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ACCELERATING THE TRANSFER OF IMPROVED PRODUCTION TECHNOLOGIES: CONTROLLING AFRICAN CASSAVA MOSAIC VIRUS DISEASE EPIDEMICS IN UGANDA

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ABSTRACT

Since 1988, epidemics of African cassava mosaic disease (ACMD) caused by a whitefly-transmitted geminivirus have caused severe devastation in Uganda resulting in food shortages and famine in some areas. In order to control the disease and restore food security in the country, appropriate technologies had to be developed and transferred quickly to farmers. A diagnostic survey was undertaken in areas severely affected by ACMD in order to understand farmers' knowledge and practices for controlling the disease. Results showed that farmers are aware of ACMD and use what they consider to be resistant varieties, select healthy planting material, rogue infected plants and change varieties in attempts at control. This information was used to develop control measures. Improved genotypes TMS 30572, TMS 60142 and TMS 30337 were compared with the local ones in multilocational and on-farm trials. The three genotypes proved superior and acceptable according to farmers' selection criteria and were released as Migyera, Nase 1 and Nase 2, respectively. A national network of cassava workers (NANEC) was created to address the problem of technology transfer. An integrated strategy for the multiplication and distribution of 'clean' virus-free stocks of the improved varieties was developed and used by NANEC. Three approaches were used for multiplication:- at institutional farms, by farming groups and by individual farmers. By 1993, 466 ha of the improved varieties were available to supply cuttings that were distributed to farmers in 26 districts seriously affected by ACMD. The advantages and disadvantages of each multiplication strategy are discussed. It is concluded that indigenous knowledge must be acquired and utilised in order to accelerate transfer of agricultural production technologies. The value of such new technologies must be tested in different agroecological conditions and farmers' circumstances, and the best technologies selected based on farmers' criteria and priorities. Moreover, obstacles to adoption must be identified and overcome.

Key Words: **Cassava, African cassava mosaic virus disease, control measures, farmers' indigenous knowledge, on-farm trials, technology transfer, propagation/distribution, virus-resistant varieties**

RÉSUMÉ

Depuis 1988, des épidémies de la mosaïque africaine du manioc (ACMD), provoquées par un virus transmis par une mouche blanche, sont à l'origine de gros dégâts dans les champs de manioc en Ouganda avec, pour conséquences, des pénuries alimentaires et une famine dans certaines régions. Dans le but de contrôler la maladie et de restaurer la sécurité alimentaire dans le pays, des technologies appropriées doivent être développées et transférées rapidement vers les agriculteurs. Une campagne de diagnostic a été entreprise dans les régions sévèrement affectées par la maladie de façon à connaître la perception de la maladie par les agriculteurs et les pratiques qu'ils mettent en oeuvre pour la contrôler. Les résultats montrent que ces derniers sont avertis de la maladie, qu'ils utilisent ce qu'ils considèrent être des variétés résistantes, qu'ils sélectionnent des boutures saines, éliminent les plants infestés et changent de variétés pour contrôler la maladie. Les génotypes améliorés TMS 30572, TMS 60142 et TMS 30337 ont été comparés avec les génotypes locaux dans des essais multilocaux et à la ferme. Ces trois génotypes se sont révélés supérieurs, acceptables selon les critères de sélection des agriculteurs et ont été diffusés sous les noms de Migyera, Nase 1 et Nase 2 respectivement. Un réseau national de chercheurs (NANEC) a été créé pour traiter le problème

du transfert de technologies. De la même façon, une stratégie intégrée pour la multiplication et la distribution de boutures saines exemptes de virus a été développée et utilisée par le NANEC. Trois types de multiplication ont été utilisés: sur les fermes expérimentales, par des groupes de fermiers (spécialement les femmes) et par les agriculteurs individuels. Au cours de l'année 1993, 446 hectares de variétés améliorées étaient disponibles pour las fourniture de boutures qui furent distribuées aux agriculteurs dans 26 districts fortement infestés par la mosaïque du manioc. Les avantages et inconvénients de chaque stratégie de multiplication sont discutés. On peut en conclure que dans le but d'accélérer le transfert des technologies de la production agricole, le savoir local doit être assimilé et utilisé. La valeur de telles technologies nouvelles doit être testée dans différents contextes agro-éecologiques et situations de la ferme, et les meilleures technologies basées sur les critères et les priorités de fermiers doivent être sélectionnées. De plus, les obstacels à leur adoption par les agriculteurs doivent être sélectionnées. De plus, les obstacles à leur adoption par les agriculteurs doivent être identifiés et éliminés.

Mots Clés: **Manioc, Épidémie de la mosaïque africaine du manioc, contrôler la maladie, trnsfert de technologie, variétés résistantes du virus**

INTRODUCTION

The factors influencing the development of pests (noxious organisms such as arthropods, pathogens and weeds) and the losses they cause are complex and influenced by a number of inter-related factors which may be socio-economic or biophysical. Knowledge of such factors provides the opportunities for improving pest management and for overcoming constraints to implementation by developing technologies appropriate to farmers and removing obstacles to their adoption.

African cassava mosaic disease (ACMD) was first reported in 1894 (Warburg, 1894). It is caused by each of two whitefly-borne geminiviruses that are widespread and cause losses estimated at 36% of total African cassava production (Fargette *et al.*, 1988). African cassava mosaic disease was first reported in Uganda in 1928 (Hall, 1928) and between 1933 and 1944 severe epidemics devastated crops in the eastern region of the country (Jameson, 1964). Breeding and selection of ACMD-resistant varieties at Amani, Tanzania, resulted in genotypes that were later widely tested in Uganda. Some were officially released as varieties (Bukalasa 8, Bukalasa 11, etc.), and they were multiplied and distributed to farmers (Jameson, 1964). A bye-law instituted in the 1950s made it mandatory for farmers to uproot all infected and susceptible local varieties and replace them with the new resistant ones (Jameson, 1964).

African cassava mosaic disease was controlled in this way in Uganda for some years. However, in 1988 a severe epidemic destroyed *c.* 2,000 ha of cassava in Buruli county of Luwero district. Subsequent reports of similar epidemics were received from other districts in eastern, northern and north-western regions and in parts of western region where severe losses and subsequent food shortages continue (Otim-Nape *et al.*, 1994). Current losses in fresh yield of tuberous roots have been estimated at *c.* US $180 million per annum (Otim-Nape, 1993).

To control ACMD and restore food security in the country, it became imperative to accelerate the development and transfer of appropriate control technologies to farmers. This necessitated an understanding and use of farmers' indigenous knowledge and practices for controlling ACMD, the criteria and constraints to adoption of control technologies by farmers and above all knowledge of the epidemiology of the disease. This paper summarises the steps taken to control ACMD in Uganda by developing and promoting control measures relevant to the farmers and by removing constraints to their adoption.

METHODOLOGY

Farmers' indigenous knowledge and practices for controlling ACMD

A diagnostic survey was undertaken in areas severely affected by ACMD to gain an understanding of farmers' knowledge and practises. Kasese, Apac and Arua districts were selected to represent western, northern and north-western regions, respectively. For each district, fifteen farmers were selected randomly in each of three sub-counties. The farmers were interviewed by trained staff using a structured questionnaire. Information from additional areas was obtained during the Rockefeller-funded Collaborative Study of Cassava in Africa (COSCA) (Bua *et al.*, 1991; Otim-Nape and Zziwa, 1991). The methodology used in COSCA is described by Carter and Jones (1990) and Nweke (1994).

Developing ACMD control technologies relevant to farmers

Multilocation trials aimed at testing the adaptability, ACMD resistance and yield of improved cassava genotypes began in the 1989-1990 and 1990-1991 seasons. Six improved cassava genotypes from the International Institute of Tropical Agriculture, Nigeria (IITA) - TMS 30572, TMS 60142, TMS 30337, TMS 30786, TMS 30395 and TMS 60140 - were compared with the local varieties, Ebwanateraka, Bao, Bukalasa 11 and Senyonjo. The trials were arranged in a randomised complete block design and were conducted at Mobuku and Kagando (Kasese district), Migyera (Luwero district) and Isimba (Masindi district). For further details see Otim-Nape (1993).

Accelerated on-farm trials. A total of 754 on-farm trials were carried out between 1990 and 1995 in 13 of the 22 districts of Uganda where cassava is an important crop (Fig. 1 a). The total number of trials in each of the thirteen districts is shown in Figure 1b. The objective of the trials was to compare the performance of the TMS genotypes with the local ones being grown so as to identify those acceptable to farmers. In each district four or five farmers were selected in each of four sub-counties. The improved cassava genotypes and the farmers' best local varieties were planted in fields prepared by the farmers using traditional methods. Subsequent management of the trials was done by the farmers using standard practices. However, field extension staff and scientists recorded ACMD incidence and severity, yield and yield parameters for each genotype studied.

At different stages of crop growth and at harvest, farmers near each trial were called to the site and briefed on the trials. They were then encouraged to make their own assessment and opinion of each

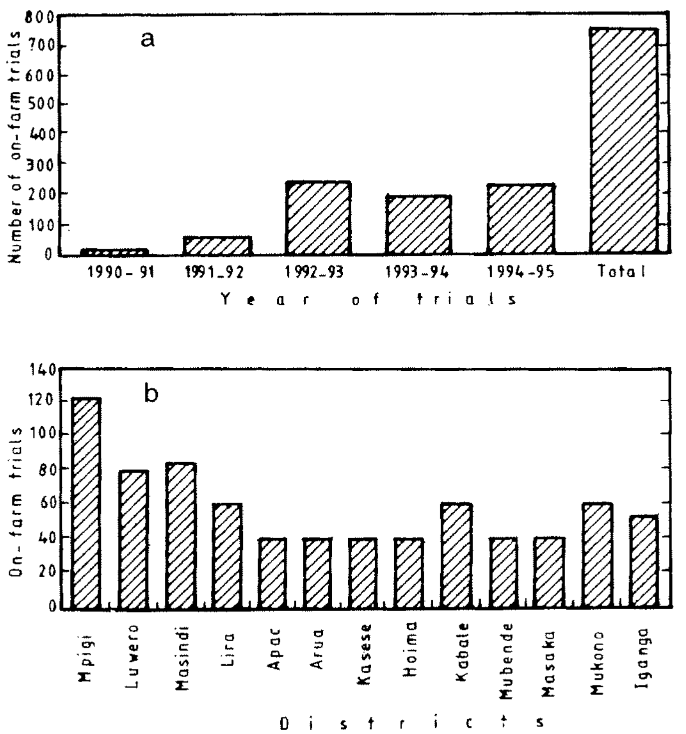

Figure 1. The number of on farm trials conducted between 1990 and 1995 (a) and in each of the thirteen districts of Uganda (b).

genotype. At harvest, the farmers were asked to assess the relative yield of each genotype. In addition, tuberous roots of each genotype were selected, peeled and cooked. A panel of farmers tested both cooked and raw roots of each genotype and scored for mealyness and bitterness of the roots on a scale of 1-3; where for mealyness, 1 and 3 meant best and worst, respectively, while for bitterness, 1 and 3 meant sweet and very bitter, respectively. Farmers were also interviewed on the importance of the different criteria they consider when adopting new cassava varieties. They were then invited to take stems and establish plantings of the preferred genotypes. The information provided by the farmers and the records collected on the performance of the genotypes were considered when selecting suitable varieties for farmers.

Eliminating constraints to adoption of ACMD control measures

The establishment of a national network of cassava workers (NANEC). The national network of cassava workers was set up to facilitate the development and adoption of ACMD control measures and resistant varieties. The network involves all those concerned in technology generation, dissemination and adoption who work in a multi-disciplinary way and operate in a 'balance and check' manner. A flow diagram for this network is shown in Figure 2.

As overall coordinator, the Director General fosters close linkages with the Directors of research institutes such as Namulonge Agricultural and Animal Production Research Institute, near Kampala and with the programmes of this institute (Fig. 2). The linkage provides fora for research planning in which technical and non-technical (policy) issues related to cassava and other commodities are prioritised as based on national interests and the resources available for research. The Root Crops Programme promotes linkages with other commodity programmes and collaborates with extension staff and NGOs in planning, training and conducting on-farm trials and multiplication of planting material.

The cassava staff train extension personnel and

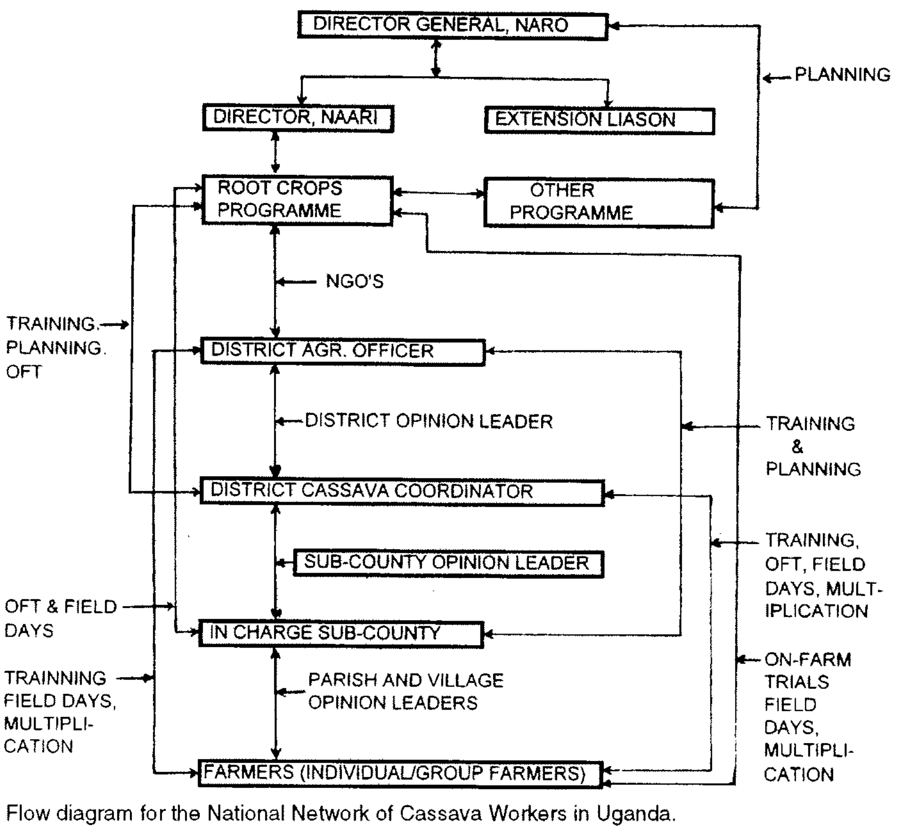

Figure 2. Flow diagram for the National Network of Cassava Workers in Uganda.

NGOs, who in turn train other extensionists and farmers who are involved in on-farm trials to validate the technologies appropriate to their natural and socio-economic environment. The field days draw together all those concerned to review the performance of the technologies tested and any necessary improvements and recommendations are made. Multiplication of the accepted cassava genotypes by the farmers is initiated here.

The extension service of the Uganda Ministry of Agriculture, Animal Industries and Fisheries extends to the 'grassroots' level. Every district has extension officers who supervise the activities of staff in the counties (sub-districts). The county officers in turn supervise those in the sub-counties and parishes. Some NGOs also have similar networks in some districts.

At the outset, a major constraint of the extension service was that district staff were ill-motivated and poorly equipped. They lacked transport and knowledge to perform their duties effectively and did not have the confidence to approach farmers. Tackling ACMD, therefore, necessitated first educating the extension personnel in targetted areas. The Agricultural Officers in charge of districts, District Plant Protection Officers, and two extension staff per targetted district were invited for a 1-2 week training workshop in Kampala in 1990. The workshop aimed to sensitise the officers on ACMD and to instruct them on improved cassava production, ACMD control methods and technologies for rapid multiplication of planting material of resistant varieties.

A District Cassava Coordinator and the Cassava Officers in charge of four sub-counties per district were also selected by the District Agricultural Officer (DAO) of each district. These officers, the DAO and the Officer in Charge of Plant Protection formed the district NANEC team. Each district team was responsible for training other extension staff, chiefs, opinion leaders and farmers in the district. They were also responsible for on-farm trials and for multiplying and distributing planting material of varieties preferred by farmers. Their activities were planned and closely supervised by scientists from the cassava programme. The team leader of the cassava programme provides the overall supervision and coordination. Annual workshops are organised for the District Cassava Coordinators to review progress, plan for the next season and update knowledge on cassava production and control technologies.

Multiplication and distribution of improved varieties resistant to ACMD

Foundation stocks of planting material. These were established at Namulonge Agricultural and Animal Production Research Institute at a 35 ha former woodland site. The trees were removed by cutting down the main branches and removing the stumps by tractor. The thick grass vegetation was slashed down by a tractor and paraquat (3 l ha^{-1}) was applied to control couch grass (*Digitaria* spp.). The land was ploughed twice and disc harrowed once before planting. The rapid multiplication technique developed at IITA (Anonymous, 1990) and routine cultural practices were adopted. At maturity the cassava stems were cut 15-20 cm above ground and two or three shoots per cut stem were allowed to form a ratoon crop of stems which were harvested 7-8 months later. This was repeated until the plants no longer produced suitable planting material, usually after four years. The plants were then harvested and the fields replanted. All stems harvested on each occasion were either distributed to farmers and/or used to initiate new district multiplication centres.

Subsequent multiplication of planting material was done in several districts to take improved planting material closer to the farmers and to minimise the costs and simplify the logistics of transporting stems. Multiplication was done at institutions (Government farms, schools and colleges) and also by farming groups and individual farmers.

Institutional Multiplication in Districts. Land was borrowed or hired from farms belonging to the Ministry of Agriculture, Prison Department or from schools and colleges. The procedures described above for multiplication of foundation material were followed. Cassava scientists planned the multiplication, provided funds and cuttings and also supervised the planting and management of the crops. The district cassava teams were responsible for the planting and management of the crops and distributed stems to farmers.

Group Multiplication in Districts. This approach involved existing farming groups working for themselves and with neighbours. The groups were selected on the strength of their leadership, the cohesion of the members and willingness to cooperate in the multiplication and to follow technical advice. These attributes were a particular feature of women's groups and those dominated by women and several such groups were selected on the basis of their previous record of working together successfully on other enterprises such as bee-keeping and fish farming. The groups selected were responsible for preparing the land, planting and all subsequent management of the crop, including distribution of mature stems. The district cassava team provided planting material and technical supervision.

Individual Multiplication in Districts. This was by individual farmers who prepared land and, planted and managed their crops independently. They distributed the matured stems to farmers of their choice, but the cassava team provided planting material and technical advice.

RESULTS

Farmers' indigenous knowledge and practices for controlling ACMD

Indigenous knowledge. Most of the farmers in the villages studied in Kasese, Arua and Apac districts considered pests and diseases, as serious risk factors in cassava production (Fig. 3a). ACMD was regarded as the most threatening disease by

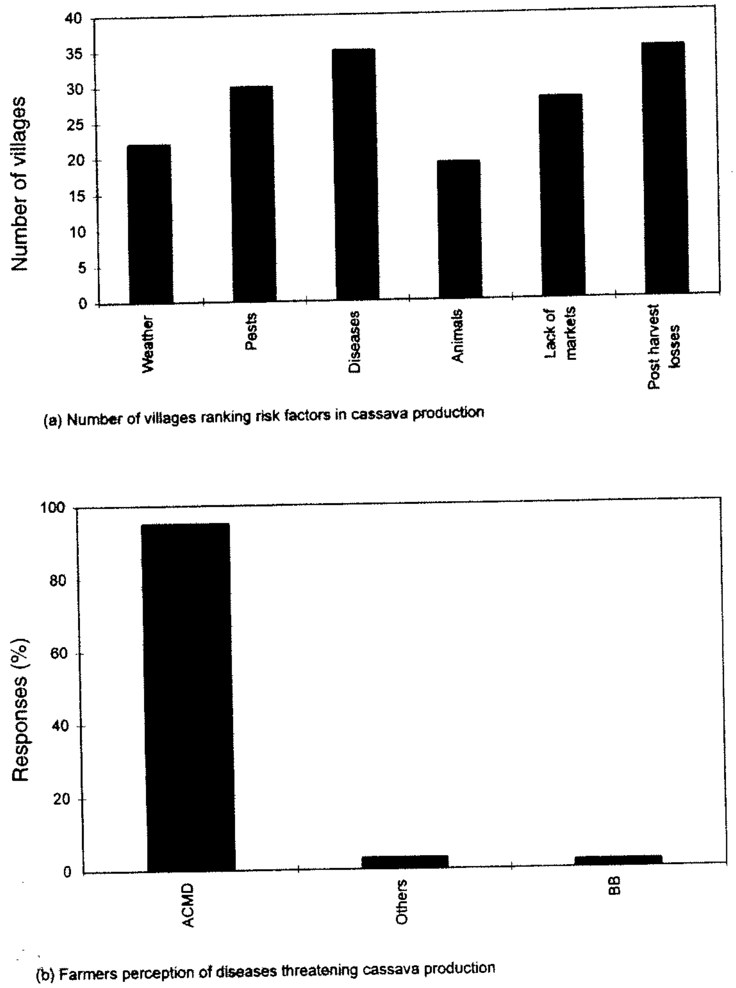

Figure 3. Risk factors affecting cassava production in Kasese, Apac and Arua districts of Uganda. BB = Bacterial blight; "others" includes mostly the fungus disease caused by *Cercospora henningsii*.

95% of the farmers interviewed, compared with only 2% who cited bacterial blight and 3% who referred to 'other' diseases (Fig. 3b). All farmers sampled in the three districts were aware of ACMD and emphasised it as a major problem which had led to a shortage of 'clean' planting material, which was another perceived constraint. They thought that ACMD came from the soil, or was due to insects, or that it was a varietal characteristic.

Farmers were aware that ACMD-affected plants always expressed conspicuous and very severe symptoms which resulted in no or very poor yields. A majority of those in the three districts were aware that the incidence and severity of symptoms varied with variety and season. Planting time and spacing were also mentioned by a few farmers as influencing symptom severity.

Indigenous control practices. Many farmers in the three districts used what they considered to be resistant varieties, selected healthy planting material, rogued infected plants and changed varieties in attempts to control ACMD (Fig. 4). Other farmers used timely planting to avoid peak whitefly vector infestations, grew more than one variety in a field to minimise the risk of total crop loss and applied insecticides in attempts to control the disease. Close spacing and intercropping were also mentioned by a few farmers as control strategies.

Change of varieties. Farmers in the three districts changed varieties as soon as existing ones became bitter or low yielding, stored poorly in the ground, provided insufficient planting material or showed unacceptable susceptibility to diseases (Fig.5a). The number of varieties said by farmers to have been abandoned between 1930 and 1980 increased progressively in each successive decade (Fig. 5b). The number of varieties said to have been introduced also increased, but both trends could

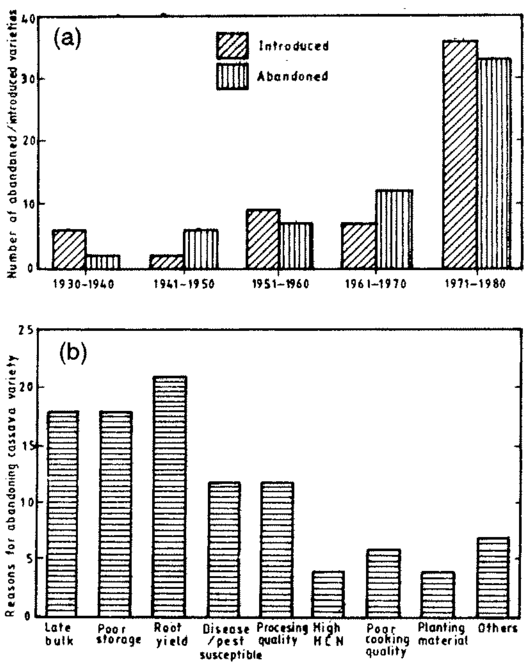

Figure 5. The number of varieties abandoned and introduced each decade between 1930 and 1980 (a), and reasons for abandoning varieties (b).

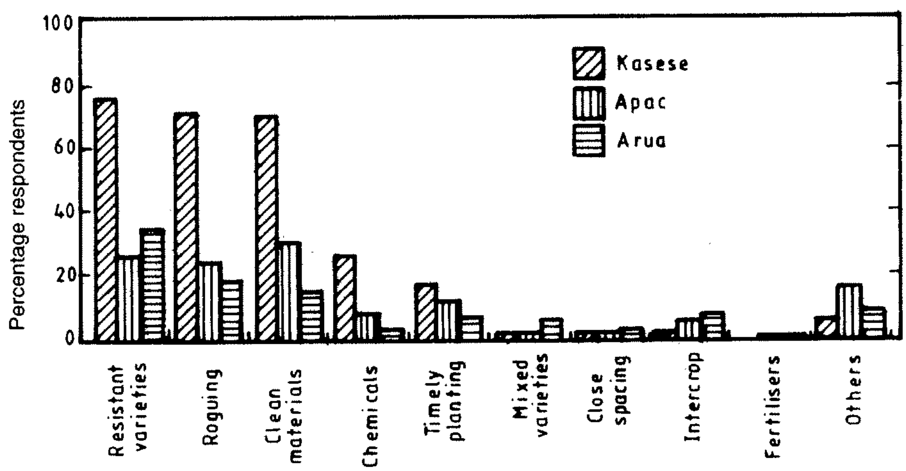

Figure 4. Farmers practices for controlling African cassava mosaic disease in Kasese, Apac and Arua districts of Uganda.

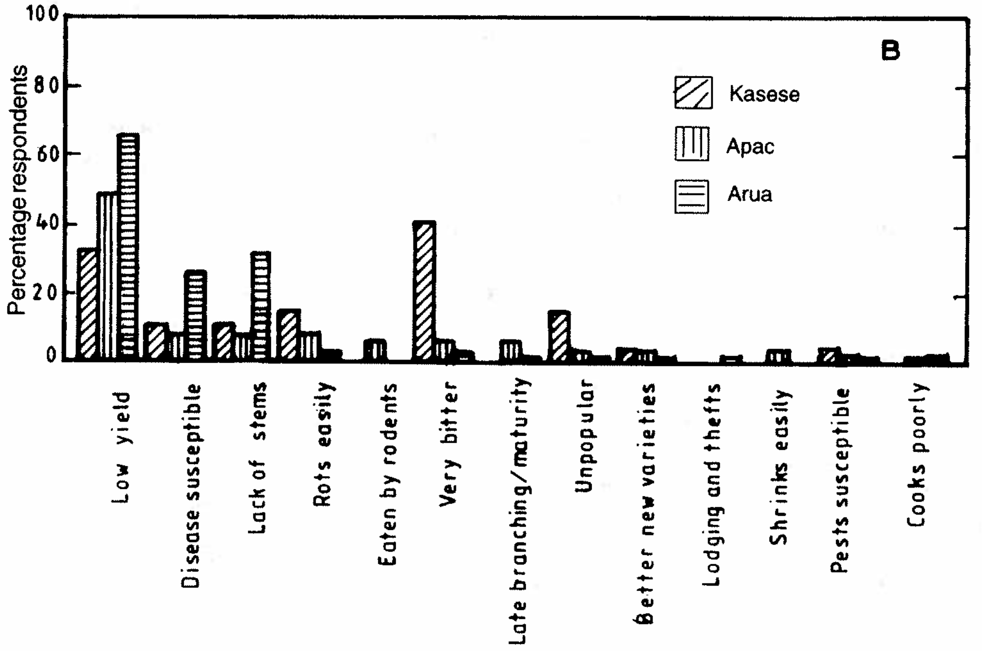

Figure 6. The reasons given by farmers for changing varieties in Kasese, Apach and Arua districts of Uganda and relative impotance of the reasons given for abandoning varieties.

have been influenced by the age of those interviewed and their ability to remember past experience. Various reasons were given for abandoning varieties of which the principal ones were poor yield and root storability, late maturity or susceptibility to diseases and pests (Fig. 6).

The varieties grown. At least 129 cassava varieties were being grown in the farms surveyed. The overall incidence of ACMD exceeded 50% in 17 of the 21 varieties encountered most frequently in the survey and the mean severity scores for affected plants ranged from 2.1 to 3.6 on the 1-5 scale of increasing severity.

Selection of healthy planting material. A majority of the farmers in the three districts obtained cuttings from their own fields or from neighbours. Relatively few farmers obtained planting material from remote fields, except in Arua district (Fig. 7a). All farmers selected planting material and the criteria adopted were absence of symptoms and the maturity, size and length of stems (Fig. 7b). Cuttings were usually

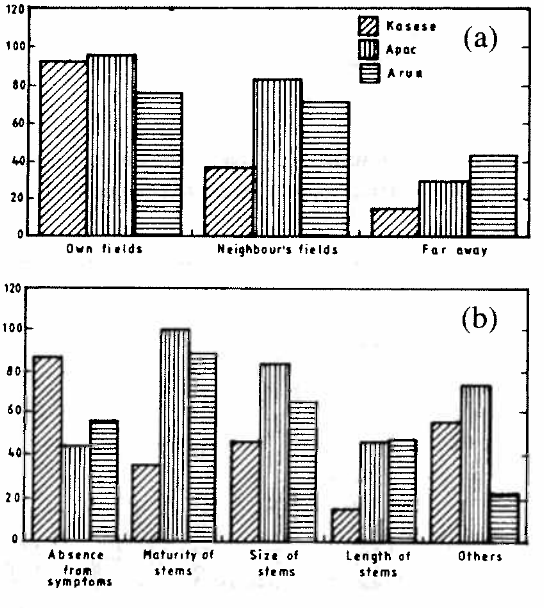

Figure 7. Sources of planting material (a) and criteria (b) for selecting planting material by farmers in Kasese, Apach and Arua districts of Uganda as percentages of total respondents.

heaped horizontally or upright under a shade for 2-14 days before planting.

Sources and frequency of new information on cassava disease problems. Friends, relatives and neighbours were important sources of new information on cassava diseases for farmers in all three districts. Radio, agricultural extension staff, local chiefs and agricultural scientists also provided new ideas for the farmers, but such sources were less important (Fig. 8a). Progressive farmers and politicians were also sources of new ideas for farmers in Apac district and to a limited extent for those in Arua. A substantial number of farmers in Kasese and Arua districts did not receive advice or new ideas from any source (Fig. 8a). The frequency of flow of new ideas to farmers varied between districts (Fig. 8b). Few farmers in Kasese district received new ideas as frequently as once or twice a year, while those in Apac and Arua received information either fortnightly, monthly or at least annually. However, a majority of farmers in all the districts either did not receive advice at all or did so very infrequently.

Developing ACMD control technologies relevant to farmers

Multilocational trials. There was no spread of ACMV to any of the varieties at the Namulonge site in either the 1989-1990 or 1990-1991 trials. Much spread occurred elsewhere to susceptible varieties and the maximum incidence of ACMD at each site in each of the cassava genotypes tested at four locations is shown in Table 1. The disease progress curves (not presented) showed consistent differences between varieties in both years and at all locations. Significant differences in the final incidence of infection were observed between locations and between genotypes within locations in each year and for all trials. At all locations in both seasons spread was most rapid in the local genotypes, especially at the Migyera (northern Luwero) and Kagando (Kasese) sites. Disease progress and maximum incidence in the TMS varieties were usually low at all locations and in all seasons, especially in TMS 30395 and TMS 30572 (Table 1). However, substantial spread occurred even in these varieties at the Kagando site of high inoculum pressure.

TABLE 1. Maximum percentage incidence of ACMD on cassava genotypes evaluated in multilocational experiments 1989-1990 and 1990-1991 and in Luwero on-farm trials in 1990-1991

Cassava varieties	Multilocational trials							On-farm trials in Luwero			
	1989-1990			1990-1991				1990-1991			
	Migyera (N.Luwero)	Bulisa (Masindi)	Mubuku (Kasese)	Kagando (Kasese)	Migyera (N.Luwero)	Bulisa (Masindi)	Mubuku (Kasese)	Kibengo	Wajjala	Nabiswera	Nakitoma
Ebwanateraka	100	92	28	99	99	98	69	79	99	95	29
Local check or Senyonjo	100	63	30	[illegible]	-	-	-	41	76	82	5
Bao	75	78	15	95	53	44	35	5	62	59	3
TMS 30786	80	56	30	90	32	22	50	7	44	56	0
Bukalasa 11	64	42	4	91	76	40	38	7	62	54	1
TMS 30337	25	5	23	83	3	9	30	9	42	38	3
TMS 60142	23	3	9	-	-	-	-	7	48	27	2
TMS 30395	12	5	2	28	5	14	2	-	-	-	-
TMS 30572	9	0	8	27	4	5	2	0	3	1	0

All five TMS genotypes showed an apparent decline in incidence of ACMD after reaching peak levels six to eight months after planting. Indeed, the proportion of plants showing ACMD symptoms in TMS 30572, TMS 30395 and TMS 60142 was usually low at the end of the growing season. This occurred because leaves with symptoms abscissed or symptoms became mild or obscured as the plants grew and a continuous canopy of foliage developed. None of the local genotypes behaved in this way and their behaviour was consistent in all locations in both seasons.

On-farm trials and farmers' criteria for adopting new varieties. Farmers considered resistance to ACMD, fresh root yield and cooked taste as primary criteria for accepting new varieties (Table 2). Other criteria such as suitability in the cropping system and the taste of raw roots were less important. Once the primary criteria were met, secondary ones became more important. These criteria and the importance attached to them by farmers were used to identify acceptable varieties. Each cassava genotype in the on-farm trials in 1990-1991 and 1991-1992 was scored

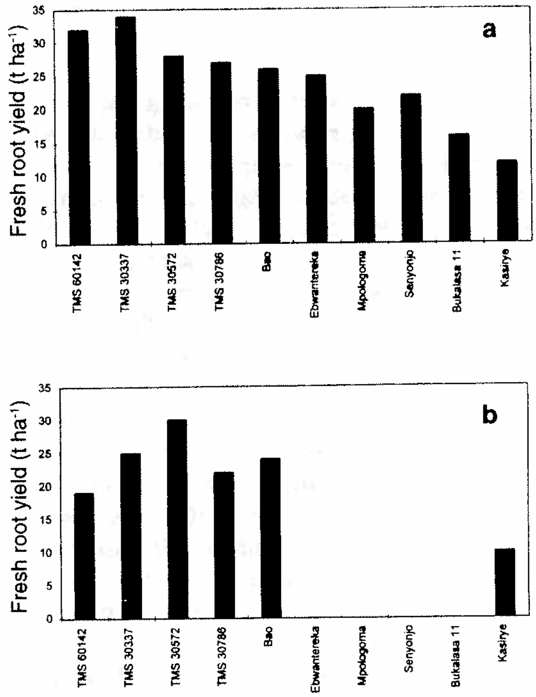

Figure 9. Fresh root yield of cassava genotypes in on-farm trials in northern Luwero district, 1990-91 (a) and 1991-1992 (b).

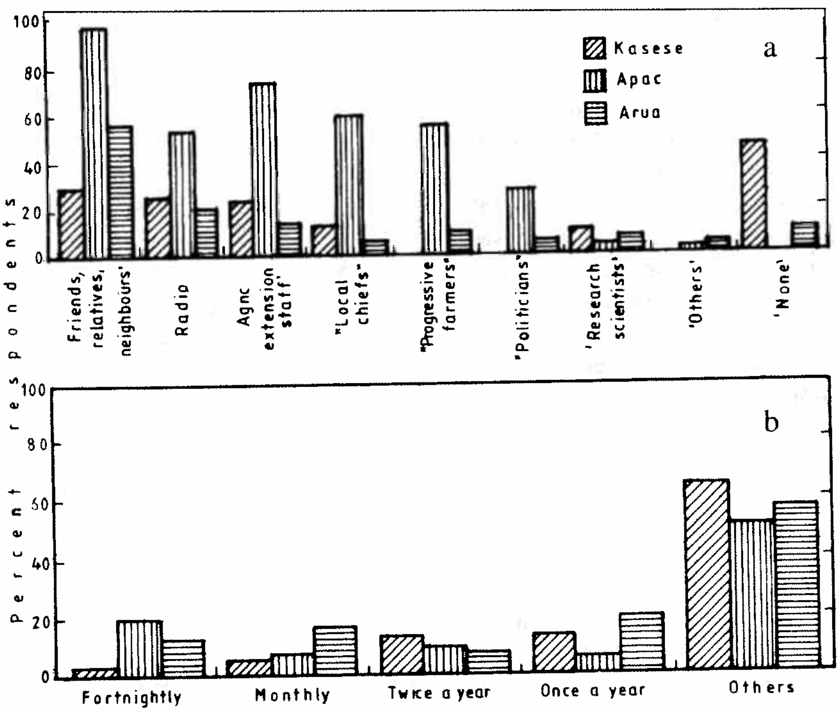

Figure 8. Farmers' knowledge of disease problems in Kasese, Apac and Arua districts of Uganda: (a) sources of advice, and (b) frequency of advice.

TABLE 2. Farmers criteria and weights for adopting new cassava varieties*

District	Resistance to ACMD		Root yield		Root raw taste		Root cooked taste		Suitability in cropping system	
	1991	1992	1991	1992	1991	1992	1991	1992	1991	1992
Lira	3.3	3.8	2.9	4.9	1.0	1.1	1.9	3.0	1.3	1.3
Masindi	2.7	3.7	3.3	4.3	1.0	1.9	3.0	2.0	1.9	2.6
Mpigi	2.6	4.3	2.6	3.9	1.9	1.9	1.9	3.3	1.9	2.8
Luwero	5.0	-	4.0	-	1.1	-	3.0	-	1.9	-
Apac	-	4.4	-	4.3	-	1.0	-	1.8	-	2.8
Mukono	-	4.5	-	3.9	-	1.1	-	1.7	-	1.4
Arua	-	3.8	-	3.4	-	1.6	-	1.2	-	3.6
Kibaale	-	4.2	-	4.0	-	1.3	-	2.0	-	3.5
Kasese	-	5.0	-	4.0	-	1.2	-	2.9	-	1.8
Hoima	-	3.9	-	4.6	-	1.0	-	2.9	-	2.1
Iganga	-	3.8	-	4.4	-	1.0	-	3.5	-	1.6
Masaka	-	3.0	-	3.3	-	1.0	-	3.5	-	2.4
Mubende	-	4.6	-	4.0	-	1.1	-	2.6	-	1.1

*Farmers in each district ranked each of the criteria on a 1 to 5 scale of increasing importance

and weighted for each farmer criterion (Fig. 9). Total values were calculated and the genotypes ranked and selected according to the total values. Fig. 10 shows data for northern Luwero, which is an area where ACMD spreads rapidly. The cassava genotypes TMS 60142, TMS 30337 and TMS 30572 consistently scored the highest values in all on-farm trials there and also in all other districts. They were officially released to farmers in 1994 as Nase 1, Nase 2 and Migyera, respectively.

Training of extension staff, opinion leaders and farmers formed an active part of the project. In 1991 all District Agricultural and Plant Protection officers in the country received training on the aetiology, epidemiology and control of ACMD. By 1992 all agricultural field extension staff in the project districts had also been trained on the disease, on improved cassava production methods and on rapid multiplication of planting material of improved varieties. The type of training and number of staff trained between 1991 and 1993 in selected districts is shown in Table 3.

Farmers' awareness campaigns were also conducted in all sub-counties of the five districts. The main aim was to create awareness of the ACMD problem, its spread and control and on methods of improved cassava production, including rapid multiplication and production of 'clean' planting material (Table 3).

Multiplication of planting material. Up to 35 ha of nuclear planting material were established at the Namulonge Agricultural and Animal Production Research Institute in each of the years 1991, 1992 and 1993. This material sufficed to plant 350 ha of improved varieties in 22 districts of the country in 1993. By the end of 1993, 466 ha of the improved varieties were being multiplied by individual farmers, farming groups and on government farms in 26 of the districts seriously affected by ACMD (Table 4). Several methods of distributing planting material were tried and evaluated in each district. It was concluded that an integrated approach was needed in order to meet the requirements of different situations. The advantages and disadvantages of each multiplication strategy are listed in Table 5.

TABLE 3. Number of District Agricultural Officers, subject matter specialists, and farmers trained in districts participating in the cassava multiplication project 1991-1993

Districts	District Agricultural Officers and subject matter specialists[1]			District Extension Staff[2]			Farmers Awareness Campaigns[3]	
	1991	1992	1993	1991	1992	1993	1992	1993
Mpigi	3	-	2	51	-	12	186	513
Apac	3	-	1	3	-	-	128	261
Luwero	3	-	2	8	-	-	122	461
Masindi	3	-	2	15	-	-	222	1,265
Lira	3	-	1	23	-	63	480	1,036
Others	41	25	17	110	110	-	-	-
Total	56	25	25	210	110	75	1,138	3,536

[1] Intensive two-week central workshop at Mukono district farm institute, Kampala.
[2] Intensive more practically oriented five-day workshop in districts.
[3] One-day awareness campaigns and demonstration on ACMD and methods of control, rapid multiplication and improved cassava production.

An integrated strategy for multiplication and distribution of planting material of improved varieties was developed from biological and socio-economic studies conducted since 1990. The system (Fig. 11) was designed to screen and generate ACMD-free stocks of virus-resistant varieties. It involves a series of activities in which the Uganda Root Crops Programme assembles germplasm from National Agricultural Research Systems, International Agricultural Research Centres and local sources. These materials are used in the breeding programme which aims at

TABLE 4. Cassava multiplication in different districts of Uganda during the period 1992/3.

District	Individual farmers	Groups and Institutional	Total
Apac (P)	10.1	15.5	25.6
Arua (F)	1.6	21.2	22.8
Gulu (N)	-	3.6	3.6
Kabarole (N)	2.2	0.2	2.4
Kampala (N)	-	4.3	4.3
Kiboga (F)	-	1.5	1.5
Kitgum (N)	-	0.3	0.3
Kumi (A)	-	15.0	15.0
Lira (P)	7.7	45.1	52.8
Luwero (P)	14.2	30.7	44.9
Masaka (F)	2.2	3.5	5.7
Masindi (P)	76.7	56.6	133.3
Mbale (N)	-	1.1	1.1
Mityana (F)	-	0.1	0.1
Moroto (N)	-	14.2	14.2
Moyo (N)	-	5.6	5.6
Mpigi (P)	4.6	56.5	61.1
Mubende (F)	-	2.4	2.4
Mukono (F)	-	6.1	6.1
Rakai (N)	-	0.6	0.6
Soroti (A)	-	17.1	17.1
Kamuli (N)	-	0.6	0.6
Hoima (F)	2.7	-	2.7
Iganga (F)	2.2	-	2.2
Kasese (F)	2.2	-	2.2
Mukono (F)	2.7	-	2.7
(Namulonge) (P)	-	(35.0)	(35.0)
Total	129.1	336.8	465.9

P = Districts covered by the Cassava Multiplication Project supported by the UK Gatsby Charitable Foundation.
F = Districts covered by the Farming Systems Support Programme (FSSP) supported by EEC.
A = Districts covered by the World Bank - supported Agricultural Development Programme (ADP).
N = Districts supported by NGO's.

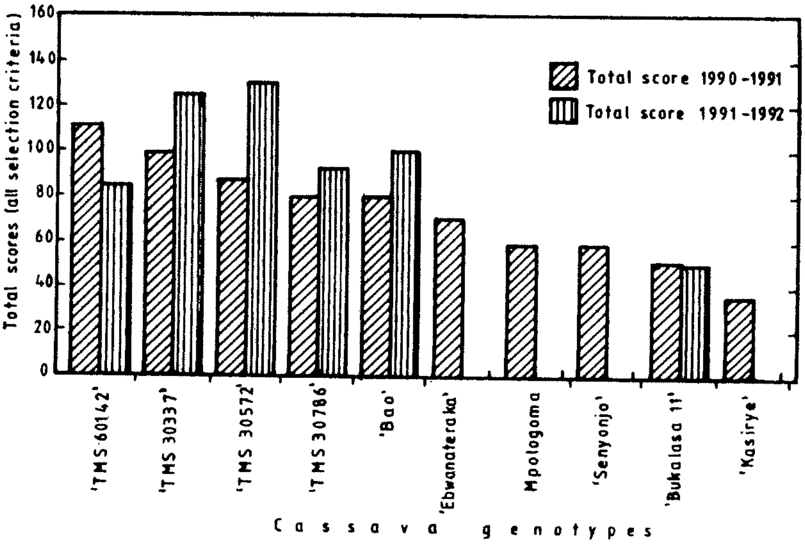

Figure 10. Total scores (all selection criteria) for cassava genotypes in on-farm trials in northern Luwero during 1990-1991 and 1991-1992.

TABLE 5. Advantages and disadvantages of each multiplication strategy

Advantages	Disadvantages
(a) Institutional multiplication	
Facilitates effective weed management	It is expensive to maintain and distribute planting material
Ensures good quality planting material	Remote from most farmers
Easy decision making on distribution of planting material to the target areas	Prone to theft
Facilitates ratooning of the planting material	Distribution subject to 'political' interference
Strengthens interaction among all parties involved in research, multiplication and distribution	Slow distribution of sufficient planting material to the farmers
Facilitates protection from animal damage	Difficult for farmers to appreciate the performance of the varieties
(b) Individual multiplication	
Facilitates proper management of sites	Much work for one person
Full personal responsibility	Slow
Host has first access to planting material	Theft of material by non-hosts
Those involved receive more material	Some farmers are selfish
Farmers motives sincere	Less land for multiplication sites
Hosts benefit from tuberous roots	Host disliked by non-hosts
Hosts can multiply as much as possible	Scope for bias in selecting hosts
Multiplication is faster	Inadequate time and money to manage the site
Individuals follow advice carefully	Few individuals have access to material
Easier for researchers to work with individuals	Labour problems
Easier for local authorities to identify responsible people	
(c) Group multiplication	
Multiplication is faster	Members may not cooperate
Activities are shared	Misunderstandings on distribution of material
Knowledge is shared	May be inequitable distribution
Less work per individual	Promotes laziness
Facilitates information exchange	Lack of ownership
More farmers have access to planting material	Problem of who provides land
Distribution of planting material is easy	

developing elite ACMD-resistant genotypes. Further, the Root Crops Programme links with extension agents, local leaders and NGOs by way of training and conducting on-farm trials to assess the performance of genotypes.

The cassava genotypes that are accepted by farmers enter the foundation and institutional multiplication stages. Any infected plants that occur are removed (rogued) to ensure that only ACMD-free stems are distributed to groups of farmers and individual large farmers. Training and roguing are practised at all stages of multiplication so as to create awareness of the production of disease-free material for the resource-poor farmers who each grow cassava in small quantities. Roguing is done to complement the resistance of the genotypes to ACMD. This is because on-farm multiplication is often in conditions of high infection pressure due to the activity of the whitefly vector.

In order to multiply and distribute 'clean' planting material, all key players in the development, transfer and adoption of cassava genotypes should be well integrated. This enables 'feed back' to be obtained on the performance of each genotype at each stage of development and multiplication so as to determine the quantity of each genotype to be multiplied in a particular infection pressure area of the country.

DISCUSSION

Farmers' indigenous knowledge and practices for controlling ACMD. Results from this study

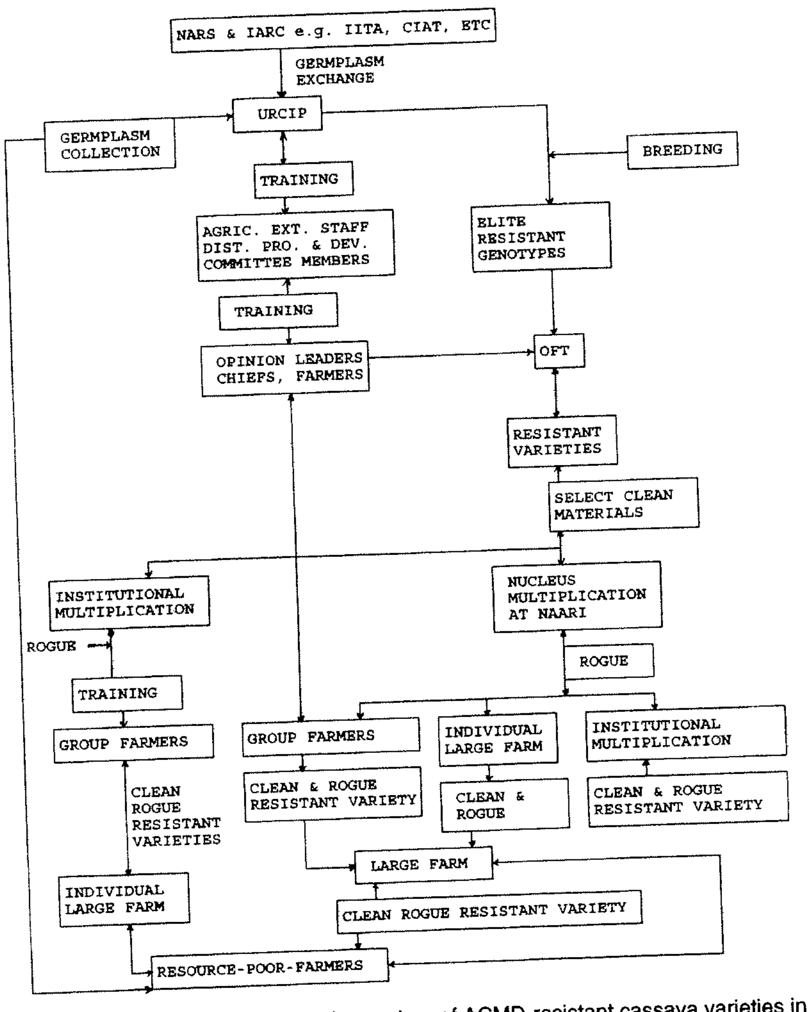

Figure 11. Flow diagram of integrated multiplication system of ACMD-resistant cassava varieties in Uganda

established that farmers were aware of the importance of ACMD and attempted to control the disease through the use of varieties considered to be resistant and also by selection of healthy planting material, roguing and by changing varieties. Consequently, developing acceptable technologies for control of the disease should centre around these key measures. Evidence also suggests that many varieties resistant to ACMD and of diverse genetic constitution, agronomic and cooking qualities were needed by farmers in order to meet their continually changing needs. Farmers depend heavily on friends, relatives and neighbours for new technologies and information on cassava. Consequently, to accelerate transfer of new technologies and information, they should be brought close to the farmers. Multiplication of ACMD-resistant varieties and training of extension staff and farmers is necessary and should be done not only in districts but also in sub-counties and villages within the districts concerned.

Developing ACMD control technologies relevant to farmers

Multilocational and on-farm trials of the improved genotypes enabled identification of four TMS genotypes suitable for the diverse local and farmers' conditions. These genotypes were evaluated by farmers and the three most acceptable to farmers were released for multiplication and commercial production. Since release, the varieties have remained very popular among farmers and the demand for additional planting material has been overwhelming.

Results from this study further reveal that farmers considered resistance to ACMD and the taste of the tuberous roots as important criteria for the adoption of new varieties, and were not only concerned with increased yields, as is often assumed. Indeed, farmers are able to accept genotypes with apparent limitations such as low yields if what they perceive as the priority constraints have been overcome. Future efforts at developing technologies should, therefore, not only concentrate on improved yields but also on the main constraints as perceived by farmers. To develop technologies acceptable to farmers, suitability in local environments must be proven in multi-locationsl trials. Moreover, the technologies should be tested in on-farm trials to identify their performance under farmers' conditions and they must be evaluated by farmers on their own criteria.

Removing obstacles to adoption of new ACMD control technologies

The main weaknesses of the extension service were addressed by creating a network and by providing training and motivation by means of incentives and transport for extension staff. Consequently, extensionists made close contact with farmers and provided them with new technologies and timely information so that such technologies became more easily available. The farmers' training and awareness programmes brought the new varieties, other technologies and new information even closer to other farmers who had not known about them before. The catalytic effect of this was that farmers who had acquired new technologies or ideas on ACMD control were able to share with neighbours, friends and relatives and resulted in rapid spread of the new ACMD-resistant varieties and other control technologies within the project areas.

The national network played a key role in the dissemination of new information and technologies to clients and in providing feedback to scientists, administrators and policy makers. It stimulated and strengthened close linkage between policy makers, researchers, extensionists and farmers through planning and setting priorities for research, training of other extension staff and farmers and by developing and disseminating appropriate and sustainable technologies for ACMD control.

Three approaches were adopted for multiplication of planting material of ACMD-resistant varieties in the project districts. This was at institutional farms, by groups and by individual farmers. The experience gained indicates that each approach has its own advantages and disadvantages and is suitable for particular circumstances (Table 5).

Institutional multiplication depends on the availability of government, school or college land and the willingness of the authorities concerned to make such land available. The system is expensive to initate and manage, and requires constant supervision by cassava programme or extension staff. However, either the district or the cassava programme staff have total control and ownership of the stems and so are able to manage production to the standard required. They can also control the distribution of the planting material. Such an approach is satisfactory where finance, manpower and skills are adequate to produce and distribute high quality planting material, as required in initiating nuclear multiplication centres.

Using existing farming groups or individual farmers for multiplying planting material is cheaper and less demanding on the time of extension or research staff because all planning, implementation, management and distribution is done by farmers. Moreover, a sense of ownership of the material is instilled in the farmers from the outset, thus ensuring sustainability. The distribution of material is influenced by social relationships rather than political influences and it is possible to avoid the difficulties that arise if it becomes necessary to enforce the transfer of material from one place to another when no concensus has been reached with farmers. The use of groups also ensures rapid uptake of new varieties in an area. Being close together, many farmers become aware of the technology and become interested in acquiring it. The biggest disadvantage is that extension or cassava staff do not have full control over the quality, quantity and manner in which the material is produced and distributed. The success of the group approach depends greatly on the quality of leadership, commitment and cohesion of the groups and on the availability of land. Extension staff find that individual farmers are more difficult to advise and/or supervise on the management and distribution of planting material.

Experience gained from this study shows that the socio-economic circumstances and resources and the ACMD infection pressure encountered influence the choice of multiplication and distribution system to adopt. Under conditions of high ACMD infection pressure, varieties to be introduced, tested on-farm, selected and multiplied for distribution should be highly resistant. Virus-free material of such varieties should be selected, planted and rogued to avoid degeneration of the material and ensure availability of 'clean' stocks for subsequent distribution. The study further suggests that it is necessary to select existing groups of farmers who share a common agricultural goal. Such a social set-up ensures cohesion, sustainability and cost effectiveness. Adequate land should be available to facilitate multiplication of planting material in large blocks for at least two propagation cycles before distribution in small lots to individual farmers.

It is concluded that indigenous knowledge must be acquired and utilised in order to accelerate transfer of agricultural production technologies. The value of such new technologies must be tested in different agroecological conditions and farmers' circumstances, and the best technologies should be selected based on farmers' criteria and priorities. Finally, obstacles to adoption must be identified and eliminated.

The experience described here was gained in responding to the crisis caused by the current severe epidemic of ACMD. The approach adopted was dependent on the cooperation of farmers and their willingness to adopt new varieties and cropping practices. This necessitated a big, difficult, time-consuming and expensive extension effort in order to disseminate the technical information and planting material required. The response to the problem posed by cassava mealybug *Phenacoccus manihotis* Mat-Fer. in Uganda and elsewhere in Africa has been very different as there has been an almost total reliance on biocontrol. This was achieved by the release of introduced natural enemies, of which the parasitoid *Epidinocarsis lopezi* (De Santis) is the most important (Neuenschwander, 1994). Once introduced and established the parasitoid has spread rapidly without the need for any further intervention by crop protection personnel. Farmers have played little role in the biological control programme which has been the responsibility of International and National programmes scientists. Thus the enormous logistical and other problems of providing adequate planting material and of contacting vast numbers of farmers and in seeking to influence their attitudes and practices have been largely avoided. The contrasting experiences and approaches adopted in the campaigns to control

ACMD and cassava mealybug are important in mounting an effective response to other pest, disease and weed problems of cassava in Africa.

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