor amendments were made.

The experimental data was studied and reviewed at the 6th IWBP Workshop held in Gainesville, Florida from 4-11th April 1990. Some preliminary conclusions were also tentatively proposed, on the occasion and are presented in the 'Report of the 6th IWBP Workshop'. The present Workshop is designed to refine those conclusions and agree recommendations on disease control.

Copies of all these reports are available free of charge from Dr J. van Kan, Director General, IOCCC, Avenue de Cortenbergh 172, Brussels, B-1040, Belgium.

2. NARRATIVE REPORT OF THE 7TH IWBP WORKSHOP

2.1 Opening Session

Participants arrived at the University of Warwick on Thursday 11th April 1991. The names, addresses, telephone, telex and telefax numbers (where applicable) of all the participants are included as Appendix A to this report. Organisational support was kindly provided by Cadbury Ltd.

The 7th IWBP Workshop started at 0900 hours on Friday 12th April 1991 with a welcome from the President of the International Office of Cocoa, Chocolate and Sugar Confectionery, (IOCCC). This was followed by an address from R.A.Lass, Executive Chairman, IWBP:

The objective of IWBP as formulated in July 1985, was to produce a management system(s) for control of witches' broom disease of cocoa in a number of cocoa growing environments in Latin America and the Caribbean. Two further objectives have been recently added to this, firstly to produce recommendations for action in the event that witches' broom spreads to areas where it is presently absent and secondly to produce detailed recommendations for the specific messages to be communicated to farmers affected by the disease.

In previous reports, I have outlined the research which is being conducted by IWBP at 17 locations around Latin America. The phase of data collection is now almost complete. We have collected a very substantial volume of data on the spread of the disease, or evaluation of chemicals and on the effect of pruning out the infected plant tissues. This data amounts to some 19 Mb of data now requiring analysis. This analysis is a very substantial task which is now well advanced. We have discussed the data analysis procedures widely within the Project and with a number of scientists having expertise in the design of such experiments and the subsequent data analysis. The scientists in each cooperating institution are now analysing the data at their own sites and at the same time the Project is analysing all their data in a comparative way following statistical methodology agreed by Project participants. The writing up has started in a number of cases. We expect the comparative analysis to be completed by the end of September 1991. The writing up as a Monograph should be completed soon afterwards.

It will be recalled that the International Witches' Broom Project has held a series of Workshops. The 1st IWBP Workshop in Pichilingue, Ecuador in July 1985, 2nd in Wageningen in Holland in October 1985, 3rd in Manizales, Colombia in July 1986, 4th in Belem, Brazil in September 1987, 5th in Trinidad in November 1988, 6th in Gainesville, Florida in April 1990. The reports have all been published. The 7th, and final, Workshop is now being held at Warwick University, UK, from 11th - 17th April 1991.

This will be followed by a meeting of the IWBP Project Management Committee. On the 18th April 1991, there will be an "Open Forum" for the scientists to report the findings to the members of the Project Management Committee and discuss them with a wider audience of scientists and others with an interest in the disease.

This Workshop is crucial to the conclusion of IWBP. All those who have participated in the field work will (i) debate in detail the scientific conclusions to be drawn from the data, (ii) derive the recommended management systems for each cocoa growing environment, (iii) prepare recommendations for the extension messages to be communicated to the cocoa farmers affected by the disease, (iv) prepare recommendations for action in the event that witches' broom spreads to areas where it is presently absent. I am mindful of the difficulty of my task in persuading 18 scientists from 8 countries (who speak three different languages) to achieve these four crucial objectives during the space of 1 week.

At the conclusion of the 7th IWBP Workshop and the "Open Forum", we will then be in a position to draft a specific and well-defined plan for the dissemination of the IWBP derived recommendations for farmers in line with the request recently made to me by the IOCCC Bureau. Unfortunately as the data is still presently being analysed, it was impossible to prepare such a plan for discussion at this meeting.

As I reported to you at the last Annual Assembly we propose to publish a Monograph on the work of IWBP. It seems appropriate to explain the market envisaged for this document. It is to be published by Elsevier Applied Science as a commercial venture at minimal cost to IOCCC in that we are merely contracted to deliver to them a Camera Ready Manuscript and to purchase 50 copies at a substantial discount to the commercial price. The market for this is anticipated to be:

- cocoa scientists (including those involved in IWBP);
- the scientific community at large (it may become a standard textbook for plant pathologists);
- the sponsors (for purposes of record);
- other research workers in other diseases of other crops (if only to highlight to them of the difficulties of mounting and managing a project like this).

The Monograph is planned to be a multi-author work, a professional publication of high quality, presentation and high quality science (suitably vetted/refereed). It is expected to reflect considerable credit on sponsors of, and participants in, IWBP. It will contain the following:

- a scientific study of the data collected at each experimental site;
- the comparative analysis of the data between each site;
- recommendation for disease management at each site;
- recommendations for actions in the case of new outbreaks of witches' broom disease;
- needs for the future scientific work on witches' broom disease of cocoa.

In addition to the Monograph, there will be a number of papers in refereed journals prepared by the scientists involved covering further analysis of the data collected for IWBP as well as that not forwarded to IWBP. It will be recalled that there have been a number of student thesis prepared with part, or whole, IWBP funding. Most of these have now been completed and publications are in preparation. There will also be a 'Report to the Sponsors of IWBP'. I believe that this document is most important and could be considered as the Executive Summary of IWBP.

I feel that the Project has gone well considering its great complexity (multitude of donors, 17 research locations, 18 scientists, 3 languages, 6 countries in Latin America). It could indeed be a model for international cooperation in agricultural research.

This was followed by a welcome from Dr Hank Purdy, Chairman of the Project Scientific Committee.

2.2 Adoption of Programme for 7th IWBP Workshop

The Objective of the 7th IWBP Workshop were fully discussed and adopted as follows:

- "I. To receive reports by countries on research on
 - a. Comparative Epidemiology Experiment
 - b. Phytosanitation and Disease Gradient Experiments
 - c. Chemical Control

- II. To receive report on activities of Data Management and Monograph Committee on
 - a. Data Management
 - b. Comparative Analysis
 - c. Monograph Progress
- III. To discuss WB disease management
- IV. To consider and decide on future plans for IWBP
 - a. Workplan and timetable for IWBP, 1990/1991
 - b. 7th IWBP Workshop
- V. To discuss other topics such as:
 - a. Witches' Broom in Bahia
 - b. Spread of Witches' Broom
 - c. Preparation of Extension Material
 - d. Future Research
 - Epidemiology
 - Tests of Management Recommendations
 - Disease Resistance
 - Chemical Control"

2.3 The Objective of IWBP

This was restarted by Tony Lass as follows:

"TO DEVELOP AN ECONOMIC MANAGEMENT SYSTEM TO CONTROL WITCHES' BROOM DISEASE OF COCOA IN A NUMBER OF COCOA GROWING ENVIRONMENTS"

To achieve this a number of subsidiary objectives have been previously established as follows:

1. "TO STUDY SYSTEMATICALLY INFECTION DYNAMICS OF WITCHES' BROOM DISEASE RELATIVE TO TIME (BOTH SEASONS AND YEARS) WITH RESPECT TO THE CRITICAL ENVIRONMENTAL FACTORS"

[To achieve this the Comparative Epidemiology Experiment has been set up].

2. "TO EXAMINE AND EVALUATE THE REACTION OF THE PATHOGEN TO AVAILABLE SYSTEMIC, PROTECTIVE AND ERADICATIVE FUNGICIDES INCLUDING THE APPLICATION TO THE SOIL AND THE EFFECT ON BASIDIOMYCETE DEVELOPMENT OF BROOMS SPRAYED WHEN GREEN"

[To achieve this experimental guidelines have been drawn up and a number of chemicals are being studied though not always using funds from IWBP sources].

3. "TO EXAMINE INOCULUM AND/OR DISEASE GRADIENT EXPERIMENTS"

[To achieve this experimental guidelines were drawn up for the 'Inoculum/Disease Gradient Experiment'].

4. "TO EXAMINE AND EVALUATE PHYTOSANITATION PRACTICES AND THEIR IMPACT ON WITCHES' BROOM DISEASE"

[To achieve this the 'Comparative Phytosanitation Experiment' was set up].

During the operation of the first three years of IWBP and in particular the discussion at the 4th IWBP, the need to breed planting material resistant to the disease was reinforced. With this in mind, a fifth subsidiary objective has been added as follows:

5. "TO DEVELOP AN APPROPRIATE STRATEGY FOR BREEDING PLANTING MATERIAL RESISTANT TO WITCHES' BROOM DISEASE AND PREPARE A PROJECT PROPOSAL FOR SUBMISSION TO ANOTHER INTERNATIONAL DONOR AGENCY FOR CONSIDERATION FOR FUNDING"

With these objectives in mind a 'Resistance Breeding Project' was drawn up and submitted to the International Cocoa Organisation (ICCO) to consider for funding. Unfortunately, this donor was unable to respond favourably but this has not devalued the importance of the initiative. Further attempts for funding should be made in due course, but that cannot easily be during the lifetime of IWBP.

3. DISEASE MANAGEMENT

3.1 Introduction

The sessions on disease management occupied most of the first two days of the Workshop and consisted of reports by the Country Co-ordinators outlining proposals for disease management practices at each site based on data collected mainly as part of the 'Comparative Epidemiology Experiment'. For these presentations the order of countries was selected at random with sites alphabetical within countries.

It was apparent that the removal of diseased material which serves as a source of inoculum (phytosanitation) remains the key management practice, and most reports emphasized this aspect. However, in many instances, the country reports also focused on the need to set such practices in the context of managing the crop in general. Two points, particularly, were made. First, that any practices for the management of WB will involve labour and should therefore be scheduled outside the harvest period. Second, management of the architecture of trees in plantations, by maintaining or reducing their height to less than 4m, should be considered basic to a disease management strategy.

Reports from Colombia and Ecuador also considered procedures for the rehabilitation of plantations severely infected with WB and partially or wholly abandoned. In some instances some general comments were made on resistance and the use of fungicides in the management of WB.

3.2 Summary Reports of Proposed Diseased Management Practices

Brazil: Teklu Andebrhan

Recommendations for phytosanitation are the same for the three sites: Altamira, Ouro Preto and Tome Acu. All diseased tissue should be removed in August/September, followed by a second removal 2-3 months later (i.e. October/December). As to the fate of the removed brooms:

- (i) Plantations with low disease incidence, particularly in pods (e.g., Altamira): ground sources should be eliminated from the plantation.
- (ii) Plantations with high disease incidence (e.g., Ouro Preto and Tome Acu): ground sources could be left in the plantation provided brooms/pods are broken-up and covered with leaf litter.

Trinidad: T.N.Sreenivasan

The site at Santa Cruz was located in a mature assessment trial of TSH material with recordings in two contiguous blocks of TSH 919 and TSH 1188. The TSH clones were developed by Freeman and some show field resistance to WB. Of the two clones at this site, TSH 919 is the more susceptible to WB. The incidence of WB at the site is high; elsewhere the incidence is less, even on TSH 919. The use of resistance must be considered as the first approach to the management of WB and this has been followed to some extent in Trinidad. The recommendations for phytosanitation are a main removal of both vegetative and cushion brooms between March and May, with a second removal September/October. Removed brooms could be left on the ground within the plantation if they did not project above the litter layer or were not left in large piles.

Grenada: Charles Williams

One removal of brooms is recommended before the onset of the rainy season in April/May. Green brooms can also be removed in this operation. The removed brooms can be left on the ground in the plantation as they rot quickly when the rains come. The data show that ground brooms contributed only 1.7% of the total basidiocarp production over 2 years. However, it is important that excised brooms fall to the ground and do not remain caught in the canopy.

Colombia: Fabio Aranzazu

In well-managed plantations where WB is already present, the most appropriate time to remove diseased material is at the middle and end of the principal dry periods:

- (i) In Caldas, around Manizales, phytosanitary and structural pruning should be completed together between February and March.
- (ii) In Los Llanos, the recommended practice should be to execute the phytosanitary and structural pruning in February and March, but to follow-up with a secondary phytosanitary pruning in June/July.

Pruned brooms can be left in the plantation but wherever possible should not be left exposed on the ground. Leaf litter should be placed on them or allowed to accumulate over them.

In severely infected plantations which have been partially or completely abandoned there should be a comprehensive rehabilitation of the estate before phytosanitation. The initial removal of diseased material in February - March must be followed by a subsidiary inspection and removal of brooms 2 months later. The routine for well-managed estates can then be followed.

For successful disease management there is a need to limit the height of the trees to 3-4 m and the main phytosanitary prune should aim to remove 90% of the brooms if the crop is to be saved. The second prune cannot be so demanding because in terms of labour it is not worth searching for green brooms.

Chemical control could only be justified on well-managed estates, in general during the period June - August, to protect the main developing crop. Each area has to define its cocoa production cycle and determine the main harvest for targeting chemical control.

Venezuela: Humberto Reyes

The presentation on disease management was introduced by an account of the main cocoa-growing regions and the nature of the problems relevant to the management of WB.

Currently, management of WB has the following features:

- (i) the rationalisation of shade, particularly the opening-up of shaded parts of the planting;
- (ii) the provision of drainage systems to relieve saturated soils;
- (iii) two phytosanitary prunes, one in March/April, the other in September/October, in which the pruned material was taken off the plantation;
- (iv) eradication of highly susceptible trees and the planting of more resistant cocoa;
- (v) protection of pods with fungicide during the first 3 months of pod development.

Changes can be made in the light of the information gained during the IWBP, most notably in respect of phytosanitation. One removal of brooms is now recommended during March and April when shoots showing signs of WB infections can be taken off at the same time as old brooms which would begin to sporulate in the succeeding season. Brooms and Crinipellis - infected fruit can be left on the ground since this material seldom constitutes a source of inoculum.

Ecuador: Alan Maddison

First, the problems of managing WB in Ecuador were outlined. These are:

- (i) The height of existing traditional cocoa (up to 8m). This makes phytosanitation difficult and the reality is that most farmers are unlikely to do a sufficiently good removal of brooms on such trees to make the operation worthwhile. Some drastic pruning schemes may prove economic and may be adopted if the farmer can see an improvement.
- (ii) Moniliasis is a serious problem and any management scheme must deal with this disease as well as WB. There is the possibility that where moniliasis is controlled, WB could increase.

In terms of phytosanitation, the recommendation is to remove brooms in September, followed by a re-pass in November. In practice, it might be possible for farmers to do one prune given current difficulties of low yield and low prices.

Ideally, the management of WB is seen as a package of cultural practices, as follows:

- (i) formation and maintenance pruning to keep the height of the trees down;

- (ii) phytosanitation to include two removals per year, with the excised material taken out of the plantation or sprayed with agricultural oil to prevent formation of basidiocarps;
- (iii) manual pollination so that pods develop during the dry period (disease escape);
- (iv) attention to shade management, spacing and fertilisation;
- (v) in the long term, selecting trees which have good pod indices and relatively low numbers of brooms for use in breeding programmes.

3.3 Discussion on Disease Management

Each of the presentations provoked considerable discussion both on general features of WB management and on aspects related to the particular site. The following general topics received most attention:

- (i) The efficiency of the phytosanitation proposed and the data on which such appraisals were made. This led to discussions on the reasons why brooms were 'missed', e.g., latent infections, the continuing development of symptoms following infection, and new infections arising from an undefined source.
- (ii) The characteristics of the particular site and thus how far the data obtained could be extrapolated. For example, Santa Cruz in Trinidad is a site with more WB than is usual for many other plantations in the Island; the Tachira site in Venezuela has more shade than many other fields. Some of these apparent problems will be covered by the comparative analysis of the data where, for example, the Tachira site will be considered primarily as a shaded one rather than a site in Venezuela. However, in other instances some site features remain to be explained, like the incidence of WB at Santa Cruz and low levels of pod loss in Grenada where pods in a susceptible phase coincide with the production of basidiocarps.
- (iii) The effects of more drastic pruning, advocated in some countries for the rehabilitation of plantations, on subsequent yield. It was generally accepted that more data are required on this aspect.

The discussion was widened further when, in a subsequent session, a draft of the "Disease Management" chapter in the Monograph (previously circulated to the Workshop participants) was reviewed by Stephen Rudgard. The main topics discussed here in relation to the recommendations made were:

- (i) The need in writing about general crop management to distinguish between achieving a height of 4m in young trees by maintenance pruning and reducing height of established trees.

- (ii) The sections on feasibility of sanitation, techniques for removal and efficiency of removal, within which alternative forms of words were proposed for some sentences.
- (iii) The need to define 'low' and 'high' disease incidence within the section dealing with the fate of removed brooms and diseased pods and to re-draft item b.
- (iv) The use of terms such as 'dormant period', 'induction period' within this chapter and the Monograph in general. It was agreed that consistency in the use of terms was a matter for the Editors.
- (v) The detailed comments on phytosanitation schedules, country by country. These were generally approved, but it was felt that the Table relating to timing was misleading and needed to be revised.
- (vi) The need to modify the Table in the section on effects of surrounding cocoa on sanitation.
- (vii) The possibility of indicating in the Rehabilitation section the limiting effects of the various treatments of yield.

It was left to the authors of the chapter to revise the draft in the light of these discussions.

4. COMPARATIVE EPIDEMIOLOGY

4.1 Introduction

This session was based on a paper outlining a chapter in the Monograph entitled, "Comparative Epidemiology of the Witches' Broom Pathosystem". This was prepared by Bob Schmidt and circulated to the Workshop participants. In introducing and speaking to this paper he highlighted what such a study might hope to achieve and what were its limitations. Hopefully, the collective data would enable confirmation of conclusions from individual sites and further conclusions to be drawn. Basically, in relation to WB this comparison would attempt to answer the questions - what was happening, where was it happening and when was it happening? The data were not particularly useful for determining causal effects. Also, it had to be accepted that there was considerable variability in the data sets because these were derived from 9 sites over 2 years. For example, over the sites the age of the trees ranged from 6-7 years to 30 years and their height from 3.1 to 7.5m; some plantings were clonal material, others hybrids of different types; shade varied from virtually none to 500 shade trees per hectare. Weather conditions varied in the 2 years and there was a certain amount of experimental error attributable to different interpretations by the field workers of the turgidity of basidiocarps and age of brooms. There were also problems of data expression such as the ways of calculating diseased pods.

4.2 Summary Presentation of Data

The progress made so far in assembling the data for a comparative epidemiology study was indicated by a series of tables and figures under three headings, as follows:

- (i) Climate. Climograms, based on long-term averages; rainfall data, including the frequency of months receiving a certain amount of rain.
- (ii) Basidiocarp production. Mean number of open basidiocarps produced on each source at each site; relative number produced at each site; relative number per source; initiation and duration of basidiocarp production per site; production in relation to broom age; basidiocarp production in 'dry weeks' and meteorological data collected during a 12-wk period of abundant basidiocarp production.
- (iii) Susceptible host tissue. Periodicity and relative amount of susceptible tissue at the sites; total number of vegetative symptoms of different types; total number of symptom types on flower cushions.

Further analyses of the data for comparative purposes were in progress. These included time series analysis, which so far had indicated some trends but none common to all data.

Analyses appropriate to disease dynamics such as the interaction between basidiocarps, susceptible tissue and disease development had only just been started.

4.3 Interim Conclusions

A summary of the main features of the data was presented, based on the analyses completed so far. It was emphasized that these could only be considered to be preliminary conclusions and should be treated as such until further analyses had been completed.

These interim conclusions were as follows:

- (i) Climate. The seasonality and amount of rain (or lack of rain) were the distinguishing climate variables among sites and years. Temperature did not differ greatly among sites and its range was usually (perhaps always) favourable for disease development. Despite the considerable variability among sites and years, the weather during the 'Comparative Epidemiology Experiment' was generally typical.
- (ii) Basidiocarp production. Conclusions here must be made with particular caution bearing in mind the relatively small samples of diseased material which were used and the variability of such material from site to site.

With this proviso, statements about basidiocarps can be placed in 4 groups:

Amount produced. Sources at some sites produced 4-5 times (even 10 times) the number of basidiocarps produced at other sites. Large quantities of basidiocarps were produced at many sites, averaging overall more than 0.5 basidiocarps/object/week. Year to year variability was great; production in some sites increased in the second year while on others it decreased.

Sources. Overall, vegetative brooms suspended in the tree crowns (regardless of height), produced the greatest number of basidiocarps (0.29 basidiocarps/object/week), equal to that of all other sources. Flower cushions were the second and pods the third ranking source. New brooms sporulated more frequently than old brooms or brooms collected when they were green but beginning to wilt (green brooms) and more basidiocarps were produced on old brooms compared to new brooms or green brooms. Suspended vegetative brooms were twice as productive as pruned vegetative brooms left on the ground. Overall, ground sources supplied only about one-quarter of the total production and there is subjective evidence that when these sources are covered with plant material their productivity is reduced. Collectively, the data indicated that in a given site or year any of the diseased material could be an important source of basidiocarps.

Periodicity. The duration of basidiocarp production ranged from about 49 weeks (in Manizales where rain occurs throughout the year), to a minimum of 16 weeks in a site with a prolonged, very dry period. Overall, basidiocarps were formed in 4-6 months in sites with dry periods. On average, basidiocarps were produced for 22 weeks on suspended brooms, but only for 5-6 weeks on ground brooms which were the most ephemeral source. Old brooms were the first to sporulate each year, requiring 6-9 weeks following rain; new brooms required 16 weeks and green brooms required 22 weeks. New brooms sporulated for an average 18 weeks.

Role of rain. Duration and amount of sporulation were positively associated with the length of the wet season and negatively associated with the length and dryness of the dry season. The period of abundant basidiocarp production was typified by abundant and frequent rain, and long daily periods of high relative humidity and plant surface wetness. Abundant basidiocarps were observed as early as 6 weeks (average 9 weeks), following the beginning of the rainy period. Days with dry afternoons followed by early morning rains were favourable for the appearance of turgid basidiocarps. In sites with well-defined dry periods few, if any, basidiocarps were observed during the dry weeks or in dry weeks even during the wet period. Attempts to develop an acceptable 'climate-driven' model for basidiocarp production from these field data were not successful. Basidiocarp production is probably a function of substrate moisture which, in turn, is influenced by many interacting factors.

- (iii) Susceptible host tissue. The conclusions can be grouped in three sections:

Vegetative. Plantations had 3-7 major vegetative flushes per year. Several sites exhibited some flushing each week, other sites had periods of 12-13 weeks without significant production of susceptible vegetative, at least in the marked areas. There was a 10-fold difference in amount of vegetative flushing among sites and years. Older trees flushed less than younger trees and shaded trees less than unshaded ones. Attempts to produce an adequate model to predict vegetative flushing were not successful.

Flower cushion. Flower cushion activity at most sites peaked once a year, although at some sites activity peaked three times in 2 years or twice each year. Whatever the pattern, there were susceptible cushions (flowers or cherelles) throughout the year. The amount of cushion activity varied 10-fold among sites and years and appeared to be inversely related to tree age.

Fruit. Either one or two periods of pod production (harvests), occurred about equally among sites. Several sites had two peaks of pod production despite having only one major period of flower cushion activity. Some sites had susceptible pods throughout the year although other sites had periods of 6-14 weeks with no, or very little, production.

- (iv) Symptom types. Terminal and axillary brooms were the most frequent vegetative symptoms, but swellings on petioles and stems were common at many sites. Also, there were differences among sites in the relative frequencies of symptoms arising from bud and non-bud infections. Infected flowers were the most frequent of the cushion symptoms, although brooms and chirimoyas were also common. Pods with WB symptoms occurred at all heights sampled but were relatively more frequent in the lower portion of the tree. There were pods infected by *Phytophthora* at all sites and pods infected by *Moniliophthora* at some sites. The presence of these other pathogens complicated the identification of pods with symptoms of WB.

4.4 Discussion on Comparative Epidemiology

Most of the discussion focussed on the form of words in the list of conclusions in the paper circulated. It was accepted that some amendments would be made in the light of these discussions.

5. COMPARATIVE PHYTOSANITATION

5.1 Introduction

Presentations within this session were made by Alan Maddison. He introduced the topic by reminding participants of the objectives of the 'Comparative Phytosanitation Experiment' and its design (Report of the 4th Workshop of IWBP,

p26, 11-17 September 1987, Belem, Brazil). He then reviewed the data obtained from the following sites: Altamira and Ouro Preto (Brazil); Guamal (Los Llanos) and Montelindo (Manizales) in Colombia; Balao Chico and Palma Chavez (Ecuador) and Tachira (Venezuela).

5.2 Summary of Results and Conclusions

I. Disease Reduction

1. Phytosanitation reduced disease considerably in most sites. Even when the rows in Area B which were close to Area A were included in the mean for B, appreciable reductions were observed in pod loss, generally to less than half of former values, except in Ecuador where the benefit of sanitation on per cent WB was less, perhaps because of the high inoculum levels in the absence of sanitary pruning. Broom numbers also decreased in most sites, but the changes were less consistent than with pods.

2. In addition to reducing the loss of pods to WB, sanitation was followed by an increase in pod production of at least 15 per cent in most sites, and up to 50 per cent in some. This could have been helped by the accompanying maintenance prune in some sites, but sites where just the removal was carried out also showed the effect. The increase was usually reflected in increased dry cocoa.

3. Sanitation of the whole site in the Palma Chavez plantation in Pichilingue after two years within Area A resulted in a further reduction in broom numbers throughout the plot, to levels that were less than a quarter of former values, but still about 40 brooms/tree. Percentage pod losses did not fall so dramatically, and even after an exhaustive sanitation which was more than 99 per cent efficient in removing vegetative and cushion brooms from the entire site, (250 m from other cocoa), pod loss to WB was 8 per cent compared to about 14 per cent before sanitation.

II. Disease Gradients

4. The gradients recorded are not the only possibilities for the sites. They could be somewhat different for example, if measured again under different weather conditions and this should be borne in mind if there is any intention to extrapolate.

5. Most sites had some gradients ("environmental") in pod production and disease incidence before pruning was started; in certain sites e.g., Ecuador, they were very marked.

6. A wide range of gradients was encountered, from steep negative exponential curves in Altamira, Brazil to horizontal curves in Balao Chico, Ecuador. In the calibration year in Altamira, per cent WB fruit fell from about 25 per cent in Area A to 20 per cent at 100 m, while after brooms were removed from Area B, the corresponding figures were 16 per cent and

3 per cent. The slope b of the negative exponential curve was -0.012 in the second year, against -0.003 in the first, with intercepts of 14.0 and 26.6 respectively.

7. Vegetative and cushion infections showed steeper gradients than infections on fruits. Thus, sometimes there were reductions in vegetative and cushion infections, but not in pod infection. This may reflect the longer period of exposure to inoculum faced by pods compared to individual shoots and flower cushions.

8. On theoretical grounds, the larger the area of diseased cocoa, the larger the amount of inoculum generated, and the greater the contribution to local and background inoculum. This could explain in part why the Balao Chico site, with more than 40 ha of contiguous cocoa, showed virtually no decrease in disease incidence up to 120 m from Area A, while in Altamira with a "source" area of only 0.15 ha, an exponential decrease was observed. Repeated movement of clouds of spores over and through Area B would account for the uniform infection relative to the calibration year in Balao Chico.

9. The moderately isolated (250 m) Palma Chavez site in Pichilingue had a smaller source area than Altamira, but a several times higher broom load. Broom incidence in this plot decreased away from the source, but losses to pods in Area B were very similar throughout the 64 m.

10. Altamira and Ouro Preto had a similar source area and degree of isolation, but different gradients were obtained. In Ouro Preto pod infection decreased somewhat close to the source, but then remained more or less the same at about 25 per cent up to 100 m; the exponential decrease did not continue. Infection was generally higher in Ouro Preto, and the Comparative Epidemiology Experiment showed other differences in disease development in the two sites.

11. Even in a light disease year, the application of copper fungicide every two weeks to half of Area B in Balao Chico as a complementary treatment to the sanitation, did not reduce pod disease except at considerable distances from Area A. This suggests that it was indeed inoculum coming from Area A and beyond that was responsible for the bulk of the infection, rather than the few missed brooms within Area B.

12. The situation for Tachira, Venezuela is complicated by the fact that because of certain logistical problems, the initial pruning was not done soon enough, and this resulted in failure to control infection on the main pod harvest, which suffered an 80 per cent loss uniformly through the site. Set against the fact that the owner of the farm had been managing WB adequately through pruning before the site was taken over, this graphically demonstrates the importance of timing in sanitation.

13. At both sites in Colombia, brooms were removed from nearly a half of the trees in Area B right at the beginning of the study, hence there was no calibration period which was equivalent to those in other sites, and interpretation regarding gradients is difficult. The results do show clearly, however, that broom incidence increased rapidly in Area A, relative to Area B, when pruning was suspended in A.

III. Interplot Interference

14. The results show that trials of management practices which leave differing amounts of infected material in the trees or on the ground will be affected by interplot interference, unless they have large guard areas. They may also be swamped by inoculum from adjacent or nearby cocoa if it is unpruned. This is especially true in regions with large areas of contiguous abandoned, or unpruned, cocoa.

15. The decision on guard rows is a balance between practicality and accuracy. If the guard rows are too small it is likely that any successful treatments will be undervalued, or their usefulness missed completely.

6. DEVELOPMENT OF RECOMMENDATIONS FOR CONTROL AND INVESTIGATIONS IN CASES OF NEW OUTBREAKS OF THE DISEASE

There were two first-hand reports of new outbreaks of WB.

St Vincent: T.N.Sreenivasan

A report to the Cocoa Research Unit in Trinidad of an outbreak of WB in St Vincent prompted a visit to the island by Dr Sreenivasan. Some disease was observed on cocoa on both sides of the island. Most WB occurred on the eastern side and there were indications that it had been present perhaps as long as 4-5 years. The plantings were all of ICS clones which had originated from Trinidad but there was no WB on the original farm where the clones were introduced. Most farms on the eastern side of the island were now abandoned. The distribution of the disease on the windward side of the island rather than near the landing area suggested that its spread might have been natural, following the line of islands Trinidad - Tobago - Grenada - St Vincent. On the Western side there was less WB and outbreaks were isolated. The interest in cocoa on this side is mainly related to water conservation and some phytosanitation is practised.

Bahia: Herminio Maia Rocha

A paper was presented (written with Ricardo Bohrer Sgrillo and Roberto A. Setubal), summarizing events from May 1989 when 12 ha of an old commercial plantation in the county of Urucuá were found with a range of disease symptoms.

In an attempt to eradicate this outbreak, the cocoa trees and the forest cover were eliminated not only in the focus area but in a surrounding 'safety belt', 350 m wide, corresponding to a total of 149 ha cleaned, cut and burned.

In October 1989 another 20 infected trees were found near the first focus and, subsequently, several foci were found in the county of Camaca, 120 km from Urucuca. At present the disease has been found on 577 farms located in 16 countries, with over 234,000 infected trees scattered in about 20,000 ha.

CEPLAC is promoting a sanitation programme through the training of farm managers and labourers at different localities in the region. This training has reached 55,000 people so far.

Meanwhile, a vigorous research programme is being implemented consisting of 8 projects and 23 experiments covering different aspects of the biology of *Crinipellis pernicioso*, epidemiology of the disease, chemical, biological and cultural control, plant resistance, disease management at farm level, and the social and economic consequences of the disease in Bahia.

7. PHENOLOGY OF COCOA AT THE IWBP SITES IN RELATION TO WEATHER CONDITIONS

Summarised data for flushing in relation to temperature and rainfall were presented by Paulo Alvim for the following sites: Itabuna (1987/89); Tome Acu (1985/87); Altamira (1985/87); Ouro Preto (1986/88); Santa Cruz, Trinidad; Pichilingue Station; Pichilingue Farm; Llanos (1986/88) and Grenada (1985/87). Within these data there did not appear to be much relationship between flushing and temperature but flushing was associated with a drop in rainfall so that, at least in some instances, there was a good correlation between flushing and dry weeks.

One hypothesis is that flushing results from the stress imposed by the drier conditions. Stress reduces the amount of abscissic acid and this affects the 'readiness' of the bud to burst. Stress thus influences differentiation and the subsequent rain stimulates growth of the flush.

Comparable data were also presented to indicate relationship between flowering and weather conditions. Flowering was also very sensitive to rain, especially to any rain which fell during a 'dry' period. However, at some sites there were significant relationships between temperature and flowering, for example at Itabuna (Brazil) and Santa Cruz (Trinidad). Further studies at Itabuna on the relationship between growth of the trunk and flowering also indicated that if there was no trunk growth (i.e. no cambial activity), there was no flowering.

The presentation elicited a lively discussion on how this information might be used in disease management and whether clones differed in their flushing behaviour in terms of response to stress factors or simply in the amount of flushing at these times.

8. PREPARATION OF IWBP MONOGRAPH

The following drafts were distributed during the 7th IWBP Workshop:

Part I

- Chapter 2 The Pathosystem (Wheeler & Suarez)

Part II

- Chapter 4 Comparative Epidemiology Studies: Introduction
(Rudgard, Andebrhan, Maddison & Schmidt)
- Chapter 5 Comparative Epidemiology Experiment: Brazil
(Andebrhan *et al.*)
- Chapter 6 Comparative Epidemiology Study: Colombia - Caldas and
Llanos Orientales (Aranzazu & Buritica)
- Chapter 7 Comparative Epidemiology Study: Ecuador
(Maddison, Macias, Moreira & Aragundi)
- Chapter 8 Comparative Epidemiology Study: Grenada
(Williams & James)
- Chapter 9 Comparative Epidemiology Study: Trinidad - Santa Cruz
(Mohan & Sreenivasan)
- Chapter 10 Comparative Epidemiology Study: Venezuela - El Pinal
(Silva-Acuna, Reyes & Colmenares)

Part IV

- Chapter 14 Disease Management
(Rudgard, Andebrhan, Maddison & Schmidt)

The contents of Chapter 14 were discussed at length during the Workshop and there was broad agreement on the contents of the other chapters which had been circulated. It was also suggested that the material presented by Paulo Alvim should be included in the Monograph as well as material indicating what to do about new outbreaks in WB.

It has already been agreed that a Spanish version of the Monograph would be prepared using the English text as the standard. This would mean that chapters written originally in Spanish would have to be edited in an English version and then re-translated back to Spanish to ensure uniformity.

Paulo Alvim agreed to get a camera-ready copy prepared of a Portuguese version and M & M Mars offered to pay the costs of preparing this copy. This offer was gratefully accepted by the Workshop participants.

It was also suggested that a copy of the publication describing symptoms of WB which had been prepared under the aegis of the IWBP might be included with each copy of the Monograph. The feasibility of doing this would be examined.

9. RESEARCH ACTIVITIES ASSOCIATED WITH IWBP

A session on extension needs elicited the following comments from the Country Co-ordinators:

Brazil: Teklu Andebrhan

Ideally some funds should be set aside from the IWBP programme to enable the co-ordinator to report the results obtained and the implication of these on disease management to all CEPLAC extension staff in the Amazon. Such a meeting would identify specific extension needs related to disease management. However, it is already apparent that in new areas where cocoa cultivation is expanding (such as the southern state of Para and the state of Acre) there is a need to prepare extension and media material to show farmers:

1. How to identify symptoms of infection at an early stage
2. How/when to remove brooms
3. How/when to do structural pruning on young plantations (trees 1-6 years old)

When cocoa prices get better there will then be a need for a strong media campaign to show farmers how to rehabilitate those farms which have been abandoned for some years (young and old trees) and to give advice on the general management of trees after control of the disease.

There might also be a need for some money to help publicise the results of the IWBP project to farmers in Bahia.

Colombia: Fabio Aranzazu

Some of the changes to disease management practices which the IWBP has indicated have not yet been implemented in Colombia. These practices and those associated with the rehabilitation of abandoned plantations need to be demonstrated through the use of sample plots under the supervision of extension agents. Such programmes aimed at the transfer of technology are already in place but there is a need for some assistance with these programmes in terms of material and funds channelled through agencies in Colombia.

Ecuador: Alan Maddison

WB has produced data that is required to help the extension worker understand the disease and the possibilities to manage it, but the information needs to be presented appropriately. There is a general need for education about the disease

at all levels, from government down to the farmer. The educational and training material could cover, for example, the recognition of the various sources of inoculum and their relative importance, pruning and tree height, gradients etc.

The requirement is for courses, videos, pamphlets, posters, and a campaign (possibly through newspapers) to make known the need to pay attention to the management of cocoa to increase yield as a necessary prerequisite to disease control.

There is also a need for material giving specific recommendations for the management of WB in certain types of cocoa using language appropriate for farmers.

Grenada: Charles Williams

Trinidad: T.N.Sreenivasan

Videos showing the dangers of not controlling WB should be made available for showing on TV in those countries

Venezuela: Humberto Reyes

Plenty of information has come out of IWBP which is relevant to control practices. IWBP could help with audio-visual material for an awareness campaign for farmers in the various geographical zones which would encourage them to use productively their different abilities and resources for dealing with cocoa and WB.

10. FUTURE RESEARCH ON WITCHES' BROOM DISEASE OF COCOA

The need for identification of resistant cultivars and their incorporation into cocoa breeding programmes in a number of locations was highlighted on a number of occasions, both at this 7th IWBP Workshop and on previous occasions. In the light of this a number of scientists involved in IWBP had gathered together in Florida in 1990 to debate this question and make firm proposals. These proposals were then submitted to the International Cocoa Organisation (ICCO, 22 Berners Street, London, W1P 3DB) for consideration for funding. Unfortunately, that body was unable to allocate the necessary resources at that time, but the need remains. With this in mind this project proposal is included as Appendix F to this report.

The need remains and so it is to be hoped that a suitable funding source could be shortly identified to support this proposal and offer adequate long-term funding.

11. ACKNOWLEDGEMENTS

IOCCC would like to record their appreciation to all the scientists who have so willingly participated in this collaborative project with such enthusiasm and commitment. Without their results and participation with such responsibility we would have achieved nothing.

The progress of the debate in this Workshop was advanced enormously by the pithy summaries of our Rapporteur - Bryan Wheeler. We, once again, owe him a great debt of gratitude. The organisational support was provided by Michelle Thomas who together with Tony Lass are staff members of Cadbury Ltd. The contribution made by Cadbury Ltd to the smooth conduct of IWBP has been substantial. Our thanks are also due to Mary Gore-Booth for her patient interpretation of our animated debates during the long hours of the Workshop.

**APPENDIX A : NAMES, ADDRESSES, TELEPHONE, TELEX AND
TELEFAX NUMBERS OF PARTICIPANTS IN 7TH
IWBP WORKSHOP**

[N.B National dialling codes included in telephone numbers wherever possible]

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**APPENDIX B : PROGRAMME FOR 7TH IWBP WORKSHOP 11TH -
17TH APRIL 1991 AT THE UNIVERSITY OF WARWICK
CONFERENCE CENTRE, UK**

Thursday 11th April 1991

- | | |
|------|--|
| AM | Arrival of overseas participants in UK (Heathrow, London) |
| 3.00 | Lunch |
| PM | Acclimatisation/recuperation |
| 8.00 | Welcome cocktail/registration (hosted by IWBP) |
| 9.30 | Dinner |
| | Informal Discussion on Texts of chapters for IWBP
Monograph |

Friday 12th April 1991

- | | |
|---------------|---|
| 8.00 | Breakfast |
| 9.00 - 10.30 | SESSION I - Administration Matters <ul style="list-style-type: none">- Welcome by Representative of IOCCC (Tony Lass on behalf of IOCCC President)- Welcome by Chairman of Project Management Committee (L.H.Purdy)- Adoption of Objectives for 7th IWBP Workshop- Adoption of Programme for 7th IWBP Workshop- Appointment of Rapporteur (B.E.J.Wheeler was nominated)- Appointment of Joint Moderators for 7th IWBP Workshop (R.A.Lass and L.H.Purdy were nominated)- Presentation of Texts of completed Chapters for IWBP Monograph - S.A.Rudgard and A.C.Maddison |
| 10.30 - 10.45 | Coffee Break |
| 10.45 - 11.45 | SESSION II * <ul style="list-style-type: none">- Presentation of Proposed Disease Management Practices with supporting data at Altamira Site by T.Andebrhan - country co-ordinator)- Discussion of Proposals for Disease Management at Altamira Site- Agree recommendations for Disease Management Practices at Altamira Site (Moderator : R.A.Lass) |

Order of countries selected at random; sites alphabetical in countries;

- 11.45 - 12.15 SESSION III
- Disease Management at Ouro Preto Site
Presentation by T. Andebrhan
 - Rest as per Session II
- 12.30 - 13.30 Lunch
- 13.30 - 15.30 SESSION III (concluded)
- SESSION IV
- Disease Management at Tome-Acu Site
Presentation by T. Andebrhan
 - Rest as per Session II
- 15.30 - 15.45 Coffee Break
- 15.45 - 17.15 SESSION V
- Disease Management at Santa Cruz Site
Presentation by T. N. Sreenivasan - country co-ordinator
 - Rest as per Session II
- SESSION VI
- Disease Management at Boulogne Site, Grenada
Presentation by S. A. Rudgard or by co-ordinator
 - Rest as per Session II
- 19.30 Dinner
No evening Session

Saturday 13th April 1991

- 08.00 Breakfast
- 09.00 - 10.30 SESSION VI (concluded)
- SESSION VII
- Disease Management at Manizales Site
Presentation by F. Aranzazu - country co-ordinator
 - Rest as per Session II
- 10.30 - 10.45 Coffee Break
- 10.45 - 12.15 SESSION VIII
- Disease Management at Llanos Site
Presentation by F. Aranzazu - country co-ordinator
 - Rest as per Session II

SESSION IX

- Disease Management at Tachira Site
Presentation by R.S.Acuna - country co-ordinator
- Rest as per Session II

2.30 - 13.30 Lunch

4.00 - 15.30 SESSION IX (concluded)

SESSION X

- Disease Management at Pichilingue Farm Site
Presentation by A.C.Maddison - country co-ordinator
- Rest as per Session II

5.30 - 15.45 Coffee Break

5.45 - 17.15 SESSION XI

- Disease Management at Pichilingue Station Site
Presentation by A.C.Maddison - country co-ordinator
- Rest as per Session II

9.30 Dinner

10.30 Meeting of Data Management and Monograph Committee

Sunday 14th April 1991

8.00 Breakfast

9.00 - 10.30 SESSION XII

Comparative Epidemiology Study
Presentation by R.A.Schmidt

10.30 - 10.45 Coffee Break

10.45 - 12.15 SESSION XII (concluded)

12.30 - 13.30 Lunch

14.00 - 15.30 SESSION XIII

Comparative Phytosanitation Study
Presentation by A.C.Maddison

15.30 - 15.45 Coffee Break

15.45 - 17.15 SESSION XIII (concluded)

19.30 Dinner

Monday 15th April 1991

08.00	Breakfast
08.30	Departure for Visit to Cadbury Ltd Factory, Bournville and Cadbury World
12.45	Lunch at Bournville At Leisure in Stratford-on-Avon
18.00	Arrival back at Warwick University
19.00	Dinner at Warwick Arts Centre, Hosted by Cadbury Ltd

Tuesday 16th April 1991

08.00	Breakfast
09.00 - 10.30	SESSION XIV Adoption of combined Disease Management Recommendations (as agreed in Session II to XIII) (Moderator : S.A.Rudgard)
10.30 - 10.45	Coffee Break
10.45 - 12.15	SESSION XIV (concluded)
12.30 - 13.30	Lunch
14.00 - 15.30	SESSION XV - Development of recommendations for control and investigations in cases of new outbreaks of the disease - Topics for further study (Moderator : L.H.Purdy)
15.30 - 15.45	Coffee Break
15.45 - 17.15	SESSION XVI Broad agreement on Chapter Contents of IWBP Monograph (Moderator : R.A.Lass)
17.15 - 18.45	Meeting of Project Scientific Committee
19.00	Dinner
20.00	Meeting of Project Scientific Committee

Wednesday 17th April 1991

- 8.00 Breakfast
- 9.00 - 10.30 SESSION XVII
- Preparation of Extension Recommendations and Media Material with estimates of Financial Costs
- (Moderator : R.A.Lass)
- 10.30 - 10.45 Coffee Break
- 10.45 - 12.15 SESSION XVIII
- Presentation on Research Activities Associated with IWBP
- Future Research needs on Witches' Broom disease of cocoa
- 12.15 Closure of 7th IWBP Workshop
- 12.30 - 13.30 Lunch
- 14.00 - 15.30 Meeting of the Project Management Committee
- 15.30 - 15.45 Coffee Break
- 15.45 - 17.15 Meeting of the Project Management Committee
- 19.30 Dinner for Workshop Participants, members of the Project Management Committee and invited guests who will be participating in the Open Forum the next day
- Hosted by BCCCA at Warwick University

Thursday 18th April 1991

OPEN FORUM ON WITCHES' BROOM DISEASE
(see Appendix C)

Friday 19th April 1991

- 8.00 Departure from Warwick University by coach
- 10.15 Arrival at Reading University, Department of Horticulture
- 10.30 Introduction by R.A.Lass (member of BCCCA Cocoa Research Committee)
- 10.45 Presentation by E.T.Beauchamp on BCCCA Cocoa Research Programme
- 11.15 Presentation by Dr Paul Hadley on Cocoa Research Work at Reading University

- 11.45 Demonstration of International Cocoa Germplasm Database
by Dr Michelle End
- 12.30 Presentation by B.E.J. Wheeler on Witches' Broom Research
at Imperial College, Silwood Park
- 13.00 - 14.00 Lunch in Senior Common Room
- 14.30 Visit to Cocoa Quarantine Facility at Shinfield Grange
- +/- 16.00 Departure for Heathrow Airport by coach
- +/- 17.00 Arrival at Heathrow drop at Terminals or at Ibis Hotel for
those flying out on 20th April

Saturday 20th April 1991

Departure for home

APPENDIX C : PROGRAMME OF OPEN FORUM ON INTERNATIONAL WITCHES' BROOM PROJECT

09.00 - 09.05	Welcome	President, IOCCC
09.05 - 09.20	Why IWBP?	B.E.J. Wheeler
09.20 - 09.35	Introduction to IWBP	R.A.Lass, Executive Chairman, IWBP
09.35 - 09.50	Rationale & Structure for Experimental Programme of IWBP	Monograph Editors
09.50 - 10.15	Results of Comparative Studies of Witches' Broom	Monograph Editors
10.15 - 10.30	Interpretation of IWBP data in terms of disease management	Monograph Editors
10.30 - 10.45	Coffee Break	
10.45 - 12.15	Open Discussion	
12.30 - 14.00	Lunch	
14.00 - 14.30	Witches' Broom in Bahia: A New Outbreak	H.Maia Rocha
14.30 - 15.30	The Future Where to now? a. Brazil b. Colombia c. Ecuador d. Grenada e. Trinidad f. Venezuela	T.Andebrhan F.Aranzazu C.Suarez C.A.Williams T.N.Sreenivasan R.S.Acuna
15.30 - 15.45	Tea Break	
15.45 - 16.45	Discussions	
	(a) Prospects for Resistance Breeding against WB	(Led by L.H.Purdy)
	(b) Prospects for Chemical control of WB	(Led by S.A.Rudgard)
	(c) Prospects for any other control methods	(Led by ?)
15.45 - 17.00	Conclusions	
17.00	Closure of 'Open Forum' and of IWBP	

APPENDIX D : REPORT ON OPEN FORUM ON WITCHES' BROOM DISEASE

Welcome

This was held on 18th April 1991 at Warwick University at the end of the 7th IWBP Workshop. The programme for the Open Forum is attached (Appendix C) together with a list of those attending (Appendix E). The Forum was opened by the President of IOCC, Dr Hermann Flotzinger, who referred to IWBP as a splendid example of co-operative scientific effort which would have benefits of itself quite apart from the contribution towards management of Witches' Broom disease.

Why IWBP?

The origins of the project were described by Dr B.E.J. Wheeler, who referred to the distribution of the disease, its effect on the cocoa tree and the challenges which it posed.

Introduction

The project itself was then introduced by R.A. Lass (Executive Chairman, IWBP) who described its origin and the objective to develop an economic management system for control of Witches' Broom disease in a number of cocoa environments. The possibility of spread of the disease beyond South America had always been in mind and it was an unfortunate fact that it had now appeared in Bahia. The possibility of this spread had been a principal motive for the original formation of IWBP.

Rationale and Structure for Experimental Programme

Dr S.A. Rudgard (Project Liaison Officer) outlined the experimental programme agreed by the 1st Workshop and said that 10 megabytes of data had been collected. The aim was to gain an understanding of the pathosystem by standardising data collection and conducting experiments in comparative epidemiology in a number of different sites and regions.

Comparative Phytosanitation Study

Dr A.C. Maddison reported on the phytosanitation studies, which had involved removal of disease tissue in the hope of breaking the disease cycle. Varying technical success had been achieved, depending apparently on three factors:

- (i) the critical timing of pruning;
- (ii) the efficiency of pruning;
- (iii) the ingress of inoculum from outside.

Comparative Epidemiology Results

Dr Rudgard said that six meetings of the Data Management and Monograph Committee had been held and data from each of the sites had been collected over at least two calendar years. Each site showed differences in the trees and in climate and it could be shown that the timing of rainfall events and the intensity of rainfall events in influencing the progress of the disease were crucial factors in its development. It was also possible to compare disease indices in the various sites and make predictions about efficacy of management practices.

Phytosanitation Results

Dr Maddison reported that the work had shown a degree of reduction in the disease after rigorous sanitation, involving removal of brooms and some opening of the canopy. In Ouro Preto, Rondonia, this had demonstrated an increase in production, but in Ecuador little difference had been found, ie. there had been no fall in the proportion of infection in a year with higher rainfall, though when rainfall was lower than average an appreciable difference had been found. Thus a wide range of responses to phytosanitation treatment had been demonstrated.

It had also been found that the incidence of vegetative and cushion brooms decreased with increasing distance from the source. Thus, infection gradients for Witches' Broom had been established for the first time. However, such gradients showed differences from site to site and there was clearly also a "neighbour" effect.

In general, it was found that rigorous sanitation would give a measure of control, except under the following circumstances:

- (i) when the trees were too tall for efficient removal of brooms;
- (ii) when the trees concerned formed a small plantation among untreated cocoa;
- (iii) when the planting material was too susceptible for appropriate treatment;
- (iv) when the timing of sanitation was inappropriate;

It is also obvious that careful phytosanitary pruning will not be carried out by growers when the cocoa price was too low to make phytosanitation economic.

Recommendations arising from 7th IWBP Workshop

The workshop discussed the topics below and conclusions were formulated. A text was drafted and agreed in principal and will be included in the IWBP Monograph in preparation. Only the headings were presented to the Forum in note form.

These are as below:

1. *General Crop Management*

Tree height
Harvest period
Shade

2. *Phytosanitation*

Feasibility
Unmanaged (Old/Tall trees)
Managed
Effects of surrounding cocoa

Techniques
Removal and fate of brooms
Efficiency of removal
Other pod diseases
Production effects

Timing (according to climate)
Primary
Secondary

3. *Rehabilitation*

Semi abandoned
Structural pruning
Structural/height pruning

Abandoned
Canopy removal (pollarding)
Chupon regeneration
Turrialba method

Timing
Removal of material
Effects on production

Discussions

In the ensuing general discussion, the following points were made:

1. The level of shade has some effect on basidiocarp production since there is less flushing under shade and therefore less infection risk.

The possibility of using guard trees as barrier might be considered but no work on this has been done as far as was known.

Brooms left uncovered on the ground tended to show greater wetting/drying and therefore a greater production of basidiocarps. Brooms should therefore either be removed from the plantation or covered by litter.

Brooms in the canopy with low water content tended to show greater production of basidiocarps. With brooms on the ground, the water content tended to be higher, leading to a predominance of other (saprophytic) fungi.

With careful pruning, WB in an isolated plot could be reduced to less than 20% pod loss. However, the economics of careful pruning were such that, (for example in Brazil) thorough pruning might take 21 man-days per hectare, a higher level of infection up to 40 man-days per hectare and the highest level of infection might make pruning uneconomic. In Colombia a very high level of infection (for example in an abandoned farm) might take 50-60 man-days per hectare for appropriate pruning.

The possibility of mycorrhiza acting as natural protectants seemed worthy of study but no information was available in the literature.

Pruning would have other beneficial effects but also drawbacks. The control of Witches' Broom would render more pods susceptible to attack by *Moniliophthora*, but equally control of *Moniliophthora* would be aided by the removal of diseased pods.

The break-even point for control of Witches' Broom by phytosanitation would be determined by the market price of cocoa compared with the rate of pay per day for field workers. At present prices, pruning would be uneconomic except where disease incidence was low.

Witches' Broom in Bahia - A New Outbreak

Reporting on the Bahia outbreak, Dr H.M. Rocha said that 85% of Brazilian cocoa was produced in Bahia and strict quarantine had been enforced to keep WB out of the state. In May 1989, however, the disease had been found in an old commercial plantation of 12 hectares in Urucua. An attempt had been made to eradicate the disease by cutting a 350m wide safety belt around the cocoa and 350 hectares had been cut and burnt. Sixty days later, however, another infection focus with 20 infected trees had been found nearby and one month later several points of infection had been found in the Camacan area. Later, further infection sites had been found in a wider area, and since the disease was found in different stages it was assumed that Camacan had been the initial infection point. The spread of the disease had been from south to north in the direction of the prevailing wind.

By March 1991, 13 million plants had been inspected over 250,000 hectares, and 40,000 infected trees had been found, ie. 1.8% of the trees were found to be infected. CEPLAC recommendations had been for the most heavily infected trees

to be cut at 20 cm from the ground level to stimulate the production of basal chupons, with the remaining trees being subjected to heavy pruning. Dr Rocha showed charts of the number of trees inspected and the number of farms found to be infected, together with the level of re-infection after drastic pruning. It seemed that after pruning a 5% higher level of infection was found, and after cutting down the level of infection was 2% lower, although the latter was not recommended since it involved too great a removal of tissue.

Predictions of the rate of spread seemed to indicate an exponential function, with the whole of Bahia being infected by end 1996, ie. over 500 million plants in 600,000 hectares.

To control the outbreak, sanitation and training programmes had been instituted with 55,000 workers having so far undergone training. Since trees in Bahia tended to flush through most of the year, with only a respite period in May-August, it could be expected that the outbreak here with a greater level of flush growth would be more severe than elsewhere. Other research programmes were urgently needed in order to study the biology of the disease cycle and chemical and biological control. The long-term prospect for control of the disease must, however, lie with resistance breeding and 20,000 accessions in the Brazilian genebank near Belem remained to be screened.

In the discussion following this presentation, it was pointed out that the prediction of exponential spread of the disease could not yet be verified since it was likely that the increasing number of outbreaks being found did not necessarily represent new outbreaks, ie. spread of the disease. During an early workshop of IWBP it had been predicted that the disease would thrive in Bahia if it reached that region and the same could probably be said if the disease reached West Africa or Malaysia. In either case, isolation seemed to present the best control measure. It was, of course, highly desirable that all planting material should be highly resistant to the pathogen but so far there was only very limited availability of primary genotypes which showed any degree of resistance.

Possible Methods of WB Management

- (i) Resistance
- (ii) Cultural
- (iii) Chemical
- (iv) Biological

Control methods:

3 and 4 are unlikely to be feasible
2 was extensively studied by IWBP
1 is logical approach in the future

The Future - Where to Now?

Presentations were given by the country co-ordinators for each of the countries where IWBP had operated - Brazil, Colombia, Ecuador, Grenada, Trinidad and Venezuela. These highlighted the somewhat depressed outlook for cocoa production in Central and South America and the Caribbean due to current low prices.

However, there was general agreement that the disease could only be satisfactorily controlled in the long term by a substantial programme of resistance breeding and the widespread replacement of present trees with improved planting material.

Prospects for Resistance Breeding

In introducing this section, Dr L.H.Purdy (Chairman, Project Scientific Committee) referred to the proposals for a resistance breeding programme which had been formulated by some members of IWBP and referred to ICCO without however achieving any offer of funding. Such a programme would be of benefit to both producers and consumers, including a potential benefit if Witches' Broom reached other areas (Africa and South East Asia). This type of breeding programme could equally be applied to other diseases. This programme still merited adequate funding.

In discussion following this introduction the following points were noted:

1. Late fruit set, as with clone ICS 95, might help pods to escape infection.
2. The screening of seedlings might be artificially severe and field testing, although taking longer, might be preferable.
3. It must be constantly remembered that selection of resistant or partially resistant material was essential before any thought of a breeding programme could be instituted.
4. The "Gainesville" system of screening with WB pathogen (as used for fusiform rust) was now also available in Ecuador and would hopefully become available in Brazil.

It was agreed that the question of resistance breeding must be followed up with the aim of finding a possible sponsor for the programme which had been set down.

Prospects for Chemical Control

Dr Rudgard reviewed the work which had been done on fungicides for control of WB springing from the 2nd IWBP Workshop held at Wageningen. The strategies investigated had involved both direct application onto pods and protection of seedlings, but with pods the major problem was the retention of fungicidal activity. It seemed likely that, although fungicides would be useful in protecting plants in

areas of high disease incidence in the nursery to give them a good chance of establishment before planting in the field, the use of fungicides for mature trees in the field seemed doubtful. Dr Maddison said some success had been achieved using fungicides with hand pollination.

In general, however, it was felt that there was little likelihood of an appropriate fungicide treatment being adopted due to insufficient economic return. In any event there was a trend to avoid the use of pesticides in many cocoa producing countries, which should clearly be supported.

Conclusions

Summarising the project as a whole, the Executive Chairman said that disease management recommendations would be forthcoming for various types of cocoa. The project had also encouraged the testing of chemicals, with mixed results. It had, however, acted as a stimulus to research on all aspects of Witches' Broom disease and information gained had been of immediate importance and of application for the Bahia outbreak.

Much work remained to be done by project participants, although the experimental work was finished. A Monograph of the scientific results is in preparation and will be completed within 12 months in English, Spanish and Portuguese. In particular, consideration needed to be given as to how the information gained by the project could be transferred for use by farmers, ie. the preparation of media material was still a matter to be tackled.

In conclusion, he expressed the thanks of the project to the main sponsors (IOCCC), to ODA (UK), CIDA (Canada), as well as the European Development Fund and the institutes in the areas where research had been carried out and their host governments. Without the generous support of all these bodies, the International Witches' Broom Project would not have existed.

Visit to Reading University

The Open Forum on 18th April was following by a visit to Reading University the following day (19th April), where presentations were given on the BCCCA cocoa research programme, on other cocoa research work at Reading University, with a demonstration of the International Cocoa Germplasm Database and a presentation on Witches' Broom research projects at Imperial College, Silwood Park.

A visit was also paid to the cocoa glasshouses maintained by the Department of Horticulture and also a visit to the cocoa quarantine facility maintained by Reading University at its field station at Shinfield Grange.

APPENDIX E : PARTICIPANTS IN THE OPEN FORUM ON WITCHES' BROOM DISEASE (18th April 1991)

Aarnoudse	NCCV; de Zaan	M.S.Fowler	BCCCA/Rowntree
Abidin	Imperial College	Mary Gore-Booth	Interpreter
S.Acuna	FONAIAP	P.Hadley	University of Reading
Aitkin	M&M/Mars	T.Harrison	BCCCA/Mars Confectionery
Andebrhan	CEPLAC/DEPEA	J.N.Hedger	University College of Wales
S.Applebaum	ACRI	M.Holderness	CAB International
Aranzazu H.	ICA	P.Holliday	Plant Pathologist
Badilla	M&M/Mars	S.Isaac	University of Liverpool
T.Beauchamp	BCCCA	K.Keunecke	BDDS
Biehl	Germany	D.Kuster	UFSC
A.Collin	University of Liverpool	R.A.Lass	IWBP/Cadbury Ltd
B.Eskes	IRCC	P.H.Leurquin	ABDS, Belgium
Flotzinger	President, IOCCC	R.Machado	University of Liverpool

PARTICIPANTS IN THE OPEN FORUM ON WITCHES' BROOM DISEASE
Cont'd.....

A.C.Maddison	ODA/INIAP	R.W.Smith	ODA
L.A.Maffia	University of Vicosá, Brazil	T.N.Sreenivasan	University of West Indies
I.R.Marks	President, BCCCA	C.Suarez	INIAP
D.Penman	University of Liverpool	M.J.Thomas	IWBP Secretariat
L.H.Purdy	University of Florida	H.Toxopeus	SVP, Wageningen
H.Reyes E.	FONIAAP	J.van Kan	IOCCC
H.M.Rocha	CEPEC	Th van der Waerden	NCCV
S.A.Rudgard	Project Liaison Officer, IWBP	B.E.J.Wheeler	Imperial College
I.Scott	UCW, Aberystwyth	C.A.Williams	CRP, Grenada
M.Segrt	Imperial College	F.Wilson	UCW, Aberystwyth
R.A.Schmidt	University of Florida	J.N.Wintgens	Nestle