FINAL TECHNICAL REPORT

An investigation into the biology, epidemiology and management of finger millet blast in low-input farming systems in East Africa

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Report compiled by	Dr N J Hayden
CPP Production System	Semi-arid

Lead Institution:

Natural Resources Institute, University of Greenwich

Mr M A Conroy
(Social Scientist)
Dr N J Hayden
(Plant Pathologist and Project Leader *wef* October 1998)
Dr J Holt
(Epidemiologist and Project Leader September 1997 – September 1998)
Dr A M Julian
(Plant Pathologist and Project Leader September 1996 – September 1998)

Collaborating Institutions and Scientists

Kenya Agricultural Research Institute

Mrs Felister Makini
(Director, KARI, Kisii Centre / Principal Collaborator)
Mr J M Ongaro, NARL
Mr S A N Moruri, Kisii
Mr S Onyango, Kisii/Migori
Mr B Etyang, Alupe
Mr W O Ogallo, Alupe
Mr S M Mbugua, NARL

ICRISAT

Mr H Ngugi, Nairobi
Mr A Illah, Alupe

District Agricultural Offices (Extension)

Mr D Mero, Kisii
Mr J O Were, Busia

World Neighbours, Busia

Mrs C Etyang
Mr D Owalalu
Mr T Paade

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Executive Summary

Finger millet is an important subsistence staple food in western Kenya. It is considered the domain of women, who also use it as a cash crop, generally managing the resulting income for the benefit of their household. Farmers cited labour and the cost of land preparation as factors which limit the cultivated area of this crop. High yield and early maturity are considered favourable variety characteristics, whereas disease susceptibility is an important negative attribute.

Farmers recognise blast (caused by *Pyricularia grisea*) as a major disease, which they, quite correctly, associate with high humidity and variety susceptibility. A large number of varieties (22) were grown in the farms surveyed. The range of varieties reflects the numerous end-uses of this crop as well as farmers' recognition that different varieties perform better in different seasons. Farmers often grew more than one variety (either in separate plots or as variety mixtures) but one variety, Enaikuru, predominated. In a survey of 200 farms in January / February 1999, 59 % of farmers grew Enaikuru as a single cultivar and more than 90 % of finger millet mixtures included this cultivar.

The need for blast resistant varieties was identified by the farmers themselves during PRA activities. As a consequence, suitability of released varieties P224 (blast tolerant) and Gulu E (moderately resistant) was investigated on-farm by participating farmers, and by a wider audience through community workshops and farmer days.

A range of domestic and culinary attributes for the released varieties and farmers' existing varieties were evaluated. Overall, women ranked Enaikuru first and then Gulu E and P224. In contrast, men ranked Gulu E first and then P224 with the traditional cultivar Enaikuru third. However, traders and extension officers ranked Gulu E as first overall, with P224 best for *ugali*. Thus the released varieties showed a high degree of socio-economic acceptability.

The yields of released varieties, P224 and Gulu E were similar to those of Enaikuru during on-farm evaluation under low disease pressure (1997 short rains). Although in the long rains (1988), yields were higher for the traditional cultivar than for either of the two released varieties, Gulu E demonstrated most resistance to blast and the observed yields were not correlated to disease scores in these experiments.

Finger millet heads displaying symptoms of blast were collected at the commencement of this project and *P. grisea* was isolated, identified in axenic culture and used to reinfect healthy finger millet. Thus it was demonstrated that crop debris may contain viable inoculum which can cause subsequent blast of finger millet crops. On-station experiments showed that under conditions of high disease pressure (artificial inoculation during the long rains crop) yield of P224 exceeded that of a known susceptible cultivar. In addition, the magnitude of loss caused by blast was affected by time of inoculation; maximum yield loss occurring in crops inoculated 90 days after sowing.

Studies were undertaken on temporal survival of *P. grisea* inoculum which showed that the fungus may survive on crop debris in the soil for up to five months although there is considerable reduction in inoculum potential two months after incorporation. Seed was also indicated as a potential source of inoculum: the blast fungus was found on 20 out of 21 samples screened (mean incidence = 9.6 %).

Data on finger millet blast collected during a final survey of 200 farms (January / February 1999) confirmed the correlation between incidence and severity. The highest average disease incidence and severity were 48.1 and 42.1 % respectively. Thus the disease resistance of Gulu E and tolerance of P224 along with their social acceptability are potentially valuable for small-holder millet growers particular if used in conjunction with cultural measures (e.g. field hygiene) to limit or delay on-set of disease.

Background

Finger millet (*Eleusine coracana*) is an important food crop within traditional low input cereal-based farming systems in Africa. It is of particular importance in upland areas of Eastern Africa e.g. Western Kenya, W. and S. Tanzania, and Uganda, where it commands a high price in the market place fetching three to five times the price of other cereals (Pande *et al*., 1995). This crop has particular relevance for food security as it is more drought tolerant than maize, and less susceptible to bird damage than sorghum. In addition finger millet may be stored for prolonged periods, showing little sign of deterioration or insect attack, and so may be the only cereal food source available at certain times of the year. Finger millet provides a valuable source of minerals and nutrients, and is recommended for pregnant or nursing mothers and infants. This is also a traditional crop and occupies a central role in ceremonies and other practices.

Although a range of fungal and bacterial diseases have been reported on finger millet, the most important pathogen of finger millet is blast caused by *Pyricularia grisea* (Cooke) Sacc. (Plate 1). This fungus causes brownish lesions on the stem and leaves, and black lesions on the inflorescence. The pathogen is highly destructive and economically important causing in excess of 50 % reductions in yield where the panicle is infected, and particularly in wet years (Dunbar, 1969: McRae, 1922). Losses of 10 – 90 % have been recorded in field studies in Uganda (Emechebe, 1975: Esele, 1989: Bisht, 1987), 64 % in Kiboko in Kenya (Pande *et al*, 1995) and near total losses in India (McRae, 1922). These losses are due to reductions in both grain number and grain mass (Rath and Mishra, 1975: Ekwamu, 1991).

Blast was first recorded in Uganda in 1933 (Emechebe, 1975), but relatively little is known of the biology and epidemiology of the causal organism *Pyricularia grisea*. The eighth EARSAM Regional Workshop on Sorghum and Millets in Sudan (December 1992) included several position papers presented by ICRISAT and National Programme scientists who agreed that comparatively little information exists on blast of finger millet.

Although blast can attack at all stages of finger millet development, from seedling stage through to maturity, causing lesions on the leaves, stem, neck and panicle little is known of the biology and sources of *P. grisea* on finger millet. Seeds, crop debris and weed hosts have been implicated as potential disease sources. Preliminary studies have now been conducted in Kenya through the project reported here (DFID project RS6733) and at ICRISAT (Pande *et al*., 1995).

P. grisea has been shown to be associated with infected seed. There are reports that heavily contaminated seeds show poor germination and there is, therefore, little opportunity for infected plants to reach maturity. However, there are reports of suspected seed transmission resulting in infection foci within the field. Research in India (Shetty *et al.*, 1985) has suggested that seed is a key source of inoculum and extremely low seed-borne incidence may initiate a blast epidemic. This is therefore an important area for further study in E. Africa.

Preliminary studies have addressed the effect of plant debris on the development of blast and infected debris has been shown to be associated with severe infections. There is, however, a need to investigate the survival of inoculum on crop debris and hence the potential of this inoculum source.

Several weed species including wild *Eleusine* spp., *Digitaria* spp. and *Setaria verticillata,* are able to support the pathogen, suggesting that these collateral hosts may be of importance under field conditions. Work in Uganda (Adipala, 1989) has indicated that some isolates of blast from weeds will also infect finger millet, hence the need for proper crop rotation and removal of alternate host species.

Epidemiological studies have demonstrated that yield losses are related to time of disease onset (Ramakrishnan, 1963). However, little is known of disease progress on different genotypes, especially those showing a measure of tolerance or resistance to the pathogen.

Differences in cardinal temperatures of the fungus isolated from different symptom types have led some authors to conclude that these represent different strains of the pathogen (Kulkarni and Govinda, 1976). This has more recently been disputed by Pande *et al.* (1995) who could not find evidence of pathogenic variation in isolates obtained from different parts of the plant.

The blast fungus, *Pyricularia grisea*, exists as numerous physiological races (Ramakrishnan, 1948). The considerable speculation which exists about the possibility for races of the pathogen is based on similarities with the related *Magnaporthe grisea,* causal agent of rice blast. However, the race structure of finger millet blast has not been described.

Preliminary experiments using molecular markers to assess variation in populations of *P. grisea* from finger millet were collected by Dr A Brown (Queens University, Belfast), during the 1995-96 extension of NRI project A0281 (R5349). The study compared isolates derived from infected finger millet panicles collected by Dr King in surveys in E. Africa. There clearly exists considerable variation among races, therefore it is essential that adaptive work such as evaluation of resistant cultivars, evaluation of fungicides or pre-adaptive work such as evaluation of the role of weeds as collateral hosts is conducted in the areas in which the work is to be promoted and adapted.

The demand for the work described in this report came from farmers themselves who rely on this important crop, from extension officers and those involved in other aspects of this crop such as staff from the National Research Programme. The agenda of the programme was initially developed as a consequence of this demand and based on existing knowledge described above. The programme was further refined following initial PRA activities (August, 1996) in Kisii and Busia / Teso, W. Kenya. These Districts were chosen in consultation with KARI and ICRISAT as they grow relatively large areas of finger millet and represent different agro-climatic zones and tribal groups. The socio-economic input was complimentary to on-going surveys by a multi-disciplinary team from KARI / ICRISAT, providing a more complete picture of finger millet production, as well as highlighting the dynamics, and potential for change within these farming system.

Project Purpose

Production System Purpose

Semi-arid purpose 2: Impact of significant pests on production from cereal (particularly sorghum) based systems minimised.

Specific objectives

The purpose of the project was to improve yields of finger millet in low-input farming systems in E. Africa by providing information on the biology and disease sources of a major production constraint, finger millet blast. This information can be used by breeders such as ICRISAT and the National Crop Improvement programmes to improve the process for selecting resistant varieties. Information can also be used towards the development of an integrated control strategy which comprises the most appropriate deployment of resistant lines in different regions, the removal of inoculum sources including debris and alternative or reservoir hosts, and planting practices. The suitability of released finger millet varieties P224 and Gulu E were evaluated through participatory work with small-holder farmers. The effect of timing of infection on yield loss was also investigated to determine whether integrated measures to delay disease onset are a potentially useful means for reducing the crop losses caused by blast.

The knowledge generated during the project has been promoted through the extension services, the KARI system and between farmers at the community level. This has enhanced farmers' indigenous knowledge of the crop disease and those steps which can presently be taken to reduce the deleterious effect of the blast pathogen on finger millet.

The finger millet crop has a vital role in nutrition, health and welfare of members of those communities associated with its production areas. It has a particularly high crude fibre and carbohydrate content which results in a low digestion rate with high sustaining power making it a valuable food for certain laborers. The phosphorus, calcium, iron and B vitamin content of finger millet add particular value to its importance in the diet of pregnant and lactating women and young children. It is considered important for cultural purposes, being used, for example, at agreement of bride-price, weddings and for brewing purposes. The crop also has medicinal roles in the treatment of measles, colds, anaemia and diarrhoea. This crop is often considered the domain of women and its successful cultivation at national level will enhance their status at both household and community level. Where sufficient yield is obtained, a portion of the crop may be sold to traders and thus become available to those sectors who may not otherwise have access to this product. Therefore minimising losses of this crop will contribute to poverty elimination through enhancing food security, welfare and livelihoods at the household and community level.

Research Activities

Output 1: The life-cycle of the finger millet blast pathogen in small-holder farming systems will be described with particular emphasis on inoculum sources and means of survival when the crop is not actively growing in the field

a) Pathogenicity of P. grisea isolated from infected finger millet heads

Finger millet heads displaying symptoms of blast were collected from the Kisii District at the commencement of the project. Isolations were made from this material (Output 2) and the identity of the fungus in axenic culture established as *Pyricularia grisea*. Aqueous suspensions were prepared of conidia from these cultures. These were combined to give a suspension of 7.2 x 10^4 spores cm^{-3}. The freshly prepared conidial suspension was used to establish that the fungus associated with the debris could act as a potential inoculum source. Thirty plants of finger millet cultivar KAT FM-1 (chosen for use because of its known susceptibility to blast) were each inoculated with 10 cm^3 of the spore suspension and another thirty plants with water. The plants were then covered with polythene bags for 24 hr in order to maintain high rh at the site of the inoculation. The temperature, rh and rainfall was recorded throughout the experiment.

b) Survival of inoculum on crop debris

Infected plant debris has been indicated as a potential source of infection although few studies on the survival of *P. grisea* have been undertaken. During farmer interviews (Output 4), it was found that finger millet crop debris, including diseased heads, are usually incorporated into the soil at the end of the season. Three experiments were carried out in which infected finger millet heads were buried in the soil at a depth either equivalent to incorporation (15 cm) or just below the surface line (SL). The methods were adjusted slightly for each experiment to try to ensure that the buried finger millet heads encountered conditions which were as close as possible to those which would be present if they were incorporated by the farmer whilst still being able to locate the heads for sampling. The average rainfall, relative humidity (%) and mean temperatures during these experiments were recorded (Table 1).

In experiment 1 (February - September 1997), 360 diseased finger millet heads were wrapped in net material (Plate 2) and placed in polythene tubes. The function of the polythene tubes was to assist in location of samples, 180 of which were buried at 15 cm and 180 just below the surface (SL). Ten samples from each of the two depths were dug up each month for a period of 7 months and examined in the laboratory for viable inoculum. Percentage pathogen survival was assessed by the number of positive isolations of *P. grisea* out of the total isolations made on ten dishes multiplied by 100.

In experiment 2 (February - September 1998), the same procedure was repeated using infected heads which had been tied to strings before burying in addition to those in polythene tubes (Plate 3).

In experiment 3 which took place from September 1998 - February 1999, a third batch of diseased heads were buried. These were placed in plastic net bags before burying at the two depths. (Plate 4)

Table 1: Average rainfall (mm), percent humidity, and mean temperatures (^{o}C) during the experimental periods

Period	Average rainfall (mm)	Average humidity (%)	Average mean temp. (^{o}C)
Experiment 1	159.8	59	20.81
Experiment 2	202.31	68.5	21.12
Experiment 3	126.38	55.4	22.02
Pathogenicity tests	94.2	51.7	22.78

Source: Meteorological Department, Kisii

c) Seed as a potential source of inoculum

Twenty one accessions of finger millet seed were screened for the presence of *P. grisea* using the blotter method of Mathur (1981). Two hundred seeds from each sample were plated onto moist blotter in Petri-dishes (25 seeds per dish). These were incubated for 24 hr in darkness at 20^{0}C and then for 24 hr at -20^{0}C. The plates were then maintained for 5 days at 20^{0}C on a 12 hr alternating cycle of darkness and NUV before examination for the presence of the blast pathogen.

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Plate 3

Plate 4

Output 2: Techniques for culturing the pathogen under artificial conditions, and screening for host plant resistance will be improved. These will be used to describe the relationship between environment, host type and pathogen strain under standardised conditions.

a) Culture and isolation of P. grisea

Isolation of *P. grisea* from crop debris has been possible by surface sterilisation of plant material in household bleach for 5-8 minutes and subsequent rinsing in sterile distilled water. The fungus may initially be isolated onto oat meal agar amended with streptomycin. The fungus requires alternating periods of darkness (12 hr) and NUV for growth and sporulation. The colonies can then be identified by morphological characters.

b) Screening for host plant resistance

Observations on the tolerance / resistance of key cultivars to blast have been undertaken under field conditions. However, ambient conditions were often too hot and dry for effective inoculation studies (Output 1). In addition, there is a requirement for a rapid bioassay so that large numbers of finger millet lines may be screened for resistance to blast under standard and repeatable conditions. A laboratory bioassay has now been developed which will enable evaluation of cultivar / pathogen interaction under controlled conditions in future research activities. This method is based on the inoculation technique for neck blast of rice developed by Guochang and Shuyuan (1992).

Panicles of finger millet cultivar KAT FM-1 were excised 0-10 days after heading. The boot leaf and one culm node were retained and the panicles placed in universal bottles containing 20 cm^3 water which was changed each 48 hr. Ten panicles were smeared with 1 % Tween-20 containing 3 x 10^4conida cm^{-3} using a soft brush and another ten panicles with either 1 % Tween-20 or water as a control. The panicles were covered with a beaker to maintain high rh and incubated for 24 h at 28^0C after which they were maintained at room temperature for 12 days (25 - 30^0C). The panicles were sprayed with a fine mist of water each morning and covered with a beaker throughout the period of the experiment. Space was maintained between the beaker and bottom surface to allow free movement of air. This experiment was repeated on four occasions.

c) Farmer participatory evaluation of finger millet varieties

The farmer participatory work described under Output 4 and also the PRA undertaken by Mrs Makini in support of her PhD studies (Makini, 1998 and NRI Internal Report 2475) identified a requirement for the deployment of blast-resistant finger millet varieties within small-holder farming systems. This output describes the evaluation of varietal resistance on-farm within a farmer participatory framework. The study focussed on evaluation of finger millet varieties P224 and Gulu E suggested by KARI for use in moist, mid-altitude locations.

1.0 Formation of a finger millet expert panel

A finger millet farmers' expert panel was formed from the farmer research group (farmers participating in the trials). An expert panel is normally a committee formed from farmers who grow a certain crop and who are experts on that particular crop. The chairman and secretary were appointed and their roles determined.

2.0 On-farm evaluation of finger millet varieties for resistance / tolerance to blast caused by *P. grisea* in Suguta, Masimba

The performance of two varieties of finger millet (P224 and Gulu E) and a farmers' local variety (mostly Enaikuru) were evaluated during the 1997, short rains (August 1997 - January, 1998) and the 1998 long rains (February - July, 1998).

Variety P224 and Gulu E were used in the trials because they were pre-release varieties recommended for western Kenya and were already commercially available (Anon, 1995a). Variety P224 is tolerant to finger millet blast (is infected by the blast but there is less adverse effect on yield compared to a susceptible variety) and Gulu E is moderately resistant (has moderate resistance to blast).

The trials were conducted on-farm by 20 farmers (= 20 replications) in Suguta village. Each farmer was provided with 100 g seeds of each variety and requested to plant on previously laid out plots of 4 x 4 m during the first season. In the second season, farmers laid out the plots and planted the provided seed themselves. Scientists (from KARI) and extension officers evaluated the trials each month. Disease scores (after flowering) and yield data were recorded. Farmers' views and evaluations of the varieties were also noted.

Disease scores were determined from the proportion of the finger millet in the plot (4 x 4 m) infected with blast where:

1 = 0 - 20 % of the crop in the plot infected with blast,

2 = 21 - 40 % infected,

3 = 41 - 60 % infected,

4 = 61 - 80 % infected,

5 = 81 - 100 % infected.

Every individual in the monitoring group (four people) gave a score for each plot and, through a consensus, the appropriate score value for the plot was recorded. As monitoring of trials was done each month, it was possible to score disease on two occasions before the crop was harvested. Cross tabulation of the scores by variety was done for both assessments (i.e. the number of plots with the same score for each variety was counted and the average between the seasons determined and presented in the form of a table).

3.0 Evaluation of finger millet varieties by farmers during the growing season in a field day held in Suguta village, Masimba

The same plots as described above were also monitored by the farmers themselves and the disease scored for every plot. Disease infection scores were taken twice during the growing season after the crop had flowered. After each visit by the members of the finger millet farmers' expert panel, a meeting was held to discuss the progress of the trials and actions to be taken such as if the crop required weeding, harvesting and weighing. Minutes were taken and recorded by the secretary to the expert panel.

A field day was held in January, 1998 to evaluate the performance of varieties during the short rains. Three farms were identified which were to be visited by all participating and non-participating farmers. The farms were chosen by the expert panel and village elders because the farms were close together (and therefore accessible for the visiting groups), treatment effects were clearly visible, and the owners of the farms were co-operative and undertook timely farm operations. At each site, the plots were labelled with the name of the variety and the agronomic practices used.

A total of 59 community members of Suguta village: 32 women and 27 men attended the field day (Plate 5). At the start of the day, the participating and non-participating farmers (from Suguta village) visited the trials on each of the three farms. At each small-holding, the host farmer and the chairman of the expert panel presented the nature and objectives of the trials and their observations during the season. Discussions were held on each farm (mostly to clarify issues to non-participating farmers). After the field visit, the chairman of the expert panel presented the data collected from all participating farmers during the season to the whole group. This information included susceptibility to blast disease and bird damage, maturity period and yield. Further discussions were held and farmers' preferences noted.

4.0 Evaluation of the domestic and culinary attributes of finger millet varieties for farmer acceptability through a utilisation workshop

A finger millet utilisation workshop was held after harvest with participating and non-participating farmers to evaluate the domestic and culinary attributes of the varieties for acceptability (Plate 6). The finger millet variety attributes evaluated were; seed colour, size and taste, malting quality, flour quality, suitability for *ugali* (stiff porridge) and *uji* (soft porridge). Farmers were provided with finger millet to mill for *ugali* and *uji* preparation. In addition, the quality of the malted seed with respect to processing as part of brewing was evaluated.

A score sheet with criteria for variety evaluation as given by farmers was prepared. Each individual was given the score sheet to record for every attribute using a scale of one to five where 1 = very good, 2 = good, 3 = not too good nor too bad, 4 = bad and 5 = very bad.

5.0 Transfer of appropriate finger millet agronomic practices to farmers through a visit to on-station finger millet research trials

At the request of farmers during one of the expert panel meetings, a visit to the Regional Research Centre was organised for 8-10 appointed participants. Ten farmers participating in the on-farm trials visited the Centre on 27th November, 1998. The programme included a briefing session, visit to the laboratory and field. (Plate 7)

6.0 Socio-economic evaluation of finger millet varieties.

During the long rains season (February - July, 1998), socio-economic evaluation of finger millet varieties was undertaken to determine the cost effectiveness of finger millet varieties P224, Gulu E and Enaikuru. Agri-economic data (based on the 4 x 4 m trial plots) which included all the individual costs of production (e.g. cost of land cultivation and seed-bed preparation, weeding, scouting, harvesting, cost of inputs, number of people involved and the time taken for each farm operation and the farm-gate prices of finger millet) were collected from the participating farmers and used to determine the net benefits and benefit:cost ratios from crops of the three finger millet varieties. This was based on the achieved yields and the farm-gate prices reported by the farmers at that time.

7.0 Evaluation of finger millet varieties to determine acceptability and likely adoption in Suguta village through a final farmers' workshop.

After the participatory trials were completed, a farmers' workshop was held during which the finger millet varieties were evaluated for acceptability and likely adoption. A total of 75 participants: 53 women, 12 men, 10 research and extension officers attended this final farmers' workshop. All the data and information collected from the area was presented and discussions held. Pairwise and matrix ranking exercises were then undertaken (by men and women separately) to determine farmers' varietal preferences and the acceptability of the introduced varieties: P224 (tolerant to blast) and Gulu E (moderately resistant). The women compared the two introduced varieties to traditional varieties Enaikuru, Marege and Mokomoni. Men, however, being less familiar with the crop, could only relate the two introduced varieties to Enaikuru.

8.0 Evaluation of finger millet varieties for marketability, acceptability and adoption through a stakeholders' workshop.

After evaluation of the agronomic, socio-economic, domestic and culinary aspects of the finger millet varieties, a stakeholders' workshop was held to further evaluate the varieties for marketability and adoption. Extension officers and traders (as partners in crop production - especially dissemination and marketing of crop varieties) were involved in this exercise.

Finger millet traders were visited in Daraja Mbili market, Central Kisii District and a date (20th November, 1998) set for the exercise. A score sheet was developed using criteria given by the traders for variety evaluation which included seed size, colour and taste, marketability, adoption, suitability for *ugali*, *uji* and brewing. During the workshop each of the traders (mainly women) were given the score sheet and asked to evaluate the three varieties P224, Gulu E and Enaikuru using a scale of one to five for each attribute as previously described. (Plate 8)

Plate 8

Output 3: The effects of time of infection on-set, type of host plant resistance and pathogen strain on yield loss will be quantified.

a) Comparison of yield losses caused by neck and head blast

On-station

Finger millet heads were collected from each of the three varieties (referred to above) from crops grown on-station at KARI, Kisii research station during the third season (November 1998 – January 1999). Thirty heads with the following characteristics were collected for each variety: 3-finger head with all fingers (spikelets) blasted, 3-finger disease-free head (healthy), 3-finger head with neck blast, 4-finger head with all fingers blasted, 4-finger disease-free head (healthy) and 4-finger head with neck blast. The heads were dried, threshed, winnowed and weighed. The weight per finger was then determined and the yield loss calculated as a percentage of healthy material per finger.

On-farm

Ten farms were randomly selected in Masimba where ten finger millet heads with either four or three fingers and which had either neck blast, head blast or were disease free (healthy) were collected. These were dried, threshed, winnowed and weighed. Yield loss was determined as described above.

b) The effect of time of blast infection on yield loss of finger millet

This investigation was undertaken on three occasions as follows:

First experiment in the 1997 short rains (August 1997 – January 1998),

Second experiment in the 1998 long rains (February 1998 – July 1998),

Third experiment in the 1998 short rains (August 1998 – January 1999).

Two finger millet varieties: P224 (tolerant to blast) and KAT FM1 (susceptible to blast) were established in a split plot design with time of inoculation as the main plot factor and variety as sub-plot factor. There were four replications.

Information on rainfall, temperature and mean humidity was collected on a monthly basis. Standard agronomic procedures for the area were used which included; a seed rate of 4 kg ha^{-1}, application of 250 kg ha^{-1} diammonium phosphate fertiliser, and weeding when necessary. Manual irrigation was undertaken when required. Bird scaring was undertaken from grain formation to harvesting.

There were five treatments for the time of inoculation:

Treatment 1 = Control (uninoculated + fungicide application)

Treatment 2 = Control (uninoculated without fungicide application)

Treatment 3 = Early inoculation (at flowering) [90 days after sowing (DAS)]

Treatment 4 = Medium inoculation (end of flowering to seed formation) [104 DAS]

Treatment 5 = Late inoculation (milk stage) [116 DAS]

Four rows of each variety were planted in a total of ten plots and subjected to the above treatments. Each row was 3m long and planted with a spacing 30 x 10 cm within 2.1 x 3 m plots. Two guard rows were planted on either side of each plot with a third cultivar, Gulu E (moderately resistant). More guard rows of variety Gulu E were planted between plots to reduce interplot interference.

Application of the protective fungicide, Dithane M45, commenced 85 DAS at the rate of 150 g in 20 l of water. During wet and cloudy periods (high disease pressure), Benlate, a systemic fungicide, was applied at the rate of 25 g in 20 l of water.

Blast inoculum was applied to the finger millet plants in the field by spraying plants with a freshly prepared conidial suspension (7.4×10^4 spores cm^{-3}) shortly before flowering.

Data collection commenced at 100 % flowering (soon after the first inoculation). Data were collected from the two innermost rows of the experimental varieties and included: total number of plants, yield, disease incidence and severity. Disease incidence and severity was recorded weekly until harvest. Disease incidence was calculated as the number of diseased plants divided by total number of plants x 100. Disease severity was calculated as the sum total of number of diseased fingers divided by total number of fingers from each infected plant in the two centre rows x 100 to give a severity score for the plot.

Yield loss for each of treatments 2, 3, 4 and 5 was calculated from the yield difference between the particular treatment and the fungicide treated control (treatment 1 - uninoculated + fungicide application). Except in the third season where the yield information from treatment 2 (uninoculated without fungicide application) was used. This was because the control treatment 1 (uninoculated + fungicide application) was adversely affected during this season.

The mean rainfall, temperature, number of days of rainfall and relative humidity per month from the time of the first inoculation (90 DAS) to harvesting are presented in Table 2 as these factors obviously influenced disease infection.

Table 2: Mean rainfall (mm), temperature (^{o}C), number of rainy days per month and relative humidity (%) starting from the time of the early inoculation (90 DAS) to harvest

Season (period)	Mean rainfall (mm)	Mean temperature (^{o}C)	Mean number of rainy days	Mean Relative Humidity (%)
1 (Nov 1997 - Jan 1998)	277.27	24.23	21	77
2 (May - Jul. 1998)	181.03	24.70	16	68
3 (Nov 1998 – Jan 1999)	94.17	26.90	8	52

Source: Meteorological Department, Kisii

Output 4: Farmers' perceptions of the importance of finger millet and blast (together with the status of their knowledge about the pathogen, its origins and means of control) will be gathered for the Busia, Kisii and Kiboko regions of Kenya (these representing 3 different tribal groups and ecological zones).

a) Farmer perceptions

A socio-economic perspective of finger millet production within small-holder farming systems in Western Kenya, together with the potential for controlling blast was gathered through a survey conducted in Kisii District and Teso / Busia. These Districts represent different agro-climatic zones and tribal groups (Kisiis in Kisii and the Samir Luhya and the Ateso in Busia / Teso). The areas covered were pre-selected using the data on pests and diseases of millets and sorghum collated during the ICRISAT / KARI survey in 1995 (S B King, unpublished). The route followed and the farms are summarised in table 3.

b) Disease survey

A disease survey was undertaken in January / February 1999 to provide quantitative information on the disease incidence and severity in farmers' fields in Kisii District.
Ten villages were selected with the assistance of the agricultural extension officers in Masimba Division, Kisii District which hosted the farmer participatory trials. Twenty farms were selected in each village, visited and their finger millet crops examined. Thirty plants were selected at random along a 'W' or 'X' - shaped path across the field. These were scored for disease incidence and severity. Disease incidence was calculated as the number of diseased plants of the total (30) examined. This was expressed as a percentage. Disease severity was scored as number of diseased fingers per finger millet head divided by the total number of fingers. Average disease severity was calculated and multiplied by 100 to give percent disease severity. It should be noted that severity was recorded when blast lesions were observed on the fingers whether or not grain filling had occurred. Twenty finger millet heads were selected at random and the blast severity of each recorded. The heads were then dried, threshed and winnowed and the grain

weighed to determine the effect of disease severity and incidence on crop yield in farmers' fields.

Table 3: Details of the farmers interviewed including their names, village and location

Code	Farmer	Village	Sub-location	Location	Division
1	Kerubo Nyamaratandi	Mwakengara	Bomwagi	Nyaribari	Keumbu
2	Mary Ogecha	Mwakengara	Bomwagi	Nyaribari	Keumbu
3	Alice Kerubo Kabete	Nyangeni	Bironuo	Nyaribari	Keumbu
4	Canina Nyanchoka				
5	Benin Amaya Tendere	Morure			
6	Jaqueline Kerubo	Suguta		Metembe	Masimba
7	Priscilla Ramacha/Mary Marumbwa	Suguta		Metembe	Masimba
8	Pacifica Basweti	Bonyamonyio	Gekonge		
9	Sarah Mabiere				
10	Agnes Nyamoita				
11	Consalata Gibiti / Mr Murimi	Mabera	Bugumbe West		Migori
12	Joseph Munyoro	Bukira	Namaranya		
13	Susannah Robi		Kebaroh	Nyabasi	
14	Group 1- Ateso women (4-5)	Akitesi Market	Apegei	Kamarinyang	Teso
15	Group 2- Ateso and Samia Luhya women (20-25)	Angoromo Market	Alupe		Busia
16	Lawrence Otemba	Angoromo	Alupe		Teso
17		Angoromo	Alupe		Teso
18	Group 3- 28 Samia Luhya women (12) and men (6)	Buyende	Sibembe		Busia
19	Group 4- Ateso women (15) and men (8)	Asinge	Apegei	Kamarinyang	Teso
20	Group 5- Ateso women (22) and men (7)	Chakole	Apegei	Kamarinyang	Teso

Results

Output 1: The life-cycle of the finger millet blast pathogen in small-holder farming systems will be described with particular emphasis on inoculum sources and means of survival when the crop is not actively growing in the field

a) Pathogenicity of P. grisea isolated from infected finger millet heads

After four weeks, 14 plants showed blast symptoms. The average temperature was 23^0C, rh 52 % and rainfall 94 mm. Thus, despite conditions being much drier than optimal for this pathogen, it was clear that crop debris contained viable inoculum which could cause blast of subsequent finger millet crops. As a consequence, studies were undertaken to determine for how long this inoculum retains its viability in the field situation.

b) Survival of inoculum on crop debris

The rate of loss of viability was similar for all the methods and depths in most cases, although it was slightly slower for inoculum in the net bag at 15 cm depth. In addition, rate of loss of viability of inoculum in the net bag at soil line also slowed down after the first month. The average rainfall and percentage humidity were lower in experiment 3 than during both experiments 1 and 2 and the temperature was higher which probably explains why loss of fungal viability was slower than during experiment 2 but slightly faster than experiment 1. These factors have been shown previously by Padwick (1950) to affect inoculum survival.

In experiment 1, there was no viable inoculum detected by the sixth month at either depth. It appeared that loss of viability occurred more quickly when debris was buried at a depth of 15 cm compared to that which occurred when debris was buried below the soil line (Figure 1).

In experiment 2 (February - September 1998) the same procedure was repeated using infected heads which had been tied to strings before burying in addition to those in polythene tubes. Again, the rate of loss of viable fungal inoculum occurred more quickly at soil depth compared to the soil line. No viable inoculum was recovered from infected heads which had been buried at 15 cm after two months whereas viable inoculum was recovered from the soil line after three months (Figure 2). The rate of loss of viability of the fungus appeared to be reduced slightly when debris was buried in the net material.

In experiment 3 which took place from September 1998 - February 1999, a third batch of diseased heads were buried. These were placed in plastic net bags before burying at the two depths. For each method, the fungus lost viability by the fourth month except for that in the net bags buried at a depth of 15 cm which remained viable until the fifth month (Figure 3). It was not possible to determine when the fungus lost viability using the strings method because it was impossible to retrieve heads tied to strings after five months.

Overall, these experiments indicate that *P. grisea* may survive on crop debris in the soil for up to five months, although there is considerable reduction in inoculum potential two months after incorporation. Therefore, incorporation of crop debris to a depth of 15 cm and a rotation period >5 months would appear necessary to reduce the inoculum potential of this source. There is, however, some benefit to be gained from a rotation period even of two months.

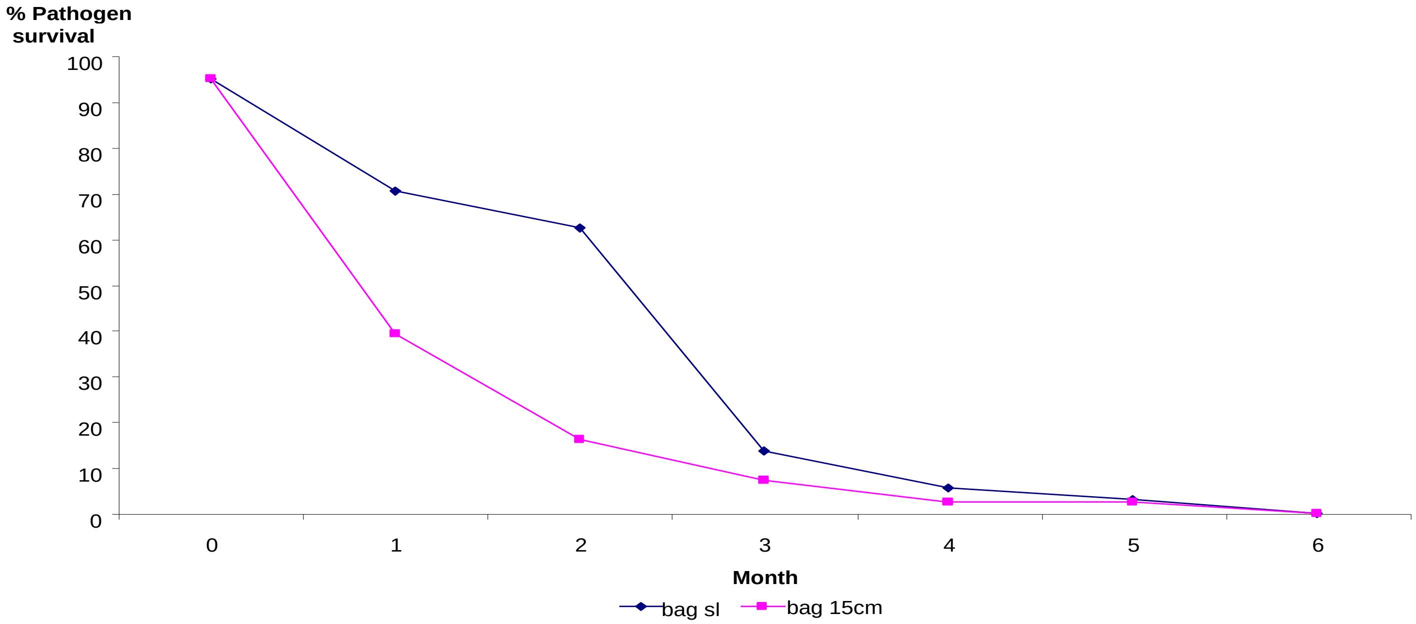

Figure 1: Percent pathogen survival in experiment using net material and polythene bags in experiment 1

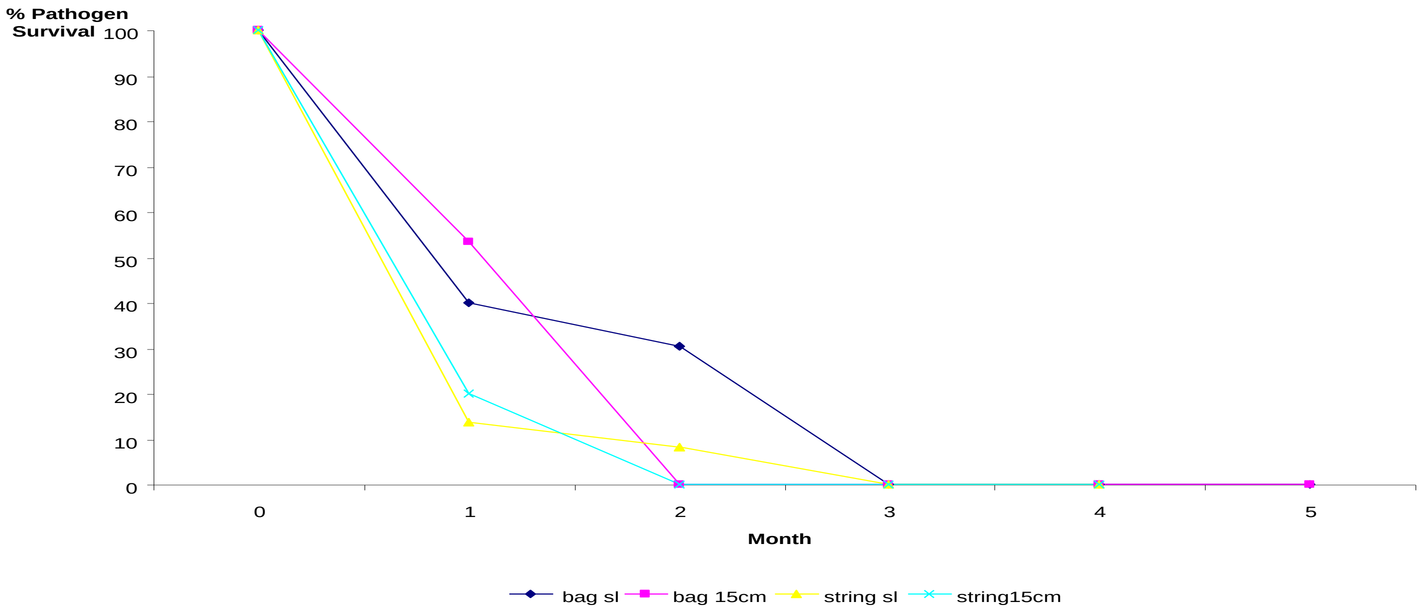

Figure 2: Percent pathogen survival in using strings, net material and polythene bags in experiment 2

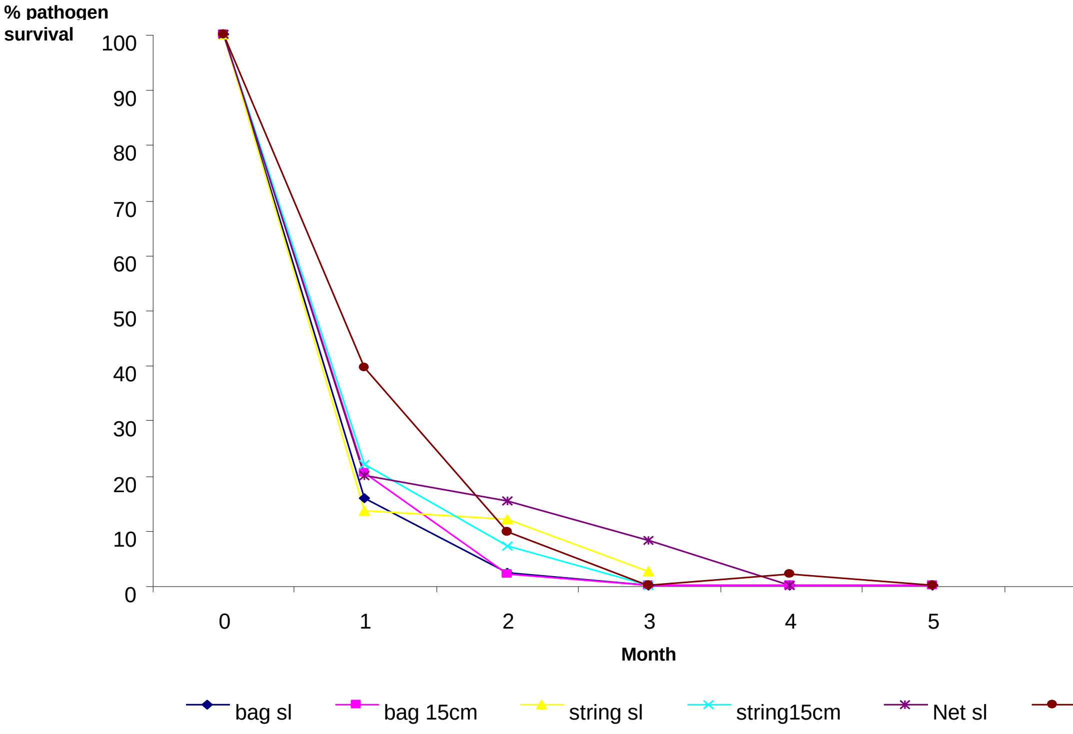

Figure 3: Percent pathogen survival using strings, net bags, net material and polythene bags in experiment 3

c) Seed as a potential source of inoculum

The blast fungus was found on 20 of the 21 samples examined. The incidence of seed infection / contamination ranged from 0-51 % (average 9.6 %) (Table 4). These observations indicate that there is a requirement for further work on seed-borne aspects which would include investigation of the relationship between seed-borne incidence, transmission and subsequent disease development.

Table 4: Incidence of *P. grisea* on finger millet seed samples

Source	Location	Variety	Seed infected (%)
Farmer	Masimba	Gulu E	0
Farmer	Kijauri	Enaikuru	0.5
Farmer	Masimba	Enaikuru	1.0
Farmer	Kijauri	Enaikuru	1.0
Farmer	Masimba	P224	1.5
Farmer	Masimba	Enaikuru	1.8
Farmer	Kijauri	Enaikuru	2.0
Farmer	Kijauri	Enaikuru	3.5
Farmer[2]	Masimba	Enaikuru	5.0
Farmer	Kijauri	Enaikuru	6.0
Farmer	Masimba	Gulu E	7.0
Farmer	Masimba	Enaikuru	7.5
Farmer	Masimba	Enaikuru	9.5
Farmer	Masimba	Gulu E	9.5
Market[1]	Keroka	Enaikuru	10.0
Farmer	Masimba	Enaikuru	11.5
Farmer	Masimba	Enaikuru	16.5
Market[1]	Nyamagesa	Enaikuru	17.0
Farmer	Masimba	Enaikuru	18.0
Farmer	Masimba	Enaikuru	21.0
Research Centre	Kisii	KAT FM-1	51.0

Output 2: Techniques for culturing the pathogen under artificial conditions, and screening for host plant resistance will be improved. These will be used to describe the relationship between environment, host type and pathogen strain under standardised conditions.

a) Culture and isolation of P. grisea

The Director and pathology staff at KARI, Kisii are proficient in axenic culture of the pathogen using suitable media / UV light combinations. Isolation of *P. grisea* from crop debris has been possible by surface sterilisation of plant material in household bleach for 5-8 minutes and subsequent rinsing in sterile distilled water. The fungus is initially isolated onto oat meal agar amended with streptomycin. The fungus requires alternating periods of darkness (12 hr) and NUV for growth and sporulation. The colonies may then be identified by morphological characters.

b) Screening for host plant resistance

No disease symptoms were observed on the controls in any of these experiments and positive infection occurred in at least 7 out of 10 inoculated panicles (Table 5). This technique is thus suitable for use in future studies to evaluate pathogenicity of different isolates of *P. grisea* on different lines of finger millet. The technique will also enable studies to be undertaken on cross infection of blast between weeds and finger millet. (Plates 9 & 10).

Table 5: Pathogenicity tests using *in vitro* panicles

	Number of panicles infected (%)	Number of panicles not infected (%)	% infection
Inoculated	9	1	90
Control (water)	0	10	0
Inoculated	10	0	100
Control (water)	0	10	0
Inoculated	7	3	70
Control (1% Tween 20)	0	10	0
Inoculated	10	0	100
Control (1% Tween 20)	0	10	0

Plate 9

Plate 10

c) Farmer participatory evaluation of finger millet varieties

1.0 Formation of a finger millet expert panel

Four farmers: two women and two men and the front-line extension officer were appointed members of this panel with the extension officer as secretary. Front-line extension officers are those extension personnel who are normally assigned to farmers, in either a location or sub-location, whom they are expected to visit on a daily basis.

2.0 On-farm evaluation of finger millet varieties for resistance / tolerance to blast caused by *P. grisea* in Suguta, Masimba

Twenty farmers were involved in the on-farm trials and most of them planted Enaikuru as their variety.

There were no significant differences in yields between varieties in the first season (short rains, 1997) (Table 6). The full statistical analysis is given in Appendix 1.

Table 6: Yield of finger millet in Suguta, Masimba over two seasons (short rains, 1997 and long rains, 1998)

		Variety		
Season	Period	P224	Gulu E	Enaikuru
1	Aug'97 – Jan '98	1.103[1]	1.142	1.009
2	Feb '98 – July '98	0.815	0.911	1.231
Combined seasons		1.042	1.076	1.095

[1]*Yield in kg per 4 x 4 m plot*

During the first season (short rains), the crop was initially affected by severe drought which led to total crop failure in some cases. As a consequence of this, six of the farmers under study did not harvest. Thus, yield information was available from only 14 farmers. Some of the crops in these farms had poor germination and were later affected by the heavy *El nino* rains. This accounts for the very poor yields in this season. Mean yields on farmers' fields ranged from 0.11 to 2.49 kg per 4 x 4 m plot (Table 7).

Table 7: Mean finger millet yields (kg per 4 x 4 m plot) on farmer's fields in Suguta, Masimba in two seasons.

Farmer's name	Mean yield (kg / 4 x 4 m plot)	
	Season 1	Season 2
Alice Kerage	0.60	1.47
Consolata Kieka	1.51	1.06
Dorica Moranga	0.34	0.65
Elizabeth Nyabuto	0.60	0.70
Eunice Areri	0.11	-
Florence Mirieri	1.55	0.78
John Manduku	2.49	1.66
Lucia Moranga	1.20	1.57
Lydia Gichaba	0.56	0.30
Mary Omare	1.87	-
Nyaboke Ramasha	1.04	1.25
Priska Mogire	0.42	0.70
Priskila Nyakiriga	1.62	0.66
Rael Osiemo	1.30	0.62
Daudi Ogwoka	-	0.49
Isabella Mogire	-	1.89
Margaret Mogire	-	0.74
Marsella Moranga	-	0.38
Nathan Mogire	-	1.54
Sabina Motiri	-	1.28

- = *No yields (due to crop failure) or farmer not involved in that particular season*

In the second season (long rains, 1998), there were highly significant differences in the yields between varieties (Table 6). Enaikuru, the local variety significantly out-yielded the introduced varieties: P224 and Gulu E and the 95 % confidence interval for the difference was 0.15 to 0.59 kg. In this season, the trial was also affected by severe drought which set in a month after planting resulting in the loss of crops from three farms and poor crop performance leading to lower than average yields in the remaining crops. Farmers' total yields ranged from 0.30 to 1.89 kg per 4 x 4 m plots (Table 7).

In the combined analysis, a significant interaction was observed between variety differences (contrast - mean of (P224 & Gulu E) - mean of Enaikuru [comparison of new and old] and season). This confirmed the different responses to the variety Enaikuru noticed in season one and two. However, no significant differences between varieties were noted in this analysis.

In the *P. grisea* disease score analysis, there were a lot of low counts in the contingency tables leading to inaccurate $\chi 2$ approximation. Analysis of variance was therefore found to be inappropriate in this case. However, a log-linear analysis was undertaken but it should be noted that the conclusions from this are only approximate.

In the first season, an examination of the average number of plots for each score and each variety and the residuals from the fit in the log linear model (variety + time + score + variety.score) showed that Gulu E had more resistance to blast than did P224 or Enaikuru. Most of the plots of Gulu E evaluated for disease, scored 1 (disease infection 0 - 20 %). Conversely, variety P224 had most counts in score 2 whilst for Enaikuru they were distributed across the scores one to three (Table 8).

Table 8: Average number of plots for finger millet varieties for each disease score[1] in Masimba over two seasons

Season	Variety	Score 1	Score 2	Score 3	Score 4
1	P224	3.5	8	1	0
1	Gulu E	11.5	1	0.5	0
1	Enaikuru	4.5	4.5	4	0
2	P224	2	8.5	1.5	3
2	Gulu E	14.5	1	0.5	0
2	Enaikuru	7	3.5	4	1.5

Note: [1] A scale of score 1 - 5 was used where 1 = 0 - 20 % infection, 2 = 21 - 40 %, 3 = 41 - 60 %, 4 = 61 - 80 %, 5 = 81 - 100 % disease infection.

A similar trend was observed in the second season with Gulu E emerging as the variety with the most resistance to blast. In this season, most Gulu E plots scored one for disease infection whereas for P224 and Enaikuru, the counts were distributed across all the scores (one to four) an indication of their susceptibility to disease infection.

Further analysis indicated that there is no correlation between the disease infection and yield ($r = 0.04$ NS at $p \geq 0.05$) (Appendix 2). This may be because yield was affected adversely by the uncharacteristic weather conditions hence the relationship between the disease and yield could not be detected.

3.0 Evaluation of finger millet varieties by farmers during the growing season (January, 1998) in a field day held in Suguta village, Masimba

The chairman of the expert panel presented information which included disease infection and progress, maturity, bird attack and yield which had been collected during monitoring and evaluation visits to all the on-farm trials throughout the season (Table 9).

Table 9: Variety attributes as presented during the field day by the farmer expert panel to Suguta farmers based on the panel's perceptions and data collection over the season

Attributes	Gulu E	P224	Farmer's cultivar
Average disease scores for time 1 and 2 [1]	1, 1.37	1.71, 1.83	1.64, 2.23
Early maturity	Low	High	Medium
Bird attack	Nil	High	High
Disease infection	Nil	Medium	High
Yield (kg / 4 x 4 m plot)	1.142	1.103	1.009

Note: [1] A scale of 1 - 5 was used where 1 = 0 - 20 % infection, 2 = 21 - 40 %, 3 = 41 - 60 %, 4 = 61 - 80 %, 5 = 81 - 100 % disease infection.

The Chairman explained that there was drought at the beginning of the season which resulted in poor germination of most crops. As the season progressed, *El nino* rains further affected the crop resulting in very low yields across the farms.

He further indicated that P224 was preferable to the other varieties. This is because it is early maturing and more tolerant to blast than Enaikuru. It is susceptible to bird damage (Table 9). The early maturity of variety P224 meant that food could be available when most other crops are still in the field thus alleviate hunger at such times. Gulu E was found to have limited damage due to birds and disease infection although it was late maturing (Table 9). Farmers also perceived it to be a high yielding variety under better environmental conditions by looking at the formation of the head. These observations were drawn in comparison to their own variety (mostly Enaikuru) which was not as early maturing as P224 and was susceptible to both disease infection and bird damage. These observations were discussed and endorsed by the farmers especially those participating in the trials. Non-participating farmers were also involved in the field day and their field observations included in the discussion.

4.0 Evaluation of the domestic and culinary attributes of finger millet varieties for farmer acceptability through a utilisation workshop

A total of 119 participants: 50 women, 60 men, 4 extension and 5 research officers attended the utilisation workshop and evaluated the three varieties (P224, Gulu E and Enaikuru) for culinary and domestic attributes. Variety P224 was ranked highest for most attributes by all the workshop participants except for seed taste and malted seed colour. For some attributes such as seed colour, malting, flour colour and *uji* taste, it was ranked the same as Enaikuru. For *ugali* (stiff porridge) , P224 was ranked highest followed by Gulu E (Table 10).

Table 10: Evaluation of finger millet varieties for different characteristics by 119 participants in a utilisation workshop, Suguta village

Characteristic	Attribute	P224	Gulu E	Enaikuru
Seed	Colour	1	2	1
	Taste	2	2	1
	Seed size	1	2	3
Germinated seed	Colour	2	2	1
	Malting	1	2	1
Flour	Colour	1	2	1
Ugali	Taste	1	2	3
	Colour	1	2	3
Uji	Taste	1	2	1
	Colour	1	2	3
Overall Ranking		1	2	3

Note: Numbers indicate the most selected score for every attribute. Every individual was asked to give overall ranking and the most selected score was selected

Evaluation of varieties was also repeated for the sub-groups women, men and research officers. All the sub-groups ranked P224 highest followed by Gulu E. However, women also ranked Enaikuru highest similar to P224 (Table 11). This is probably because they found P224 to be similar to Enaikuru and ranked them the same for malting, *uji* taste, flour, *ugali*, and *uji* colour.

Table 11: A summary of the overall ranking of finger millet varieties by different sub-groups

Sub-group	P224	Gulu E	Enaikuru
Women	1	3	1
Men	1	2	3
Research officers	1	2	3

Note: Numbers indicate the most selected score

Extension officers were too few and hence it was not possible to determine their preferences. However, during the stakeholders evaluations they were more in number and their preferences are presented under that section. This evaluation was done after the first season (short rains, 1997) of growing the introduced varieties. Generally, it appears that the released variety, P224,was preferred and the most acceptable.

5.0 Transfer of appropriate finger millet agronomic practices to farmers through a visit to on-station finger millet research trials

Ten farmers visited the KARI, Kisii Research Centre and toured finger millet trials. They noted the performance of the crop under recommended agronomic practices and realised they were potentially able to improve their finger millet yields through application of these practices. Thus awareness of improved practices and opportunities was created through the tour. This had an impact on their participation and interest in the on-farm trials. Awareness of the opportunities through availability of improved technologies from the research centre was also created resulting in several requests for advisory services on finger millet and other areas of work undertaken at the centre including sourcing materials from the centre such as improved banana varieties, information on banana production, advice on livestock production and various control methods for crop diseases and pests.

6.0 Economic evaluation of finger millet varieties

The cost benefit analysis indicated that in this particular season (long rains, 1998), the farmers' variety was the most cost effective variety to grow and gave the highest net benefit (profit) followed by Gulu E (Table 12). Finger millet variety P224 gave a negative net benefit and benefit cost ratio (indicating that it is not cost effective to grow this variety) under the conditions experienced in this particular long rains season (February to July, 1998). It should be noted that total costs and farm-gate prices were the same for all the varieties hence the differences obtained were based on yields achieved in this particular season.

Table 12: Determination of the cost effectiveness of three finger millet varieties [costs (£) per hectare].

Activity	P224 (Cost[1] £ ha^{-1})	Gulu E (Cost £ ha^{-1})	Farmer's Variety (Cost £ ha^{-1})
Land preparation	23.71	23.71	23.71
Seedbed preparation	18.87	18.87	18.87
Cost of fertiliser	37.42	37.42	37.42
Cost of seed	14.52	14.52	14.52
Cost of planting	20.56	20.56	20.56
1st weeding	31.61	31.61	31.61
2nd weeding	16.03	16.03	16.03
Harvesting	29.02	29.02	29.02
Scouting	3.79	3.79	3.79
Carrying from field	15.94	15.94	15.94
Drying,threshing, winnowing	16.30	16.30	16.30
Total cost (a)	227.80	227.80	227.80
Yield	3.73	4.14	5.40
Farm-gate price per kg	0.33	0.33	0.33
Gross benefit (b)	123.78	138.92	178.98
Net benefit (b-a)	-107.96	134.77	173.57
Benefit cost ratio [(b-a) / a]	-0.42	0.61	0.81

Note:

Figures are averages from all the participating farms (18)

[1] *Figures were converted from Kshs using a rate of Ksh. 100 = £1*

7.0 Evaluation of finger millet varieties to determine acceptability and likely adoption in Suguta village through a final farmers' Workshop

A total of 75 participants: 53 women, 12 men, 10 research and extension officers attended the final farmers' workshop. All the data and information collected from the area was presented and discussions held (Plate 11). Pairwise and matrix ranking exercises were then undertaken (by men and women separately) to determine farmers' varietal preferences and the acceptability of the introduced varieties: P224 (tolerant to blast) and Gulu E (moderately resistant) (Table 13 & 14). The women compared the two introduced varieties to traditional varieties Enaikuru, Marege and Mokomoni. Men however, being less familiar with the crop, could only relate the two introduced varieties to Enaikuru.

Womens' preferences in order of priority were Enaikuru, Gulu E and P224. Conversely, men's preferences differed from women and were Gulu E, P224 and Enaikuru respectively (Table 14). Several reasons were given for these preferences which include disease, drought and bird damage resistance, maturity, colour, taste, yield and marketability (Table 15).

The results indicate that Gulu E was preferred for high yields and for disease, resistance bird damage and drought resistance. Although Gulu E did not perform better than Enaikuru in the on-farm trials, farmers perceived it to be a high yielding variety.

Plate 11

Table 13: Pairwise ranking of finger millet varieties grown in Suguta village after the introduction of P224 and Gulu E as given by 53 women farmers participating in the final farmers workshop

	P224	Gulu E	Enaikuru	Marege	Mokomoni	Score	Rank
P224	x	Gulu E	Enaikuru	P224	P224	2	3
Gulu E		x	Enaikuru	Gulu E	Gulu E	3	2
Enaikuru			X	Enaikuru	Enaikuru	4	1
Marege				x	Marege	1	4
Mokomoni					x	0	5

Table 14: Pairwise ranking of P224, Gulu E and Enaikuru as given by 53 women (12 men) in Suguta village

	P224	Gulu E	Enaikuru	Score		Rank	
				Women	Men	Women	Men
P224	x	Gulu E (Gulu E)	Enaikuru (P224)	0	1	3	2
Gulu E		x	Enaikuru (Gulu E)	1	2	2	1
Enaikuru			x	2	0	1	3

Note: Brackets indicate men's preferences in each case

Table 15: Matrix ranking of finger millet varieties as given by 65 community members in Suguta village

Cultivar	Disease Resistance	Maturity	Bird Resistance	Colour	Yield	Drought Resistance	Taste	Marketability
P224	2	1	3	2	3	2	1	3
Gulu E	1	3	1	3	1	1	3	2
Enaikuru	3	2	2	1	2	2	2	1

8.0 Evaluation of finger millet varieties for marketability, acceptability and adoption through a stakeholders workshop

Nine finger millet traders and seven extension officers were involved in the evaluation of the three finger millet varieties. The criteria for evaluation included seed colour, size and taste, marketability, likely adoption and whether preferred for food (*uji* and *ugali*) preparation or brewing alcohol.

Both traders and extension officers ranked Gulu E highest in seed colour, brewing and overall. In addition, they ranked P224 as best for *ugali* and Enaikuru for seed taste. The combined data analysis confirms this trend with Gulu E emerging as the best variety (Table 16).

Table 16: Evaluation of P224 and Gulu E in comparison with Enaikuru by 16 stakeholders.

Attribute	Enaikuru	Gulu E	P224
Seed colour	2	1	2
Seed taste	1	2	3
Seed size	3	1	2
Marketability	2	2	2
Adoption	2	2	3
Ugali	2	2	2
Uji	2	2	2
Brewing	2	1	3
Overall	3	1	2

Note: Numbers indicate the most selected score

Output 3: The effects of time of infection on-set, type of host plant resistance and pathogen strain on yield loss will be quantified.

a) & b) Determination of yield losses caused by neck and head blast

Yield losses per finger caused by head blast (all fingers blasted) ranged from 42 to 72 % on-station and were up to 87.5 % on-farm whereas for neck blast they ranged from 0 – 91 % on-station and up to 36 % in farmers' fields.

Table 17: Mean yield (g) and percent yield losses in on-station trials and on farmers' fields.

Cultivar	Weight per finger (disease-free)	Weight per finger in head blast (g) (% yield loss)[1]	Weight per finger in neck blast (g) (% yield loss)
Gulu E	0.91	0.53 (42.0)	1.19 (0)
KAT FM-1	1.28	0.36 (72.0)	0.31 (76)
P224	1.07	0.36 (66.0)	0.10 (91)
Enaikuru (Farmer's fields)	1.12	0.14 (87.5)	0.43 (61)

[1] Figures in brackets are yield losses per finger

Gulu E, a moderately resistant variety, had the lowest yield losses caused by head blast and none by neck blast. These observations are thus consistent with the low disease scores reported for this variety (Table 8). In the on-station trials, KAT FM-1 had the highest losses caused by head blast whereas for neck blast, P224 had the highest losses. However, both of these varieties had higher yield losses caused by neck blast than did Gulu E. On farmers' fields, head blast caused higher losses per finger compared to neck blast.

c) The effect of time of blast infection on finger millet yield

In the first season, no significant differences were noted between the two varieties using orthogonal contrasts. Additionally, no significant interaction was observed between treatments and varieties which implies that the varieties had a similar response to the inoculation times (Appendix 2). However, there were highly significant differences between the treatments in this season. At 5 % level, the control treatment, uninoculated + fungicide application (treatment 1), significantly out-yielded the second control treatment, uninoculated without fungicide application (treatment 2), and the 95 % confidence interval for the difference was 0.08 to 0.25 kg (Appendix 2).

Similarly, the mean yield of the two controls (treatment 1 and 2) were significantly higher than the mean yield of the early, medium and late inoculation treatments, 3, 4 and 5. The 95 % confidence interval for the difference was 0.03 to 0.14 kg. Additionally, a significant linear relationship between mean yield and the time of inoculation was found (Figure 4).

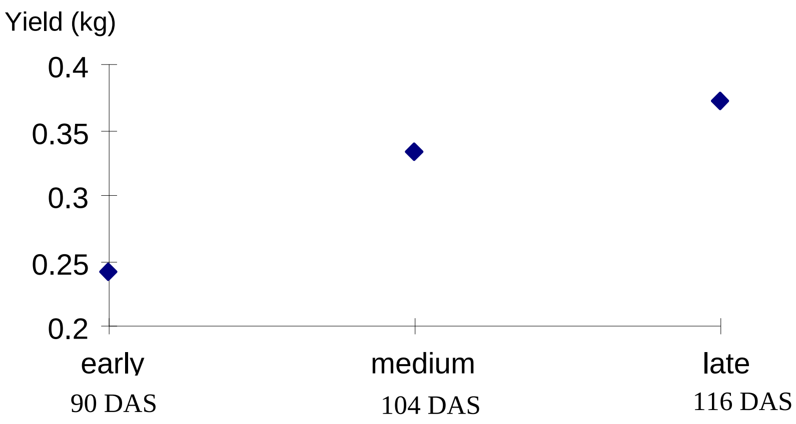

Figure 4: **Yield against time of inoculation**

Yield was higher when inoculation took place later in the season. Crops of treatment 5 (inoculated at milk stage) had the highest yield (Figure 4, Table 18).

In the second season, no significant differences in yield were found apart from that between varieties where KAT FM-1 had significantly higher yields than P224 with a 95 % confidence interval for the difference of 0.04 to 0.38 kg (Appendix 3 and Table 18).

In the third season, the second control treatment (uninoculated without fungicide application) was significantly better at 5 % than the first control treatment (uninoculated + fungicide application) with a 95 % confidence interval of -1.27 to -0.48 kg (Appendix 3 and Table 18). The average of the yields for the inoculation treatments were significantly higher than the average of the controls with a 95 % confidence interval for the difference of -0.61 to -0.10 kg. This is because the control (uninoculated with fungicide treatment) was adversely affected by chemical scorching resulting in much lower yields than the inoculated treatments.

Table 18: Finger millet treatment, variety and mean yields (kg) and yield losses (%) for three seasons

Season[1]	Variety	Control (Treatment1) (uninoculated + fungicide application)	Control (Treatment 2) (uninoculated without fungicide application)	Early inoculation (90 DAS)	Medium inoculation (104 DAS)	Late Inoculation (116 DAS)	Variety Mean yield (kg)
1	P224	0.43 (0)[2]	0.28 (35)	0.26 (40)	0.30 (30)	0.36 (16)	0.33 (11)
1	KAT FM-1	0.54 (0)	0.36 (33)	0.23 (57)	0.37 (31)	0.38 (30)	0.37 (0)
1	Mean	0.48 (0)	0.32 (33)	0.24 (50)	0.33 (31)	0.37 (23)	
2	P224	0.80 (0)	0.78 (2)	0.72 (10)	0.72 (10)	0.78 (2)	0.76 (21)
2	KAT FM-1	0.91 (0)	1.02 (0)	0.91 (0)	1.00 (0)	1.00 (0)	0.97 (0)
2	Mean	0.85 (0)	0.90 (0)	0.81 (5)	0.85 (0)	0.89 (0)	
3	P224	0.26 (78)[3]	1.20 (0)	1.10 (8)	0.92 (23)	1.15 (4)	0.92 (0)
3	KAT FM-1	0.22 (79)[3]	1.04 (0)	1.05 (0)	0.82 (21)	1.17 (0)	0.86 (7)
3	Mean	0.24 (79)[3]	1.12 (0)	1.07 (4)	0.87 (22)	1.16 (0)	

Note:

DAS = Days after sowing

[1]Season 1 = Short rains, 1997 (Aug 1997 to Jan 1998) 2 = Long rains, 1998 (Feb 1998 to July 1998) 3 = Short rains, 1998 (Aug 1998 to Jan 1999)

[2] Figures in brackets are percent yield losses. [3] Yield losses not caused by blast

Yield losses ranging from 0 to 57 % were noted (Table 18). In the first season, yield reduction for variety P224 ranged from 16 to 40 % with the early inoculation (treatment 3) treatment recording the highest yield loss (40 %) followed by the control uninoculated without fungicide application (treatment 2) (35 %) and medium inoculation (treatment 4) (30 %) treatments respectively. Finger millet inoculated later in the season (treatment 5) had the smallest yield loss. Yield losses for variety KAT FM-1 were highest with the early inoculation treatment (57 %) and lowest with the late inoculation treatment (30 %). Yield losses for this variety ranged from 30 to 57 %.

In the second season a similar trend was noted although for P224 yield reduction was the same for both the early (treatment 3) and medium (treatment 4) inoculation. None of treatments appeared to cause a reduction in yield of variety KAT FM-1 during this season.

During the third season, the medium timing of inoculation (treatment 4) for both varieties had the highest yield losses P224 (23 %) and KAT FM-1 (21 %) including the mean yields (22 %). The lowest reduction occurred with the late inoculation treatment (treatment 5) [P224 (4); KAT FM-1 (0); mean yield (0) respectively].

Output 4: Farmers' perceptions of the importance of finger millet and blast (together with the status of their knowledge about the pathogen, its origins and means of control) will be gathered for the Busia, Kisii and Kiboko regions of Kenya (these representing 3 different tribal groups and ecological zones).

a) Farmer perceptions

1.0 Agronomic

A wide range of crops were grown in both Districts. There was a high level of consistency in the farmers' selections of the five most important crops, with the majority of the farmers interviewed during the survey ranking the starch staples i.e. finger millet, maize, sorghum, cassava and sweet potato as most important (Table 19). Cash crops such as tea and pyrethrum, and food crops such as beans and groundnuts were also mentioned, particularly in the Kisii area. However, there appeared to be significant differences in the relative importance of the starch staples between the two regions. Thus in Kisii District, finger millet was universally considered to be the most important crop followed by maize, whilst in Busia / Teso districts finger millet and cassava were considered most important followed by sorghum and then maize. It is possible to speculate that these differences could be due to a range of factors including agro-climatic conditions, local customs and market demand / prices. The farmers were therefore asked what they thought the advantages and disadvantages of the major crops were. These are summarised in Table 20.

Table 19: Ranking of top 5 crop enterprises by 8 farmers in Kisii District, and 6 farmers or farmer groups in the Busia/Teso Districts

Crop	**Kisii District**								**Busia / Teso District**					
	6 (W[a])	6 (M[a])	8	9	10	11	12	13	14 (G[b])	15 (G[b])	17	18 (G[b])	19 (G[b])	20 (G[b])
Finger millet	1	1	1	1	1	1	1	1	1	3	4		1	1
Sorghum						4	2		2	2	2		2	3
Maize	3	2	2	2	3	2	3	2	4	4	5		4	4
Cassava						3			3	1	1		3	2
Pyrethrum	2		3		4									
Potatoes	4	4		4		5			5	5	3			
Tea	5	5		5	2									
Beans		3		3				3						
Groundnuts													5	5

Notes:

a M = men, W = women
b G = denotes a large i.e. > 10 person, farmer group

Ranking based on a 1-5 scale where 1 = most important and 5 = least important

Table 20: A summary of the reasons given by farmers in the Kisii and Busia areas for preferring certain crops .

Crop	Positive reasons	Negative reasons
Finger millet	Good market price Many uses: ugali, uji, busara, yeast, beer Stores well; fewer storage pests Medicinal value of porridge; recommended by rural clinics Matures earlier than maize; food security Likes the taste Very strong ugali, can last you all day Used for ceremonies and for "mahari" (bride price) Traditional "in the blood" Can be easily ground on a stone	Has to be eaten with meat Kids don't like colour (like soil) or texture High labour requirement (e.g. for weeding, harvesting) – although some farmer remarked that when broadcast it required little labour compared to maize which has to be row planted
Sorghum	Less required in mix with cassava to make ugali Very filling, one meal can last all day Can be preserved with ash for longer than maize Yields better than maize on poorer soils Traditional practices Cash crop - higher market price than maize during times of shortage (in Busia area)	Susceptible to weevils and rats in store Low market price at harvest time Can't be eaten alone (has to be mixed with cassava or finger millet) Dust irritates the skin Intolerant of weed competition so has to be weeded Susceptible to birds
Maize	Less labour requirement than other cereals Cash crop Children prefer ugali (whiter and softer)	Susceptible to weevils and larger grain borer Doesn't satisfy them nutritionally
Cassava	Multiple uses - can be chewed directly, chips or ugali Can be mixed with different cereals or beans for ugali Food security – available during drought period in April/May Drought resistant Heavy – takes a long time to digest Produces sweet ugali	Cassava mosaic virus
Pyrethrum	Source of cash	
Tea	Source of cash	

The reasons given by farmers indicate that a range of factors including food security issues, the suitability of the land for growing the crop, storability, taste preferences, customs and traditions, market demand and potential for income generation, all influence the choice of cropping system. In Busia / Teso districts, there was a greater emphasis on food security, especially during March and April, which may explain the improved rating of cassava in this district.

One of the reasons given by farmers for growing finger millet was the multitude of uses for the crop (Table 20). In contrast to comparatively new crops such as maize, tea and pyrethrum, finger millet forms an integral part of the culture of the peoples of Western Kenya, and the diversity of uses to which it is put reflect this. Farmers' uses of finger millet in Kisii and Busia / Teso districts are summarised in Table 21.

Table 21: Uses for finger millet in Kisii (13 farmers interviewed) and Busia (1 small group of farmers interviewed)

Uses for finger millet	**Number of farmers using for this purpose**	
	Kisii	**Busia**
Ugali (thick porridge)	13	1
Uji (thin porridge)	13	1
Semi-fermented, but non alcoholic drink "busara"	2	
Production of yeast or beer (*busa* or *pombe*)	8	1
Nutrition/medicine	4	1
For traditional ceremonies and celebrations	6	1
For sale (grain, yeast)	13	1
Stalks used to make baskets	2	
Stovers for livestock feed	1	

All of the farmers interviewed during the survey said that they used finger millet to prepare *ugali*, and *uji* (Plate 12). Important benefits of finger millet were the perceived nutritional and medicinal properties. As well as a source of food, finger millet is used to make both alcoholic and non-alcoholic beverages for home consumption and sale. These also play an important role in traditional ceremonies, e.g. for remembering the dead or communicating with ancestors. In some areas, these practices have been discouraged by temperate religious beliefs and, in some parts of Kisii, only the men were allowed to consume alcohol. Although over 50% of the farmers said that they used finger millet for these purposes, in view of the various social and legal taboos surrounding the brewing and consumption of alcohol and the disclosure of details of traditional ceremonies, this figure may, in reality, have been higher.

Plate 12

Finger millet is usually regarded as the woman's crop, and she usually keeps any cash generated for herself. (By contrast, the cash generated from the sale of crops such as maize, pyrethrum, tea and coffee is usually kept by the men.) All of the farmers interviewed sold finger millet to neighbours or at local markets, either as grain or fermented to give yeast for brewing. Several of the women regarded the latter as a business enterprise, and would purchase finger millet grain when prices were low in order to produce yeast for re-sale. The sale price of finger millet is extremely variable, and prices are always much lower at the time of harvest (Table 22), rising as the year progresses. Several factors appear to be implicated in this price increase. The first is seasonal availability and the impact of free market supply and demand, where prices rise as the commodity, or substitute commodities (in this case maize and sorghum), become scarce. The second was that apparently finger millet improves with age and, with the exception of variety Enaikuru, materials are only suitable for yeast and beer production after storage for several months. A further reason given for selling finger millet late in the season is that by then farmers will know whether they have sufficient food for their own households, having harvested other crops including maize, as well as storage losses due to weevils and other pests.

Table 22: Finger millet prices (Kenyan shillings) in different parts of Kisii and Busia districts and at different times of year (maize prices quoted where known for comparison

	Kisii District[a]											Busia district
	1	2[b]	3[b]	4	5	6	7	8	9	10	11	14
Newly harvested	20	7-13	14-18	17.5	20	12.5	12-13	15-20	15	7	10	15
Maize prices	5				7.5						10	
Stored finger millet	Nd	17.5	Nd	25	Nd	17	17.5	Nd	Nd	16.5	22.5	20
Yeast						17-18				20		

a For the key to farmers see Appendix 1
b Variety Enakuru fetches the higher market price in this location

ND = not disclosed

Note: Although people sell finger millet and sorghum in 2 kg tins or debes *in this region the prices quoted have been adjusted to give a value in shillings per kg.*

The information on production systems gathered from the 13 farmers interviewed in the Kisii area, and one of the older ladies interviewed in the Busia district, is summarised in Table 23.

Table 23: Finger millet production systems in Kisii, and Busia Districts in Kenya (summary of data collected in 14 semi-structured interviews)

	Farmer 1	2	3	4	5	6	7	8	9	10	11	12	13	14
Land area (acres)	0.25	2 x 1	2 x 0.5	0.75	0.25	0.25	1	2	0.75	0.5	2	0.75	0.25	1
Land preparation[a]	H	H	H	O	H	H	H	O	O	H	O	O	O	H
Who prepares the land[b]	W	W + H	W + M	W + M[i]	W	W + M[i]	W	W + M[i]	W + M[i]	W	W + M[i]	M	W + M[i]	W
Planting method[c]	R	B + R	R	R	B	B	R	R	R	B	B	B	B	B
Fertilizer[d]	C	N + C	C	C	C	C	C	C	C	C	M	M	N	N
Labour for Weeding[e]	W + H	W	W	C	W + M[j]	C	W	C + M	C + H	H	W + M, C + H	W + M	C	C
Time taken to weed[f]	3	Nd	3	40	14	12	nd	28	150	56	150	14	nd	nd
Rotation[g]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Yield[h]	240	250	120	230	Nd	120 - 320	170-190	200	200	128	300	390	nd	nd

a Land preparation: O = oxen, H = hand hoe
b Who prepares the land: W = woman (+ kids), M = man, H = hired help
c Planting method: R = row planting, B = broadcasting
d Fertilizer: C = chemical e.g. DAP, M = organic manure, N = none
e Who provides labour for weeding: W= women (= kids), M = men, C = communal, H = hired help
f Time taken to weed = in person days (N.B. may be inaccurate because in some cases people only weed for a few hours each day)
g Crop rotation: Y = yes, N = no
h Yield: anticipated yield in kg per ha
i Men prepare the land, and women sow the seed
j Men used to in the olden days when plots were bigger
nd no data

Land preparation and planting

Finger millet was described by several farmers as a multiple stage crop. Land is first prepared using oxen or a hand hoe, and then left for a period of time (3 days - 2 weeks) before harrowing to remove couch grass. Planting commences a few days after harrowing. There are two methods for planting. The traditional method involves broadcasting seed, either singly, or mixed with other cereals such as sorghum. After sowing, some farmers then use an ox to drag a branch around the field and cover the seed. The newer method, currently heavily promoted by the extension service, involves making rows using a string and hand hoe or oxen. However, whilst the former requires only one person, who can plant c. 0.5 acre per day, the latter requires two or three people who may take up to three days to sow one acre (Table 24). Information on row planting appeared to originate from several sources. Many of those interviewed said they had obtained the information from KARI or the extension service, although one lady said that she learnt to do it on a training course in 1966. Others had observed neighbor's plots or developed it themselves by adapting their technique from their maize production practices. It was noted that there were some farmers who row planted maize, but broadcast finger millet (and sorghum). Most of the plots observed were mono-cropped with a few maize, sorghum or banana plants mixed in. This may be because finger millet is relatively short (from 0.5 - 0.75 m depending on variety), and would be susceptible to shading from taller crops.

Fertilizer

The reason that most farmers used fertilizer was that shortage of land had resulted in more intensive cropping practices, and decline in soil fertility. Where farmers did not use fertilizer several reasons were given, including lack of capital, sickness (money used to purchase medication ?), or in one case that as the land was leased there was no point in improving it.

The majority of the farmers interviewed applied 16-20 kg acre^{-1} diammonium phosphate (DAP). Where seed was broadcast, fertilizer was either mixed in with the seed, or applied subsequently. Total fertiliser required was reduced by mixing the required quantity with the seed prior to broadcasting and it was easier since sowing and fertilizer application became a one-stage process. Accuracy of placement of fertiliser in relation to seed could potentially be better where these operations are combined in broadcasted crops. However, if farmers inadvertently mixed fertiliser with more seed than required then the seed could not be stored or eaten. Farmers applied fertilizer to row planted finger millet by sprinkling it along the rows after planting. Some farmers considered row planting unsuitable because they felt it required higher and unaffordable fertiliser inputs. It is unclear what the basis of this theory is, and whether this is the case, or whether farmers have confused the extension message.

Some farmers used well-rotted cattle manure which was applied to the field prior to sowing. Although farmers noted that this improved yields (and reduced the incidence of *Striga*), a major difficulty was in transporting it from the boma to the field without a wheelbarrow. For this reason, farmers tended to preferentially treat fields near the boma. An additional problem raised in the Busia area was the recent trypanosomiasis outbreak which had devastated the cattle population.

Weeding

Farmers cited the requirement for weeding and the demand on labour this generates as the major constraint to finger millet production. It is more difficult to weed finger millet than other crops because it is harder to differentiate between millet plants and the weeds, especially wild *Eleusine* spp. which are almost indistinguishable from *E. coracana* until panicle development. For this reason, many women prefer to undertake the weeding operations themselves rather than allowing the younger children to help. The situation is exacerbated by the traditional sowing practice since plants grown from broadcast seed are very close together, and have to be weeded by hand rather than with a small hoe. This is an extremely time consuming process. Although in some cases people were able to hire labour to assist with weeding, many used a communal labour system (Plate 13) whereby a group of farmers would weed each other's land in return for food or beer. This also appeared to be a social occasion.

Superficially, the weeding problem would appear to be a good reason for farmers to adopt the new row planting method. However, although many of the farmers interviewed during the survey (Table 23) were using this technique it was clear that, overall, the proportion of farmers row planting is relatively low. Farmers were asked for their views on this issue. The points raised are summarised in Table 24.

Table 24: Farmers' perceptions of the advantages and disadvantages of row planting finger millet in Kisii district

Advantages of row planting	**Disadvantages of row planting**
• it is more time consuming (and expensive) to weed broadcast plots. Row planting can reduce weeding time to around third, as it is possible to use a small jembe instead of having to do it by hand. Also children can weed row planted plots. • Fertilizer applications are easier, with less wastage • higher yields[a] • less competition between plants (for aeration) giving bigger fingers	• more work to prepare the rows i.e. 3 d to plough, 3 d to harrow and remove couch grass, and then 2-3 people to mark-out the rows using a stick and string **(Question: is there a quicker way of row planting?).** • problems with competition for labour at planting time e.g. for other crops **(Question: is labour less constrained at weeding time ?)** • necessity for planting as soon as it starts raining, as late planted crops show poor germination and may be more affected by diseases such as blast **(Question: evaluate dry planting ?)** • old/sick people may not have the energy to make the rows • tradition - have always broadcast

a although as many farmers have adopted a package of technologies including row planting and fertilizer it is difficult to separate the effects.

Harvesting and post-harvest processing

Finger millet is harvested by cutting the heads with a sharp knife (Plate 14) and the panicles are then returned to the household for drying, threshing, winnowing and storage. Seed selection may be directly after harvest, or from the threshed grain. A major advantage of finger millet is that it stores well and is little attacked by storage pests such as weevils, larger grain borer (LGB). This has important implications for food security, especially during March-April, and also for marketing as older finger millet usually fetches a better market price than newly harvested grain.

Rotations

Crop debris, including diseased heads, are usually incorporated into the soil at the end of the season to improve soil fertility levels for the next season. All of the farmers interviewed practiced crop rotation with a range of crops including maize, cassava, pyrethrum, Irish potatoes. The reasons given for this were that (1) yields declined otherwise, although generally finger millet was thought to improve soil fertility, and (2) that it reduced the incidence of *Striga.* The rotations described were extremely varied (Table 25)

Table 25: Examples of cropping sequences in the Kisii and Busia areas

Kisii	
1.	finger millet - maize - beans
2.	pyrethrum - finger millet - maize - pyrethrum - potatoes
3.	finger millet - maize - Irish potatoes - beans
4.	maize - finger millet - cassava - maize - sweet potatoes
5.	fallow - finger millet - cassava
Busia	
1.	finger millet - cotton - finger millet - cotton
2.	finger millet - sorghum - cassava - finger millet

Finger millet is traditionally seen as a woman's crop, and many of the labour inputs are by women and children, either singly or in communal groups (Table 20). However, it became clear that men do assist in land clearance and ploughing, and ,occasionally, with weeding. Men who were closely involved with the crop tended to be older, which confirms the view that this is a traditional crop. One of the older women interviewed said that, in olden times when land areas were larger, men were more involved but these days women can deal with the relatively small patches grown.

Plate 14

2.0 Seed Sources and Varietal Preferences

Three issues were addressed within this topic area. First which varieties farmers were growing, secondly which factors are considered important when making the selections, and thirdly seed source, and the effect of this on varietal selection. The varieties recorded during the survey, together with their major characteristics, are summarised in Table 26.

It can be seen that, even in the fairly small sample covered by this survey, a large number of different local varieties were being grown. A single variety "Enaikuru" (= from Nakuru) is the most popular, and grown at several locations. When asked why this particular variety was so popular, farmers referred to its high yield, suitability for brewing and yeast production, and early maturity. There was some discrepancy over blast resistance - some farmers felt it was resistant and others susceptible - which may reflect heterogeneity in the germplasm, or a race structure in pathogen populations in the region. One older lady was also able to describe the old varieties from the 1940's-50's. When asked why these were no longer used she said that times changed, and that as for maize, new varieties came along.

Despite the popularity of Enaikuru, many farmers grew cultivar mixtures, with different varieties grown in separate patches or in a mixture. When asked why this was, several farmers said they wanted to spread the risk, as in some years different varieties yielded better. Other reasons given were that different varieties had different uses e.g. some were better for *ugali*, and some for brewing, or that the original seed had been mixed when purchased or given. In the latter case many farmers were intending to select out the preferred variety for future use. Farmers showed a high degree of innovation in their approach to varietal selection, and said that they were always keen to try out new materials. Several were conducting experiments growing new varieties obtained from friends or neighbours adjacent to their own varieties to see which they preferred, or which had resistance to blast.

Table 26: A summary of the finger millet varieties grown by the 14 farmers / farmer groups surveyed in the Kisii and Busia / Teso districts, together with their main characteristics and uses.

Cultivar	No. of farmers growing	Characteristics
Kisii District		
Enaikuru	9	Tall, dark brown, early maturing, good market price, good for yeast and porridge
Enyandabu	1	White, 3 fingers, good for ugali
Emarage	2	White, 4 folded fingers, high yield late maturing
Sasheve	1	(= new) recent introduction, early maturity
Enyandabu	4	White, early maturing, high yield, folded fingers
Endere	4	Straight fingers, early maturity
Embariri	1	Red, folded fingers
Egekumoto	1	Brown, folded fingers
Barikongo	1	Six folded fingers, black/brown, big grains, good for sweet porridge, blast resistant
Egesanda	1	Many folded fingers, light brown, blast resistant
Erichombochi	1	Many straight fingers, light brown, blast susceptible
Karuma	2	4-6 folded fingers, reddish early maturing, disease resistant
Bokumo	1	Information not available
Ekebotos	1	Early maturing
Gatiogeti	1	Straight fingers
Egetassia	1	Information not available
Old Varieties		
Enyandabu	old variety	White, early maturing, straight fingers
Omokomoni	old variety	Light brown, late maturing, straight fingers
Egeteregenye	old variety	Light yellow, early maturing, folded fingers
Egetui	old variety	Red, late maturing, folded fingers
Busia District		
Emomwari	1	Black, good for beer but not ugali
Opusi	1	Red-brown, high yielding, late maturity
Erani	1	Red-brown, early maturing
Epalat	1	Grey, tastes good for ugali, good for yeast

The factors influencing the farmer's choice of variety are summarised in Table 27. The data show that the most widely applied criteria are yield, followed by early maturity, blast resistance and sweetness when prepared as porridge or *ugali*. Other factors discussed were colour, suitability for yeast or beer production and bird resistance. The reason why only one person mentioned market price is that, generally, price is dependent on grain age rather than variety, thus finger millet harvested in the preceding season fetches more than newly harvested materials. Similarly the woman who mentioned suitability for brewing was producing yeast for sale. Colour preferences varied, thus some preferred the white varieties which produced ugali similar to maize, whereas other preferred red / brown varieties which were more traditional.

Table 27: Criteria used by farmers to select finger millet varieties in the Kisii and Busia Districts

Criteria	**Number of farmers who considered this important**
Yield	9
Market price	1
Suitability for yeast/brewing	2
Sweetness (for porridge or ugali)	4
Blast resistance	7
Early maturity	8
Colour	3
Resistance to birds	1

Note: summary of data from 14 farmer interviews, together with the number of farmers who considered this factor when making varietal selections

Farmers were then asked where they sourced their seed and why. Their remarks are summarised in Table 28. This information shows that the majority of farmers interviewed in Kisii District tend to obtain seed from a friend or relative and thereafter save their own selection. Generally people preferred not to buy from the market, as in addition to the expense they were unable to guarantee the quality, frequently purchasing mixtures of varieties. Farmers are quite innovative, and if they see a variety that they like in a neighbour's field will obtain the seed.

Table 28: Source of finger millet seed and reasons for using that source.

Farmer	No. cvs grown	Seed source	Reasons
1	2	Bought from market (prefers to select her own)	sick in previous year so did not select
2	3	Own selection and from neighbours	Experimenting (maturity and yield)
3	2	Own selection	
4	2	From neighbour	Experimenting (disease resistance)
5	3	Own selection and from daughter	wants to keep a specific variety
6	1	Own selection	
7	1	Nk	
8	2	Own selection (originally from a friend)	mixes to spread risk
9	3	Own selection (bought from market originally)	
10	1	Own selection (from a relative originally)	
11	3	Own selection (sometimes a neighbour)	will obtain from a neighbour if he likes the look of their millet
12	3	Own selection	
13	4	Own selection	
14	4	Given by relatives or KARI Alupe station	wanted to try new varieties out

Note: 14 farmers / farmer groups were interviewed during the finger millet survey (farmers 1-13 Kisii District, farmer group 14 Busia District).

3.0 Production Constraints

General constraints

Farmers were asked to list, and then rank their constraints to finger millet production. The rankings varied depending on how many constraints were listed, thus some cited two or three, and some as many as six. This information is summarised in Table 29, which shows each factor, together with the number of farmers (total of 14) who ranked it in each category.

Table 29: Farmers' perceptions of the major constraints to finger millet production..

Production constraint	Number of farmers ranking the constraint in each category			
	1	2	3	Not ranked[a]
Labour for weeding	5	1		1
Labour for harvest/post harvest prep	1	6		1
Disease	1	2	2	2
Land availability	2	1	1	
Fertility	2		1	
Labour for planting	1	1		
Striga	1		1	

Note: Ranking from 1(most important) to 3.
a referred to as a constraint by the farmer but not ranked
Other factors which were cited but not ranked in the last column

Overall, labour constraints are perceived to be the most important production problem by farmers, with labour for weeding generally ranking higher than that for harvest and post-harvest processing. Other problems included disease caused by the finger millet blast pathogen *P. grisea*, followed by land availability, fertility (including cost of purchasing fertilizer), labour for [row] planting and finally *Striga*, called *Emoto* (meaning = someone who likes exploiting others) or *Egetoka*. Weaver birds were also mentioned by two farmers, although it was clear that they were more of a problem on sorghum. Generally, *Striga* was more prevalent in Busia District and in the Migori area than around Kisii. This is probably due to the low night temperatures at the higher elevations. Farmers knew that *Striga* was associated with poor soil fertility, and one said that he up-rooted the parasitic weeds and burnt them before seed set. Other control options practiced included application of manure and inclusion of non-host crops in the rotation.

Finger millet blast

One of the objectives of the survey was to determine farmers' perceptions of finger millet blast, and determine the potential for controlling the pathogen within the farming systems practiced in the region. Further specific questions therefore focused on this topic. All of the farmers interviewed in Kisii area mentioned finger millet blast which was most commonly called *Egetabu* or *Orobega* (= something which only affects one part). Other names included *Rikuba* (= cold), *Embeo-embe* (=bad wind) and *Ekeroi* (bad soil). When asked to describe what they thought caused the problem, farmers said that it was a disease, some comparing it with humans catching a cold. Although none were very clear about where it came from originally, one or two suggested that it could be wind or soil-borne. None of the farmers asked felt that it was associated with poor seed. All of the farmers said that disease severity levels were extremely variable between seasons and years, and whilst in some seasons hardly any was observed, in others the crop could be completely destroyed. They had also noted that it often had a patchy distribution within the field, and even on a single panicle, with some fingers more affected than others (hence the common name *Egetabu*). In view of this variation, the farmers were asked which factors they associated with higher levels of disease. The information gathered is summarised in Table 30.

Table 30: Farmers' perceptions of the factors influencing finger millet blast severity

Factor	**Number of farmers who cited this factor**
Rainfall/fog/mist (near rivers)	6
Wind borne inoculum	1
Variety susceptibility	7
First growing season	6
Second growing season	4
Late or early planting	2
Intensive cultivation	1
Broadcasting	2
High plant populations	2
Comes from the soil	1

Note: a total of 13 were interviewed about the pathogen

The information presented in Table 30 clearly shows that farmers have a good observational understanding of the disease, which appears to be associated with variety susceptibility, and high levels of atmospheric moisture. Other ideas were that it was associated with intensive cultivation practices including high plant populations. The concepts that it may come from the soil or be wind-borne are also potentially correct. The apparent discrepancy between disease levels in the first and second growing season may reflect local climatic variation between locations, whether a neighbor's crops provide an inoculum source or even the length of time since finger millet was last grown on the plot. Such an increase from one season to the next could be due to a seed-borne source of inoculum. Consideration of farmers' perceptions lead to identification of need for the potential research areas upon which the project reported here was based i.e.

evaluation of varietal resistance and increasing the knowledge of primary inoculum sources.

c) Disease survey

Mean disease incidence for the area surveyed was 27.9 % with a range of 0.8 to 48.1 % and the mean severity was 22.7 % with a range of 0.8 to 42.1 % (Table 31).

Table 31: Average disease incidences and severities and their ranges in ten villages in Masimba Division, Kisii District

Villages	Disease incidence (range) (%)	Average disease incidence (%)	Disease severity (range) (%)	Average disease severity (%)
Nyamarambe	0 – 43.3	23.5	0 – 35.3	23.8
Metembe	3.3 – 80.0	43.3	1.3 – 79.3	37.9
Ibanchore	0 – 36.7	10.8	0 – 29.3	7.7
Moremani	10.0 – 73.3	36.5	5.7 – 66.7	26.5
Ikenya	0 – 53.3	7.0	0 – 30.4	4.4
Masabo	3.3 – 56.7	12.9	3.3 – 31.0	9.2
Matibo	16.7 – 86.7	48.1	14.7 – 85.0	42.1
Kerema	10.0 – 76.7	46.8	7.5 – 65.2	40.0
Bongonta	0 – 66.7	38.1	0 – 53.9	29.5
Suguta	0 – 10.0	0.8	0 – 10.0	0.8
Mean total	0.8 – 48.1	27.9	0.8 – 42.1	22.7

The highest average disease incidence and severity (48.1 and 42.1 % respectively) was found on finger millet crops grown in Matibo village. The next highest were found in Kerema (46.8 and 40.0 %) and Metembe (43.3 and 37.9 %). The least disease incidence and severity was in Suguta village (0.8 and 0.8 %). This is the village in which the participatory research trials (Output 2) were conducted.

Finger millet was grown as varietal mixtures (27.5 %) or as single varieties (Table 26). Most farmers grew Enaikuru as a single variety (59 %). Of the 27.5 % of farmers who grew variety mixtures 94.5 % of them included variety Enaikuru in the mixture. The most popular mixture was Enaikuru / Enyandabu which was grown on 12 % of the farms visited. The one mixture which did not include Enaikuru was a mixture of Enyandabu and Enyakundi (Table 32).

Table 32: Disease incidence and severity of the varieties and mixtures grown in Masimba Division and the number of farms growing them out of the 200 farm surveyed.

Variety / Mixture (arrayed in order of popularity)	Number of farmers (%) [1]	Average Disease incidence (%)	Average disease severity (%)
Enaikuru	118 (59.0)	25.2	20.7
Enaikuru/Enyandabu	25 (12.5)	34.9	27.6
Enaikuru/Enyakundi	14 (7.0)	30.2	20.9
Enyakundi	13 (6.5)	30.3	23.3
Enyandabu	7 (3.5)	38.6	29.2
Enaikuru/Enyandabu/Enyakundi	6 (3.0)	41.7	32.1
Marege	5 (2.5)	19.3	14.3
Enaikuru/Marege	5 (2.5)	19.3	12.1
Enyandabu/Enyakundi	2 (1.0)	71.7	61.2
Enaikuru/Enyandabu/Enyamarambe	1 (0.5)	16.7	14.7
Enaikuru/Marege/Enyakundi	1 (0.5)	26.7	19.7
Gulu E	1 (0.5)	0	0
P224	1 (0.5)	0	0
P224/Gulu E/Enaikuru	1 (0.5)	0	0

[1] *Figures in brackets indicate percentage of farmers growing the varieties*

Each village had a different combination of varieties, hence the incidence and severity data for Enaikuru, the most popular variety grown in every village was used in the analysis to identify if differences existed between villages. Highly significant differences were noted between the villages for both severity and incidence (Appendix 4). Because of this, village was used as a covariate for the analysis of the incidence and severity data which was first transformed using arc sine to satisfy the assumptions of analysis of variance. This analysis showed that there were no significant differences between varieties nor between single varieties and mixtures (Appendix 4). However, the data may be biased because some varieties have very small replication.

Correlation analysis on yield and disease incidence (r=0.01; NS) and severity (r=0.02; NS) tested on individual farm data indicated that there was no significant correlation at $p \leq 0.05$ between these two variables and yields (Table 33 & Figure 5). However, a highly significant correlation (r=0.98) at $p < 0.05$ was found between disease incidence and severity.

Table 33: Average disease severity and incidence of blasted finger millet heads and corresponding yields in Masimba

Village	Average disease incidence (%)	Average disease severity (%)	Average Yields (g)
Moremani	59.50	51.05	63.35
Nyamarambe	51.58	45.37	64.89
Masabo	47.75	38.64	64.58
Ibanchore	23.55	14.74	61.20
Ikenya	16.50	11.58	58.00
Suguta	4.00	2.95	56.85
Bongonta	47.40	37.30	57.30
Matibo	48.00	42.19	47.05
Metembe	49.50	41.11	55.95
Kerema	49.50	38.51	47.50
Mean total	**39.73**	**32.34**	**57.67**
Correlation to yield (r)	0.01	0.02	

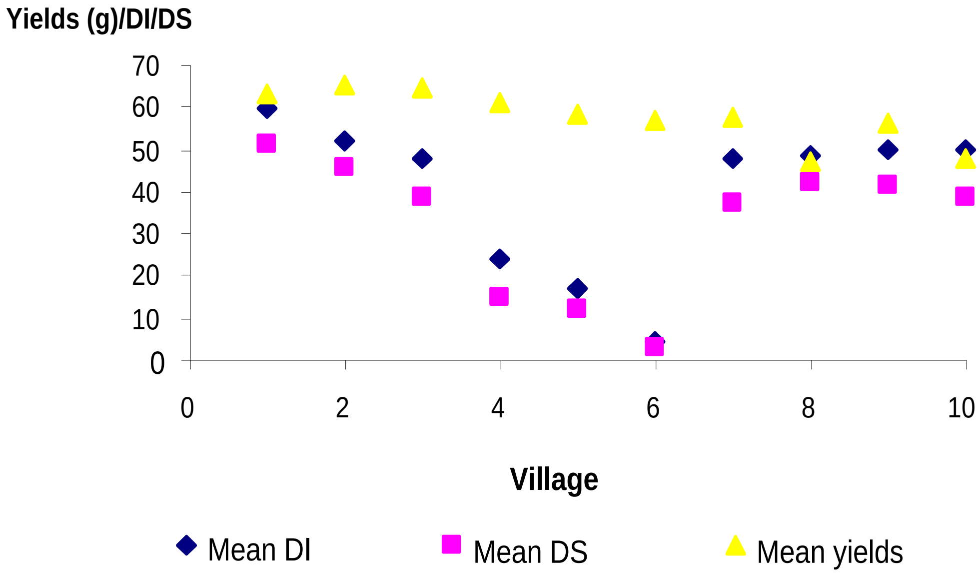

Figure 5: A scatter plot of yields vs disease incidence (DI) and severity (DS)

It should be noted that throughout the survey total inhibition of grain formation due to blast was rarely encountered.

Contribution of outputs

Contribution of outputs to project goal (= production system purpose)

Impact of significant diseases on cereals-based production systems minimised.
Progress towards sustainable control of blast on finger millet has been achieved through:

1) identification of cultural and field hygiene measures to reduce disease carry-over;
2) documentation of the agronomic and socio-economic context into which control strategies need, necessarily, be placed;
3) farmer participatory evaluation of released varieties P224 and Gulu E;
4) development of a laboratory based bioassay to screen finger millet varieties / blast isolates for resistance / pathogenicity.

Pathway whereby present and anticipated future outputs will impact on poverty alleviation or sustainable livelihoods:

The project activities have involved groups of farmers (participating and non-participating), finger millet traders (mostly women whose livelihoods depend on the income derived from finger millet trading rather than on growing the crop for use by the immediate family) and agricultural extension officers. In addition to the benefits to be gained through dissemination of information by the agricultural extension officers to farmers, there will also be farmer-farmer, trader-consumer pathways of communication. The information derived through these pathways will empower the small-holder farmer to reduce potential losses due to finger millet blast through modification of cultural practices particularly rotation and field hygiene and growing of improved varieties. The enhancement of production should enhance food security at the family level and, if sufficient production achieved, generate increased household income through sale of grain to traders. Availability of the crop to traders would result in an enhancement of their income and increase grain availability to those who may be unable to grow the crop e.g. due to land shortage.

Publications

Thesis

Makini, F. W. M. (1990) Epidemiology and control of finger millet blast using farmer participatory methods. PhD thesis. University of Greenwich.

Internal reports

JULIAN A. M., CONROY M. A. and ONGARO J. M. (1999) Finger millet and sorghum production in western Kenya with particular reference to crop diseases. NRI Internal Report No. 2474 (compiled by N J Hayden).

MAKINI, F.W. (1998) A diagnostic study of finger millet production, its constraints and the initiation of farmer participatory trials with a bias to finger millet blast disease (*Pyricularia grisea*) in Masimba, Kisii District. NRI Internal Report No. 2475

HAYDEN, N. J. (1998) Back to Office Report / File Note – Kenya . Discussion of progress and future directions of finger millet blast research activities. 19-21 October 1998.

HAYDEN, N.J. (1998) Back to Office Report / File Note - Uganda. Discussion of research and development requirements for key crops in the semi-arid Teso cropping system. 21-24 October 1998.

HAYDEN, N.J. (1999) Back to Office Report- Kenya to monitor field activities and discuss follow on activities for sorghum (A0509) and millet (A0589) pathology projects. 16-30 January 1999.

Other dissemination of results, training etc:

ANON (1998) Finger millet husbandry. Farmer Workshops (5) held at KARI, Kisii.

ANON (1998) Finger millet husbandry. Training Day for extension workers and traders at KARI, Kisii

ANON (1998) Finger millet husbandry: processing qualities of different varieties. Training Day for traders at KARI, Kisii.

In preparation:

Two short publications are in envisaged from the work reported here.

Follow-up activities

The project team's views are that further aspects need clarification in order to develop a more refined integrated control strategy for this significant disease of finger millet. In particular, further work in Kenya is required to:

1) determine disease vs yield loss relationships taking into account compensatory growth to determine whether breeders should aim for low or high numbers of fingers in new lines;
2) to further evaluate the potential role of resistant varieties in reducing disease losses through screening of farmers' varietes and other existing germplasm using the laboratory bioassay developed in the present project. This should include a range of blast isolates whose molecular variability will be charcterised;
3) farmer participatory evaluation of selected germplasm concurrent with sampling and molecular characterisation of *P. grisea* populations present at those sites.

In addition, finger millet has been identified as a key crop in the Teso Agricultural System in Uganda through NARO's prioritisation. A subsequent DFID/ NARO needs assessment exercise has indicated a need for improved varieties and reduction of blast.
This requirement is perceived both by farmers and scientists. A visit was made to the SAARI, Serere, Uganda in October 1998 and the following activities considered appropriate to further achieve the longer term project purpose (= production system output):

1) evaluation of seed-borne incidence and transmission of blast;
2) investigation of management of blast through use of seed treatments;
3) identification and evaluation of blast resistant finger millet cultivars in the context of variable pathogen populatons.

The work would also require socio-economic studies to determine:

1) farmers' perceptions of the disease;
2) factors affecting the place of this crop in the rotation;
3) timing of sowing;
4) varietal choice;
5) possible constraints to implementation of potential control measures;
6) incidence and severity of blast.

These proposed future activities in Kenya have been endorsed by the Centre Director, KARI, Kisii Centre, the extension officials and the farmers themselves with whom the recently completed phase of activities have been based. The requirements for activities in Uganda have been endorsed through both the NARO / DFID needs assessment exercise and by SAARI staff at Serere i.e. Dr P Esele.

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Appendix 1: Analysis of variance of on-farm data

Analysis of the season 1 yield data.

Source of variation	d.f.(m.v.)	s.s.	m.s.	v.r.	F pr.
farm stratum	13	20.2681	1.5591	6.61	
farm.*Units* stratum					
variety	2	0.1318	0.0659	0.28	0.759
P224/Gulu	1	0.0106	0.0106	0.04	0.834
(P224 & Gulu)/Enaikuru	1	0.1212	0.1212	0.51	0.481
Residual	22 (4)	5.1885	0.2358		
Total	37 (4)	23.7619			

Note
contrast 1 mean of P224 - mean Gulu (comparison of new varieties),
contrast 2 mean of (P224 & Gulu) - mean of Enaikuru (comparison of new & old).

Analysis of the season 2 yield data.

Source of variation	d.f.(m.v.)	s.s.	m.s.	v.r.	F pr.
farms stratum	17	12.0271	0.7075	5.10	
farms2.*Units* stratum					
var2	2	1.7107	0.8554	6.17	0.005
P224/Gulu	1	0.0846	0.0846	0.61	0.440
(P224 & Gulu)/Enaikuru	1	1.6261	1.6261	11.73	0.002
Residual	32 (2)	4.4377	0.1387		
Total	51 (2)	17.4392			

Combined analysis for two seasons for 11 farmers

Source of variation	d.f.(m.v.)	s.s.	m.s.	v.r.	F pr.
season	1	0.5369	0.5369	2.60	0.116
season.farm	20	19.3359	0.9668	4.68	<.001
variety	2	0.0316	0.0158	0.08	0.926
Contrast 1	1	0.0133	0.0133	0.06	0.801
Contrast 2	1	0.0184	0.0184	0.09	0.767
season.variety	2	0.8787	0.4393	2.13	0.134
season.Contrast 1	1	0.0045	0.0045	0.02	0.883
season.Contrast 2	1	0.8742	0.8742	4.23	0.047
Residual	36 (4)	7.4330	0.2065		
Total	61 (4)	26.2962			

Appendix 2: Split-plot analysis of variance of yield in the yield loss studies

Season one

Variate: yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep	3	0.01633	0.00544	0.91	
Main					
trt	4	0.25461	0.06365	10.60	<.001
Contrast 1	1	0.11089	0.11089	18.47	0.001
Contrast 2	1	0.07197	0.07197	11.99	0.005
Contrast 3	1	0.06799	0.06799	11.32	0.006
Contrast 4	1	0.00376	0.00376	0.63	0.444
Residual	12	0.07205	0.00600	0.26	
Split					
var	1	0.02309	0.02309	1.01	0.331
trt.var	4	0.02110	0.00528	0.23	0.91
Residual	15	0.34328	0.02289		
Total	39	0.73046			

Note
Contrasts for treatments

contrast	description
1	comparison of two controls
2	comparison of controls with early, medium and late times
3	linear response of early, medium and late times
4	quadratic response of early, medium and late times

Season 2.

Variate: yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep	3	0.64936	0.21645	8.98	
main					
trt	4	0.03622	0.00905	0.38	0.822
Contrast 1	1	0.00856	0.00856	0.35	0.562
Contrast 2	1	0.00499	0.00499	0.21	0.657
Contrast 3	1	0.02265	0.02265	0.94	0.352
Contrast 4	1	0.00002	0.00002	0.00	0.975
Residual	12	0.28934	0.02411	0.68	

Split					
var	1	0.42766	0.42766	11.99	0.003
trt.var	4	0.03066	0.00766	0.21	0.926
Residual	15	0.53496	0.03566		
Total	39	1.96820			

Season 3

Variate: yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep	3	0.57388	0.19129	1.44	
Main					
trt	4	4.67377	1.16844	8.80	0.001
Contrast 1	1	3.11346	3.11346	23.45	<.001
Contrast 2	1	1.20473	1.20473	9.07	0.011
Contrast 3	1	0.02789	0.02789	0.21	0.655
Contrast 4	1	0.32769	0.32769	2.47	0.142
Residual	12	1.59345	0.13279	4.58	
split					
var	1	0.04032	0.04032	1.39	0.256
trt.var	4	0.03880	0.00970	0.33	0.850
Residual	15	0.43457	0.02897		
Total	39	7.35479			

Appendix 3: Analysis of variance for season 1 disease incidence

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
reps stratum	3	29075.6	9691.9	3.71	
reps.treat stratum					
treat	4	14562.4	3640.6	1.39	0.294
controls	1	5476.5	5476.5	2.10	0.173
cont/innoc	1	5052.6	5052.6	1.93	0.190
linear	1	187.5	187.5	0.07	0.793
quadratic	1	3845.8	3845.8	1.47	0.248
Residual	12	31342.8	2611.9		
reps.treat.variety stratum					
variety	1	6725.2	6725.2	7.63	0.014
treat.variety	4	582.7	145.7	0.17	0.953
controls.variety	1	82.1	82.1	0.09	0.764
cont/innoc.variety	1	56.2	56.2	0.06	0.804
linear.variety	1	390.2	390.2	0.44	0.516
quadratic.variety	1	54.2	54.2	0.06	0.808
Residual	15	13213.1	880.9		
reps.treat.variety.time stratum*					
time	5	26779.2	5355.8	42.96	<.001
treat.time	20	5689.1	284.5	2.28	0.026
controls.time	5	838.4	167.7	1.34	0.270
cont/innoc.time	5	2673.8	534.8	4.29	0.017
linear.time	5	509.3	101.9	0.82	0.444
quadratic.time	5	1667.6	333.5	2.68	0.075
variety.time	5	60.0	12.0	0.10	0.905
treat.variety.time	20	1161.7	58.1	0.47	0.890
Residual	150	18701.8	124.7		
Total	239	147893.8			

* degrees of freedom corrected by Greenhouse Geisser epsilon = 0.486