R2140(S)

Investigations into the causes and prevention of heating and discoloration ('Stackburn') in bag stored maize

Report No. 5: EC DGXII Research Project Workshop, Harare, Zimbabwe, 6 - 10 June 1994

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Project Nos. A0227 and C0326

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Annexes

Acknowledgement

We are very grateful to Dr Desiree Cole and the University of Zimbabwe for hosting the first workshop of this project. Funding for the workshop was provided from within the framework of the European Community Research Programme with a financial contribution by the European Commission and the Natural Resources Department of the UK Overseas Development Administration.

Participants attending the Harare workshop (June 1994).

Grain Marketing Board Aspindale depot showing 4500 tonnes of maize in polypropylene bags stacked on an outdoor hardstanding in the foreground.

OBJECTIVES OF THE WORKSHOP

1. As part of the EC DGXII project (TS3*-CT92-0097) "Investigation of maize stackburn in national stocks of stored maize in sub-Saharan Africa", workshops are planned to disseminate research results. The first workshop was held (after the completion of year 1) in Harare from 6 to 10 June 1994. The objectives of the workshop were to:

(a) review project progress, exchange information and appraise methodology; and,

(b) define priority research areas for year 2 based on results to date and refine work plans.

2. The programme workshop was developed in collaboration with all co-workers and included a day of visits to a Grain Marketing Board (GMB) depot and the laboratories of the Crop Science Department at the University of Zimbabwe (Annex 1).

OVERVIEW

3. Representatives from the four collaborating institutions (each with a different role and area of work within the project) and two sub-contractors involved in the field work attended the workshop. The areas of work covered by each institution is shown in Figure 1.

MAIN POINTS ARISING FROM WORK COMPLETED DURING YEAR 1

4. Full results completed during the first year are reported in the Annual Technical Report (Annex 2). These were discussed during the Workshop with additional background data on maize storage in Ghana and Zimbabwe.

Figure 1: Organisational work areas

Project Objectives

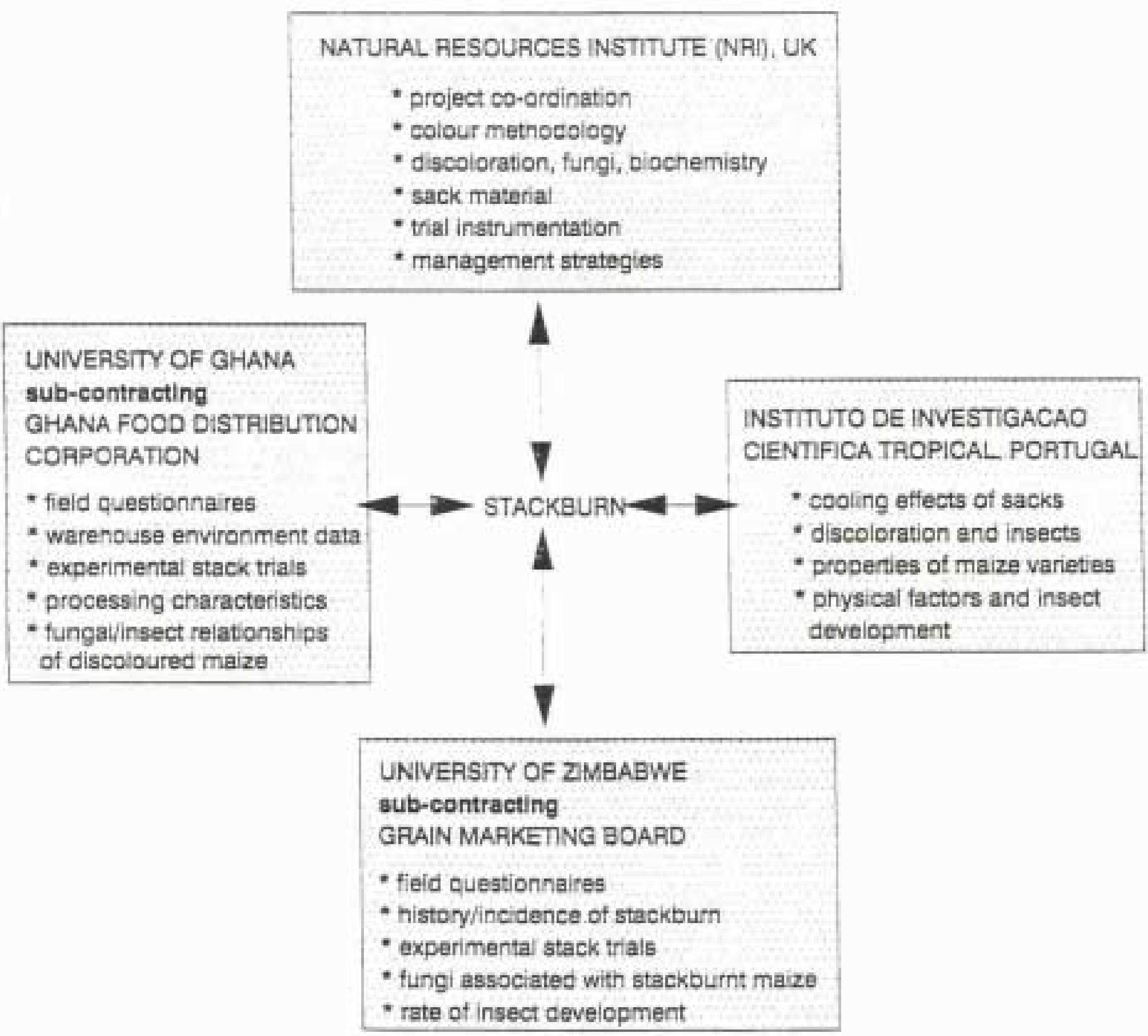
1. To identify the causes of stackburn in stocks of stored maize in sub-Saharan Africa.

2. To determine the causal relationship, if any, between stackburn and the introduction of grain bags made from polypropylene tape.

3. To examine potentially effective methods of minimising the incidence of stackburn.

4. To develop efficient, effective and appropriate maize management strategies.

5. To communicate the strategies to managers of national food stocks, government agencies and traders.



Maize storage

5. Distinct differences exist in maize production and storage in Ghana and Zimbabwe. In Zimbabwe, maize production can amount to over 2 million tonnes, comprising large- and small-scale commercial and communal production. Predominantly, a mixture of white hybrid maize varieties is grown with smaller quantities of yellow maize for stock feed. Around 55% of the crop is retained and 45% sold to the GMB. As a result of market liberalisation, commercial farmers are storing more of their crop. Of the amount sold, 80% is stored in bags in outdoor tarpaulin covered stacks and 15% in silos. Insect control on depots is achieved by fumigation: phosphine is used to treat maize in silos and methyl bromide is used on outdoor stacks. A standard outdoor hardstanding contains up to 4500 tonnes. Contact insecticides are used on maize stored on the farm and this has resulted in a reduction in losses from 15% to 2% (Giga, personal communication).

6. Maize production in Ghana is on a much smaller scale; present annual production is estimated at around 600,000 tonnes which includes a large variety of white, yellow and intermediate types. A high proportion of grain is stored on-farm in traditional structures and traded via middlewomen. About 10% of this production is stored by the Ghana Food Distribution Corporation (GFDC), mostly in rented cocoa warehouses with limited ventilation. In contrast to Zimbabwe, stack size may only be of the order of 150 tonnes. Ethylene dibromide is used to fumigate stacks. On-farm storage in traditional structures is similar in both Ghana and Zimbabwe.

7. In both countries, polypropylene sacks have replaced jute sacks (in the late 1980s) and are now widely used for maize storage. The problem of maize stackburn appears to have increased since the introduction of polypropylene bags. Stackburn affects the central core of maize bag stacks (both indoor and outdoor) resulting in downgrading or rejection of

grain. Stackburn has also occurred frequently in food aid maize in several countries including Angola, Mozambique, Swaziland and Zambia. In many cases, it is associated with storage periods of four months or longer.

Characteristics of stackburn

8. Maize stackburn is characterised by a brown discoloration of the pericarp and germ, ranging from light to dark brown. It represents a form of heat damage to the grain. Most discoloured grain is downgraded or rejected; in some instances, damaged grain may be blended with good quality grain on despatch. Toxicological and nutritional implications of stackburnt grain are not fully understood and need to be addressed.

9. Stackburnt maize has been associated with both "wet" (14-15% moisture content) and "dry" (12-13% moisture content) grain.

Questionnaire data

10. Questionnaires were designed and distributed in both Ghana and Zimbabwe to provide information on the uses of polypropylene bags and stackburn incidence. Because less was known of the stackburn situation in Ghana, the questionnaire there was more wide ranging covering store types and structures. These questionnaires provided some feedback on the potential linkage of stackburn with polypropylene bags.

11. One questionnaire on bag usage, targeted at middlewomen in Ghana, showed the majority using jute bags compared to polypropylene sacks. Of those questioned, more than 95% preferred jute bags with half the respondents giving discoloration in polypropylene bags as the reason. A second questionnaire on bag usage will be targeted at farmers.

12. Questionnaires were distributed to GFDC depots; information covering store design and stocks as well as stackburn incidence was collected.

13. In Zimbabwe, questionnaires were distributed to GMB depots. These highlighted that stackburn was regarded as the second most important maize storage problem after insects; it was the main problem in some depots. Estimates of the amount of grain damaged by stackburn ranged from 5 to 20%. All depot managers were familiar with the problem of stackburn and regarded it as more prevalent in maize stored in polypropylene than in jute sacks. Many associated it with high temperatures and moist grain with a development period of between 1 and 12 months. There was a feeling that grain from commercial farmers which had been artificially dried was more prone to stackburn than that from commercial farmers (naturally dried); this may be linked to differences in grain water uptake and should be investigated. One manager suggested that grain stored in silos and then bagged may be more susceptible to stackburn; this should be investigated.

Causes of maize stackburn

14. Stackburn or discoloration of maize grains is a form of heat damage. Experimental data from the Natural Resources Institute (NRI) has shown that discoloration results from moisture and temperature dependent chemical reactions, part of which may be non-enzymic browning. Increased discoloration is characterised by a loss of lysine and a conversion of sucrose to reducing sugars which may subsequently act as reactants in further chemical complexes. Every grain is susceptible to heat damage. Further characterisation of the chemistry of discoloration may give further leads as to the rate of chemical reaction. Data collected may ultimately be applied to a form of predictive modelling.

15. Embryo discoloration may be distinct from external kernel discoloration. Discoloration can occur at low

moistures (<13%) and high temperatures (>45°C) but more rapidly at high moisture contents combined with high temperatures. Preparation of water sorption isotherms for all maize varieties, particularly at higher temperatures, will form an important aspect of the research.

16. NRI/GMB experimental stack data from Zimbabwe has shown that stackburn progression is characterised by heating to a maximum of 43°C over a period of about 100 days, followed by cooling. In food aid maize, temperatures reached may well be higher. There is no temperature data, as yet, from Ghana but two stacks will be instrumented with thermocouples to obtain some data in 1994/95.

Causes of grain heating

Climatic

17. Stacks that were instrumented by NRI and GMB with temperature sensors have shown that ambient climatic conditions in Zimbabwe influence only the outer layers of large stacks. Whilst daily fluctuations in temperature may cause temperature changes in the outer bags up to one metre into the stack, this effect quickly falls away so that after two metres it has little, if any, effect.

18. Store environment data (of ventilated and non-ventilated warehouses) is being gathered in Ghana.

19. The GMB has carried out some research on the effects of tarpaulin type on internal stack heating. There was no apparent difference when white coloured tarpaulins were used to cover stacks as compared to the normal black, bituminised tarpaulins. Although the trial was concluded early, it is not thought that using light coloured tarpaulins influences internal stack temperature and it was felt that no further work was necessary in this area.

Chemical reactions

20. Certain chemical reactions are exothermic though whether they could make any significant contribution to grain heating is not known; one of these is lipid oxidation which will be investigated later in 1994.

Grain respiration

21. The role of grain respiration as a heat source needs to be considered but it is generally thought to be of insignificant magnitude in comparison with fungal and insect respiration. Difficulties have been experienced at NRI, and by previous workers, in its measurement and detection in dry grain. When moisture contents reach 15% fungal respiration comes into play and it is impossible to distinguish the role played by grain respiration; studies are continuing. The possible role of anaerobic respiration needs to be investigated, particularly in view of reduced oxygen to carbon dioxide ratio in bags at the centre of stacks; the possibility of measuring CO_2 in experimental stacks in Zimbabwe is under consideration. Studies on grain respiration are being made at the University of Ghana by stimulating germination in normal and stackburnt grains (although stackburn often results in loss of germ viability).

Insects

22. Although insects are ubiquitous, their role in heating is not clear. Numbers found in the NRI/GMB experimental stacks ranged from 25 to 200 insects per kilogram, however there was little correlation of insect presence to colour values. Temperature profiles of instrumented stacks were similar to those which could be caused by insect heating. Stacks that were instrumented with microphones revealed that insects survived fumigation in some parts of the stack (thermistors at the same locations showed that in some, but not all, cases where insects had survived the temperature

continued to increase). In one stack (Mvurwi Depot) comprising 75% communal maize with heavy insect infestation, temperatures rose within a few days even before construction of the stack was completed (a period of three weeks). Further investigation is needed to determine whether early heating occurs in stacks built of communal and commercial maize in the planned Zimbabwe field trials.

23. Theoretical predictions of heat production by insects have been made and these will be assessed for inclusion into any predictive model of stackburn. The role of insects in causing stackburn and the rate of insect development on stackburnt maize need further investigation.

Fungi

24. Fungi are capable of causing grain heating to a higher temperature maximum (of up to 60°C) than insects (of up to 45°C). However, fungal growth is highly dependant on moisture content, with growth at equilibrium relative humidities (erh) of more than 70-75%. Analysis of some samples of stackburnt maize and particularly food aid grain has shown a high proportion of thermophilic or thermotolerant fungi. Many of these species are associated with grain of over 16% moisture content and could cause grain heating both at temperatures of around 35-45°C and higher. Species of *Paecilomyces/Thermoascus* have been commonly isolated from stackburnt maize; these are capable of growing under conditions of low oxygen tension.

25. The precise role of fungi in causing stackburn is not clear. Many fungi are capable of causing germ discoloration and death; their enzymes break down grain constituents such as starch to reducing sugars, enabling further chemical reactions. Their role may therefore be to indirectly accelerate chemical changes in the grain.

26. The detection of fungi in stackburnt grain has proved difficult; visible observation is important. Initial fungal growth is often only detected in the embryo just under the pericarp and may not be visible from external observation of whole grains. An important point to note is that fungi may have grown and then died; interpretation of fungal isolation data should be carefully considered as direct plating and dilution plating methods will only detect viable fungi.

Insect/fungal interactions

27. The relationship between moisture content, temperature, fungi and insects and their association with discoloration is extremely complex and is being addressed by the project. Several studies are underway on moisture, temperature and discoloration. The Instituto Investigação Científica Tropical (IICT) are setting up insect study trials. Initial heating caused by insects with subsequent moisture increase and its detection in relation to the initiation of fungal growth should be considered. Some preliminary studies are being carried out at the University of Ghana on insects as substrates for fungal growth.

Sack material

28. Studies have been made at NRI on the properties of sack material in terms of airflow and water vapour transmission. At atmospheric pressure, there was no difference between Zimbabwean jute and polypropylene bags, but at a pressure of 2 tonnes/m^2, polypropylene bags were more resistant to air and water vapour movement. More studies need to be conducted to confirm these results at higher pressures, similar to those found at the core of the Zimbabwe stacks. Sacks from Zimbabwe and Ghana will be included in the tests at NRI.

29. Initial studies by IICT staff at NRI on rate of cooling in stacks showed that (in a small stack, uniformly heated up to 40°C and allowed to cool to 15°C) jute sacks cooled

slightly quicker than polypropylene. Filling the bags so that they were tighter and introducing voids in the stacks led to much quicker rates of cooling. These initial studies are now being modelled and further trials will be conducted if suitable controlled temperature and humidity facilities can be found. It is hoped to field test channels and chimneys (introduced as voids during stack construction) during the coming storage season in Zimbabwe and Ghana.

Processing characteristics and maize varieties

30. There are over 20 methods of processing maize commonly in use in Ghana. Work has started to investigate how stackburnt maize affects processing characteristics. This work, which includes the measurement of seed water absorption and swelling, and maize dough fermentation is being undertaken at the University of Ghana.

31. Investigations into the susceptibility of different varieties of Zimbabwean and Ghanaian maize to stackburn is needed. Isotherm studies on selected varieties with different seed characteristics are planned by IICT in 1994/95.

WORKPLANS AND TIMEFRAMES FOR YEAR 2

32. Workplans for year 2 were developed by each collaborating organisation and presented at the workshop to resolve any areas of duplication and to ensure all the major areas of research were covered. Summaries of these workplans, together with planned timeframes for the year May 1994 to April 1995 are given in Table 1.

33. The main focus of the field work will be two trials of instrumented maize stacks. Large-scale stacks of white maize will be built in Zimbabwe to test the effects of maize source (communal vs commercial) and sack material (jute vs polypropylene). Two small-scale stacks will be built in

Ghana to test the effects of warehouse type (ventilated vs non-ventilated). The experimental design and layout of sensors is given in Annex 3.

METHODOLOGY

34. Methodologies for colour measurement, moisture content determination, sack sampling and insect loss assessments were designed for use in the field trials in Ghana and Zimbabwe.

Colour

35. L*, a* and b* values will be measured using Minolta chromameters. All readings should be absolute and the meters calibrated against white tiles.

36. Certain problems have been found with the use of the hedonic colour rating scheme, particularly with categories 1, 2 and 3 in white maize. Recent field survey data from Zimbabwe indicates that categories 1 and 2 should be regarded as a normal colour for white maize, with 3 as lightly stackburnt. Grain embryo categories should be maintained as they are.

37. Because maize colour in Ghanaian varieties differs from that of Zimbabwean white maize, the University of Ghana will devise its own visual colour rating scheme, but it is likely to have 5 categories also. Samples of the scales will be sent to all collaborators. Likewise, a colour rating scheme for yellow maize will be devised.

38. The accelerated heating test for detection of potential stackburn damage will continue to be used. All collaborators should monitor their autoclaves for time taken to heat to pressure (15 psi) and time taken to cool following processing at 15 psi for 15 minutes. The germ

Table 1: Workplans of collaborating organisations 1994/95

NRI, UK	IICT, PORTUGAL	UG/GFDC, GHANA	UZ/GMB, ZIMBABWE
TRAINING Data logger instrumentation - handling and data analysis for experimental stacks, Zimbabwe; Ghana inputs to be decided following initial experimental stack results. **July/August 1994**	LABORATORY STUDIES Clarification of the role of insects in causing stackburn and their interaction with moisture, temperature and mould growth. **June - December 1994**	SMALL-SCALE TRIALS IN TWO WAREHOUSES Stackburn incidence in two stacks (each of 60 tonnes) during storage for 12 months (in ventilated and non-ventilated warehouses). **August 1994 - August 1995**	LARGE-SCALE TRIALS AT MVURWI DEPOT Two stacks (each 1500 tonnes) will be monitored for temperature and moisture content; 1 stack jute sacks (half commercial /half communal) and 1 stack polypropylene sacks (half commercial/half communal). **August 1994 - August 1995**
LITERATURE REVIEWS, DISSEMINATION OF INFORMATION Insect/fungal interactions; effects of fumigants on germination (and mould growth); lipid reactions. Project newsletter. **September 1994/March 1995**	EFFECT OF VOIDS ON STACK COOLING Modelling studies and trials on the effect of voids on cooling rates. **June 1994 - June 1995**	FIELD SURVEY Insect/fungal infestation of grain in local barns and warehouses. Further work on questionnaires on the use of polypropylene sacks will be pursued. **September 1994**	CALIBRATION Oven and meters with samples at 9, 11, 13, 15 and 17% mc. **September 1994**
COLOUR METHODOLOGY Clearer definition of accelerated heating test and implications. **November 1994**	CROSS CALIBRATION OF MOISTURE METERS Conditioning of samples from Zimbabwe and Ghana for moisture content calibrations. **July - August 1994**	VARIETAL EFFECTS Representation of extent of damage of whole kernel and germ on a visual scoring hedonic scale; definition of colour changes in grains (simulated heating to induce stackburn, naturally stackburnt samples) using Minolta Chromameter. **September - December 1994**	VARIETAL SUSCEPTIBILITY TO STACKBURN Selected varieties will be subjected to accelerated heating tests. Samples will be collected immediately (5kg from seed merchants). **December 1994**

RESPIRATION & BIOCHEMISTRY OF DISCOLORATION Role in heating; O_2/CO_2 measurements; grain respiration in relation to discoloration. Non-enzymic browning; polyphenol oxidases; lipid oxidation (enzymic reactions). **January 1995**	WATER ACTIVITY Water activities of different maize varieties at high temperatures. **November 1994 - March 1995**	RESPIRATION AND STACKBURN DEVELOPMENT Factors to be considered include age, moisture content, grain variety, physiological state. **September - December 1994**	HEATING & MOISTURE INFLUENCE ON STACKBURN 11-13.5% moisture content and 25-45°C of minibags in incubators to assess (a) discoloration and (b) microflora changes. Relative humidity inside the incubators will be monitored. **April 1995**
NUTRITIONAL STUDIES Usage of stackburnt maize; feeding trials, toxicity, analysis. **April 1995**	MOISTURE TEMPERATURE RELATIONSHIPS Investigations of the moisture and temperature conditions for the development of stackburn and mould growth. **December 1994 - March 1995**	PROCESSING CHARACTERISTICS Physical, chemical and processing characteristics of stackburnt and non-stackburnt white and yellow maize varieties. **December 1994**	INSECT DEVELOPMENT Comparison of good and stackburnt maize on weevil development/multiplication. **April 1995**
SACK MATERIAL PROPERTIES Behaviour under pressure; air/water/fumigant transmission; moisture migration. **April 1995**		LABORATORY STUDIES Physical, mycological and entomological parameters influencing stackburn. **June 1995**	ARTIFICIAL VS NATURAL DRYING Samples from trial stacks will be tested for susceptibility to stackburn. **April 1995**
PROJECT CO-ORDINATION Short activity reports. **September 1994** Co-ordination visit, Ghana, Zimbabwe, Portugal. **January 1995** Annual technical report and costs statement. **March 1995**			HISTORICAL DATA OF STACKBURN At selected depots with a history of stackburn. This will involve looking at GMB records since 1990. **June 1995**

colour of normal grains following autoclaving should be no more than 2. Results of any accelerated tests with abnormal results should be communicated to all collaborators.

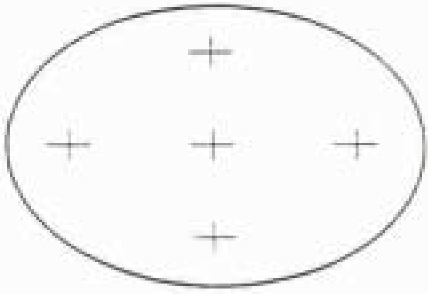
Moisture content determination

39. The ISO 6540 oven method of determining moisture content will be used by all collaborators. Samples should be collected in aluminium tins and sealed with plastic tape between sampling and determination.

Sampling

40. All instrumented bags will be sampled according to the following methodology during stack building and again on despatch:

(a) sacks should be opened at one end by unstitching and five spear samples taken in the shape of a cross (see diagram below) down the length of the sack using a compartmented sampling spear;



+ : **SPEAR POSITIONS**

(b) sacks can then be restitched by hand and instrumented;

(c) the sample obtained should be at least 1.5 kg;

(d) reduction to this amount should be done using a riffle divider, if necessary;

(e) using a plastic scoop, approximately 50 g from this sample should be put directly into an aluminium tin, sealed with plastic tape and labelled for moisture content determination (avoid touching the directly sample with hands);

(f) the sample should be divided into two working samples (one of 1 kg minimum, one of 0.5 kg minimum) using a riffle divider and put into plastic sample bags, labelled both inside and outside and then securely fastened.

41. The 1 kg working sample will be used for the following analyses:

(a)	insect damage	(1000 g); and then,
(b)	hidden infestation	(400 g).

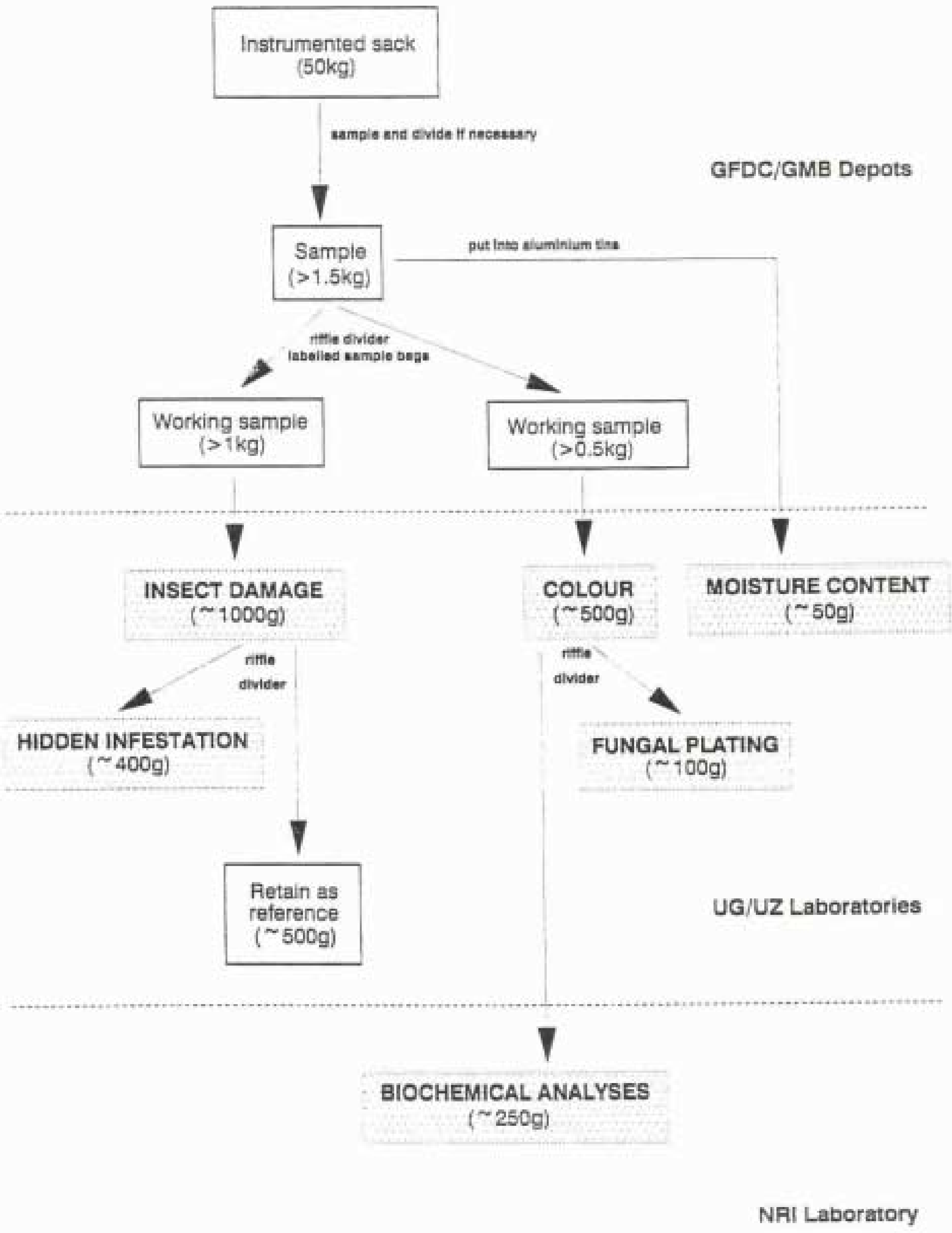
42. The 0.5 kg working sample will be used for the following analyses:

(a)	colour	(500 g); then divided for,
(b)	fungal plating	(100 g); and,
(c)	biochemical analyses	(250 g).

43. All analyses will be done at the Universities of Ghana and Zimbabwe with the exception of the biochemical analyses which will be undertaken at NRI.

44. The sampling methodology is summarised in Figure 2.

Figure 2: Sampling methodology for University of Ghana and University of Zimbabwe trial stacks



Insect damage

45. An assessment of insect damage will be made at the beginning and end of the trial, as follows:

(a) 1000 g will be subdivided into 3 replicates, each of approximately 300 g;

(b) each grain will be graded for obvious insect damage (holes) into 3 categories:

(i) 1 hole,
(ii) 2 holes,
(iii) 3 holes or more;

(c) those grains with no insect damage but showing other damage (chipped/broken, rodent and other coloured) will be separated;

(d) the number of grains of each category will be counted.

46. Following sampling at the end of the trial, each instrumented bag will be sieved. All dust and insects should be collected, bagged and labelled. In the laboratory all samples can then be further sieved to remove dead insects (using a fine mesh sieve) and these counted.

PROJECT MILESTONES/DEADLINES

Milestones

47. Revised project milestones were discussed and agreed (below).

Month 5: initial project training and method evaluation
Month 6: initiation of field survey/questionnaire studies
Month 10: preliminary questionnaire studies completed
Month 15: workshop held in Zimbabwe to review first year progress and questionnaire data, refine year 2 work plans
Month 16: experimental stack trials set up in Zimbabwe; instrumentation training completed
Month 18: experimental stack trials set up in Ghana
Month 26: completion of experimental stack trials workshop held in Ghana to review progress and formulate remedial actions
Month 32: feasibility of remedial actions assessed
Month 36: reports completed, seminars held.

48. These milestones should be read in conjunction with the technical annex of the contract document.

Deadlines

49. Each country project co-ordinator is responsible for submitting project progress reports and cost statements to the overall project co-ordinator (S Phillips, NRI) for transmission to the EC by certain deadlines. To allow time for overall co-ordination of reports, the following deadlines should be adhered to:

- Short activity report (1 page covering main activities from 1 April 1994 to 30 September 1994) to reach NRI by 10 September 1994.

- Annual technical progress report (long report covering all scientific results for the period 1 April 1994 to 31 March 1995) to reach NRI by 15 March 1995.

- Annual cost statement[1] to reach NRI by 15 March 1995.

PUBLICATIONS AND DISSEMINATION OF INFORMATION

50. A list of reports and papers published by the project is given in Annex 2. There are many suggestions for further publications in international and regional journals and those discussed are listed in Annex 2.

51. Collaborators agreed that joint publications should be submitted as well as individual ones. As stated in Annex II of the stackburn project contract (Article 6, 7), participants in the project should be aware that all reports should be regarded as confidential. Any communication or publication of the progress of work under the contract (including at seminars and conferences) must include the following statement:

> "Research was carried out by (name of organisation/s) in the framework of the European Community Research Programme with a financial contribution by the European Commission."

52. It was agreed that NRI should produce a newsletter twice a year (March and September) and information should be sent to Chatham by end of February and August respectively for inclusion. The first newsletter will be distributed in September 1994.

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1 The annual technical progress report and the annual cost statement have to be sent together to the EC. It is important to keep to deadlines as production of these documents on time is vital to obtain the next instalment of funds.

ANNEX 1: WORKSHOP PROGRAMME

Date	Time	Subject	Presenter
Monday 6 June	0900	Welcome	Dr D Cole
	0915	Introduction to stackburn project	S Phillips
	0945	Introduction to maize storage in Ghana	J Edwards
	1015	Introduction to maize storage in Zimbabwe	R Tanyongana
	1030	Coffee	
	1100	Initial stackburn studies (1990-92)	T Donaldson
	1200	Lunch	
	1300	Progress report - NRI	S Phillips
	1330	Progress report - IICT	G Barros
	1400	Progress report - UG	Prof Odamtten
	1430	Progress report - UZ	Dr D Cole
	1500	Tea	
	1530	Group Discussion	
Tuesday 7 June	0800	Depart for Aspindale depot * Tour of bagstacks * Demonstration of stacking pattern * Tour of silos * Tour of laboratory * Demonstration of maize grading * Demonstration of instrumentation	R Tanyongana
	1200	Depart for Courteney Hotel	
	1330	Depart for University of Zimbabwe (by taxi)	Dr D Cole
	1400	* Tour of laboratory * Recent stackburn samples * Demonstration of Chromameter	
	1530	Depart for Courteney Hotel	

Date	Time	Subject	Presenter
Wednesday 8 June	0800	Poly/jute comparisons	T Donaldson
	0830	Stackburn in food aid maize - case studies * Zambia * Mozambique * Swaziland * Zimbabwe	T Donaldson R Tanyongana
	1000	Shipment of food aid - case study * Angola	S Phillips
	1030	Coffee	
	1100	Results of questionnaires - Ghana	Prof Odamtten
	1120	Results of questionnaires - Zimbabwe	Dr D Cole Prof D Giga
	1140	Group discussion	
	1200	Lunch	
	1300	Field survey data from Ghana	Prof Odamtten Dr J Allotey
	1400	Field survey data from Zimbabwe	Dr D Cole Prof D Giga
	1500	Tea	
	1515	Group discussion	

Thursday 9 June	0800	Laboratory studies at NRI	S Phillips
	0830	Stack heating/cooling	A Maia
	0900	Laboratory studies - Ghana	Prof Odamtten
	0930	Laboratory studies - Zimbabwe	Dr D Cole
	1000	Coffee	
	1015	Field trials with tarpaulins	
	1030	Methodology	S Phillips
	1200	Lunch	
	1300	Group discussion - priority research areas for field trials	
	1400	Group discussion - priority research areas for laboratory studies	
	1500	Tea	
	1530	Summary - finalisation of work plans	

Date	Time	Subject	Presenter
Friday 10 June	0800	Presentation of work plans and timeframes * UZ * IICT * NRI * UG	 Prof D Giga A Maia S Phillips Prof Odamtten
	0900	Identification of 'training needs'	
	0930	Publications	
	1000	Coffee	
	1030	Meetings between Individual Teams	
	1200	Lunch	
	1300	Meetings between Individual Teams	
	1430	Review of Technical Annex of Contract	
	1500	Tea	
	1530	Work Plans 1994/95	S Phillips
	1545	Close	Dr D Cole

ANNEX 2: REPORTS PRODUCED TO DATE AND LIST OF POSSIBLE JOURNALS FOR FUTURE PUBLICATIONS

Reports produced to date

Donaldson, T.J. (1993). *Report No.2: Assessment of spoilage and loss within stackburned maize*. NRI Report R2073(S). Chatham, UK: Natural Resources Institute.

Kennedy, L. and Devereau, A.D. (1994). *Observations on large scale outdoor maize storage in jute and polypropylene sacks in Zimbabwe*. Paper presented at the XI International Working Conference on Stored Products Protection, Canberra , Australia.

Locke, M.T., Donaldson, T.J. and Gough, M.C. (1993). *Report No.1: Quality changes in an outdoor stack of bagged maize*. NRI Report R2085(S). Chatham, UK: Natural Resources Institute.

Phillips, S.I. (ed.) (1994). Annual Report on ECDGXII project (contract TS3*-CT92-0097).

Tyler, P.S. (1992). *Heat and discoloration of bagged maize*. World Grain, September 1992, pp. 14-16.

Tyler, P.S. and Kutukwa, N. (1993). *Report No.3: Technical note on a coordination visit to Ghana*. NRI Report R2042(C). Chatham, UK: Natural Resources Institute.

Tyler, P.S. and New, J.H. (in press). *Using woven polypropylene sacks for agricultural produce*. SPORE.

List of journals for future publications

International

Journal of Stored Products Research
Post-Harvest Biology and Technology
International Journal of Food Microbiology
Food Microbiology
Tropical Science
Cereal Science
Courier (EU)
ACIAR newsletter
GASGA newsletter

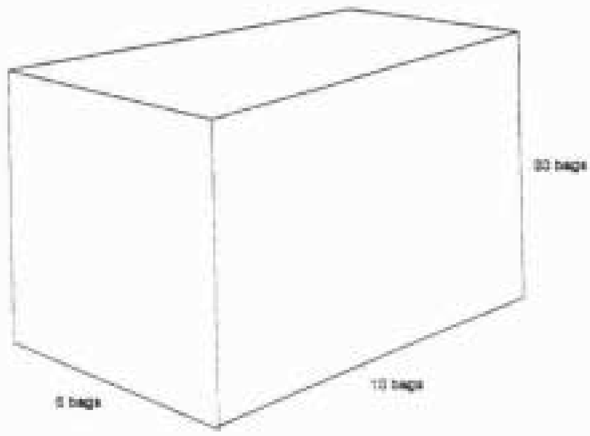
Regional

Discovery and Innovation (Kenya)
Engineering Society (Portugal)
Ghana Journal of Agricultural Science
Ghana Science Abstracts
Zimbabwe Journal of Agricultural Research
SADC newsletter
Resource (NRI)

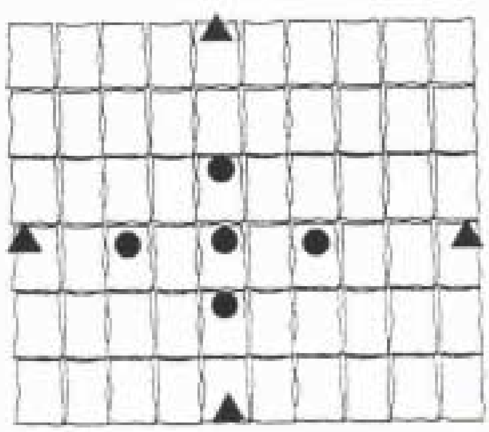
ANNEX 3: EXPERIMENTAL STACK DESIGN (GHANA AND ZIMBABWE)

Ghana trial stacks

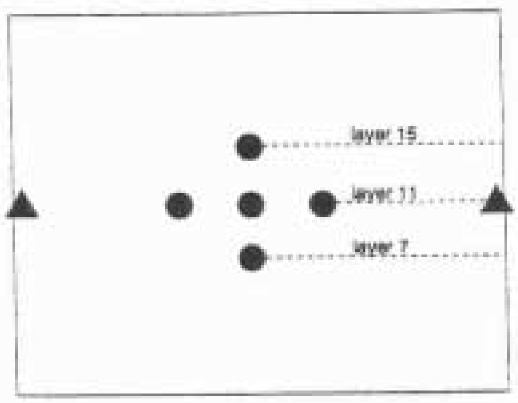
Dimensions of stack (total 1,200 x 50kg bags)



Plan



Elevation

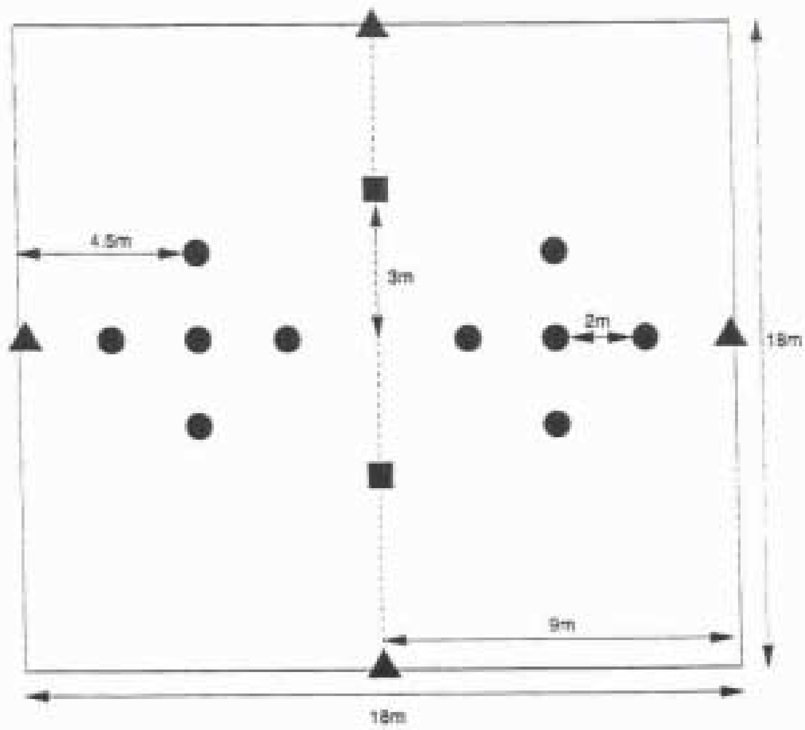


● : internal sensor position

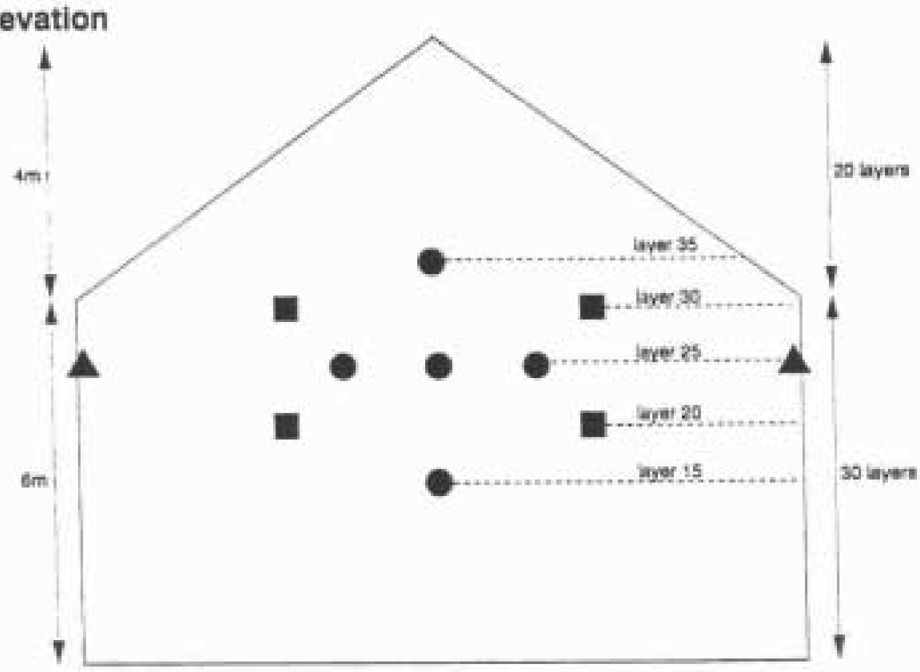
▲ : external sensor position

Zimbabwe trial stacks

Plan



End Elevation



Summary of sensor positions

● : 2 @ level 15, 10 @ L25, 2@ L35

■ : 2 @ L20, 2 @ L30

▲ : 4 @ L25

ANNEX 4: CURRENT STATUS OF STACKBURN IN MOZAMBIQUE

BACKGROUND

1. The visit to Maputo was part of an EC DGXII research project "Investigation on stackburn in national stocks of stored maize in Sub-Saharan Africa" contract TS3*-CT92 0097.

2. The programme was arranged by Mr Tim Donaldson, NRI Post-Harvest Grains Specialist, in conjunction with Mr Thomas Keusters, UNILOG Manager (WFP-Mozambique) and Eng. Marina Pancas, Head of Plant Protection Department, National Directorate of Agriculture.

3. The objectives of the visit were:

(a) to brief WFP on the EC DGXII stackburn project;

(b) to become familiar with the methods of storage used in the Manica warehouses in Maputo;

(c) through discussions with WFP, to estimate the total quantities of relief aid that suffered stackburn in 1993, and to report on the quantities still remaining;

(d) to collect samples of stackburn maize for laboratory studies at IICT;

(e) to hold discussions with FAO/DSV on the phytosanitary operations carried out at Maputo port.

DIARY NOTES OF MEETINGS AND DISCUSSIONS

13th June

4. A meeting with Mr Keusters, UNILOG Manager, was held at UNILOG headquarters in Maputo. UNILOG is the Logistic Unit of WFP and contracts agents for the handling and storage of food aid, namely cereals, pulses and oil, of which maize is the main commodity.

5. During the period January 1993 to May 1994, over 214,000 tonnes of yellow maize from donors (chiefly the US and EU) were received by WFP in Mozambique. Of this total more than 83,000 tonnes arrived during January to April 1993 and 131,000 tonnes during the next year. In the 16 month period imports at the main ports of Maputo, Beira and Nacala were 81,800 tonnes, 110,300 tonnes and 16,800 tonnes respectively. A small quantity of 5,200 tonnes was received by road in the northern district of Cabo Delgado.

6. After a few months of storage, varying degrees discoloration or browning of the maize kernels was apparent. This was first noticed in June 1993 in the storage centres of Maputo, Beira, Nacala and Quelimane. Although the warehouses structures and management practices differed, affected stacks all had discoloured maize in the central core. This discoloration is similar to that found in Zimbabwe and is commonly referred to as stackburn.

7. In all affected stacks, bags containing normal bright yellow maize were segregated from bags with stackburn. Stackburnt maize totalled approximately 31,200 tonnes at the following ports:

Beira	14,000 tonnes;
Maputo	10,500 tonnes;
Nacala	5,500 tonnes;
Quelimane	1,200 tonnes.

The stocks at Quelimane were shipped by coaster from Nacala by ex-MV Overseas Marilyn.

8. The maize with stackburn was fundamentally from the stocks ex-MV.

	Port of Entry	Off Loaded	Date	M.C. origin	M.C. storage
Apollon	Beira	5,525 t	16/05/93		
Delphi	Beira	24,716 t	08/03/93	12.2%	
Texas City	Beira	22,858 t	20/06/93		
Apollon	Maputo	3,100 t	06/05/93		
Lake Wales	Maputo	18,046 t	17/06/93		14.5% (25 Aug) 14.2% (17 Oct)
Ov. Marilyn	Nacala	16,522 t	06/07/93	13.7-13.9%	
	TOTAL	**90,767 t**			

The total amount of maize in store by December 1993 before the segregation operation was approximately 67,500 tonnes.

9. Stackburnt maize was sold internationally as animal feed. Presently there remains only 2,500 tonnes awaiting a buyer. It is stored in a Manica godown at Matola (Maputo), built many years ago. The commodity, ex-MV Lake Wales, in 50 kg sacks of woven polypropylene, is stacked in stacks of approximately 400 tonnes on pallets, together with other commodities owned by other parties in the same warehouse. Although showing evidence of a good storage management, it was possible to detect some live insects, *Sitophilus* sp., *Tribolium* sp. and *Lepidoptera* which were collected. Samples of maize were collected for analyses at CEFA/IICT on hidden infestation and colour measurements using a Minolta Chromameter.

10. Imports of relief maize for Mozambique are planned for June 1995 to May 1995. The need is estimated at 182,000 tonnes, of which 13,000 tonnes is currently in store . Of the remainder (169,000 tonnes), 116,000 tonnes has been pledged and 53,000 tonnes will be purchased commercially. Maize is available, firstly from a surplus of the 1994 harvest in the northern producing areas of Mozambique, and secondly from the SADC region (South Africa is being considered).

11. Various factors are believed to have contributed to stackburn in WFP maize:

(a) high moisture content values, bearing in mind that grain was stored under relatively high temperatures (28-32°C);

(b) high levels of admixture and mechanically damaged grains in the consignments;

(c) overloading of the storage system, due to uneven delivery, which led to much longer storage periods than originally envisaged; and,

(d) inadequate storage facilities.

14th June

12. A meeting was held with Eng. Marina Pancas, Head of Dept. Sanidade Vegetal (DSV), National Directorate of Agriculture (DINA); Dr Arne Jensen, Leader of the DANIDA project on strengthening of Plant Protection; Dr Boaventura Nuvunga, Head of Plant Quarantine, and Eng. Mário Mutxeco, Head of Post-Harvest, for discussion on the measures being taken to improve the phytosanitary service.

13. The Plant Protection Department is part of the National Directorate of Agriculture of the Ministry of Agriculture. The Department is involved in: Administration; Quarantine/Plant Health Inspection; Pesticides; Migratory Pests; Biological Control; and, Diagnosis, Identification and Investigations.

14. A project financed by Danish International Development Assistance (DANIDA) started in 1991 with the aim of strengthening the whole plant protection sector in Mozambique. All areas in the department are supported by the project. The project supplied transport and other equipment to the department and in the provinces and are also assisting with some of the running costs. FAO is assisting the plant health inspection service with special attention to the prevention of the introduction of the *Prostephanus truncatus*. Advisers have been attached to the department for nearly a year and a regional program is underway. GTZ and SADC are giving technical support to work on migratory pests with special emphasis on Red Locust warning and control.

15. The sectors of Quarantine and Plant Health Inspection are established in Maputo, Beira and Nacala in order to prevent the introduction of dangerous pests and pathogens. Phytosanitary inspectors are placed at the main entry points, especially the ports, the main land frontiers and Maputo airport. They are responsible for training phytosanitary inspectors and updating the legislation. Within this sector there is a section specialising in Post-Harvest work. In relation to *Prostephanus truncatus* the areas at most risk are Angonia and Tsangano which border Malawi, and the border with Tanzania where there is free trade between the countries. Monitoring of this pest is being done in warehouses at Nacala, Beira and Maputo ports, and regularly at some areas on the borders. To date *Prostephanus truncatus* has not been detected in Mozambique. In relation to mycotoxins, analysis are made by the Laboratório Nacional de Higiene Alimentar (LNHA), part of the Ministry of Health. This Ministry decides if a commodity is suitable or not for human consumption.

16. Pesticides sector functions are: registration and control of the import of pesticides in co-ordination with the Ministry of Health, importers and distributors; inspection and control of pesticide stores; evaluation and control of the activities of chemical companies; evaluation of spraying equipment and inspection of pesticide stocks kept for national security against the outbreak of migratory pests.

17. Migratory Pests carries out periodic campaigns to control pests such as locusts, army worm, field rats, mice and weaver birds.

18. Biological Control is engaged in the biological control of cassava mealy-bug and rears its natural enemies, such as parasitic wasps.

19. Diagnosis, Identification and Investigations deals with plant pathology, entomology, nematology and weeds. The aim is to help the agricultural sector directly but also to increase the knowledge of occurrence of diseases, pests and weeds. Surveys are made in collaboration with provincial staff.

20. Visits were made to the different sectors of DSV, as well as to phytosanitary inspectors building and laboratory at Maputo port.

21. At SEMOC (Sementes de Moçambique), the Planning Manager, Dr Victor Vera explained that they only produce national improved varieties of white maize, of open pollination, also importing maize seeds from Zambia. They do not have problems with the storage of seeds, as its production is low and the period of storage short, 6 to 8 months. The seed stores (one was visited) have very good storage conditions and are new. The annual plan of seed imports is updated

every 3 months and Zambia and Zimbabwe are the countries who export most seed to Mozambique.

15h June

22. A meeting was held with Eng. Anastácio Tamele, Director of the National Directorate of Agriculture, Eng. Mário Mutxeco, Head of Post-Harvest section and Mr Hassane Munemua, Phytosanitary Inspector. The National Institute for Cereals which will replace AGRICOM is now responsible for all storage and trade with farmers, and is part the Ministry of Commerce. The Department of Food Security of the Ministry of Commerce has representatives in the Ministry of Agriculture and links with South African Development Community (SADC) food reserve. SADC aggregates Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, Swaziland, Tanzania, Zambia and Zimbabwe.

OBSERVATIONS

23. During all meetings, the revision of Law No. 120/87 was discussed, especially with regard to maximum allowable moisture content which is 14% and considered too high for normal safe storage of maize in Mozambique.

CONCLUSIONS

24. During the period January 1993 to May 1994 WFP received 214,100 tonnes of yellow maize as emergency food relief aid. This maize was mainly of US and EU origin derived from stocks held in respective countries of origin.

25. Several instances of maize stackburn (heating that causes discoloration) in WFP stocks occurred. Approximately 31,200 tonnes of yellow maize was clearly discoloured and was segregated from a total of 67,500 tonnes in stock at November 1993. Most of the discoloured maize was sold internationally as animal feed, but some 2,500 tonnes still remains. Samples of stackburnt maize were collected for analysis at IICT/CEFA for colour and hidden infestation measurements.

26. Relief maize imports are planned for June 1994 to May 1995. WFP estimate a total of 182,000 tonnes is needed.

27. At present there are no plans to import through Mozambican ports to other SADC countries, although it was not possible to confirm if any commercial maize imports were passing via this route countries.

28. Plant Protection Department (DSV) is well aware of its phytosanitary duties and responsibilities and is doing its upmost to accomplish them. The international projects to which it is linked are recognised as very important, although presently there is still a reduced number of national specialists.

ITINERARY

12 June (Sunday)		Arrival Maputo from Harare, 18:55 flight (Linhas Aéreas de Moçambique) TM343. Met by a WFP driver and taken to the Terminus Hotel.
13 June (Monday)	8:30	Meeting with Mr Thomas Keusters, UNILOG Manager - WFP - Mozambique - for briefing on the EC DGXII stackburn project and for discussions and overview of the logistics of maize imports to Mozambique and recent occurrence of maize discoloration in WFP

		stocks. Visit to Manica warehouses in Matola.
	16:00	Report to the Portuguese Embassy. Set up meetings for the following day.
14 June (Tuesday)	8:30	Meeting with Eng. Marina Pancas, Head of Dept. Sanidade Vegetal (DSV), National Directorate of Agriculture (DINA); Dr Arne Jensen, Leader of the DANIDA project on strengthening of Plant Protection; Dr Boaventura Nuvunga, Head of Plant Quarantine, and Eng. Mario Mutxeco, Head of Post-Harvest, for briefing on the EC DGXII stackburn project and for discussion on the measures being taken to improve the phytosanitary service.
	11:30	Meeting with Dr Josè Vera, SEMOC Planning Office, for briefing on the EC DGXII stackburn project, inquire about possible occurrence of stackburn on seed storage and visit a seed storage warehouse.
	14:30	Visit to Dept. Sanidade Vegetal phytosanitary laboratories. Meeting with Eng. Elsa, Seed Dept., DINA, for briefing on the EC DGXII stackburn project and inquire about possible occurrence of stackburn on seed storage. Visit to Plant Quarantine laboratories.
15 June (Wednesday)	11:30	Meeting with Eng. Anastácio Tamele, Director of the National Directorate of Agriculture, for briefing on the EC DGXII stackburn project, discussion on the work of the National Institute for Cereals, storage policies and research programmes.
		Departure Maputo for Lisbon, 16:40 flight (TAP)TP 222.

Antonio Maia and Graça Barros, July 1994

ANNEX 5: CONTACT ADDRESSES OF COLLABORATING SCIENTISTS

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