CROP PROTECTION PROGRAMME

Maximising, disseminating and promoting the benefits to farmers of cassava varieties resistant to cassava mosaic disease

R8303 (ZA0575)

FINAL TECHNICAL REPORT

1st April 2003 to 31st March 2005

RW Gibson

University of Greenwich, Natural Resources Institute, Chatham Maritime, Kent. ME4 4TB, UK

This publication is an output from a research project funded by the United Kingdom Department for International Development for the benefit of developing countries. The views expressed are not necessarily those of DFID. R8303: Crop Protection Programme

Executive Summary

The project has tested with farmer groups in both Uganda and Tanzania the use of CMD-resistant varieties and different cultural control practices, notably roguing and intercropping with a resistant cassava variety to protect a susceptible one. Field demonstration plots in 5 farmers' fields in Mukono have demonstrated to farmers (and validated for researchers) the lower incidence of CMD in resistant varieties (00067; TME14; TME204 and NASE 10) and in CMD susceptible landraces (Njule; Kabwa) planted amongst a CMD-resistant variety (00067). Resistance was the most effective means of controlling CMD but the cultural control measures did help sustain production of moderately resistant local landraces.

A leaflet describing the causes, means of spread and various means of controlling CMD through the use of high-yielding resistant varieties has been developed by the Uganda team in English, Luganda and Luo. This has also been translated into Swahili by the Tanzanian team. 10,000 leaflets have been printed. Members of the Tanzanian team have also visited Uganda to exchange ideas.

Training in how to control CMD has been provided to farmers in the collaborating farmer groups in Uganda. Here, however, the pandemic has long been established and most farmers are already aware of the causes of the disease. In Tanzania, this is not the case and the project has collaborated with other organisations, notably the Norwegian people's Aid (NPA), to provide training for extensionists, mostly within the Lake Zone but also further afield in the country. This collaboration with NPA has also extended to providing technical aid in the dissemination of planting material of resistant varieties.

Populations of whiteflies 100x greater than before the CMD pandemic are now observed in Uganda and elsewhere. Sooty mould is often observed blackening middle and lower leaves where whitefly excreta have become infected with fungi. Chlorosis and stunting of middle and upper leaves occurs, caused on the upper leaves by adults feeding and on middle leaves mainly by nymphs feeding. In a trial in Uganda repeated in two seasons and involving eight varieties, insecticides which controlled the whiteflies removed observable signs of whitefly feeding damage, reduced spread of CMD in susceptible varieties and led to a greater root yield even in some CMD near–immune varieties. Screening Ugandan landraces (279) for resistance to whiteflies has led to the identification of a few resistant ones, e.g., Njule. Some released varieties also supported relatively few whiteflies. Screening of advanced clonal accessions has identified resistance in clones in national advanced and uniform yield trials (AYT & UYT). In particular, the clones MM96/4271 and MM96/0686 supported few whiteflies and whitefly nymphs in UYT and were also chosen by farmers and scientists using other criteria. Resistance of identified clones has been confirmed in screenhouse preference tests.

Project scientists have also identified the presence of an outbreak of another whitefly-borne virus, cassava brown streak, in Uganda. This seems likely to result from the large numbers of whiteflies affecting cassava crops here and whitefly resistance may be a key component in its control.

Background

Cassava is the second (after maize) most important food crop grown in Africa, overall providing about a fifth of the calories in the diet. Although most important in West Africa, Tanzania, with the largest production in East Africa, has the 4th largest production in Africa (FAOSTAT); in both Tanzania and Uganda, it is the most important crop of about half the farmers and the 2nd most important staple food crop (Hillocks et al., 2002). The storage roots of cassava are commonly boiled fresh and eaten daily as part of a meal (with meat or vegetable sauce) but they are also fermented and/or sun-dried into chips which can be ground into a flour. Most varieties of cassava can be harvested over many months, and both the dried chips and the flour can be stored for several months or years, adding to the crop's food security value. The crop is relatively drought tolerant and can yield even in relatively infertile soils, hence, its importance to relatively poor families farming marginal lands (Robertson & Ruhode, 2001). Although the crop is important for all sectors of the population in most areas of both countries, problems with the crop inevitably cause more hardship to poorer members of society because they have few resources and fewer alternatives. Women are involved in all operations of production, processing and marketing (Kebe et al., 2001). FAO also identifies cassava as the crop in East Africa that *"will spur rural industrial development and raise incomes for producers, processors, and traders. Cassava will contribute to the food security status of its producing and consuming households"* (Kebe et al., 2001).

Cassava mosaic disease (CMD) is the main biotic constraint of cassava in Africa, diminishing production by an estimated 15% to 24% or 12 to 23 million tonnes per annum (Thresh et al., 1997). CMD is caused by viruses belonging to the genus *Begomovirus*, family *Geminiviridae*. Cassava mosaic geminiviruses (CMGs) are transmitted in the persistent manner by the whitefly *Bemisia tabaci* (*Hemiptera: Aleyrodidae*) and CMD is the most damaging, insect-borne disease of African food crops (Fauquet & Fargette, 1990; Geddes, 1990). Harrison et al. (1991, 1995) identified two CMGs - *African cassava mosaic virus* (ACMV) and *East African cassava mosaic virus* (EACMV) - from CMD-affected plants from different parts of Africa. Initially, ACMV and EACMV seemed to have largely non-overlapping geographic distributions. EACMV was detected only in West Africa in a sample collected in Côte d'Ivoire from a variety introduced from Madagascar but was otherwise found in East Africa in Malawi, Madagascar, Zimbabwe and the coastal regions of Tanzania and Kenya. ACMV occurred in all the West African countries sampled (Benin, Burkina Faso, Ghana, Côte d'Ivoire, Nigeria and Senegal) and also in Angola, Burundi, Cameroon, Chad, Congo, Mozambique, South Africa, Zambia, Uganda, Western Tanzania and Western Kenya. More recent surveys show that EACMV now has a much wider distribution, occurring in western Kenya and Tanzania (Ogbe et al., 1996; 1997; Harrison et al., 1997) and even in West Africa, in Cameroon, Togo, Ghana, Nigeria, Benin and Guinea.

Serious losses in yield due to CMD were first observed in East Africa in the 1920s (Hall, 1928). The earliest recorded epidemics of the disease in the region occurred in the 1930s and 1940s (Jameson, 1964) and were contained by phytosanitation and the use of resistant or tolerant varieties. CMD, though endemic, largely remained at a low incidence in Uganda until the late 1980s when outbreaks of a severe form were reported in northern Uganda (Otim-Nape et al., 2001). Previous project results (R5240; R6614) showed that the epidemic was associated with unusually large whitefly populations, rapid spread of CMD and very severe CMD symptoms (Gibson et. al., 1996), and had devastating consequences on cassava production. A novel strain was described from infected cassava plants taken from areas in the country then experiencing the epidemic (Harrison et al., 1997). Despite having the serological properties of ACMV, nucleotide sequencing data showed that it was predominantly EACMV and was a natural recombinant of ACMV and EACMV (Zhou et al., 1997). This strain, called the Uganda variant (UgV)(Harrison et al., 1997) or EACMV-Ug, alone or in dual infections with ACMV (hitherto the only reported cause of CMD in Uganda), were shown experimentally to cause the severe symptoms typical of the epidemic. The epidemic expanded southwards throughout Uganda in the 1990s and now many other countries in East and Central Africa are affected (Harrison et al., 1997; Legg, 1999; Legg et al., 1999; Neuenschwander et al., 2002), becoming a pandemic. Its arrival in Tanzania around the turn of this century has resulted in the Department of Research and Development giving highest priority to controlling virus diseases of root crops (principally CMD) in the Lake Zone. The pandemic has already created much hardship in areas affected to the west of Lake Victoria, although the northern part of this area (northern Kagera Region) is primarily a banana growing zone. The impact looks set to increase dramatically as severe CMD spreads to the south and east of the Lake, where farming communities depend even more on cassava for their livelihoods.

Work began in the Colonial period in several countries, particularly in Madagascar and at the Amani Research Station in what is now Tanzania, to develop CMD-resistant varieties (Jennings, 1960). Adequate resistance was only identified within wild species, notably the ceara rubber plant, *Manihot glaziovii* (Nichols, 1947). Resistant clones with satisfactory yields were developed from crosses with the cultivated species. When breeding work in Tanzania was terminated in the late 1950s, material was transferred to Nigeria and a selection was used at the International Institute of Tropical Agriculture (IITA) as a source of resistance. Breeding there has led to a series (Tropical *Manihot* species, coded TMS) of agronomically improved resistant cassava clones and seed stocks being released to national programmes in Africa (Hahn, 1994). Another source of resistance has more recently been identified in some West African landraces, controlled by a dominant gene (Akano et al., 2002), the TME (Tropical *Manihot esculenta*) series. Some of the TME x TMS crosses appear to be effectively immune to CMGs. Both the Tanzanian and Ugandan national programmes have acquired both TMS and TME genotypes and also seed from IITA to make their own selections. Many of the best new materials are the result of TME by TMS crosses and these feature strongly in advanced germplasm in both Uganda and Tanzania. For example, Akena (I92/0067) is the product of TMS 91934xTME 1 half sib. Omongole (I92/0057) is TMS 30555xTME 1 half sib. I91/02324 and I91/02327, both of which are highly resistant, are TME 1 half sibs.

CMGs systemically infect stem cuttings, the normal means of propagating this crop. Consequently farming activities disseminate CMGs geographically and maintain them through successive cropping cycles. Whiteflies then cause spread within and between crops, the extent of each varying with the local balance of the whitefly populations and disease inoculum within and surrounding the crop (Fargette, Fauquet & Thouvenel, 1988; Fauquet & Fargette, 1990; Fargette et al., 1990; Byabakama, 1996; Legg et al., 1997; Legg & Ogwal, 1998). In areas where the viruses are spread slowly by vectors, cutting-derived infection can, as in coastal Kenya (Bock & Guthrie, 1982), be the main source of diseased plants. Efforts to rehabilitate the cassava industry in Uganda in the 1990s using large-scale introduction of disease-free, 'clean', planting material following 'wipe-out' by CMD (but without systematic eradication) were relatively unsuccessful (Otim-Nape et al., 1997) until more resistant varieties became available. On a local scale, planting largely clean cuttings and roguing out diseased plants from newly established crops is a recommended practice (Bock & Guthrie, 1982; Thresh et al., 1997) but a serious limitation on its efficacy seems to be that much spread of CMD originates outside of crops. Cultural control measures do, however, seem to offer a practical means of CMD management for at least some African savannah-type agro-ecosystems when combined with an appropriate level of varietal resistance (Bock, 1994) and could be a component of most control strategies. In both TMS and TME clones, several facets of resistance seem to offer opportunities to combine resistance with cultural control. These include resistance to infection, and resistance to systemic spread of the virus such that plants may recover from infection (Storey and Nichols, 1938; Terry, 1982) and cuttings taken from diseased plants may revert to being disease-free (Pacubamba, 1985; Fauquet et al., 1988). In practice, reversion is extremely important in together preventing the gradual build-up of disease which would otherwise be inevitable even in resistant varieties during successive cycles of vegetative propagation (Fargette, Thresh & Otim-Nape, 1994).

CMD-resistant varieties have been the main means of controlling CMD epidemics in Africa for many decades and the deployment of several CMD-resistant cassava varieties by the Ugandan National Cassava Programme (UNCP) has provided a classic example of their role in bringing the epidemic under control. However, it is clear from work conducted by R7505, PL480-funded surveys etc that resistant varieties need to be adapted to the local agricultural and socio-economic environment if they are to be adopted. To date, 12 CMD-resistant varieties (coded Nase 1 to 12) have been released in Uganda and many other clones are at advanced stages of breeding. Recommendations have applied only to the use of varieties grown as a monocrop. It has been shown experimentally that CMD-susceptible cassava landraces can be protected from CMD by growing them amongst resistant varieties, presumably because viruliferous whiteflies seldom generate further sources of infected plants when they feed on resistant varieties (Sserubombwe, 1998; 2001).

Although much knowledge has already been applied in Uganda to control the CMD pandemic there, elsewhere it continues to limit cassava production. Some CMD-resistant varieties have already been deployed in neighbouring countries now affected by the pandemic, particularly Kenya, Tanzania and Rwanda. The Tanzanian Government is introducing farmer field schools (FFs) as a training approach throughout the country providing opportunity for expanding farmer participation in work on CMD and extensive scope for development and promotion of CMD management approaches there. Multiplication of CMD resistant cassava varieties has been initiated in Kagera (north-western Tanzania) in response to the devastating impact of the severe CMD pandemic on local varieties. These circumstances provide opportunity here to achieve extensive training in CMD control.

Plate 1: A large multiplication block of CMD resistant cultivar TME 204 showing drooping and yellowing of leaves initiated by heavy feeding by *B*. *tabaci* adults and nymphs. Looking on with concern is Mr. George Kituka, Farm Manager of Mukono Agricultural Research and Development Centre (ARDC), Uganda.

Work in West Africa showed that the *B. tabaci* colonising cassava there was restricted largely to this host; *B. tabaci* colonising cotton, sweet potato and other plants were unable to survive on cassava (Burban, et al., 1992). Work funded by ODA under R5240 showed that whitefly on cassava in Uganda are similarly host-restricted (Legg, Gibson & Otim-Nape, 1994; Legg, 1995). As well as a novel virus, an increased abundance of the whitefly vector, *B. tabaci*, especially at the epidemic front (Legg, 1995), drives the pandemic and passage of the epidemic was, in all cases, associated with boosted whitefly populations. Although the acuteness of the CMD epidemic declined following the initial stage of rapid spread, the elevated *B. tabaci* populations associated with the epidemic (Otim-Nape *et al*, 1997; Legg and Ogwal, 1998) have remained seemingly permanently elevated in areas affected by the pandemic. In many places these populations are 100 times the pre-epidemic levels, and it has been noticeable that abundances have been even greater still on some of the newly-introduced CMD-resistant varieties. Lower leaves of cassava plants are being observed covered in black sooty moulds thriving on the abundant whitefly excreta (often called 'black mosaic' by Ugandan farmers) and blocking photosynthesis. Plants are also being drained of sap to the extent that the whiteflies themselves seem to be a direct pest on cassava. This has previously been unknown anywhere in Africa and the Ugandan National Cassava Programme (UNCP) was extremely concerned at this new situation. The elevated numbers are at least partly mediated by infection with EACMV-Ug increasing the fecundity of *B. tabaci* on cassava (R6614) (Colvin et al., 2004). In other crops elsewhere, changes both in the number of whitefly and their ability to transmit diseases have also been attributed to the evolution or introduction of new whitefly biotypes. Possible changes in the *B. tabaci* population associated with the epidemic in Uganda (Gibson et al., 1996) appear to be being confirmed by molecular evidence for a distinct *B. tabaci* genotype cluster associated with the pandemic (Legg et al., 2002).

Symptoms of whitefly damage are most evident during dry periods of the year. Direct damage symptoms are caused both by adults and nymphs. Direct damage symptoms caused by adults comprise a diffuse mottled chlorosis on shoot tips, where the adults are concentrated. In severe cases, the yellowing can be quite marked and there is a clear reduction in leaf size. Nymphs also cause direct damage to lower leaves through their feeding activity. In the worst cases there is a marked reduction in leaf size, a tendency for the leaves to dry out and where this occurs there is often early abscission. More obvious, however, is the indirect damage caused by the immature stages, where exuded honeydew falls onto lower leaves, providing a substrate for the development of sooty moulds. In the worst cases, this can lead to the blackening of leaves, petioles and stems on the lower part of the plant leading to a reduction in the efficiency of photosynthesis and impaired leaf growth. The net result of all of these symptoms is a reduction in starch formation in the tuberous roots leading to reduced yields. These reductions are not of the magnitude of those caused by the severe epidemic CMD, or other acute pests such as the cassava mealybug and, during the rainy seasons, symptoms may disappear and the trauma that the plant has suffered is not immediately apparent. Experience from work on the cassava green mite, *Mononychellus tanajoa* has, however, shown that pests that are primarily active during dry periods, and from which there is an apparent recovery during rains, may still give rise to substantial yield losses. In the case of the cassava green mite, yield losses have typically been reported to be of the order of 50%. It was therefore surmised that there may be a similar situation for *Bemisia tabaci* whiteflies, with substantial yields losses being incurred in spite of the seasonal nature of the symptoms. The increase in the population of whiteflies also increases enormously the selection pressure for virus isolates able to overcome the current CMD-resistance - and, if this occurred, the effects would be devastating. It also increased the risk of whitefly-borne viruses belonging to groups other than the Geminiviridae – such as a *Crinivirus* or *Ipomovirus* - affecting cassava crops in the Lake Zone. *Cassava brown streak virus*, for example, is a whitefly-borne *Ipomovirus* currently restricted to lowland cassava crops and it's adaptation to mid-altitude conditions could be disastrous to Ugandan farmers. However, just as several of the CMD-resistant varieties (e.g., Nase 4) seem to support large whitefly populations, UNCP scientists identified that some local genotypes supported relatively few. It was considered essential that this diversity should be a) recorded, b) understood, including the risk of its breakdown in plants infected with EACMV-UG, and c) exploited. Controlling the whitefly vector through host plant resistance would complement both CMD resistance and cultural controls. Work at CIAT has identified American cassava genotypes resistant to an indigenous whitefly species but selecting plants resistant to *B. tabaci* has never been reported as a main aim of cassava breeding programmes in Africa.

References cited

Akano, A.O., Dixon, A.G.O., Mba, C., Barrera, E., and Fregene, M. 2002. Genetic mapping of a dominant gene conferring resistance to cassava mosaic disease. *Theoretical and Applied Genetics* **105**:521-525 (published online 8 May 2002) [http://link.springer.de/].

Bock, KR (1983). Epidemiology of cassava mosaic in Kenya. in *Plant Virus Disease Epidemiology*, pp 337-347. Eds RT Plumb & JM Thresh. Blackwell, Oxford.

Bock, KR & Guthrie, EJ (1982). Control of cassava mosaic disease in Kenya. *Tropical Pest Management* **28**, 219-222.

Burban, C, Fishpool, LDC, Fauquet, C, Fargette, D & Thouvenel, J-C (1992). Host-associated biotypes within West African populations of the whitefly *Bemisia tabaci* (Genn.) (Aleyrodidae). *Journal of Applied Entomology***, 113,** 416-423.

Byabakama, B.A, Adipala, E., Ogenga-Latigo, M.W., Tusiime, G. & Otim-Nape, G.W. (1997). The resistance of improved cassava varieties to cassava mosaic disease in Uganda. *African Journal of Plant Protection* **7**, 45-57.

Colvin,J., Omongo, C.A., Maruthi, M.N., Otim-Nape, G.W., & Thresh, J.M. (2004). Dual begomovirus infections and high Bemisia tabaci populations: two factors that drive the spread of a cassava mosaic disease pandemic. Plant Pathology, 53, in press.

Cours-Darne, G. 1968. Improving cassava in Africa. The Abidjan Conference. Agricultural Research Priorities for Economic Development in Africa. U.S. *Academy of Sciences* **2**: 330-339.

Fargette, D, Faucquet, C & Thouvenel, J-C (1988). Yield losses induced by African cassava mosaic virus in relation to the mode and date of infection. *Tropical Pest Management* **34,**89-91.

Fargette, D, Thresh, JM & Otim-Nape (1994). The epidemiology of African cassava mosaic virus: reversion and the concept of equilibrium. *Tropical Science* **34,** 123-133.

Fargette, D, Faucquet, C, Grenier, E & Thresh, JM. (1990). The spread of African cassava mosaic virus into and within cassava fields. *Journal of Phytopathology* **130,** 289-302.

Fauquet, C & Fargette, D (1990). African cassava mosaic virus: etiology, epidemiology, and control. *Plant Disease* **74,** 404-411.

Fauquet, C., Fargette, D., and Thouvenel, J.-C. 1988. Selection of healthy cassava plants obtained by reversion in cassava fields. In: C. Fauquet and D. Fargette (eds) *Proceedings International Seminar on African Cassava Mosaic Disease and Its Control.* Yamoussoukro, Cote d'Ivoire, 4-8 May. 1987. Pp. 146-149. CTA/FAO/ORSTOM/ IITA/IAPC.

Geddes, AMW (1990). The relative importance of crop pests in sub-Saharan Africa. *Natural Resources Institute Bulletin* **No 36,** vi + 69pp.

Gibson, R.W., Legg, J.P. and Otim-Nape, G.W. 1996. Unusually severe symptoms are a characteristic of the current epidemic of mosaic virus disease in Uganda. *Annals of Applied Biology* 128**:479-490.**

Hall, F.W. 1928. Annual Report of the Department of Agriculture, Uganda. p. 35. Government Printer, Entebbe.

Hahn, SK, 1994. Root crops for food security in sub-Saharan Africa. *Proceedings of the 5th Triennial Symposium of the International Society for Tropical Root Crops – Africa Branch.* Pp 16-21.

Harrison, B.D., Swanson, M.M., McGrath, P.F., Fargette, D. (1991) Patterns of antigenic variation in whitefly-transmitted geminiviruses. *Report of the Scottish Crop Research Institute for 1990*, pp88-90.

Harrison, B.D., Swanson, M.M., & Robinson, D.J. (1995) Cassava viruses in the Old World. pp463-472, Volume 2. *Proceedings:* Second *International Scientific Meeting of the Cassava Biotechnology Network*, Bogor, Indonesia, 22-26 August 1994 Working Document No 150, CBN/CRIFC/AARD/CIAT.

Harrison, B.D., Liu, Y.L., Zhou, X., Robinson, D.J., Calvert, L., & Otim-Nape, G.W. (1997) Properties, differentiation and geographical distribution of geminiviruses that cause cassava mosaic**.** *African Journal of Root and Tuber Crops* **2,** 19-22.

Hillocks, RJ, Thresh, JM & Belloti, A. (2002). Cassava: Biology, Production, and Utilization. CABI Publishing, CAB International.

Jameson J.D. 1964. Cassava mosaic disease in Uganda. *East African Agricultural and Forestry Journal* **29**:208-213.

Jennings, D.L. 1960. Observations on virus diseases of cassava in resistant and susceptible varieties I. Mosaic disease. *Empire Journal of Experimental Agriculture* **28**:23-24.

Kebe, B, Lutaladio, N, Norman, JC & Akoroda, MO. 2001. Global cassava development strategy: the African regional component. *African Crop Science Conference Proceedings* **5**, 571-577.

Kikafunda, J. 1994. Contribution of root and tuber crops to Uganda's food security: a nutritional perspective. *Proceedings of the 5th Triennial Symposium of the International Society for Tropical Root Crops – Africa Branch.* Pp 47-49.

Legg, J.P. (1995). PhD Thesis. University of Reading.

Legg J.P. 1999. Emergence, spread and strategies for controlling the pandemic of cassava mosaic virus disease in east and central Africa. *Crop Protection* **18**:627-637.

Legg, J.P., Gibson, R.W. & Otim-Nape, G.W. (1994). Genetic polymorphism amongst Ugandan populations of *Bemisia tabaci* (Gennadius)(Homoptera: Aleyrodidae), vector of African cassava mosaic geminivirus. *Tropical Science* **34**, 82 - 91.

Legg, J. James, B., Cudjoe, A., Saizonou S., Gbaguidi, B., Ogbe, F., Ntonifor N., Ogwal, S., Thresh, J.M. & Hughes, J. d'A. (1997). A regional collaborative approach to the study of cassava mosaic disease epidemiology in sub-Saharan Africa. In: *Proceedings African Crop Science Conference*, Pretoria, South Africa **3**, 1021-1033.

Legg, J.P. & Ogwal, S. (1998). Changes in the incidence of African cassava mosaic virus disease and the abundance of its whitefly vector along south-north transects in Uganda. *Journal of Applied Entomology* **122**, 169-178.

Legg, J.P., Sseruwagi, P., Kamau, J., Ajanga, S., Jeremia, S.C., Arirua, V., Otim-Nape, G.W., Muiba-Kankolongo, A., Gibson, R.W. and Thresh, J.M. 1999. The pandemic of severe cassava mosaic disease in East Africa: current status and future threats. In: M.P. Akoroda and J.M. Teri (eds). *Food Security and Crop*

Diversification in SADC countries: the Role of Cassava and Sweet Potato. Proceedings of the Sciencitific Workshop of Southern African Root Crops Research Network. Pp. 236-251. SADC, IITA, CIP.

Legg, J.P., French, R., Rogan, D., Okao-Okuja, G. & Brown, J.K. 2002. A distinct *Bemisia tabaci* (Gennadius)(Hemiptera: Sternorrhyncha: Aleyrodidae) genotype clust is associated with the epidemic of severe cassava mosaic virus disease in Uganda. *Molecular Ecology* **11:** 1219-1229.

Mahungu, N.M., Dixon, A.G.O., and Kumbira, J.M. 1994. Breeding cassava for multiple pest resistance in Africa. *African Crop Science Journal* **2**:539-552.

Neuenschwander, P., Hughes, J. d'A., Ogbe, F., Ngatse, J.M. and Legg, J.P. 2002. The occurrence of the Uganda variant of East African cassava mosaic virus (EACMV-UG) in western Democratic Republic of Congo and the Congo Republic defines the westernmost extent of the CMD pandemic in East/Central Africa. *New Disease Reports* **4**[http://www.bspp.org.uk/ndr/]. *Plant Pathology* **51**:385.

NARO, 2000. *A strategy for 2000 2010. Facing the research challenges for the modernisation of agriculture.* National Agricultural Research Organisation, Uganda, 36pp.

Nichols R.F.W. 1947. Breeding cassava for virus resistance. *East African Agricultural Journal* **12**:184-194.

Nweke, F.I., Dixon, A.G.O., Asiedu, R., and Folayan, S.A. (1994). Cassava varietal needs of farmers and the potential for production growth in Africa. Working Paper No. 10. Collaborative Study of Cassava in Africa. IITA, Ibadan, 239pp.

Ogbe, F.O., Atiri, G.I., Dixon, A.G.O. & Thottappilly, G. (2003). Symptom severity of cassava mosaic disease in relation to the concentration of African cassava mosaic virus in different cassava genotypes. *Plant Pathology* **52**, 84-91.

Ogbe, F.O., Legg, J., Raya, M.D., Muimba-Kankalongo, A., Theu, M.P., Kaitisha, G., Phiri, N.A., & Chalwe, A. (1997). Diagnostic survey of cassava mosaic viruses in Tanzania, Malawi and Zambia. *Roots* **4**, 12-15.

Ogbe, F.O., Songa, W., & Kamau, J.W. (1996). Survey of the incidence of African cassava mosaic and East African cassava mosaic viruses in Kenya and Uganda using a monoclonal antibody based diagnostic test**.** *Roots* **3**, 10-13.

Otim-Nape, G.W., Alicai, T. and Thresh, J.M. 2001. Changes in the incidence and severity of cassava mosaic virus disease, varietal diversity and cassava production in Uganda. *Annals of Applied Biology* **138**:313-327.

Otim-Nape, G.W., Bua, A. & Thresh, J.M. (1997). Editors: *Progress in Cassava Technology Transfer in Uganda.* NARO/Gatsby/NRI publication, University of Greenwich. 139pp.

Otim-Nape G.W., Bua, A., Thesh, J.M., Baguma, Y., Ogwal, S., Ssemakula, G.N., Acola, G., Byabakama, B.A., Colvin, J., Cooter, R.J., and Martin, A. 2000*. The current pandemic of cassava mosaic virus disease in East Africa and its control.* NARO/NRI/DFID Publication, Chatham, UK. 100pp.

Pacumbaba, R.P. 1985. Virus-free shoots from cassava stem cuttings infected with cassava latent virus. *Plant Diseases* **69**:231-232.

Robertson, AI & Ruhode, T 2001. The potential advantages of cassava over hybrid maize as a food security crop and a cash crop in the Southern African semi-arid zone. African Crop Science Conference Proceddings Vol 5, 539-542.

Rossel, HW, Asiedu, R & Dixon, AGO (1992). Resistance of cassava to African cassava mosaic virus; what really pertains. *Tropical Root and Tuber Crops bulletin* **No 6,** 2.

Storey, H.H.and Nichols R.F.W. 1938. Studies on the mosaic diseases of cassava. *Annals of Applied Biology* **25**:790-806.

Sserubombwe, W. (1998) Progress of cassava mosaic virus disease (CMD) and its effect on growth and yield in different cassava varieties under epidemic conditions in Uganda. *MSc Thesis, Makerere University, Kampala, Uganda*.

Sserubombwe, W.S., Thresh, J.M., Otim-Nape, G.W. and Osiru, D.O.S. (2001) Progress of cassava mosaic virus disease and whitefly vector populations in single and mixed stands of four varieties grown under epidemic conditions in Uganda. *Annals of Applied Biology* **138,** 161-170.

Terry E.R. 1982. Resistance to African cassava mosaic and productivity of improved cassava cultivars. In: E.H. Belen and M. Villanueva (eds). *Proceedings 5th Symposium International Society Tropical Root and Tuber Crops.* Pp. 415-429. PCSRRD, Philippines.

Terry, ER & Hahn, SK (1980). The effect of cassava mosaic disease on growth and yield of a local and an improved variety of cassava. **Tropical Pest Management 26,** 34-37.

Thresh, J.M., Otim-Nape, G.W., Legg, J.P., and Fargett, D. 1997. African cassava mosaic virus disease: the magnitude of the problem. *African Journal of Root and Tuber Crops* **2**:13-19.

Thresh, J.M., Otim-Nape, G.W. & Jennings, D.L. (1994). Exploiting resistance to African cassava mosaic virus. *Aspects of Applied Biology,* **39**, 51-60.

Zhou, X., Liu, Y., Calvert, L., Munoz, C., Otim-Nape, G.W., Robinson, D.J., and Harrison, B.D. 1997. Evidence that DNA-A of a geminivirus associated with severe cassava mosaic disease in Uganda has arisen by interspecific recombination. *Journal of General Virology* **78**:2101-2111.

Project Purpose

Modern resistant varieties (MOVs) provide the main control strategy for the cassava mosaic disease (CMD) pandemic in Africa, but no single variety is perfect. The project, in partnership with the international Tropical Whitefly IPM Project, aimed to validate MOVs and other control technologies including selection of planting material and mixing susceptible landraces with resistant varieties in a close working collaboration with farmers in Uganda (planned: Lira and Mukono Districts; actual: Apac and Mukono Districts) and Tanzania (Lake Zone). Using this collaboration as a "test-bed", it sought to develop farmer-validated promotional systems/materials for national (e.g. NAADS) and regional dissemination (IITA, EARRNET). Research on-station also sought cassava genotypes resistant to *Bemisia tabaci,* the whitefly vector of CMD, to provide protection additional to the existing CMD-resistances.

Specific aims of the project included to:

- Work with farmer groups to:
  - identify appropriate CMD-resistant varieties and the basis for their adoption;
  - identify practices for the sustained production of moderately CMD-resistant landraces;
  - test whether CMD-resistant varieties can protect moderately CMD-resistant landraces in mixtures.

- Use the above collaborations with farmers as test-beds to develop and validate training materials, systems and general promotional materials for informing farmers. These will be made available to regional organisations for wider promotion. Training in CMD control will be provided to:
  - collaborating farmers;
  - facilitators to both train further farmers and to train trainers.

- Quantify the apparent direct damage being caused by *B. tabaci* to susceptible released cassava varieties.

- Confirm the apparent presence of *B. tabaci*-resistance within African cassava germplasm, identify resistant genotypes and test whether this resistance is maintained in CMD-affected plants.

Research Activities

Output 1. Current yield losses due to *B. tabaci* assessed, *B. tabaci*-resistant cassava genotypes identified and resistance described, including effect of CMD.

Activity 1.1. Assessment of yield losses attributable to *B. tabaci* direct damage. Two replicate trials were planted, one in October 2002 and the other a year later, at the Namulonge-Sendusu experimental station. The main treatment comprised whitefly protected and whitefly unprotected plots arranged in a randomised design of four replicates. Protected plots were treated with two insecticides to maintain whitefly populations at very low levels of abundance. The systemic neonicotinoid, imidacloprid (trade name 'Confidor') was applied as a soil drench around the base of each cassava plant in the trials shortly after sprouting (one month after planting [MAP]) and at four months after planting. Foliar applications of the contact pyrethroid, cypermethrin (trade name 'Ambush') were made at weekly intervals throughout the duration of each of the trials. Unprotected plots received no insecticide. Each of the above plots comprised subplots of eight varieties, again arranged in a randomised design; each subplot comprised 5 x 5 plants each spaced at 1m by 1m. The varieties used were: Ebwanateraka (local CMD-susceptible), Njule (local CMD-susceptible), Nase 3 (= TMS 30572, = Migyera, improved CMD-resistant), Nase 4 (= SS4, improved CMD-resistant), Nase 10 (= 0063, improved CMD-resistant), Nase 12 (= 0414, improved CMD-resistant), 0057 (= Omongole, improved CMD-resistant) and 0067 (= Akena, improved CMD-resistant). Sorghum barriers were planted between subplots to minimize the effects of spray drift and spray was applied to protected subplots during the early evening when wind tended to be moderate to light and to minimize the possibility of spray burn during daylight hours.

Each trial ran for a period of 12 months. Whitefly adults were counted each week on five plants per subplot during the growing period: all adult *B. tabaci* on the top five leaves of the tallest shoot of each selected plant were counted. The incidence and severity of cassava mosaic disease (CMD) were recorded for all plants in the trial at monthly intervals. Severity was scored using the standard 1 - 5 scale in which 1 represents a symptom-free plant and 5 a plant with the most severe symptoms comprising strong chlorotic mosaic, leaf distortion and plant stunting. Assessments were also made at monthly intervals of the severity of sooty mould and feeding damage caused by whiteflies, again using severity scores ranging from 1 - 5, with 1 representing absence of symptoms and 5 the most severe symptoms. At harvest, all plants within each varietal plot were harvested. Data were analyzed for each parameter using analysis of variance and interrelationships examined using Pearson's correlation analysis and multiple regression.

Activities 1.1 – 1.5. Assessment of whitefly resistance in the field and in screenhouse tests. The Ugandan National Cassava Programme breeding scheme comprises successive stages of seedling nursery, clonal evaluation trial, preliminary yield trial (PYT), advanced yield trial (AYT), uniform yield trial (UYT) and on-farm evaluations. The seed lots planted in the seedling nursery are normally obtained from deliberate crosses (by hand) between selected elite genotypes as parents or from open pollinated plants in a crossing block planted with selected elite parents. The number of accessions declines progressively down the chain as clones are eliminated because of non-compliance with target attributes. The major target attributes have been resistance to CMD and major arthropod pests (cassava green mite & mealybug) and acceptable tuberous root quality. With the identification of whiteflies as a direct pest of cassava, resistance to them started being included in scoring beginning with cassava genotypes planted in May 2003 in the AYT and UYT trials at Namulonge Agricultural and Animal Production Research Institute (NAARI). AYT and UYT trials are designed as randomised complete block trials replicated four times, each accession being planted in four plots each 5m x 6m with a 2 m wide unplanted border between plots and blocks. *B. tabaci* adults and nymphs were counted each month on the five top open leaves for each of 20 randomly selected plants in each plot from 3 months after planting (MAP) to 7 MAP. Mean values were calculated for adult and nymph counts and the data were subjected to repeated measures analysis of variance (ANOVA) using GENSTAT to examine statistical significance.

A large number of cassava germplasm grown under the auspices of EARRNET (East African Root Research Network) are periodically evaluated in the field at Serere Agricultural and Animal Production Research Institute (SAARI) in eastern Uganda. The member countries, of which Uganda is one, can freely access the germplasm and select lines to feed into their own variety development schemes. A germplasm batch was planted between May and June 2003 and 393 genotypes of these were also screened for resistance to *B*. *tabaci*. Since the number of lines to be screened was very large, a quick protocol was devised. This involved counting *B*. *tabaci* adults and nymphs only on the middle leaflet of the four top open leaves per plant starting 3 months after planting (MAP). Data were taken every month until 6 MAP. The data were summarised and population means for each genotype were obtained from the two replications used. Some 66 genotypes were selected in April 2004 for further evaluation at NAARI but unfortunately the planting material died due to a prolonged drought that occurred from May to August 2004. Backup material is being obtained from SAARI to repeat this trial.

In a further approach to accessing diversity, >200 landraces were collected in Uganda as part of a separate EU-funded project in 2002. Cuttings obtained from symptomless plants of each landrace were planted at NAARI in single row plots (10 plants/row) in two replicates. Numbers of adult whiteflies on the top 5 open leaves of all plants had been recorded as part of the study and were therefore available for analysis. Four successive records from the trial were summarised for all the plants per variety and mean values from the two replicates obtained.

Whitefly resistance was apparent amongst the landraces but there was a need to confirm this, especially for the landraces which were least colonized, partly to exclude any confounding effect on colonization of CMD (most landraces are very susceptible to CMD). Thus cuttings from symptomless plants were re-collected for 15 selected landraces in September 2004; cuttings of 4 CMD resistant varieties were also obtained. These were planted directly in the soil floor of an insect-proof screenhouse at NAARI in a randomised block design comprising three replicate plots of each cultivar, each plot comprising three plants. At 21 days after planting (DAP) random samples of *B*. *tabaci* adults of both sexes in unknown proportion picked from the middle of a multiplication block (CMD-free) of improved CMD resistant cassava variety Nase 10 were released in the experimental screenhouse. The whiteflies were allowed seven days after released to settle on the plants. Thereafter adult numbers on the top five leaves of every plant were counted at interval of every seven days. Data taking was stopped after three consecutive records to avoid inclusion of newly emerged adults in counts. The data were subjected to a repeated measures analysis of variance using GENSTAT.

Activities 2,3 &4. Developing, validating and promoting training messages and materials on the control of CMD in Uganda and Tanzania

Overview: These activities aimed to work with farmer groups in Tanzania and Uganda using a participatory research approach to develop and validate various control strategies for CMD including the use of resistant varieties and phytosanitation, and training materials to promote these control strategies. The activities had a different emphasis in Tanzania and Uganda. In Tanzania, particularly in Kagera Region where the project was located, the pandemic is having a devastating effect on farmers so there was an immediate need to assist as quickly as possible. The project achieved this particularly by being integrated within the Tanzanian Government efforts in the Lake Zone through its base at Agricultural Research Institute (ARI–) Maruku, part of the Lake Zone Agricultural Research and Development Institute (LZARDI) and by linking with activities of the donor, Norwegian Peoples' Aid (NPA) in Kagera Region. Farmer field schools are being promoted extensively both by the national government extension service, allowing the project to build on this approach. The devastation caused initially in Uganda by the pandemic has now largely been overcome there by the use of CMD-resistant varieties. The knowledge base on how to control the CMD pandemic is consequently strong but also the removal of the threat of food shortages caused by the pandemic provide a circumstance in which farmers are beginning to re-emphasise quality characteristics associated with their original landraces. NAARI also has both close links to farmers and to nearby Kampala, with its extensive communication service industry, allowing easy development of training and promotional materials.

Activities based in Uganda

Testing the use of CMD-resistant variety mixtures to protect CMD-susceptible landraces: Despite the vulnerability of landraces to CMD, farmers in Uganda continue to grow them, mainly because of the excellent cooking qualities of their tuberous roots and their suitability in the local cropping systems. The use of variety mixtures to restrict the spread of CMD to susceptible varieties has been demonstrated in on-station experiments in Uganda (Sserubombwe *et al*., 2001). The practical on-farm usage of cassava variety mixtures and CMD-resistant varieties were therefore evaluated, exposing farmers to the benefits of using CMD-resistant varieties both as sole crops and in mixtures to control CMD (Table 1).

Table 1: Variety mixtures evaluated on farmers' fields in Mukono and Apac districts

	Treatments and component varieties[1]	
District	Mixed cultivars plots	Single cultivar plots
Mukono	1:1 (Njule + *TMS I 92/0067*)	Njule
	1:1 (Kabwa + *TMS I 92/0067*)	Kabwa
		TMS I 92/0067
		TME 14
		TME 204
		Nase 10
Apac	1:1 (Bao + *TMS I 92/0067*)	Bao
	1:1 (Awulo awulo + *TMS I 92/0067*)	Awulo awulo
		TMS I 92/0067
		TME 14
		TME 204
		Nase 10

[1]CMD-resistant varieties are indicated in italics. Only TMS I 92/0067 was used in mixtures with landraces, two in each district

The activities were conducted in Goma sub-county n Mukono district and in Loro sub-county in Apac district. The two districts were chosen because of the importance of cassava in the areas and their contrasting cassava cropping systems. During the first season (2003/2004), trials were planted in Mukono and Lira Districts. However, as a result of the security situation in Lira, the trials there had to be abandoned and re-planted later in Apac. In Mukono, cassava is commonly grown together with other crops and different cassava varieties are often grown on the same field; in Apac the common practice is growing a single cassava variety in large blocks as a monocrop. The team of researchers from Namulonge had meetings with extension workers from the Departments of Agriculture of the two districts to select farmers for each trial. Meetings were also held with officers from Mukono Agricultural Research and Development Centre (ARDC) and Local Council (LC) leaders. The farmer groups identified in each district to participate in the trial were Kalagala Organic Farmers' Group in Goma sub-county, Mukono district and Anyaponenikweri Farmers' Group in Loro sub-county in Apac district. The group in Mukono had 18 members (12 women and 6 men), while the Apac group had 30 members (11 women and 19 men). The farmers confirmed in an initial meeting that they wanted to participate and further meetings were organised with the help of an extension officer during which the background, objectives and procedures of the trial were explained and roles for the farmers and researchers were agreed upon. Farmers also received group training in CMD management (see later). Both trials involved the same four CMD-resistant varieties plus two landraces popular in the respective districts (chosen by farmers). The CMD-resistant varieties planted in both districts were TMS I 92/0067, TME 14, TME 204 and Nase 10. A deliberate decision was taken to give farmers wider exposure to improved varieties by including 2 pre-release and 1 released elite CMD-resistant varieties. The local varieties planted were Njule and Kabwa in Mukono, and Bao and Awulo awulo in Apac. The researchers then chose the CMD-resistant variety TMS I 92/0067 to be used in the mixtures in both districts based on its similarity to the selected landraces in terms of growth characteristics and therefore likely compatibility. Five individual farmers from each group were identified by group consensus to host the trials and each farmer was given stem cuttings to plant eight plots comprised of 4 plots of resistant varieties, 2 plots of local varieties and 2 plots of mixtures (2 local varieties with TMS I 92/0067). As part of the training, all stem cuttings for planting were taken from CMD-free plants. The plot size was 9 m by 9 m (i.e. 8 x 8 array of plants) and each plot comprised one cassava variety or a mixture of two varieties. A randomized complete block design (RCBD) was used with each farmer as a replicate, so there were five replications per district. The rows were separated by an inter-plot space of 2 m to permit free movement by farmers during evaluations. The trials were managed by the farmers following their usual methods. The spatial arrangement of plants in the mixtures plots was that of systematic mixture in which every plant of the susceptible variety is sandwiched by plants of the resistant variety and *vice versa*. The combinations of the mixtures and pure stands of varieties planted in the two districts are summarised in Table 1.

The trials were evaluated three, six and twelve months after planting (MAP) by group members and other interested farmers, researchers and extension workers together walking from plot to plot to permit participating farmers to compare the test entries. During the participatory evaluations before harvest, the farmers mainly assessed the sole plots and mixtures for vegetative growth performance and responses to CMD and whiteflies; at harvest, the evaluation included yield, taste and tuberous root quality attributes. In addition, host farmers followed the progress of disease by taking their own records of the presence (√) and absence (X) of CMD symptoms on individual plants, as well as noting missing plants (-). This was done in a notebook on a tabular field plan where each plant was represented by a box. The farmers kept the notebooks. The information obtained by farmers from the interaction with researchers and also from their own records provided the basis to derive their perceptions and preferences of mixtures and pure stands of landraces and CMD = resistant varieties.

Researchers also took records every two months, starting 1 MAP, of the presence or absence of CMD symptoms on individual plants and numbers of adult cassava whiteflies. A severity scale of 1 - 5 (1 = symptomless, 5 = very severe symptoms) was used for scoring occurrence of CMD. Scores for symptomless plants were omitted in calculating mean CMD severities.
Data were transformed to stabilise the variance of the response variables. Incidence data were arcsine-transformed prior to analysis. Severity data and whitefly counts were square root transformed. The means of the replicate (farmer) plots were then subjected to analysis of variance using the Genstat computer statistical package.

Training and developing training materials: Three main activities were carried out: training of extension workers and farmers, development and production leaflets on the spread and control of CMD and development of a training manual on CMD for extension workers.

Training was provided to farmers in Mukono and to government extensionists in both Mukono and Apac as part of the project's participatory research activities (see above) there. Aims were:

- To impart extension workers and farmers with skills of identifying CMD and other major diseases and pests of cassava and with knowledge of control options
- To equip extension workers and farmers with technical knowledge and skills of improved cassava production

The training topics/messages covered the following topics;

- Importance of cassava
- Identification and control of CMD, cassava bacterial blight (CBB), cassava whiteflies, cassava green mites and cassava mealybugs
- Identification of commonly grown CMD-resistant varieties
- Agronomy of cassava
- Rapid multiplication and stem preservation
- Processing and utilisation of cassava

Half-day training sessions used visual aids to enhance the learning process and afterwards the participants received practical exercises on aspects such as identification of CMD, CBB and other pests of cassava, rapid multiplication of cassava, stem storage, seedbed preparation and planting of cassava. These were designed to provide the farmers with practical hands-on experience while learning. In order to improve the training package, participants then evaluated the training process, topics, content and presentation at the end of the training event. The first training event was organised for farmers belonging to Kalagala Organic Farmers' Group in Goma sub-county, Mukono district in April 2004 (see above). The training was held at a community centre within the village and was conducted by researchers from NCP. Two extension workers from Apac district also attended the training and were expected to transfer the knowledge to the farmers' group in Apac that had been selected to participate in the project. During the training farmers articulated their experiences and challenges in growing cassava and also in conducting the trial. The farmers also evaluated the training event. Another training was held at Mukono Agricultural Research and Development Centre (ARDC) in May 2004 for extension workers and researchers. All participants were from Mukono district and comprised extension workers from the Department of Agriculture of Mukono district local government, sub-county National Agricultural Advisory Services (NAADS) extension workers and researchers from Mukono ARDC responsible for dissemination. It was planned that these would in turn extend the learning by training other farmers in villages or parishes where they operate during their routine work.

In order to promote adoption of CMD control practices, especially CMD-resistant varieties more widely, an extension leaflet was produced for both extensionists and literate farmers. It was decided in initial planning sessions that the leaflet should comprise three main parts: (i) description of the CMD problem, (ii) explanation of CMD (cause and effect) and (iii) how to solving the CMD problem and that a professional designer should be provided with the text and appropriate photographs to develop the first draft of the leaflet. Pictures representing mild and severe manifestations of CMD, whitefly and cutting infections, adult whiteflies and CMD-resistant varieties to illustrate the disease were therefore provided. Researchers also collated information gathered on CMD over the years, included information about some of the CMD-resistant varieties commonly grown in Uganda. The leaflet was prepared in English and then translated into three other languages, namely, Swahili (by colleagues in Tanzania), Luganda and Luo. The English and Luganda leaflets were pre-tested with farmers and extension workers in Mukono district, while the Luo version was pre-tested in Lira and Apac districts. The leaflets were revised and finalized based on the suggestions and comments during pre-testing. In the pre-testing process, the draft materials were given to the farmers and extension workers to read. They were then given questionnaires that had provisions for comments on points such as relevance of messages, clarity of messages, simplicity of language, length of messages, overall layout and print style, as well as appropriateness, clarity and quality of illustrations and pictures. They were also asked to give their views on the practical applicability of the materials and on what type of farmer/extension worker would understand the material. Questions were also asked to ascertain whether the materials had been understood. They were finally asked to rank the material as bad, fair or good and make suggestions for improvement. A total of 10,000 leaflets were printed in four languages; English (4000), Luganda (2250), Luo (2250) and Swahili (1500) (Table 2). The leaflets will be distributed to farmers and extension workers both directly by NCP and through channels including Departments of Agriculture at districts and partner agencies such as NGOs, NAADS and ARDCs. Feedback about the performance of the leaflets will be obtained through the same channels.

In view of the enormity of effort needed for nationwide training of farmers on the management of CMD, it was also decided to produce a technical training manual for routine use by extension workers. The researchers developed the outline of the manual to include; (i) history of CMD, (ii) causes of CMD, (iii) common symptoms of CMD, (iv) effects of CMD, (v) epidemiology of CMD, (vi) how to record CMD incidence, severity and whitefly numbers, (vii) how to control CMD, and (vii) an account of the recent pandemic of CMD in the Great Lakes region. Whereas the leaflet contains specific technical information on CMD, the manual has more detailed information and includes some elements of experimentation and how to record CMD and whitefly numbers. The training manual has so far been produced only in English. It has been pre-tested as with the leaflet, with extension workers of seven NGOs in Lira (1), Apac (1), Gulu (2), Kibale (2) and Kiboga (1) districts. The training guide has to undergo further testing with staff of ARDCs and extension workers of districts and NAADS. Once this is completed and corrections are made, the material will be printed and disseminated.

Activities based in Tanzania

Logistics of all locally-based activities in Tanzania involved IITA: staff were recruited and funds paid through IITA's office in Dar es Salaam. Some initiatives to counteract the yield loss caused by the CMD pandemic such as the introduction of CMD resistant cassava varieties, some training of extensionists and a survey to track the pandemic were also done in collaboration with other projects involving IITA (e.g., the Office of Foreign Disaster Assistance (OFDA) CMD project and the DFID-funded Tropical Whitefly IPM project) or with the Tanzanian Ministry of Agriculture and Food Security (MAFS) through ARDI-Maruku. Large-scale training and dissemination of CMD-resistant varieties, particularly in southern Kagera, involved activities funded by the Norwegian People's Aid (NPA). In all these circumstances, project members provided pivotal inputs to these other activities. Some of these project activities were also done side-by-side with work on sweet potato virus disease control under R8243. These collaborations were often relatively 'seamless' enabling project outputs to achieve greater benefits and for more poor people though making it difficult sometimes to distinguish efforts clearly.

Four farmer groups were initiated in Bukoba and Muleba districts, namely Abatekanasha group at Kanazi, Neema group at Kyema, Twende na wakati group at Kyaka and Umoja group at Ngenge. Farmers received training on CMD epidemiology and management and early evaluation of new cassava varieties whilst the project learnt about the process and involvement of farmers in evaluation and tested different phytosanitation practices (selection and early roguing of CMD infected plants) as CMD management practices. Training was also undertaken on regular basis because many farmers who were expected to evaluate and benefit from the variety didn't know much about CMD and its management and both farmers and extensionists emphasised on their need to learn. Moreover, the varieties available were not immune to CMD and use of even varieties with high levels of resistance needs to be accompanied with appropriate extension messages. The farmer group facilitators (extension staff) were therefore invited to ARI-Maruku for training on CMD and other pathological problems in cassava aspects on agronomy, breeding and the farmer field school (FFS) approach. The farmers' training curriculum was developed and provided on-site to the farmer groups by the facilitators.

Trials implemented with all four farmer groups included a variety trial involving evaluation of 10 CMD-resistant varieties: MM 96/4684, MM 96/4446, MM 96/5725, MM 96/3075B, MM 96/4619, MM 96/8233, MM 96/8450, MM 96/5373, TMS 4(2)1425 and I 91/00063, and two moderately CMD-resistant varieties: Msitu Zanzibar and Lwabakanga. Trials involved a single replicate at each site, each plot comprising 36 plants planted 1m apart. It was not practical to replicate trials because plots of cassava are necessarily large, land is scarce and main aims of the trials were to act as focal points for training discussions and as demonstrations: the varieties had already been shown on-station to be high-yielding and CMD-resistant. Phytosanitation experiments located alongside the variety screening trials also included cvs Msitu Zanzibar and Lwabakanga. Farmers at each site also chose a local preferred variety for which at least some CMD-free planting material was available. The chosen local varieties were Rushula at Kyaka, Bukarasa at Kyema, Konyu at Kanazi and Kaitampunu nyeupe at Ngenge. Each plot under the variety trial contained one variety and had 36 plants while the plot under phytosanitation. Plots in the phytosanitation trial comprised 100 plants and, for each variety there were two plots, one rogued one month after planting and another not rogued. For both the variety and the phytosanitation trials, planting material was chosen from apparently CMD-free parent plants. Data on sprouting and the number of plants sprouting with CMD were collected one month after planting. Further data collection were collected at 3,6,9 and 12 months after planting (MAP). Farmers in each group met twice a month for additional training and to discuss any new findings.

At harvest, farmers were the principal evaluators of the performance of varieties and the effectiveness of the different phytosanitation practices tested, using separate men and women groups to examine any gender-based differences in preferences.

During the first season, it was learnt that all the varieties grown in the phytosanitation trials (Msitu Zanzibar, Rushula, Konyu, Bukarasa and Kaitampunu nyeupe (Sengerema)) succumbed to CMD yet the resistant varieties tested in the variety evaluation trial remained largely CMD-free. In the second growing season, the farmer group members decided to replant these more promising cassava varieties on a larger scale as a re-evaluation cum multiplication stage using the same approach and collective management by the group. Ten groups at Kyaka and Ngenge decided to embark on mass multiplication.

Outputs

Output 1. Current yield losses due to *B. tabaci* assessed, *B. tabaci*-resistant cassava genotypes identified and resistance described, including effect of CMD.

Further details are available in the following internal reports:
- **J. Legg.** Activity 1.1. Assessment of yield losses attributable to *Bemisia tabaci* direct damage
- **C. Omongo.** Host plant resistance to cassava whitefly, *Bemisia tabaci*, in Uganda

Output 1.1. Assessment of yield losses attributable to *B. tabaci* direct damage. Comparison of the abundance of *B. tabaci* adults between the treated (Fig. 2) and untreated (Fig. 1) plots revealed populations in the treated plots were generally about one hundredth of those in the untreated plots, demonstrating the efficacy of the insecticides and requiring the two sets of results to be drawn with different scales. The low abundances recorded in the protected plots were nevertheless comparable to populations recorded in unprotected plots of the local variety 'Bao' at Namulonge during the pre-epidemic period in 1992-3 (fig. 2). It is remarkable that in order to hold *B. tabaci* populations at a level equivalent to the pre-epidemic levels, a dual pesticide regime needs to be imposed comprising two applications per season of imidacloprid in addition to weekly sprays with cypermethrin. Considering the whitefly unprotected plots alone (Fig. 1), populations during both trials were extremely high, with the peak mean value for all varieties being over 200 in the first trial and almost 800 in the second. Highest records obtained for individual plants were 1,274 at 20 WAP in 2002-3 and 4,339 at 10 WAP in 2003-4. In comparison with other similar datasets, these values are well above all other reported population measures for *B. tabaci* on cassava in Africa, but are comparable with populations that can be attained by other whitefly species, notably *Aleurotrachelus socialis*, that are physical pests of cassava in Latin America. Although the main purpose of the trials was not to compare varietal susceptibility to whiteflies, it is noteworthy that populations were least on Njule in both years.

Table 2. Mean abundance of *B. tabaci* adults per top five leaves in whitefly protected (treated) and unprotected (untreated) plots for eight cassava varieties

	Whitefly abundance			
Variety	*2002-3*		*2003-4*	
	Treated	*Untreated*	*Treated*	*Untreated*
Nase 10	0.55	48.5	1.37	139.0
0057	0.74	48.0	1.15	126.0
Nase 12	1.01	65.2	1.10	116.4
Ebwanateraka	0.69	42.6	1.40	90.5
Njule	0.48	24.1	0.82	73.2
Nase 4	0.57	57.2	1.40	116.6
0067	0.47	38.8	1.15	102.0
Nase 3	0.56	45.5	0.97	82.5
Mean	0.63	46.2	1.17	105.8

CMD incidence differed both between varieties (P <0.001) and between treatments (P <0.001) in both years (Table 3). In unprotected plots, the two local varieties, Ebwanateraka and Njule, as anticipated, showed disease at an early stage, all plants becoming infected in 2003-4 and >90% infected in 2003-4. Although four of the six CMD-resistant varieties had varying degrees of infection in both trials, Nase 10 and Nase 12 remained CMD-free throughout. Nase 12 is claimed to be immune or near immune. Despite CMD being so prevalent in the two local CMD-susceptible varieties when grown unprotected by insecticides, CMD was much rarer in protected subplots of both of these varieties and of the partially-resistant improved varieties (Nase 3 and 0067). It was surprising that controlling

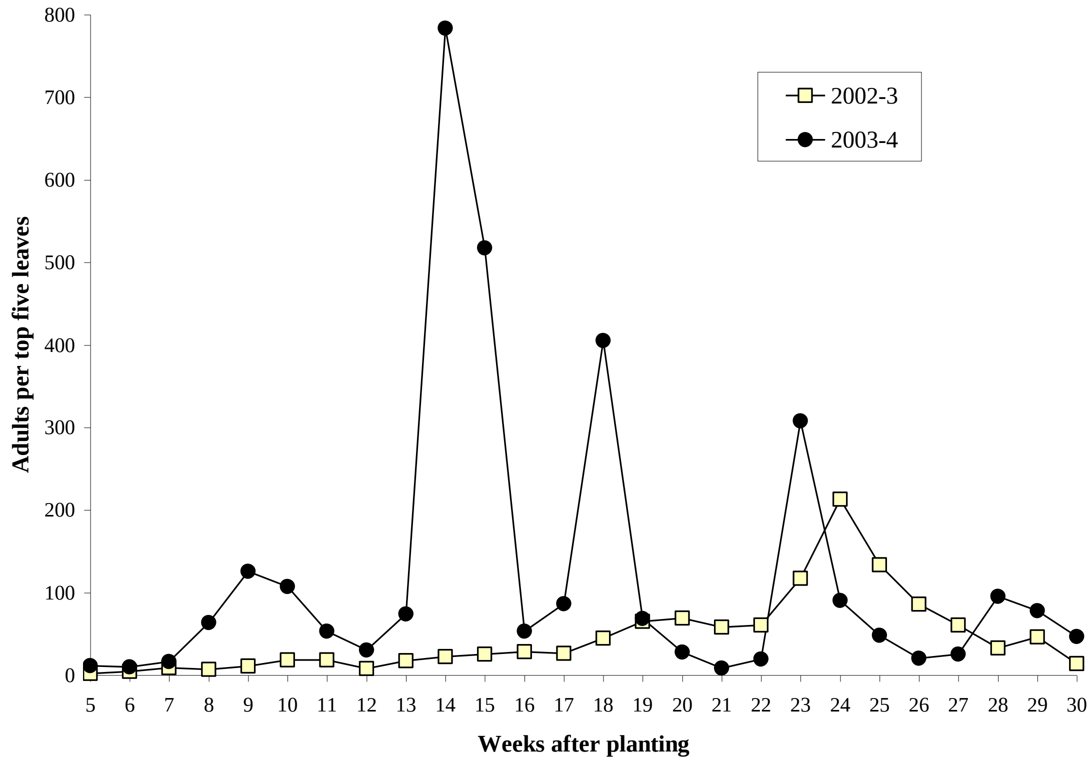


Figure 1. Mean abundance of adult *B. tabaci* per top five leaves in untreated plots of eight cassava varieties at Namulonge, Uganda, 2002-3 and 2003-4

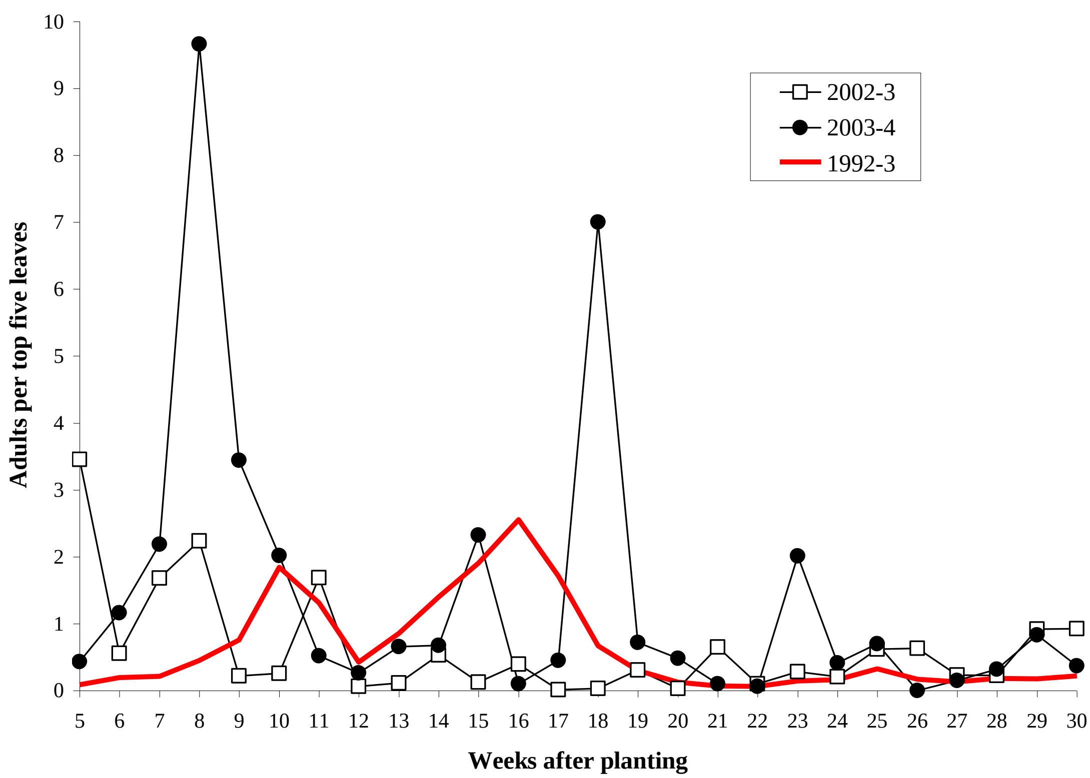


Figure 2. Mean abundance of adult *B. tabaci* per top five leaves in plots treated (for whitefly control) of eight cassava varieties at Namulonge, Uganda, 2002-3 and 2003-4, compared with untreated plots of cv. Bao in 1992-93 whiteflies was as effective as it was in reducing CMD incidence, not least since

protected plots were only separated from unprotected plots by a rather porous sorghum barrier. Sooty mould was present only on plants in unprotected plots (Table 4). The least damaged varieties overall were Ebwanateraka, Njule and 0057. The three worst-affected varieties, Nase 3, Nase 4 and Nase 12, were all CMD-resistant varieties recently promoted through programmes targeting the management of the CMD pandemic.

Table 3. Final incidence of CMD (%) in whitefly protected (treated) and unprotected (untreated) plots for eight cassava varieties

	CMD incidence (%)			
Variety	*2002-3*		*2003-4*	
	Treated	*Untreated*	*Treated*	*Untreated*
Nase 10	0	0	0	0
0057	17.3	60.0	6.1	79.2
Nase 12	0	0	0	0
Ebwanateraka	43.3	98.9	45.3	100
Njule	18.4	94.6	32.0	100
Nase 4	6.9	16.6	0	13.2
0067	3.3	5.2	6.1	34.1
Nase 3	24.9	61.3	9.5	72
Mean	*14.3*	*42.1*	*12.4*	*49.8*

Table 4. Sooty mould damage (1-5 scale) in whitefly protected (treated) and unprotected (untreated) plots for eight cassava varieties

	Sooty mould damage			
Variety	*2002-3*		*2003-4*	
	Treated	*Untreated*	*Treated*	*Untreated*
Nase 10	1.0	2.98	1.0	3.15
0057	1.0	3.03	1.0	2.0
Nase 12	1.0	3.65	1.0	3.95
Ebwanateraka	1.0	3.03	1.0	2.33
Njule	1.0	2.65	1.0	2.58
Nase 4	1.0	3.10	1.0	3.68
0067	1.0	2.90	1.0	3.73
Nase 3	1.0	3.15	1.0	3.63
Mean	*1.0*	*3.06*	*1.0*	*3.13*

Table 5. Whitefly feeding damage (1-5 scale) in whitefly protected (treated) and unprotected (untreated) plots for eight cassava varieties, Namulonge, Uganda

	Whitefly feeding damage			
Variety	*2002-3*		*2003-4*	
	Treated	*Untreated*	*Treated*	*Untreated*
Nase 10	1.0	3.05	1.0	2.50
0057	1.0	1.8	1.0	1.35
Nase 12	1.0	2.33	1.0	2.15
Ebwanateraka	1.0	1.9	1.0	1.60
Njule	1.0	2.68	1.0	1.88
Nase 4	1.03	3.03	1.0	2.40
0067	1.0	2.18	1.0	1.58
Nase 3	1.0	3.13	1.0	2.0
Mean	*1.0*	*2.51*	*1.0*	*1.93*

Whitefly feeding damage, observed as a chlorotic mottling on upper leaves, was also restricted to the unprotected plots (Table 5). Most severely affected varieties included Nase 3, Nase 4 and Nase 10, whilst the most lightly damaged included Ebwanateraka and 0057.

Yields for each of the varieties in the treated plots were similar but there were significant differences in yields of varieties in untreated plots and between treatments for both the 2002-3 and 2003-4 seasons ($P < 0.001$; $P = 0.019$) (Table 6). Differences in varietal yields amongst untreated plots ranged from the equivalent of the treated plot (Nase 10 in 2002-3) to approximately 10% of that of the treated plot (Ebwanateraka in 2003-4). Local CMD-susceptible varieties, when protected, gave yields as great as or greater than those given by the CMD-resistant varieties. In unprotected subplots, yields of the local varieties were less than that of any of the improved varieties, presumably due to the combined effects of severe CMD and whitefly damage. Yield losses, calculated from the comparison of yield data obtained from the protected and unprotected plots, ranged from nothing (Nase 10 in 2002-3) to >90% (Ebwanateraka in 2003-4). Although for many of the varieties, losses were likely to be a result of the combined effects of CMD and whiteflies, no CMD was recorded in either Nase 10 or Nase 12. Data for these varieties, therefore, describe the losses attributable to whiteflies alone. The yield losses of more than 44% in both seasons in the CMD near-immune Nase 12 provide compelling evidence of the impact that whiteflies can have on cassava.

Table 6. Tuberous root yield (kg per plant) in whitefly protected (treated) and unprotected (untreated) plots for eight cassava varieties

	Tuberous root yield (kg/plant)					
Variety	*2002-3*			*2003-4*		
	Treated	*Untreated*	*Loss (%)*	*Treated*	*Untreated*	*Loss (%)*
Nase 10	5.43	5.45	0	4.80	3.50	27
0057	3.69	3.62	2	4.07	2.24	45
Nase 12	5.33	2.95	45	4.89	2.72	45
Ebwanateraka	3.10	1.44	54	5.20	0.46	91
Njule	4.49	2.43	46	4.43	1.73	61
Nase 4	5.41	3.71	32	5.64	2.81	50
0067	5.72	4.92	14	5.18	3.49	33
Nase 3	5.16	2.44	53	4.75	2.78	42
Mean	*4.79*	*3.37*	*30*	*4.87*	*2.46*	*49*

Outputs 1.1 – 1.5. Assessment of whitefly resistance in the field and in screenhouse tests. In both the advanced yield trial (AYT) and the uniform yield trial (UYT), populations of adult and nymphal *B. tabaci* varied significantly on different genotypes. In AYT, populations were smaller on genotypes Nase 12-161(1), Nase 12-161(8), Nase 12-161(6) and Nase 10 (Table 7). Mean adult and nymph numbers on 87-TME 14(10) (35.7 $\pm$ 4.4; 121.6 $\pm$ 5.7) were about twice those on Nase 12-161(6) (14.6 $\pm$ 2.8; 61.0 $\pm$ 12.0). Nase 12 is considered very susceptible to *B. tabaci* so it is interesting that some of its siblings apparently are somewhat resistant. Although requiring further evaluation, this does indicate that whitefly resistance may be introgressed into a CMD-resistant line that lacks whitefly resistance. It is also noteworthy that Nase 12 is a premium variety with excellent tuber attributes desired by farmers.

In the UYT, accessions 4271 and 0116 had fewest *B. tabaci* (Table 8). Indeed, mean adult and nymph populations on 4271 (12.9 $\pm$ 1.6; 143.9 $\pm$ 38.5) were only a fifth those on accession 4235 (67.9 $\pm$ 20.7; 605.3 $\pm$ 170.5). Of the 10 genotypes evaluated, 4271, 0686, 0469 and 4799 were selected by farmers in this and other UYT trials for further testing at on-farm trial. Most of these accessions were not especially whitefly-resistant implying that the farmers had included other attributes such as resistance to CMD and acceptable storage root qualities in their selection of 4271 and the other selected cultivars. None-the-less, whitefly resistance, including that of genotype 4271, will be evaluated further in multilocational trials including whitefly "hotspots" across Uganda.

Table 7. Mean numbers (± SE) of *B. tabaci* adults and nymphs/top 5 leaves on CMD-resistant cassava genotypes in an advanced yield trial at Namulonge, planted on 21 May 2003

Genotype	Adults	Nymphs
87-TME 14(10)	35.7 ± 4.4	121.6 ± 5.7
*Nase 12	33.8 ± 5.3	102.8 ± 10.2
87-TME 14(8b)	31.0 ± 4.3	110.5 ± 8.5
Nase 12-87(1)	29.8 ± 5.0	105.4 ± 16.5
87-MSK(3)	28.2 ± 1.4	83.3 ± 3.2
87-TME 14(6)	25.9 ± 7.6	95.2 ± 21.7
87-TME 14(12)	23.8 ± 4.2	135.5 ± 14.5
87-MSK(8)	22.3 ± 3.0	93.3 ± 7.0
87-TME 14(20)	20.9 ± 0.5	88.4 ± 27.8
87-TME 14(1)	19.7 ± 4.3	93.3 ± 50.3
87-Nase 10(1)	19.3 ± 0.2	118.3 ± 17.2
Nase 12-161(1)	17.5 ± 1.6	63.7 ± 6.5
Nase 12-161(8)	17.5 ± 2.7	89.5 ± 20.9
*Nase 10	16.6 ± 4.5	79.5 ± 17.0
Nase 12-161(6)	14.6 ± 2.8	61.0 ± 12.0
F value:	*3.1*	*1.0*
DF:	*14*	*14*
P:	*0.005*	*0.447*

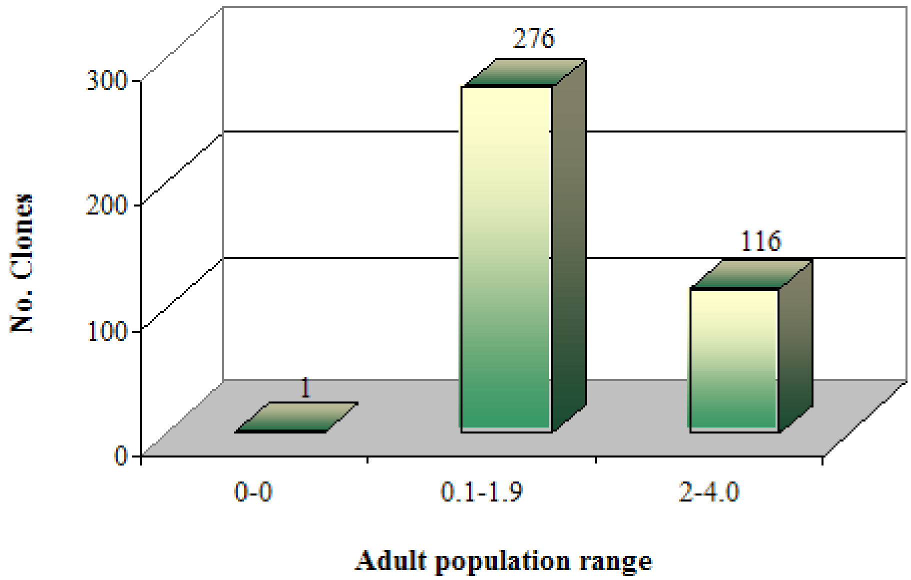
* Variety already released to farmers

Table 8. Mean numbers (± SE) of *B. tabaci* adults and nymphs/5 top leaves on CMD-resistant cassava genotypes in a uniform yield trial at Namulonge planted on 21 May 2003

Genotype	Adults	Nymphs
4235	67.9 ± 20.7	605.3 ± 170.5
0102	30.6 ± 6.3	319.0 ± 13.4
0469	29.8 ± 9.2	377.9 ±106.6
0686	29.3 ± 4.1	314.9 ± 38.7
4799	28.6 ± 1.3	276.3 ± 66.6
*Nase 10	23.9 ± 6.4	243.7 ± 79.5
*Nase 12	23.6 ± 3.8	174.0 ± 32.1
0232	23.4 ± 5.2	179.0 ± 40.3
0116	18.8 ± 1.3	189.3 ± 30.5
4271	12.9 ± 1.6	143.9 ± 38.5
F value:	*3.0*	*3.1*
DF:	*9*	*9*
P:	*0.02*	*0.01*

* Variety already released to farmers

At the time when the EARRNET trials at SAARI were evaluated, the *B. tabaci* population was relatively low and the highest mean numbers for adults and nymphs obtained were 4 and 22.5 per top 4 middle leaf lobes, respectively. This still allowed the genotypes to be grouped into three broad categories (Fig. 3) allowing 116 genotypes to be eliminated as susceptible.



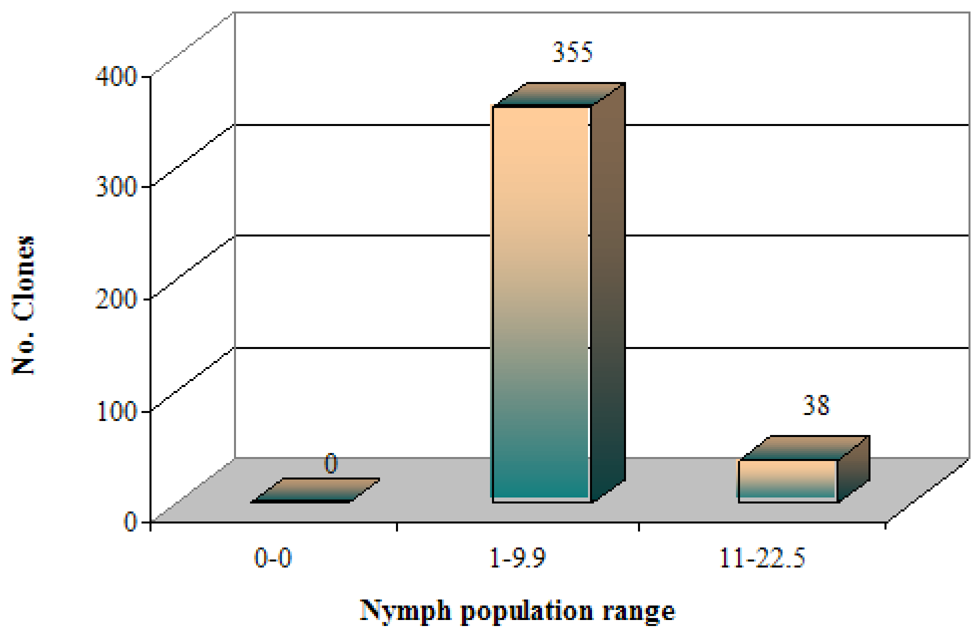


Figure 3. Numbers of adult and nymphal whiteflies on EARRNET cassava clones screened for resistance to whiteflies (*B. tabaci*)

Numbers of adult whiteflies had also been recorded on >200 Ugandan cassava landraces trialled at NAARI. Results derived from four successive records are illustrated for 21 of these landraces in Fig 4. Differential reactions of *B. tabaci* to the landraces were again evident: Mutesa, Nabwire 1 and Mercury had the fewest whiteflies and Egabu, Kagits 3 and Duma 1 the most.

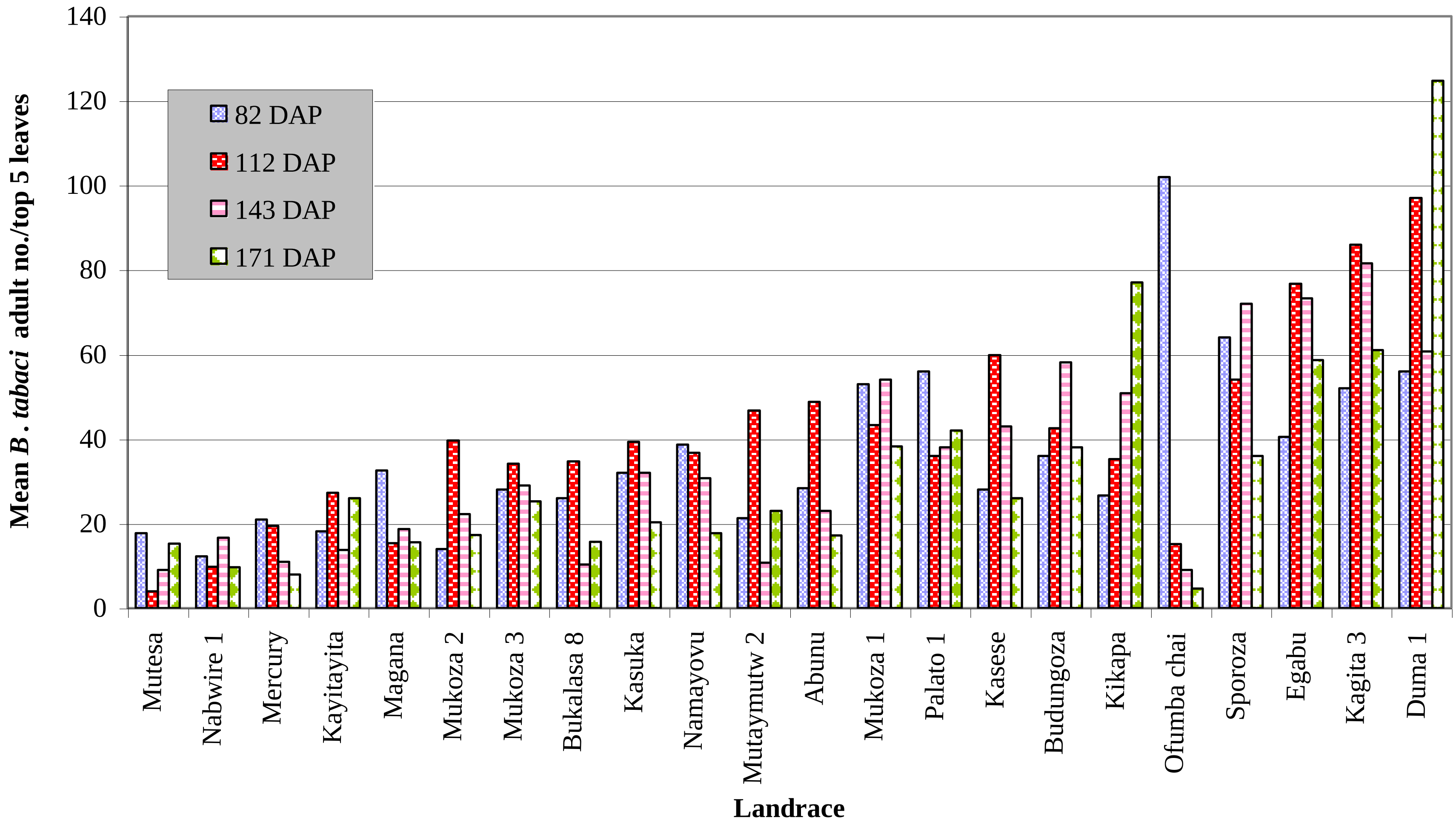


Figure 4. Mean numbers of *B. tabaci* counted on the terminal leaflet of the top 4 leaves of cassava landraces

Following on from this initial screening, a further evaluation of resistance of selected landraces was made in a screenhouse (see Activities). Counts of adults revealed numbers were greater on modern CMD-resistant cultivars (00067, Nase 3, Nase 9 & Nase 12) than on the landraces (Table 9) with fewest adults on Njule red. Although the relative abundance of whiteflies in this test does not exactly mirror those obtained in the field at SAARI (Fig. 4), the landrace Duma once again was colonised by many adult *B. tabaci*.

Table 9. Mean number of *B. tabaci* adults (± SE) on the top 5 leaves of cassava cultivars tested in the screen-house at NAARI

Cultivar	Number of adults
*00067	39.2 ± 4.4
Duma	37.4 ± 7.2
*Nase 3	37.1 ± 8.3
Bukalasa 8	32.9 ± 3.6
*Nase 9	30.8 ± 5.1
*Nase 12	30.3 ± 4.8
Aladu	27.1 ± 9.0
Magana	25.7 ± 6.9
Mutesa	23.3 ± 5.0
Mercury	21.3 ± 6.2
Egabu	21.2 ± 6.4
Senyonjo	16.4 ± 3.5
Nylon	15.9 ± 2.8
Namayovu	14.5 ± 3.0
Ebwanatereka	12.9 ± 2.9
Njule White	12.7 ± 2.9
Bao	11.4 ± 2.6
Soya	11.3 ± 2.4
Njule Red	5.4 ± 1.7
F value:	4.1
DF:	18
P:	< 0.001

* CMD resistant cultivars

The total number of *B. tabaci* eggs and nymphs on cassava leaves was another criterion used to assess whitefly susceptibility. Once again, most of the CMD resistant cultivars had most eggs and nymphs (> 900 /top 5 leaves) (Table 10) confirming their attractiveness and indicating their particular suitability for oviposition to *B. tabaci*. This should make them more prone to physical damage due to feeding by the nymphs. In contrast, the relatively low numbers of eggs and nymphs (< 500/top 5 leaves) on Njule red, Bao, Tereka and Soya indicated that these cultivars are less preferred for oviposition and damage on them is likely to be less.

Table 10. Mean number of eggs and nymphs of B. tabaci (± SE) on the top five leaves of 37-day old cassava cultivars planted in the screen-house at NAARI

Cultivar	Mean eggs + nymphs
*00067	1393.8 ± 160.6
Aladu	1308.8 ± 382.8
*Nase 9	1176.0 ± 234.2
Duma	1161.6 ± 201.0
Egabu	971.0 ± 187.7
*Nase 3	912.2 ± 229.3
Namayovu	795.8 ± 341.0
Mercury	746.1 ± 185.3
Mutesa	632.1 ± 73.3
Magana	624.6 ± 158.2
Nylon	581.0 ± 99.4
Bukalasa 8	575.7 ± 87.9
Senyonjo	563.1 ± 35.0
*Nase 12	550.4 ± 75.8
Njule White	535.2 ± 110.4
Soya	457.4 ± 86.6
Tereka	436.2 ± 107.2
Bao	431.4 ± 103.9
Njule Red	228.6 ± 98.0
F value:	3.1
DF:	18
P:	< 0.001

* CMD resistant cultivars

Feeding by whitefly adults and nymphs induces a characteristic yellow-to-green mottled appearance and twisting or curling, particularly on apical leaves (Plate 2). This leads to defoliation in extreme cases. Honeydew that is frequently excreted by adults and nymphs also allows the development of sooty moulds on the upper surfaces of lower leaves. Cassava fields that are heavily infested usually appear unsightly with drooping leaves covered by sooty moulds. The landraces and improved CMD resistant cultivars that had been planted in a NAARI screenhouse in September 2004 were exposed to several generations of *B. tabaci* which increased to several thousand adults/top 5 leaves and levels of physical damage due to feeding and severity of sooty moulds on the plants were scored. All the CMD resistant cultivars had very high damage and high sooty mould scores (Table 11) and Njule red, Njule white and Senyonjo were among the best performing landraces (Plate 3).

Plate 2. Young CMD resistant cassava plant with curled leaves caused by heavy feeding by *B. tabaci.* On the lower leaves is black sooty mould beginning to develop.

Table 11. Mean physical damage and sooty mould scores at 83 days after planting cassava cultivars in the screen-house at NAARI

Cultivar	Mean damage score (scale 1-5)/cultivar	Mean sooty mould severity (scale 1-5)/cultivar
Duma	4.2	5.0
*00067	3.8	4.8
*Nase 3	3.9	4.7
Egabu	4.0	4.6
*Nase 12	4.2	4.6
Nylon	3.8	4.4
*Nase 9	3.5	4.4
Magana	3.8	4.3
Namayovu	3.6	4.3
Bukalasa 8	3.6	4.2
Aladu	3.4	3.9
Bao	3.0	3.9
Soya	3.3	3.8
Tereka	3.3	3.6
Mutesa	3.1	3.4
Mercury	3.3	3.3
Senyonjo	2.9	3.3
Njule White	2.4	3.0
Njule Red	2.1	2.6
F value:	21.4	12.9
DF:	18	18
P:	< 0.001	< 0.001

* CMD resistant cultivars

Plate 3. Physical damage symptoms due to feeding by *B. tabaci* adults and nymphs on landraces Aladu and Njule red planted in the screenhouse at NAARI.

Outputs 2, 3 & 4. Developing, validating and promoting training messages and materials on the control of CMD in Uganda and Tanzania

Outputs based in Uganda

Further details of these outputs are available in the following reports:

- **T. Alicai, A. Bua, J. Amenet, C.A. Omongo, A. Apok, B. Adolph, Y. Baguma, R. Kawuki and R.W. Gibson** (2005). Farmer participatory evaluation of variety mixtures for the control of cassava mosaic disease in Mukono and Apac districts in Uganda
- **T. Alicai, B. Adolph, D. Akullo, C.A. Omongo, Y. Baguma, A. Bua, R. Kawuki and R.W. Gibson** (2005). Training of extension workers and farmers and production of training and dissemination materials on cassava mosaic disease.

Testing the use of CMD-resistant variety mixtures to protect CMD-susceptible landraces: The trial in Mukono has been concluded and data analysed. The trial in Apac was started one year late to replace the trial planted a year earlier in Lira abandoned because of insecurity in the area. Consequently, only initial data for this are presented.

The pure stand of TMS I 92/0067 remained virtually free of CMD (<1% incidence) and reached only 2% when planted with Njule. CMD incidence in the plots of the other CMD-resistant varieties (TME 14, TME 204 and Nase 10) planted also remained at negligible incidences. Overall, all mixtures gave reduced incidence of CMD. In Mukono, planting local varieties mixed with the CMD-resistant variety TMS I 92/0067 significantly reduced CMD incidence in the local varieties (P<0.001). From 3 MAP up to maturity, CMD incidences in the landraces Njule and Kabwa planted in mixtures with TMS I 92/0067 were at least 20% less than incidences of the same landraces planted singly (Table 12). Among the local varieties, CMD incidence was greater in Njule compared to Kabwa in both their pure and mixed stands. In Apac, a similar lower incidence of CMD in the local varieties when mixed with TMS 1 92/0067 is also apparent 3 MAP (Table 13). The almost total infection of landraces evident at both locations when planted as a monocrop reflects the vulnerability of landraces. Planting them in mixtures with resistant varieties was beneficial since it minimises spread of CMD. However, in terms of effective control of CMD, the CMD-resistant TMS 1 92/0067 was even better. This is highlighted in the results already available from the Apac trials where the incidences in landraces have already exceeded 50% (Table 13). The trials also identified that CMD severity was slightly less for the landraces planted as mixtures than when planted as a pure stand, perhaps because most infections were single infections of $EACMV_{UG}$ (data not shown). There were no significant differences in whitefly numbers between landraces grown in mixtures and grown as a single variety, suggesting that the main effect of the mixtures was in reducing the number of viruliferous whiteflies rather than by reducing overall numbers of whiteflies.

Table 12. Mean incidence (%) of cassava mosaic disease in pure and mixed stands of three cassava varieties in Mukono district

	Mean CMD incidence (%)			
Treatment	1 MAP	3 MAP	6 MAP	9 MAP
Njule (sole)	0.0	50.4	84.1	95.7
Kabwa (sole)	0.0	52.1	59.5	67.9
TMS I 92/0067 (sole)	0.0	0.4	0.4	0.4
Njule in mixture 1 (Njule:*TMS I 92/0067*)	0.0	21.9	48.6	73.0
TMS I 92/0067 in mixture 1	0.0	0.5	2.3	2.3
Kabwa in mixture 2 (Kabwa:*TMS I 92/0067*)	0.0	29.0	38.1	44.7
TMS I 92/0067 in mixture 2	0.0	1.3	0.4	0.4

$LSD_{.05}$ Treatment: 9.7
Age of crop: 6.4
Treatment x Age: 19.3

P Treatment: <0.001
Age of crop: <0.001
Treatment x Age: <0.001

Table 13. Mean incidence (%) of cassava mosaic disease in pure and mixed stands of three cassava varieties planted in Apac district

	Mean CMD incidence (%)	
Treatment	1 MAP	3 MAP
Bao (sole)	0.0	72.5
Nyaraboke (sole)	0.0	82.7
TMS I 92/0067 (sole)	0.0	0.4
Bao in mixture 1 (Bao:*TMS I 92/0067*)	0.0	56.8
TMS I 92/0067 in mixture 1	0.0	7.3
Nyaraboke in mixture 2 (Nyaraboke:*TMS I 92/0067*)	0.0	57.8
TMS I 92/0067 in mixture 2	0.0	2.0

$LSD_{.05}$ Treatment: 10.9
Age of crop: 5.4
Treatment x Age: 15.4

P Treatment: <0.001
Age of crop: <0.001
Treatment x Age: <0.001

There was no clear effect of mixture on yield of cassava. Although the mean yield (t/ha) for Kabwa planted in the mixture was greater than yield from the sole plot, the benefit from both mixtures was generally not significant (Table 14). The effect of mixture was slightly negative on the yield of Njule, but there was a positive and significant effect on the TMS I 92/0067 component of the mixture ($P<0.001$). This may be attributed to compensation for the yield reduction of CMD-affected plants of Njule by the TMS I 92/0067 component that largely remained CMD-free. The overall lack of yield improvement in the mixtures can also be attributed to the slow build up of disease and the generally moderate disease severities.

Table 14. Yield response of variety mixtures of two landraces and one CMD-resistant variety with their component and other CMD-resistant varieties in pure stands planted in Mukono district

	Yield of cassava	
Treatment	Tubers per plant	t/ha
Njule (sole)	4.7	17.9
Kabwa (sole)	4.2	20.5
Njule in mixture 1 (Njule:*TMS I 92/0067*)	6.5	15.5
TMS I 92/0067 in mixture 1	5.1	45.1
Kabwa in mixture 2 (Kabwa:*TMS I 92/0067*)	3.3	21.7
TMS I 92/0067 in mixture 2	4.7	30.9
TMS I 92/0067 (sole)	2.0	28.8
TME 14 (sole)	7.3	19.8
TME 204 (sole)	7.2	23.0
Nase 10 (sole)	6.6	24.8
$LSD_{.05}$	1.1	7.8
P	<0.001	<0.001

From the interaction with researchers and their own trial records, farmers learnt that that planting landraces in mixtures with CMD-resistant varieties had advantages. In general, farmers observed that variety mixtures resulted in low levels of CMD incidence in the landraces relative to the means of the sole crops of landraces and infection of plants was also delayed in mixtures, giving the likelihood of relatively higher yields of cassava. In Mukono district where the average landholding is small (<1 ha), a key benefit of growing mixtures recognised by farmers was suitability for farmers with small pieces of land. It permits a diversity of varieties to be grown on the same piece of land, allowing for different preferences and saving on labour.

Despite such advantages, farmers experienced some limitations in the use of mixtures. The main disadvantage was the complexity of planting and harvesting. This was a big problem in Apac where families commonly own large expanses of land and usually plant large acreages of single varieties. Here, the farmers stated that they would prefer smaller separate blocks of different CMD-resistant varieties rather than planting two or more varieties as a mixture in the same field. Similarly at harvest time, the common practice in Apac is to harvest large areas of cassava fields for bulk sale of fresh tuberous roots or for processing into sun-dried chips. Harvesting mixtures presents such practical problems as the need for careful sorting. However this ceases to be a problem if indiscriminate harvesting from mixtures does not adversely consumers' quality requirements. Similarly, farmers in Mukono district pointed out that varying times taken by the component varieties to mature complicates piece-meal harvesting which is the usual practice in the area. Other problems mentioned about mixtures include difficulty in identifying component varieties and constraints on operations such as weeding associated with differences in growth characteristics of the components.

Many farmers in Mukono district regarded mixtures as a good practice both as a means of controlling CMD and increasing productivity in an intensive system. The mixture of Kabwa and TMS I 92/0067 and the pure stand of the CMD-resistant variety TME 204 were the most preferred. In Apac, farmers generally preferred planting varieties in pure stands, which is the traditional way of planting cassava in northern and eastern Uganda. Bao and TME 14 planted in pure stands were the most popular.

Table 15. Attributes of cassava variety mixtures and pure stands identified by farmers

District	Attributes identified by farmers			
	Mixtures	**% farmers**	**Pure stands**	**% farmers**
Mukono	Positive			
	Low CMD incidence in landraces compared with pure stands	30.7	Resistant varieties free of CMD	81.0
	Delayed infection and slow rate of infection of plants of landraces	18.4	Intercropping is easy	19.0
	An intensive system suitable for farmers with small land holdings	14.9		
	Diversity of varieties grown with different tastes	10.3		
	Vigorous growth of components due to low disease levels	6.5		
	Generally greater yields than pure stands	9.2		
	Labour-saving in terms of land area to be prepared and weeded	4.9		
	High sprouting percentage of component varieties	5.1		
	Negative			
	Piece-meal harvesting difficult due to different maturity periods	53.6	Most plants of landraces CMD-affected	76.6
	TMS I 92/0067 partially overshadowed the landraces	46.4	Low yields due to CMD	23.4
Apac	Positive			
	Low CMD incidence in landraces compared with pure stands	40.8	Extensive harvesting is simple compared to mixtures	82.0
	Delayed infection and slow rate of infection of plants of landraces	30.3		
	Vigorous growth of components due to low disease levels	18.0	Identification of varieties is easy	18.0
	High sprouting percentage of component varieties	10.9		
	Negative			
	Planting is complex	26.5	Fields of landraces can get totally infected	*58.8*
	Weeding is difficult because of differences in growth of components	25.7		
	Difficulty in harvesting due to different maturity times of component varieties	23.0	Spread of CMD among landraces is fast	41.2
	Piece-meal harvesting difficult due to different maturity periods	12.8		
	Distinguishing component varieties may be difficult	12.0		

Table 16. Farmers' preferences of cassava variety mixtures and pure stands

District	Treatments and component varieties[1]	Number of farmers who favoured treatment
Mukono	Mixtures	
	1:1 (Njule + *TMS I 92/0067*)	12
	1:1 (Kabwa + *TMS I 92/0067*)	*15*
	Monocultures	
	Njule	7
	Kabwa	10
	TMS I 92/0067	14
	TME 14	12
	TME 204	15
	Nase 10	9
Apac	Mixtures	
	1:1 (Bao + *TMS I 92/0067*)	5
	1:1 (Awulo awulo + *TMS I 92/0067*)	7
	Monocultures	
	Bao	27
	Awulo awulo	23
	TMS I 92/0067	12
	TME 14	26
	TME 204	20
	Nase 10	13

[1]CMD-resistant varieties are indicated in italics. Only TMS I 92/0067 was used in mixtures with landraces, two in each district

Training and developing training materials: The first training event was organised for farmers belonging to Kalagala Organic Farmers' Group in Goma sub-county, Mukono district in April 2004. The training was held at a community centre within the village and was conducted by researchers from NCP. Two extension workers from Apac district also attended the training and were expected to transfer the knowledge to the farmers' group in Apac that had been selected to participate in the project. A total of 18 farmers (12 women and 6 men) were trained (Table 17). A further training event was held at Mukono Agricultural Research and Development Centre (ARDC) in May 2004 for extension workers from the Department of Agriculture of Mukono district local government, sub-county National Agricultural Advisory Services (NAADS) extension workers and researchers from Mukono ARDC responsible for dissemination. A total of 20 people were trained, 8 women and 12 men (Table 17).

Table 17. Categories and numbers of extension workers and farmers trained in Mukono district

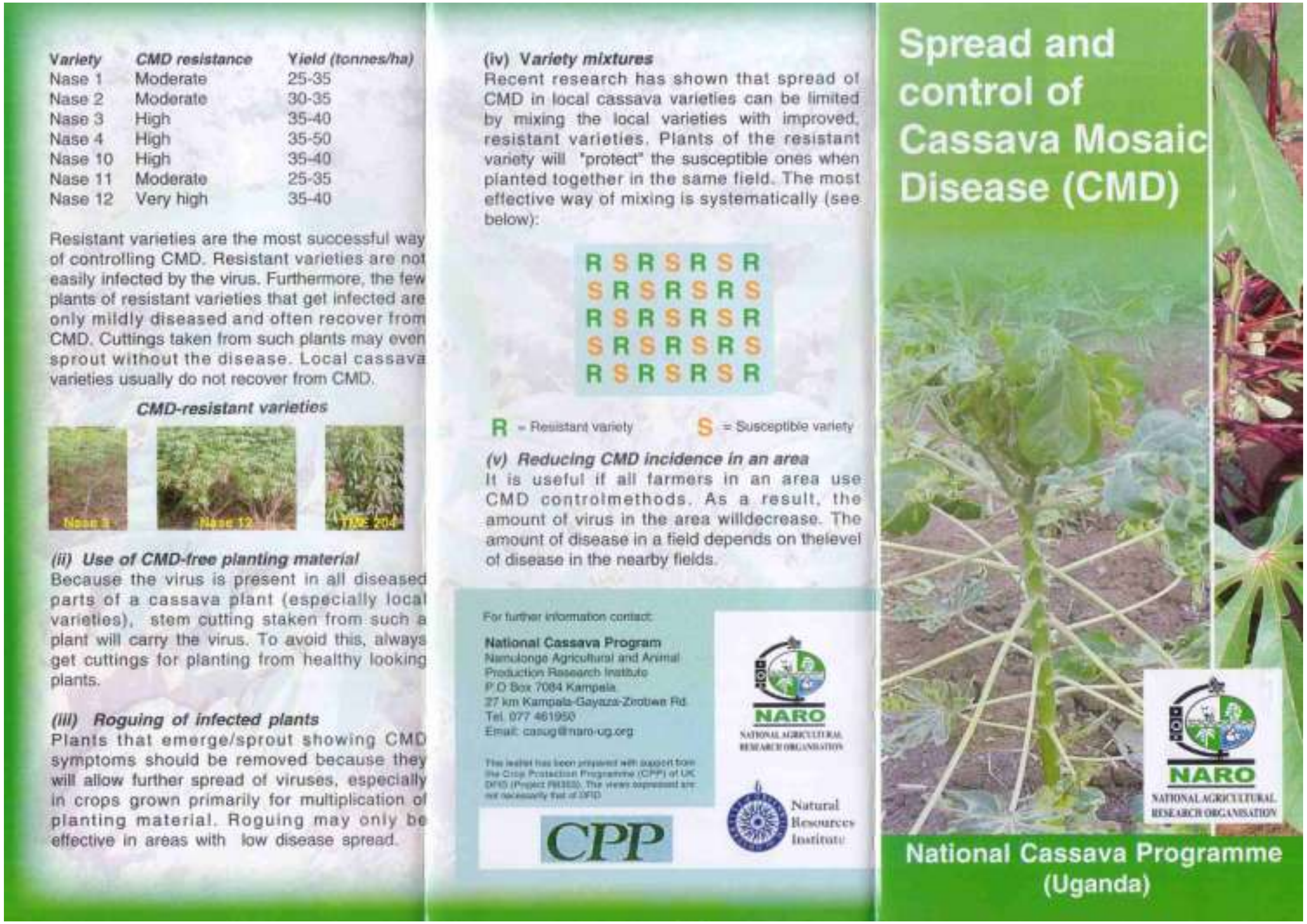
Type of training	**Categories of people trained**	**No. of participants**	
		Male	**Female**
Village level training	Farmers	**6**	**12**
District level training	Agricultural Officer	5	2
	Assistant Agricultural Officer	2	3
	Assistant Agricultural Officer (NAADS)	1	1
	Technicians (ARDC)	3	1
	Research Officer (ARDC)	1	1
	Total	**12**	**8**
OVERALL TOTAL		**18**	**20**

The leaflets were revised and finalized based on the suggestions and comments during pre-testing. A total of 10,000 leaflets were printed in four languages; English (4000) (Fig. 5), Luganda (2250), Luo (2250) and Swahili (1500) (Table 18) (Fig. 6). The leaflets will be distributed to farmers and extension workers both directly by NCP and through channels including Departments of Agriculture at districts and partner agencies such as NGOs, NAADS and ARDCs. Feedback about the performance of the leaflets will be obtained through the same channels. The training guide has not been printed because it still has to undergo further testing with staff of ARDCs and extension workers of districts and NAADS. Once this is completed and corrections are made, the material will be printed and disseminated.

Table 18. Summary information on dissemination materials produced

Title of material	Objective	Message	Target group
Spread and control of cassava mosaic disease (CMD) – Leaflet in English Luganda, Luo and Swahili	Control of CMD	Use resistant and high yielding varieties for effective control of CMD. Other practices such as selection of stem cuttings for planting from CMD-free plants, roguing and planting mixtures of susceptible and resistant varieties also offer some control.	Farmers in all cassava growing areas of Uganda
Control of cassava mosaic disease – a technical training guide	Effective training of farmers on control of cassava mosaic disease	Clear information on common symptoms of CMD, how CMD spreads and how it can be controlled	Extension workers of NGOs, NAADS, staff at ARDCs and district departments of agriculture

Figure 5. The two opposing pages of the English version of the CMD advisory brochure



Variety	*CMD resistance*	*Yield (tonnes/ha)*
Nase 1	Moderate	25-35
Nase 2	Moderate	30-35
Nase 3	High	35-40
Nase 4	High	35-50
Nase 10	High	35-40
Nase 11	Moderate	25-35
Nase 12	Very high	35-40

Resistant varieties are the most successful way of controlling CMD. Resistant varieties are not easily infected by the virus. Furthermore, the few plants of resistant varieties that get infected are only mildly diseased and often recover from CMD. Cuttings taken from such plants may even sprout without the disease. Local cassava varieties usually do not recover from CMD.

CMD-resistant varieties

Nase 3 Nase 12 TME 204

(ii) Use of CMD-free planting material
Because the virus is present in all diseased parts of a cassava plant (especially local varieties), stem cutting staken from such a plant will carry the virus. To avoid this, always get cuttings for planting from healthy looking plants.

(iii) Roguing of infected plants
Plants that emerge/sprout showing CMD symptoms should be removed because they will allow further spread of viruses, especially in crops grown primarily for multiplication of planting material. Roguing may only be effective in areas with low disease spread.

(iv) Variety mixtures
Recent research has shown that spread of CMD in local cassava varieties can be limited by mixing the local varieties with improved, resistant varieties. Plants of the resistant variety will "protect" the susceptible ones when planted together in the same field. The most effective way of mixing is systematically (see below):

R S R S R S R
S R S R S R S
R S R S R S R
S R S R S R S
R S R S R S R

R = Resistant variety S = Susceptible variety

(v) Reducing CMD incidence in an area
It is useful if all farmers in an area use CMD controlmethods. As a result, the amount of virus in the area willdecrease. The amount of disease in a field depends on thelevel of disease in the nearby fields.

For further information contact:

National Cassava Program
Namulonge Agricultural and Animal Production Research Institute
P.O Box 7084 Kampala
27 km Kampala-Gayaza-Zirobwe Rd
Tel. 077 461950
Email: casug@naro-ug.org

This leaflet has been prepared with support from the Crop Protection Programme (CPP) of UK DFID (Project [illegible]). The views expressed are not necessarily that of DFID.

CPP

NARO
NATIONAL AGRICULTURAL RESEARCH ORGANISATION

Natural Resources Institute

Spread and control of Cassava Mosaic Disease (CMD)

NARO
NATIONAL AGRICULTURAL RESEARCH ORGANISATION

National Cassava Programme (Uganda)

Figure 5 continued

Introduction

Cassava mosaic disease (CMD) is caused by a virus, just like HIV/AIDS. The virus only survives inside a living organism. It damages the leaves resulting in low yield. This leaflet explains how to recognise a plant affected by CMD, how the virus infects a cassava plant and how the diseasecan be controlled.

Common symptoms of CMD

Cassava plants affected by CMD look different from healthy plants:

- The leaves become partly yellow, fail to expand and maycurl to one side.
- The growth of the plant is slower than that of a healthy plant. Diseased plants often remain stunted.
- Most importantly, the root yield of CMD-affected plants is low, especially if the plants are infected at an early stage (within the first three months).

A CMD affected plant will remain short and produce smalland few tubers.

Transmission and spread of CMD

(i) Whitefly infection

The virus causing CMD is carried by small white insects called whiteflies, just like malaria is carried by mosquitoes. The whiteflies are usually found on the bottom side of cassava leaves. They feed on the sap in the leaves, just like mosquitoes feed on blood. The virus lives in the sap of the plant. So, when a whitefly feeds on an infected plant, the virus is carried along with the sap into its body.

Adult whiteflies feeding on the bottom surface of a cassava leaf

If the same whitefly feeds on a healthy plant, its saliva mixes with the plant sap and the virus is transmitted to the healthy plant. A plant infected through whiteflies will usually show symptoms after 3-4 weeks. In such a plant,only upper leaves initially show symptoms and the lower leaves do not have symptoms.

(ii) Cutting infection

CMD is also spread/perpetuated when cuttings are taken from a diseased plant. Cuttings then sprout with the disease.

Cuttings may also sprout with disease even if only a part of the parent plant was diseased or if the parent plant was only recently infected and not yet showing symptoms.

Whitefly infection: *Only upper leaves show CMD symptoms, lower leaves are symptomless*

Cutting infection: *Leaves formed soon afteremergence, as well as other leaves formed later have symptoms*

Methods of controlling CMD

(i) Planting resistant varieties

The National Cassava Programme of NARO has developed and released high yielding CMD resistant cassava varieties. They perform well even when the disease pressure is high. Some of the commonly grown varieties are listed below.

Figure 6. The Swahili, Luganda and Luo versions of the CMD advisory brochure

Swahili Luganda Luo

Activities based in Tanzania

Further details can be found in the following reports:

- **GM Rwegesira & EF Marandu.** Monitoring visit to NPA initiated activities in collaboration with MARDI, 2004.
- **R Gibson & B Adolph.** Report on a project visit (A1076 (SPVD) & A1105 (CMD)) to Kagera Region, Tanzania, 8-13 November 2004.
- **G. M. Rwegasira & E. F. Marandu**. Final monitoring report to NPA activities. 2005.
- **G. M. Rwegasira, E. F. Marandu & C. V. Mwita.** General evaluation of NPA work and support to MARDI. 2005.
- **S. C. Jeremiah, E. Marandu & G. Rwegesira.** Annual report on CMD pandemic and CGM in the Lkae Zone of Tanzania in 2003/04 seasons.
- **G. M. Rwegesira & E. F. Marandu**. 3rd Monitoring of NPA activities with partners.
- **G. M. Rwegesira, E. F. Marandu & R. W. Gibson.** Maximizing, disseminating and promoting the benefits to farmers of cassava varieties resistant to cassava mosaic disease in the Lake Zone of Tanzania in 2004.
- **B. Adolph, I. Ndyetabura, G Rwegesira & E. Marandu**. Multiplying and distributing CMD resistant cassava varieties in north-western Tanzania – experiences from Ngara and Muleba Districts of Kagera Region.

Training was provided to the four group facilitators at ARI-Maruku and the following training curriculum (Table 19) for the farmer groups was developed based on the crop cycle. One of the failings of this initial curriculum was that it could be based only on researchers' and extensionists' experiences and farmers' experiences needed to be incorporated.

Table 19. Cassava FFS training curriculum

When	Activity	Topic	Objectives	Tools & materials	Who*
4WBP	Site selection	Criteria for site selection	Identify suitable land for the respective crop	Leaflets, handout and group discussion	F, GM & R
3WBP	Land preparation	Land preparation techniques	To have suitable tilth of the land	Bush knives, hoes	F & GM
2WBP	Field layout	Fitting the field size with the intended crop	To have field that satisfy the intended objectives of the trial	Pegs, tape measure, sisal twine, manilla sheet, leaflets, marker pen, notebooks, pencil	F, GM & R
1WBP	*Ridge making	This will depend on the requirements of the crop and what farmers want to try (not a must)		FYM, compost, weeds or none	F & GM
0WBP	Selection of planting materials	How to select & why	Obtain healthy planting materials of good varieties	Knives, sisal/ropes, samples for healthy/diseased plants	F, GM & R
0WAP	Planting • Production • Multiplication	Spacing, planting techniques, agronomic yield	End up with appropriate plant population for high yield, planting materials or both	Planting materials, tape measure, notebooks, knives, labels, sisal twine etc.	F, GM & R
4WAP	Sprouting data	The ability of planted cuttings to sprout	To identify the sprouted cuttings Plan for gap filling	Note books, pen/pencils, counter	F & GM
5WAP	AESA**	Introduction to AESA	How farmers do/examine things for themselves How to keep record	Field tools, marker pens, pencils, label, notebooks etc	F & GM
6WAP	1st AESA	How to undertake the 1st AESA	Assess the performance of crops and environment	Field tools, marker pens, pencils, label, notebooks etc	F & GM
8WAP	2nd AESA	Crop vigour, first weed	Assess how the crop copes with existing environment	Vigour scale, marker pens, pencils, label, notebooks etc	F & GM
10WAP	3rd AESA	Crop response to weed competition	Assess how the planted crop are competing with weeds How competitive is weed	Weed samples, field weed guide, marker pens, pencils, label, notebooks etc	F, GM & R
12WAP	4th AESA	Crop response to diseases	What diseases affect the crop What part of the crop is affected	Diseased plant samples, field guide for cassava diseases, pencils, label, notebooks etc	F, GM & R
15WAP	5th AESA	Crop response to insect & vertebrate pests and weeds	Identify and determine important crop pests Assess need for second weeding	Field guide for cassava diseases, marker pens, pencils, label, notebooks etc	F, GM & R
24WAP	6th AESA	Crop response to drought & related insect and diseases	Determine crop response to drought Identify drought related pests and diseases	Field guide for physiological response of cassava to abiotic stress, marker pens, pencils, label, notebooks etc	F & GM
36-40WAP	7thAESA	Crop maturity & preparation for harvesting	Determine crop maturity Assess yield/planting materials expectations	Counter, tape measure, marker pens, pencils, label, notebooks etc	F & GM
48WAP	Marketing	Identification of markets.	Identify the markets. Determine products with good price Assess needs for processing	Market, means of transport, pen, notebooks, products recipes guide, etc	F, GM & R
52WAP	Harvesting	Different methods of harvesting	How piecemeal/whole plant harvesting is done Final evaluation of crop based on the yield	Mature crop, hoes, knives, pen, notebooks, data sheets, colour charts, etc	F, GM & R

* F = Facilitator; GM = Group members, R = Researchers; **Agro-ecology systems analysis

During the first season, Msitu Zanzibar, Rushula, Konyu, Bukarasa and Kaitampunu nyeupe (Sengerema) all succumbed to CMD and the phytosanitation trials were abandoned. They/we learnt that phytosanitation practice is not possible to practice with susceptible varieties where the disease pressure is high and resistant varieties are the only solution in managing CMD during the pandemic. The rest of the varieties tested had adequate resistance to CMD and were re-planted (Table 20) in the field managed by each group on the basis that the material obtained from the multiplication field will be divided amongst group members for further multiplication cycle.

Table 20. Varieties selected for further multiplication

Variety	Kanazi	Kyema	Kyaka	Ngenge
MM96/ 4446	√	√	√	√
MM96/ 4619	√	√	√	√
MM96/ 8233	√	√	√	√
MM96/ 3075B	√	√	√	√
MM96/ 8450	√	√	√	√
MM96/ 4684	√	√	√	√
MM96/ 5725	√	√	√	√
MM96/ 5373	√	√	X	X
TMS 4(2)1425	√	√	√	√
I 91/ 00063	√	√	√	√
Msitu Zanzibar	X	X	X	X
Lwakitangaza	X	X	√	√
Local	√	X	X	X

Symbols: √ = to be multiplied; X= Not to be multiplied

Table 21. The response of the planted cassava varieties to CMD, CGM and CBB

Variety	Average incidences (%) over the growing season											
	Kanazi			Kyema			Kyaka			Ngenge		
	CMD	CGM	CBB	CMD	CGM	CBB	CMD	CGM	CBB	CMD	CGM	CBB
MM96/ 4446	0	28	18	0	75	9	0.3	77	14	0	30	31
MM96/ 4619	0	25	18	0	75	16	1.6	8	0	0	85	37
MM96/ 8233	0	15	12	3	66	24	0.6	48	0	0	86	61
MM96/ 3075B	0	37	44	0	96	31	0	11	0	0	43	18
MM96/ 8450	0	19	20	0	86	32	0	28	0	0	86	56
MM96/ 4684	0	16	52	0	75	33	0	66	0	0	63	50
MM96/ 5725	0	3	6	0	88	60	0	92	0	0	25	71
MM96/ 5373	0	23	50	5	88	47	64	35	0	13	19	60
TMS 4(2)1425	3	26	50	3	84	33	68	90	0	37	55	22
I 91/ 00063	0	9	30	0	12	18	0	91	3	0	44	33
Msitu Zanzibar	20	62	4	29	76	22	84	78	0	100	100	0
Local	33	21	9	84	54	0	100	0	0	100	91	8

The introduced varieties sprouted and established adequately. The introduced varieties apart from Msitu Zanzibar also confirmed their resistance to CMD throughout their growing period whereas all local varieties again succumbed (Table 21). Cassava green mites (CGM) affected all the varieties during the dry season although damage appeared to vary with respect to the variety and the environment. In sites dominated by drought, such as Kyaka and Ngenge, CGM incidences and severity were high compared to wetter sites like Kanazi and Kyema. However, Kanazi and Kyema had particularly high incidences of CBB during the rainy season, three to six months after planting.

Farmers evaluated cassava varieties groups going through plots of each variety and asking farmers to comment on any aspect that was visualised to be important on the respective variety. Positive and negative comments are summarised in Table 22. Most of the introduced varieties were judged to have performed well against CMD with exception of TMS 4(2)1425, MM96/ 5373 and Msitu Zanzibar. The suitability of a variety for planting materials was based on short internode length and high branching height which allow many cuttings to be taken from a stem. The suitability for intercropping depended on an upright canopy that allows more light to enter and easy growth of the intra-row crop (needed early in crop establishment) while the good canopy cover was achieved by multiple branching and suppresses weeds. Good as vegetable implied there were a lot of young tender leaves that can be harvested as a vegetable.

Table 22. Assessment by participating farmers on varieties characteristics

Variety	Characteristics as per response from participants							
	Good planting material	CMD resistant	Good for intercropping	Good as vegetable	Tolerant of drought	Good canopy cover	Susceptible to	
							CGM	CBB
MM96/ 4446	2, 3, 4	1, 2, 3, 4	1, 4		2	3		
MM96/ 4619		1, 2, 3, 4	1, 3, 4		3, 4		2	
MM96/ 8233	1, 2, 3,4	1, 2, 3, 4		1, 4	2,3, 4	2,3,4		1
MM96/ 3075B	1,3, 4	1, 2, 3, 4		3	1, 3	3	2, 4	1
MM96/ 8450	1, 2, 4	1, 2, 3, 4	2, 4				2, 4	1
MM96/ 4684	1,3,4	1, 2, 3, 4		3, 4		3		1
MM96/ 5725	1, 2, 3, 4	1, 2, 3, 4	2,3	1, 4	1, 4			
MM96/ 5373	3	1, 2	4	4	4		2	1, 2
TMS 4(2)1425	1, 3, 4	1		3, 4	3,4	3, 4	2	2
I 91/ 00063	1, 2,3, 4	1, 2, 3, 4		2, 3, 4	1, 3	3	4	2
MSITU ZANZIBAR	1, 2, 3			2	1, 3	1, 2, 3	1, 3	
LOCAL	1,3, 4			1, 4	1, 4	1	1	

Key to number used in Table 6: 1=Kanazi, 2= Kyema, 3= Kyaka, 4= Ngenge

Farmers also evaluated raw roots for eating qualities, extrapolating to the taste of the cooked ones. Female and males evaluated separately. Unfortunately, the bitter varieties like Sengerema (local) could not be tasted. A worrying result was that for many of the introduced varieties the outcome appeared unstable suggesting their qualities varied greatly with sites.

Table 23. General root quality evaluation (1 = bad; 5 = excellent) by female participants

Variety	Appearance	Taste	Flavour	Starchiness	Lack of fibre	General evaluation
MM96/ 4446	3.0	3.0	3.0	3.5	4.5	4.5
MM96/ 4619	4.0	4.0	4.5	3.5	4.0	4.0
MM96/ 8233	3.5	4.0	3.5	4.5	5.0	4.0
MM96/ 3075B	4.0	2.5	3.0	3.0	4.0	3.0
MM96/ 8450	4.5	4.5	4.5	4.0	4.5	4.5
MM96/ 4684	5.0	4.0	3.5	4.5	4.5	4.5
MM96/ 5725	4.0	3.0	3.5	4.0	3.5	4.0
MM96/ 5373	4.5	3.0	3.5	2.5	4.0	4.0
TMS 4(2)1425	4.0	2.5	2.5	2.0	4.0	3.0
I 91/ 00063	5.0	4.0	2.5	2.5	3.0	3.5
Msitu Zanzibar	2.5	3.5	3.0	3.5	4.0	2.5
Local	4.0	3.0	3.0	3.5	2.5	4.5

The local variety was rated highly overall by both men and women (Tables 23 & 24). However, several of the introduced varieties were given quite high scores suggesting they are likely to be adopted given the impact of the pandemic on yield of the locals. However, both men and women gave relatively low scores to Msitu Zanzibar. This was also the only variety tested for which roguing had any real relevance (local varieties were too susceptible to CMD for it to work whereas the other introduced varieties were all so resistant that roguing was unnecessary) and that Msitu Zanzibar did not have a particularly good taste may have been a further reason why farmers rejected continuing with the phytosanitation trials.

Table 24. General root quality evaluation by male participants

Variety	Appearance	Taste	Flavour	Starchiness	Lack of fibre	General evaluation
MM96/ 4446	3.5	3.25	3.75	3.75	4.0	4.0
MM96/ 4619	4.25	4.0	4.25	3.5	4.5	4.25
MM96/ 8233	2.75	3.0	3.75	2.25	3.0	3.0
MM96/ 3075B	4.5	4.25	4.75	4.0	4.25	4.75
MM96/ 8450	3.5	4.0	4.0	4.25	4.25	3.75
MM96/ 4684	3.75	3.5	4.5	4.5	4.75	4.75
MM96/ 5725	3.75	3.0	3.0	4.5	3.5	3.75
MM96/ 5373	3.5	2.5	2.5	3.25	4.0	3.75
TMS 4(2)1425	4.0	3.5	3.75	4.0	4.5	4.0
I 91/ 00063	4.5	3.75	3.75	3.75	4.0	4.0
Msitu Zanzibar	2.33	4.0	3.66	4.0	4.33	3.0
Local	4.2	4.25	4.0	4.5	5.0	4.5

Additional successes of the trials were the following:

- At the end of the first season, farmer at Kyaka managed to sell 20,000 cuttings of CMD resistant cassava planting material worthy 400,000Tsh, to Action Aid in Kigoma. The rest of the cuttings were planted for multiplication and they have initiated a loan scheme under which each member can borrow some money, do petty business and repay with interest. They also managed to open a bank account with one of the local banks.
- At Kanazi, farmers sold a portion of the planting material and the harvested storage roots to add to their bank reserve. They opened a small shop (kiosk) where they sell various items to the rest of the community.
- At Ngenge, farmers decided to maintain all the materials in a collective farmer and are seeking to register as certified seed multipliers of CMD resistant cassava planting materials.

Farmers in all groups stated that they valued highly the additional knowledge they had gained.

Training packages developed

Collaboration with the NAARI scientists achieved a Swahili version of the brochure on CMD management: 'Maambukizi na udhibiti wa batobato kali ya mhogo' (Figs 5 & 6). Other training materials developed included a training manual for extensionist and farmers entitled 'Utunzaji bora wa mbegu ya mhogo ngazi ya kaya' and an extensionist guide for training on both cassava and sweet potato and handling of planting materials entitled 'Batobato na udhibiti wake, mwongozo kwa maafisa ughani'. All three have been reviewed and recommended for use by the information committee at ARI-Maruku: researchers are already using some of these for technology transfer. An informal guide for training extensionists as leaders of farmer field schools has also been developed 'Kilimo cha zao la mhogo na viazi' An English and Swahili training programme was also developed out of Mwanza workshop conducted in co-operation with the ministry of Agriculture (Crop Promotion Section) and this is also available to most stakeholders on both cassava and sweet potato.

Training was provided to four different groups: i) districts extension personnel and NPA officials, ii) farmer groups under FFS, iii) FFS group facilitators and field officers, and iv) districts and prison agricultural officers from selected districts and stations in Tanzania (Table 24). The training covered broad aspects on cassava but in particular the crop protection. Much emphasis was on CMD and other diseases and pests of economic importance including CGM, CBB and Mealybugs. The description of the diseases, its causes, spreading mechanisms, symptoms and management techniques were covered. Other insect pests and vertebrate pests of cassava and their control were also covered. Agronomy and general management were covered including handling and storage of planting materials when harvesting is done at times when planting can't be done due to weather or unprepared land. In addition, The farmer field school (FFS) approach, parameters for variety selection, development of the training curriculum and working calendar and data collection and management were trained. The different training were collaboratively organised between the project staff and NPA as well as MAFS. The training workshop organised in Mwanza in collaboration with MAFS had a nation-wide outreach involving researchers in root and tuber crops in the Lake Zone and districts and prisons agricultural officers from all over Tanzania participated. CMD-UgV and SPVD were the principle themes of the training, and these were covered by the project staff.

Table 25. Numbers of trainees and different themes

Date	Theme	Trained cadres	No. of participants
5 - 6th June 2003	Sweet potato and cassava as additional food and cash crops in Kagera region	DC's, DALDOs, Researchers, Councillors, extensionist	120
13 -18th October, 2003	CMD-UgV management, Cassava breeding and agronomy, FFS approach, data collection and management; and curriculum development	Extensionist, Field officers & coordinator from NPA, DALDO's offices Ngara and Biharamulo, group contact farmers	38 persons
22nd Dec. 2003 –12 Jan, 2004	CMD-UgV description of the disease, symptoms and management practice. Emphasis on phytosanitation and resistant varieties. CGM and CBB symptoms. Cassava agronomy and introduction to FFS approach and data collection.	On site training of FFS group members & few non-FFS members	93 persons
27 - 29th January 2004	Cassava crop protection (CMD, CGM, CBB, Mealybugs, scales & vertebrate pests), PPB, FFS approaches, Sweet potato agronomy and Post harvest techniques	Farmer groups facilitators and Field officers at ARI-Maruku	15 persons
18 - 22nd October, 2004	Detailed knowledge on cassava diseases and pests with emphasis on CMD-UgV. Breeding, agronomy and rapid multiplication of cassava. Post harvest techniques and processing technologies etc.	District crop officers, produce inspectors and prison agricultural officers	22 persons

CMD-resistant varieties were also multiplied and disseminated as an integral part of the training programme in CMD management for Kagera Region. The resistant varieties are initially multiplied at ARI-Maruku and then transferred to other organisations including NGOs, prison farms and agricultural training institutions. NPA also received initial planting material from ARI-Maruku (Table 26). Project staff were involved throughout this line of dissemination. We developed a particularly close link with a dissemination funded by Norwegian People's Aid (NPA) which is both working directly on variety multiplication, for example, at its plant nursery at Nyakahura, and funding others to do so too. The process involved and its achievements have been examined in the report by B. Adolph, I. Ndyetabura, G. Rwegesira and E. Marandu, Multiplying and distributing CMD resistant varieties in north-western Tanzania – experiences from Ngara and Muleba districts of Kagera Region.

Table 26. Cassava varieties received by NPA from ARI-Maruku, 2001-2004

Variety	Year	Number of cuttings
TMS4(2)1425	2002	159,650
SS4	2002	15,000
Rwakitangaza	2002	300
MM96/4446	2002	300
MM96/8450	2002	200
MM96/4684	2002	230
MM96/8100	2002	300
MM96/5373	2002	300
Total		**175,000**
TMS (4)21425	2003	113,402
MM 96/8233	2003	2,200
MM 96/4446	2003	3,320
MM 94/3075B	2003	602
MM 96/4619	2003	1,682
MM 96/4684	2003	1,600
Migyera	2003	770
MM 96/0876	2003	2,404
SS4	2003	1987
Total		**127,967**
Grand total		**302,967**

Some of these cassava cuttings were planted directly at NPA's Nyakahura nursery, starting in 2002 with a trial field on 1.2 acres concentrating on two varieties TMS 4(2)1425 and SS4. In 2003/2004 season, the area for multiplication was extended to 10.5 acres incorporating other newly released varieties under OFDA (Table 27). Extensive plantings of CMD-resistant varieties have also been achieved under NPA funding by the NGOs REDESO, RUDDO, CHEMA and CARITAS.

Table 27. CMD-resistant cassava varieties planted at NPA's Nyakahura Nursery

Variety	Number of cuttings	Acreage	Comments
TMS4(2)1425	82,629	5.0	1.2 acres planted during 2002/2003 season
SS4	8,224	0.5	
MM96/4684	7,636	0.5	
MM96/8450	8,080	0.5	
MM96/5373	10,897	0.5	
MM96/4446	6,258	0.5	
RWAKITANGAZA	12,698	1.0	
MM96/8100	0352		The combined area for the ten varieties sums to 1 acre
MM96/4619	0078		
MM96/3075B	15.52		
MM96/8233B	1,416		
MM3075	0520		
MIGERIA	4324	1.0	
MM96/0876	0674		
MM96/8450B	0496		
MM96/5725	1,380		
MM96/8233	1,344		
TMS30337	2,228	1.0	
TOTAL	150,786	10.5	

Plate 4. Part of NPA's cassava nursery plot at Nyakahura

This material is now being extended to farmer groups within Ngara and Biharimulo districts. This distribution is very diverse and it is difficult therefore to provide exact data covering the whole exercise. Tables 28 & 29 below give instead a limited picture of the scale and achievements of the operation.

Table 28. Cassava multiplication at Nyakahura ward in Biharamulo 2003/2004 seasons

VILLAGE	Number Of Groups	Group Members		Total Acreage	Number of Cuttings Given
		2003	2004		
Nyakahura	2	19	45	16	65,410
Mabare	3	10	80	34	134,719
Mihongora	2	10	124	28	111,313
Nyabugombe	1	0	13	3	13,000
TOTAL	8	39	262	81	324,442

Plate 5. The NPA coordinator and a scientist inspecting planting material

Table 29. CMD-resistant planting materials multiplied under NPA-funding and available for distribution as identified in a survey in November 2004

Site	Modality	Source of materials	Amount and beneficiaries
Biharamulo Daldo's office	Materials Grant	Nyakahura Primary Nursery	More than 150,000 cuttings to be taken to various farmer groups
Ngara Daldo's office	Materials Grant	Nyakahura Primary Nursery	About 180,000 cuttings to be distributed to farmer groups
Rusahunga division Kalenge	Loan	RUDDO	71,000 cuttings to be loaned to 5-farmer groups
Nyantakara, Iyengamirilo & mavota	Loan	RUDDO	180,000 cuttings to be loaned to farmer groups
Nyarubungo Division	Loan	RUDDO	243,000 cuttings to be loaned to 15-farmer groups in 8 villages
Murusagamba division Muganza ward	Loan	RUDDO	68,000 cuttings to be provided to 5-farmers groups in 3 villages
Mulonze & Nyakanazi Rulenge division	Loan	RUDDO	114,000 cuttings provided to 2 groups
Keza, Bukirilo and Rulenge wards	Loan	RUDDO	315,000 cuttings provided to 24 groups
> 9 farmers' groups	Loan	Songambele farmers group	9.5 to be ratooned and distributed to farmers
CARITAS	Multiplication	Main nursery	Expansion of multiplication plot to 21,800 plants
Igabiro Agricultural Training Institute	Loan	On-station nursery	5 farmer groups at Biilabo, Omurunazi, Kabirizi, Kashanda and Ngenge to receive planting materials for >2 acres each

Additional activities

Project staff participated in a survey conducted in 2003 throughout the Lake Zone of CMD and other cassava pests (S.C. Jeremiah, Marandu, E. and Rwegesira, G. Annual Report on CMD pandemic and CGM in the Lake Zone of Tanzania in 2003/4 seasons). This report confirmed the continuing spread of the pandemic in the Lake Zone.

Cassava brown streak virus (CBSV) has also been identified for the first time to be prevalent in Uganda. CBSV, apparently a whitefly-borne virus, has been reported previously there but never as a sustained epidemic. These latest observations are giving rise to concern that the large numbers of whiteflies associated with the pandemic may be enabling CBSV to escape from its previous restriction to low altitude areas of East and southern Africa.

Contribution of Outputs to developmental impact

Cassava is the second most important staple food throughout Africa but is particularly important in conditions of widespread drought when it, unlike the main staple maize, can often continue to yield. Such conditions are expected to increase in Africa as a consequence of global warming. Cassava is also a particularly important food for poor people as it can grow with no or few inputs apart from labour on marginal soils to which poor farmers are often restricted and is often also the cheapest source of carbohydrate for urban poor.

Cassava can also be readily dried as chips and ground into flour which is used in porridge and other local dishes. Both the chips and the flour can be stored long-term, again explaining cassava's importance as a source of food security but also providing the potential to use the crop as an industrial feedstuff. In this way, cassava is amongst only a few crops widely grown in Africa which have the potential to be the basis for development of industries both for food and various chemicals. It is thus a very important crop both for Africa's survival and also its development.

The CMD pandemic is the main current threat to the crop; it has already spread to affect production in most countries in East and Central Africa and is likely to affect all sub-Saharan Africa. Nigeria, by far the largest producer of cassava in Africa, neighbours a country (Cameroon) which is already affected. The pandemic has had devastating impact on cassava production in all affected countries including Uganda and Tanzania. Its adverse effects have mainly been on the poorer sectors of communities. We currently have no means of preventing the further expansion of the epidemic – only means of minimising its effects. These effects could potentially be much worse when it reaches West Africa because of the greater importance of the crop there. The project has, with others, played a key role in advertising these risks

The development and dissemination of highly CMD-resistant varieties has been the main driving force behind the recovery of cassava production in Uganda, the first country to report the pandemic. Cultural practices including intercropping and clean planting material are also beneficial. Its means of achieving this recovery have been described in a brochure in English and other national languages more widely used by poorer farmers; a training manual is also being developed.

Tanzania is currently being invaded by the pandemic; lessons learnt in Uganda were applied there in the Lake Zone by the project to limit its impact. Extensive training and training materials have been provided in Swahili. Links with Ugandan researchers were promoted. Other donors notably NPA have been assisted to participate in the dissemination of effective training messages and materials including the multiplication and dissemination of resistant varieties. Experiential learning in groups, considered to be more appropriate to farmers, has been the preferred means of training. NPA particularly targets poorer communities. Although it proved impossible to motivate farmers to adopt resistant varieties before the actual arrival of the pandemic, it is certain that farmers are gaining access to these varieties and training very soon after the arrival of the pandemic. Resistant varieties are again a most effective means of combating the pandemic. A study has been made into how effective different methods of dissemination are, for use elsewhere as the pandemic spreads.

Although the project has had a clear focus on developing and disseminating training messages and materials, it has also continued research into understanding the dynamics of the pandemic. Early observations identified that large numbers of the whitefly vector, *B. tabaci*, are associated with the pandemic. Whilst the prevalence of CMD has been controlled by the use of CMD-resistant varieties, the large whitefly populations have persisted and, if anything, increased to the extent that the whitefly has now been shown to cause quite massive yield losses by itself to some varieties. The project has therefore screened a wide range of cassava accessions available in Uganda and identified several potential sources of resistance. These have been made available to the newly-recruited national cassava breeder at NAARI. A few resistant accessions have been identified within material close to release as varieties and these represent an opportunity to address this new pest very speedily. Work is therefore being focused on their further testing and potential release in a project extension.

The project has also highlighted the enhancement of the risk of other whitefly-borne diseases occurring in association with these increased numbers of whiteflies. An increasing diversity of begomoviruses has already been observed and the project personnel have also been key to identifying the increase in prevalence of the whitefly-borne *Ipomovirus* CBSV in Uganda.

Publications:

- **T Alicai, A Bua, GW Otim-Nape, YK Baguma, GN Ssemakula, W Sserubobwe, CA Omongo, D Akullo, S Tumwesigye & M Apok. 2003.** Research and development strategies for controlling cassava mosaic disease and enhancing the competitiveness of cassava in Uganda. . ***Abstracts of Symposium of International Society of Tropical Root Crops***
- **J. Colvin, R.V. Chowda Reddy, A.R. Rekha, P. Sseruwagi, V. Muniyappa, S.E. Seal, M.N. Maruthi, 2004.** Ecological and reproductive isolation amongst African and Asian *Bemisia tabaci* populations. Abstract for the 2nd European Whitefly Symposium, Cavtat, Croatia - 5-9 October 2004.
- **Colvin,J., Omongo, C.A., Maruthi, M.N., Otim-Nape, G.W., & Thresh, J.M. (2004)** Dual begomovirus infections and high *Bemisia tabaci* populations: two factors that drive the spread of a cassava mosaic disease pandemic. Plant Pathology, 53, in press.
- **J.P. Legg, P. Sseruwagi & J. Brown. 2004**. *Bemisia* whiteflies cause physical damage and yield losses to cassava in Africa. *6th Intrtl. Sci. Meeting Cassava Biotechnology Network (Abstr.)* p65.
- **CA Omongo, J Colvin, T Alicai, W Sserubombwe, JP Legg & GW Otim-Nape. 2003.** Host selection by *Bemisia tabaci* of CMD-symptomatic and non-symptomatic cassava plants. . ***Abstracts of Symposium of International Society of Tropical Root Crops.***
- **C.A. Omongo, J. Colvin, W. Sserubombwe, T. Alicai, Y. Baguma, A. Bua, J.P. Legg & R.W. Gibson 2004**. Host plant resistance to African *Bemisia tabaci* in local landraces and improved cassava mosaic disease resistant genotypes in Uganda. *6th Intntl. Sci. Meeting Cassava Biotechnology Network (Abstr.),* p84.

Internal Reports:

- **B. Adolph, I. Ndyetabura, G Rwegesira & E. Marandu**. Multiplying and distributing CMD resistant cassava varieties in north-western Tanzania – experiences from Ngara and Muleba Districts of Kagera Region.
- **T. Alicai, B. Adolph, D. Akullo, C.A. Omongo, Y. Baguma, A. Bua, R. Kawuki and R.W. Gibson** (2005). Training of extension workers and farmers and production of training and dissemination materials on cassava mosaic disease.
- **T. Alicai, A. Bua, J. Amenet, C.A. Omongo, A. Apok, B. Adolph, Y. Baguma, R. Kawuki and R.W. Gibson** (2005). Farmer participatory evaluation of variety mixtures for the control of cassava mosaic disease in Mukono and Apac districts in Uganda
- **R Gibson.** Quarterly and annual reports to CPP.
- **J Legg.** Visit to Kagera Region, Tanzania, 5 – 9 July, 2004.
- **J. Legg.** Activity 1.1 Assessment of yield losses attributable to *Bemisia tabaci* direct damage
- **R Gibson & B Adolph.** Report on a project visit (A1076 (SPVD) & A1105 (CMD)) to Kagera Region, Tanzania, 8-13 November 2004.
- **S. C. Jeremiah, E. Marandu & G. Rwegesira.** Annual report on CMD pandemic and CGM in the Lkae Zone of Tanzania in 2003/04 seasons.
- **C. Omongo.** Host plant resistance to cassava whitefly, *Bemisia tabaci*, in Uganda
- **GM Rwegesira & EF Marandu.** Monitoring visit to NPA initiated activities in collaboration with MARDI, 2004.
- **G. M. Rwegasira & E. F. Marandu**. Final monitoring report to NPA activities. 2005.
- **G. M. Rwegasira, E. F. Marandu & C. V. Mwita.** General evaluation of NPA work and support to MARDI. 2005.
- **G. M. Rwegesira & E. F. Marandu**. 3rd Monitoring of NPA activities with partners.
- **G. M. Rwegesira, E. F. Marandu & R. W. Gibson.** Maximizing, disseminating and promoting the benefits to farmers of cassava varieties resistant to cassava mosaic disease in the Lake Zone of Tanzania in 2004.

Other Disseminations of Results:

- **T Alicai, A Bua, GW Otim-Nape, YK Baguma, GN Ssemakula, W Sserubobwe, CA Omongo, D Akullo, S Tumwesigye & M Apok. 2003.** Research and development strategies for controlling cassava mosaic disease and enhancing the competitiveness of cassava in Uganda. . ***Presentation at Symposium of International Society of Tropical Root Crops***
- **J. Colvin, R.V. Chowda Reddy, A.R. Rekha, P. Sseruwagi, V. Muniyappa, S.E. Seal, M.N. Maruthi, 2004.** Ecological and reproductive isolation amongst African and Asian *Bemisia tabaci* populations. Presentation at the 2nd European Whitefly Symposium, Cavtat, Croatia - 5-9 October 2004.
- **J.P. Legg, P. Sseruwagi & J. Brown. 2004**. *Bemisia* whiteflies cause physical damage and yield losses to cassava in Africa. Presentation at *6th Intrtl. Sci. Meeting Cassava Biotechnology Network*
- **CA Omongo, J Colvin, T Alicai, W Sserubombwe, JP Legg & GW Otim-Nape. 2003.** Host selection by *Bemisia tabaci* of CMD-symptomatic and non-symptomatic cassava plants. . ***Presentation at Symposium of International Society of Tropical Root Crops***
- **C.A. Omongo, J. Colvin, W. Sserubombwe, T. Alicai, Y. Baguma, A. Bua, J.P. Legg & R.W. Gibson 2004**. Host plant resistance to African *Bemisia tabaci* in local landraces and improved cassava mosaic disease resistant genotypes in Uganda. Presentation at *6th Intntl. Sci. Meeting Cassava Biotechnology Network*.
- **C. A. Omongo, J. Colvin, A. Bua, T. Alicai, J.P. Legg & Y. Baguma.** The emergence of *Bemisia tabaci* (Hemiptera: Aleyrodidae) as a direct pest threatens sustainable cassava production in Uganda. Presentation made to the International Society for Tropical Root Crops - Africa Branch 9th Triennial Symposium, 31st Oct. – 5 Nov., 2004 in Mombasa, Kenya

Competency in Statistics of Dr CA Omongo, principal investigator for the research work on whitefly resistance in Uganda (the work in Tanzania primarily involved developing, validating and promoting training messages).

From: caomongo@naro-ug.org
Date sent: Wed, 27 Apr 2005 10:16:26 +0300 (EAT)
Subject: Competency in Statistics in Agriculture
To: "Dr. Colvin John" <johncolvin@btopenworld.com>

Dear Richard,

Please find listed below courses attended and other exposures that have helped build my statistical knowledge so that I now employ it with relative ease to handle my research activities in Agriculture:

1) Makerere University (Uganda) where I did my Bachelor (October 1989-June 1993) and Master (October 1993-November 1996) of Science degrees in Agriculture offer introductory statistics and Biometrics at undergraduate level and advanced Biometrics in Agriculture at graduate level. Both courses are compulsory and I benefited a lot from them.

2) In 1994 I attended a one month statistics in agriculture workshop at the University of Zimbabwe organised and facilitated by Sr. J. Canhao, Department of Crop Science, University of Zimbabwe and A. Hasted, Q.I. Statistics Readings, U.K. This workshop was funded by Rockefeller Foundation Forum. The statistical package GENSTAT was core in this training.

3) To date I am confident of my knowledge of Genstat and it is the package I have been using routinely and also used it immensely in my PhD work at NRI, University of Greenwich, (2000-2003). I added more knowledge on this package through interactions with Drs. David Jeffries and Flavia Joliffe both of whom were at NRI, albeit at different times, when I was for my PhD studies.

4) Challenges in statistics are dynamic and whenever need arises there are two statisticians who have always helped NARO scientists: Dr. Nabasirye at the Faculty of Agriculture, Makerere University and Dr. Rwagama for IITA-Uganda. I have been in touch with both and certainly will continue as and when required.

As I said earlier the challenges are dynamic and I keep my mind open for any opportunity of new knowledge in statistics in agriculture.

Best Regards,

Chris