Why sustainable management of xanthomonas wilt of banana in east and central africa has been elusive

Article *in* Acta Horticulturae · April 2013

DOI: 10.17660/ActaHortic.2013.986.16

CITATIONS
18

READS
222

8 authors, including:

W. Tinzaara
Consultative Group on International Agricultural Research
67 PUBLICATIONS **1,003** CITATIONS
SEE PROFILE

Eldad B. Karamura
Consultative Group on International Agricultural Research
95 PUBLICATIONS **1,598** CITATIONS
SEE PROFILE

Guy Blomme
Bioversity International
226 PUBLICATIONS **2,605** CITATIONS
SEE PROFILE

Wellington Jogo
International Potato Center
37 PUBLICATIONS **410** CITATIONS
SEE PROFILE

Why Sustainable Management of Xanthomonas Wilt of Banana in East and Central Africa Has Been Elusive

W. Tinzaara[1], E.B. Karamura[1], G. Blomme[1], W. Jogo[1], W. Ocimati[1], A. Rietveld[1], J. Kubiriba[2] and F. Opio[3]
[1] Bioversity International, Plot 106, Katalima Road, PO Box 24384, Kampala, Uganda
[2] National Agricultural Research Organization, PO Box 7065, Kampala, Uganda
[3] Association for Strengthening Agricultural Research in East and Central Africa (ASARECA), PO Box 295, Entebbe, Uganda

Keywords: awareness, disease transmission, management options, resurgence, *Xanthomonas campestris* pv. *musacearum*, yield

Abstract

Banana is an important food and cash crop and constitutes a large proportion of the total crop production in East and Central African (ECA) countries. Banana production has been threatened by Xanthomonas wilt (BXW) disease caused by the bacterium *Xanthomonas campestris* pv. *musacearum*. Besides being a threat to food security in the region, the disease has severe economic implications, which emanate from yield losses and management costs. Without proper management, yields in affected areas are reduced to zero. Management approaches of the disease include use of cultural practices and awareness creation among the stakeholders along the banana value chain. These efforts to control the disease produced partial results, and the disease has continued to encroach into previously disease-free areas and to resurge in areas where it had been controlled. One of the major challenges to sustainable management of the disease has been poor understanding by stakeholders of the factors influencing disease spread and severity. Awareness creation among stakeholders has not been sustained due to limited technical, financial and infrastructural capacity. Incorrect application of cultural practices and lack of appropriate methods for field disinfection of tools coupled with weak institutional frameworks for enforcing byelaws and quarantine measures are key drivers to the continued presence of the disease in ECA. It should however be emphasized that no single management option is adequate to sustainably manage the disease. In this paper, we review mechanisms of disease transmission and drivers of the continued disease presence, and suggest approaches for sustainable management of BXW.

INTRODUCTION

Banana is a major staple food, supplying up to 25% of carbohydrates for approximately 70 million people in tropical and subtropical Africa (FAOSTAT, 2006). The East and Central Africa (ECA) subregion alone produces about 20 million tons annually (FAOSTAT, 2006). Despite the key position of banana in the region's food security, smallholder farming communities engaged in its production derive inadequate income from it. The crop is threatened by various constraints including socioeconomic problems (poor market access, high crop management costs, limited postharvest handling/utilization), declining soil fertility, pests (banana weevil, nematodes) and diseases (black leaf streak, Fusarium wilt, banana streak virus disease and banana bunch top disease) (Gold et al., 2001; Tushemereirwe et al., 2004; Bagamba et al., 2006; Ndungo et al., 2006). Xanthomonas wilt of banana (BXW), caused by *Xanthomonas campestris* pv. *musearum* (Xcm), has become a new and serious challenge to banana production in ECA.

Bacterial wilt diseases have been destructive to banana production in Indonesia (blood disease), Latin America (Moko) and the Philippines (Bugtok) (Molina, 1999). The Xcm pathogen that causes bacterial wilt of Enset (*Ensete ventricosum*) and banana in Ethiopia spread to central Uganda and eastern Democratic Republic of Congo (DRC) in 2001. In Uganda, the disease was first reported on bananas in the Mukono and Kayunga

districts (Tushemereirwe et al., 2003), while in DRC the disease first appeared in Masisi, North Kivu (Ndungo et al., 2006). The disease subsequently spread to Rwanda, Kenya, Tanzania and Burundi (Karamura and Tinzaara, 2009). All banana germplasm in eastern Africa, including endemic highland cooking and brewing cultivars (AAA-EA), exotic brewing, dessert and roasting types (AB, AAA, AAB, ABB) and hybrids, are susceptible. No cultivar with meaningful BXW resistance has so far been identified (Ssekiwoko et al., 2006). Some ABB cultivars, e.g., 'Pisang Awak', are particularly susceptible to insect vector transmission and are believed to facilitate the rapid spread of the disease (Tushemereirwe et al., 2003).

The impact of BXW is both extreme and rapid, unlike those of many other diseases, which cause gradually increasing losses over years. The economic impact of BXW is due to death of the mother plant that would otherwise contribute to the ratoon plant production cycles. This disease has similarities to other bacterial wilts of banana, caused by *Ralstonia solanacearum* (Thwaites et al., 2000). Once these pathogens have become established, disease control is very difficult and eradication impossible (Eden-Green, 2004). In ECA, there are cases where the disease has been eradicated while there are cases where the disease is persistent (Karamura and Tinzaara, 2009). There are also areas where the disease has been controlled but only to resurge a few months later. In this paper, we review BXW transmission pathways, control measures that have been used by farmers and indicate those that worked or failed to work, discuss the drivers of continued disease presence in specific areas of the region, and suggest approaches that can enhance the sustainable management of the disease in ECA.

DISEASE TRANSMISSION

Insect transmission is believed to be behind the BXW epidemic, along with the use of contaminated tools and infected planting materials. Insects are an important vector in transmission of the disease over short distances through floral parts (Tinzaara et al., 2006). Healthy plants are infected when the bacteria are carried by insects from oozing peduncles to fresh cushions on the peduncle from which male flowers/bracts have recently dehisced. In Uganda, the most important insect species in general are honey and stingless bees, drosophilids, chloropids and wasps, although the composition and abundance of insect species depend on the geographic location (Tinzaara et al., 2006). The rate of spread of the disease by insects is affected by the suitability of the environment to the development of the insect vectors. For example, it has been noted that the rate of spread in DRC is much slower from farm to farm but higher within the farm than that in Uganda, suggesting that environmental factors may be in play (Mwangi et al., 2006). Temperatures are lower at higher altitudes than at lower altitudes, which decreases insect activity and their geographic distribution range (Coakley et al., 1999). Disease spread by insects is also highly affected by the cultivar's inflorescence traits (e.g., quantity of nectar, persistence of male bracts and flowers) (Tripathi et al., 2009). Banana cultivars which have persistent male flowers and/or male bracts do not allow insect contamination, as no open wounds are created on the rachis.

Tools are another important transmission route of BXW, especially in East African highland banana cultivars (Tinzaara et al., 2009). Mechanical injuries can be inflicted on plants during farm operations, e.g., during harvesting, removing dry leaves, desuckering or corm-paring prior to planting. Tool infection is also very important in the trading system where sellers pass from field to field, using the same tools to harvest mature bunches.

Transmission over long distances is believed to be largely due to human activities (such as the movement of infected plants and plant parts). Isolated outbreaks at a distance from known affected areas may suggest that banana material is being exchanged widely and across international boundaries. Like insects, various small birds are commonly found collecting nectar from male buds and may pose a serious threat when it comes to long-distance transmission, as their flight range is considerably larger than that of insects. Studies carried out by the National Agricultural Research Organization (NARO), Uganda,

have revealed the presence and persistence of bacteria on various birds' beaks (Buregyeya, 2010). On the other hand, some big birds (like hornbills) are suspected of long-distance transmission of the disease. These large birds visit banana fields and often jump from leaf to leaf, during their search for ripe fruits or bunches. Bacteria attached to their sharp claws and beaks can thus be transmitted from plant to plant. Monkeys, porcupine, cows, goats and sheep can also transmit the disease while browsing on a healthy plant after having browsed on a contaminated one.

CONTROL STRATEGIES AVAILABLE TO FARMERS

A clear understanding of the etiology and epidemiology of the BXW epidemic is key to effective control of the disease. It is also very important to understand the key epidemic drivers and their respective magnitudes, as well as understanding disease vector relationships. It is also crucial that a viable control programme should be regularly monitored to ensure that planned actions are executed, corrective adjustments are made in time and lessons learnt are documented.

The existing control options are largely derived from assumptions based on the experience from other similar diseases. The recommended methods to control BXW disseminated in the region include destruction and disposal of infected plants, disinfecting tools used in the plantation, using clean planting material, removing male buds, keeping browsing animals out of infected fields and quarantine measures. While these measures, if adhered to, will contribute to slow the spread of the disease, they hardly constitute a remedy in already infected areas and do not offer promise for long-term control of the disease, considering the rapid spread of BXW (Karamura and Tinzaara, 2009). Moreover, no single method seems to provide a 'silver bullet' for the management of BXW in ECA. An integrated approach remains the most feasible option, involving surveillance of disease outbreak, use of cultural control practices and awareness creation among all stakeholders (Tinzaara et al., 2009).

DRIVERS OF CONTINUED DISEASE PRESENCE IN ECA

In some parts of ECA, especially in Uganda, there are cases where the disease has been successfully eradicated but there also areas where the disease has been controlled only to resurge a few months later (Karamura and Tinzaara, 2009). Sustainable management of the disease seems to be elusive. The key drivers of the epidemic in ECA include highly susceptible host cultivars, ineffective control options, limited access to clean planting material, limited level of farmer awareness and institutional mechanisms in place.

Host Cultivars

The key drivers of bacterial epidemics include a highly disease-susceptible cultivar. The ABB cultivars are said to have high sugar content in the flower nectar which attracts a diversity of insects from where the bacterium has been isolated (Table 1). In ECA, the ABB genome is represented by two main cultivars: 'Kayinja' or 'Pisang Awak' and 'Silver Bluggoe' (also called 'Kivuvu'); these cultivars are grown in most areas of the region. In Central Uganda, for example, the cultivation of 'Kayinja' over large lowland areas (rich in insect fauna) is said to have enhanced the development of the BXW epidemic in that region (Tushemereirwe et al., 2004). The same cultivar occupies the Lake shores in DRC where BXW epidemic started (Ndungo et al., 2006).

Control Methods

While the host plant may be a pre-requisite for driving the disease epidemic, some cultural agronomic practices can also be extremely important. Cultural control practices including the timely removal of male buds (de-budding), total destruction of infected mats, use of disinfected farm tools, and use of clean planting material have been recommended, based on their effectiveness in controlling other banana bacterial wilts in Latin America and Asia. These practices provide an effective way of reducing the

inoculum in infested fields (Tushemereirwe et al., 2004; Blomme et al., 2005).

These methods have been widely promoted and proved to be very effective in controlling BXW in some parts of ECA using community action and other participatory methods, such as farmer field schools (FFS) (Karamura and Tinzaara, 2009). The majority of farmers in most East African communities are aware of BXW control options (Jogo et al., 2011). However, adoption of the control measures is generally low (Jogo et al., 2011), thereby further limiting the potential for success for control of the disease. In Uganda, for instance, gardens of 'Kayinja' are rarely weeded and their male buds are not removed (as is the case for East African highland bananas). The presence of male buds in 'Kayinja' can initiate and drive an epidemic through insect transmission. For this reason, the likelihood of epidemics could be reduced by massive campaigns to debud all banana flowers. Jogo et al. (2011) report the challenges to adoption of BXW control methods, which include: (i) difficulties in persuading farmers to destroy diseased mats; (ii) labour-intensiveness of measures for destroying diseased mats; (iii) costly and non-user friendly disinfectants; (iv) negative attitudes towards unfamiliar technologies; and (v) lack of integrated packages for disease and pest management. These challenges have resulted in the continued spread of the disease in ECA.

Access to Planting Material

Supply of clean planting material is crucial to sustained food security in areas affected with BXW. Farmers usually obtain their planting material by removing suckers from their own fields or neighbors' fields, or by purchasing such self-produced suckers from the neighborhood. The main reason for this farmer behavior is the high cost and availability of planting material produced by other means such as micro-propagation. In fact, farmers have generally limited access to sources of tissue culture or macro-propagation material. This increases therefore the risk of obtaining suckers from unregulated sources that could be carrying BXW. Supporting the establishment of community-based, private-sector-driven banana multiplication schemes could provide sufficient safe, clean planting material. This would encourage farmers to destroy their diseased plants for sustainable production when threatened by BXW. The use of macro-propagation technology to rapidly multiply clean planting material for improved and preferred banana cultivars has been promoted in the region. However, farmers still need to be organized in groups to understand the benefits of the improved technology (Njukwe et al., 2011). Cross-border policies with respect to banana planting material and products need to be reviewed to reduce trans-boundary movements of infected material. Policies should be harmonized across the region and between countries.

Farmer Awareness Levels

Farmers' knowledge about disease diagnosis is very important in the management of the epidemic. Most farmers in ECA confuse BXW with Fusarium wilt and as result control measures are not targeted to the epidemic (Karamura and Tinzaara, 2009). The continued presence of the disease is partially attributed to both inadequate knowledge and sensitization of farmers, local leaders, extensionists and other stakeholders along the banana value chain. The quality of stakeholder response will depend on the quality of messages received. All key stakeholders need to be given clear and appropriate messages, stating what needs to be done by whom, how, where and when so that they in turn can play their roles effectively. Message design should consider the nature of the content, the medium and the time of transmission to achieve the maximum and predictable effects on all who receive them.

There are communication channels which have been identified to work effectively in many parts of ECA (Table 2) (Tinzaara et al., 2009). Several others such as televisions and phone text messaging can be used to communicate control messages but are not readily available or accessed by farmers. Posters, pamphlets, leaflets, brochures and billboards have been disseminated to different stakeholders but the challenge to their effectiveness is that these are sometimes designed without considering the level of

literacy in the target areas and population. These communication channels need to be evaluated and those that work well be identified and promoted in the region. The choice and nature of the communication strategies should take into account the capacity (literacy levels, numbers of radio receivers, extension support) available in the target area.

Continued existence of the disease has also been attributed to limited understanding of the magnitude of the disease problem by farmers and other stakeholders. The farmers need to be empowered to effectively own the problem and this should include all stakeholders along the value chain. Stakeholder empowerment is greatly boosted if effective communication strategies with clear messages are in place. In Uganda, a concept of participatory development communication was adopted to better reach out to the public with BXW control messages (Tushemereirwe et al., 2006). The approach centres on facilitating communities to develop action plans to address specific problems facing them. It uses visual tools to attract attention in public places like markets, churches and schooldays in order to communicate to the public about the disease symptoms, spread and control measures and to solicit their support in the control campaigns. Collectively, these approaches have been termed "going public" (Tushemereirwe et al., 2006). Although these approaches may lead to sustainable management of the disease, they are still localized in few areas and there is need to be scaled up and out in the region.

Solid surveillance mechanisms are crucial in the control of the disease. The mobile phone (and text messaging) system has been successfully piloted in Uganda for purposes of information flows on disease surveillance and control for BXW (Tushemereirwe et al., 2006). It is a bidirectional, immediate communication between science (disease diagnosis and control) and practice (grower's observations and needs). The approach involves having competently trained community knowledge workers who can train the local communities. The local communities then provide government and researchers with information on disease occurrence through text messaging. This provides opportunities for obtaining a wealth of data previously not available and accrued in a cost effective manner. Currently, there is lack of national and regional surveillance and monitoring mechanisms which are necessary for the management of the disease. The potential of scaling out the technology in other ECA countries should be explored and its application widened to manage various disease and pest occurrences.

Institutional Mechanisms

Another important aspect that is integral to the effective delivery of control options is the need to coordinate strategies in order to exploit synergies and save resources. This includes both coordination within countries and between countries so that efforts deployed by one team in one location or country are re-enforced in the other. In countries where successes have been registered, there are national action plans at different levels that promote effective information delivery and control coordination strategies. In Uganda, a national action plan was established with a steering committee made up of senior management from agriculture sector ministries to provide policy guidance and mobilize resources for the BXW control initiative. Under the steering committee, a technical committee coordinates all the research and extension activities and is itself made up of technical working groups on research, surveillance, public awareness and information packaging and dissemination (Tushemereirwe et al., 2006). Task forces were formed at different levels, from national level up to village level. In most parts of the region, however, such BXW action plans are lacking.

The FFS approach has worked in Uganda to effectively disseminate and equip farmers with knowledge to control the disease (Kubiriba et al., 2012). FFS is a community-based approach that empowers farmers to make logical crop management decisions, exposes farmers to new ways of thinking and problem solving, and encourages them to implement and discuss own solutions. FFS also shortens the time between the emergence of findings from research stations to their adoption, and facilitates the building of coherent farmer groups able to demand services. The FFS approach has been recently

initiated in Kenya but is not practiced in all other countries of the region.

There is limited regional collaboration among the stakeholders of affected countries to control the disease. This disease knows no borders and has systematically spread to all countries within the region. At a regional level, the Banana Research Network for Eastern and Southern Africa (BARNESA) provides the regional frame for the affected countries to collaborate on the BXW control. Through the BARNESA framework, technologies and approaches developed and disseminated in Uganda were transferred to all countries affected by the wilt.

Quarantine measures are taken to exclude and contain the disease through minimizing spread of the pathogen. They are used to supplement other disease management practices. In Uganda, after the outbreak of the disease at the district level, each district was imposing local quarantine on infected areas (Tushemereirwe et al., 2004). Quarantine measures can be reinforced with byelaws and other policy innovations but this requires appropriate institutional frameworks, such as task force formation or implementation to make them work**.** Trade in banana products within ECA is one of the potential spread pathways of BXW. Bananas are usually wrapped with banana leaf sheaths to protect them from damage during transportation and are transported over long distances from production areas to market. Quarantine application within and between countries is not an easy task. In addition, cross-border policies to enforce quarantine measures are lacking in the region.

CONCLUSION

BXW continues to be present in banana cropping systems in ECA, although within each agro-ecology, there are still pockets of disease-free but threatened areas. Several methods such as cultural control, awareness creation and quarantine have been recommended to farmers but adoption of the measures is generally low and the disease is still spreading across the region. The farmers lack leadership to integrate a sustainable management of BXW in their cropping systems and do not practice the recommended cultural control options. The farmers also expect immediate results from recommended control measures and, when these are not achieved, they are discouraged and abandon the management practices. The methods and other experimentally effective strategies need to be improved through basic research while emerging effective strategies need massive scaling up and out (within and across borders) in the quest to generate and promote demand-driven technologies and innovations and to maximize impacts. On the other hand, national and international NGOs and research institutes have not yet identified resistant cultivars and effective management programs to critically high disease levels. It will be vital for crop protection managers in ECA to incorporate BXW into the national integrated pest and disease management programs, and to develop and mainstream knowledge of BXW biology and control into informal and formal curricula in order to strengthen the sustainability of the control measures of the disease.

Literature Cited

Bagamba, F., Kikulwe, E., Tushemereirwe, W.K., Ngambeki, D., Muhangi, J., Kagezi, G.H. and Green, S. 2006. Awareness of Banana bacterial wilt control in Uganda. Farmers' perspective. Afr. Crop Sc. J. 14:157-164.

Blomme, G., Mukasa, H., Ssekiwoko, F. and Eden-Green, S. 2005. On-farm assessment of banana bacterial wilt control options. African Crop Science Society Conference Proceedings, Entebbe, Uganda, 5-9 December 2005. p.317-320.

Buregyeya, H. 2010. Evaluation of the Contribution of Birds, Bats and from Tools in the Long Distance Transmission of Banana Bacterial Wilt in Uganda. M.Sc. Thesis. Makerere University, Kampala.

Coakley, S.M., Scherm, H. and Chakraborty, S. 1999. Climate change and plant disease management. Ann. Rev. Phytopath. 37:399-426.

Eden-Green, S. 2004. How can the advance of banana Xanthomonas wilt be halted? InfoMusa 13:38-41.

FAOSTAT Agriculture Data. 2006. http://apps.fao.org.
Gold, C.S., Pena, J.E. and Karamura, E.B. 2001. Biology and integrated pest management for the banana weevil, *Cosmopolites sordidus* (Germar) (*Coleoptera*: *Curculionidae*). Int. Pest Manag. Rev. 6:79-155.
Jogo, W., Karamura, E.K., Kubiriba, J., Tinzaara, W., Rietveld, A., Onyango, M. and Odongo, M. 2011. Farmers' awareness and application of banana Xanthomonas wilt control options: the case of Uganda and Kenya. J. Dev. Agric. Econ. 3:561-571.
Karamura, E. and Tinzaara, W. 2009. Management of Banana Xanthomonas wilt in East and Central Africa. Proceedings of the workshop on the review of the strategy for the management of banana Xanthomonas wilt, 23-27 July 2007.
Kubiriba, J., Karamura, E.B., Jogo, W., Tushemereirwe, W.K. and Tinzaara, W. 2012. Community mobilization: a key to effective control of banana xanthomonas wilt. J. Dev. Agric. Econ. 4(5):125-131.
Molina, A.B. 1999. Fruit root disease for cooking banana in South East Asia. InfoMusa 8:29-30.
Mwangi, M., Tinzaara, W., Vigheri, N., Namu, F.N., Ragama, P. and Bandyopadhyay, R. 2006. Comparative study of banana Xanthomonas wilt spread in mid and high altitudes of the Great Lakes region of Africa. Tropentag symposium 2006, Bonn, Germany. http://elewa.org/pestdseagric.html.
Ndungo, V., Bakelana, K., Eden-Green, S. and Blomme, G. 2006. An outbreak of banana Xanthomonas wilt (*Xanthomonas campestris* pv. *musacearum*) in the Democratic Republic of Congo. InfoMusa 13:43-48.
Njukwe, E., Ouma, E. and van Asten, P. 2011. Challenges and opportunities for macropropagastion for *Musa* among small holder farmers and small and medium scale enterprises. Abstracts of the Conference on Challenges and Opportunities for Agricultural Intensification of the Humid Highland Systems of Sub Saharan Africa, Kigali Rwanda, 23-27 October 2011. p.127.
Ssekiwoko, F., Taligoola, H.K. and Tushemereirwe, W.K. 2006. *Xanthomonas campestris* pv. *musacearum* host range in Uganda. Afr. Crop Sc. J. 14:111-120.
Thwaites, R., Eden-Green, S. and Black, R. 2000. Diseases Caused by Bacteria. p.213-239. In: D.R. Jones (ed.), Diseases of Banana, Abacá and Enset. CABI Publishing, Wallingford.
Tinzaara, W., Karamura, E.B., Kubiriba, J., Byabachwezi, M., Tushemereirwe, W. and Opio, F. 2009. The integrated approach for the management of banana Xanthomonas wilt in East and Central Africa. African Crop Science Proceedings 9:691-696.
Tinzaara, W., Gold, C.S., Ssekiwoko, F., Tushemereirwe, W., Bandyopadhyay, R., Abera, A. and Eden-Green, S.J. 2006. The possible role of insects in the transmission of banana Xanthomonas wilt. Afr. Crop Sc. J. 14:105-110.
Tripathi, L., Mwangi, M., Abele, S., Aritua, V., Tushemereirwe, W.K. and Bandyopadhyay, R. 2009. Xanthomonas wilt: a threat to banana production in East and Central Africa. Plant Disease 93:422-451.
Tushemereirwe, W.K., Okaasai, O., Kubiriba, J., Nankinga, C., Muhangi, J., Odoi, N. and Opio, F. 2006. Status of Banana Bacterial Wilt in Uganda. In: Banana Bacterial Wilt in Uganda: A disease that threatens livelihoods. Afr. Crop Sc. J. 14:74-82.
Tushemereirwe, W., Kangire, A., Ssekiwoko, F., Offord, L.C., Crozier, J., Boa, E., Rutherford, M. and Smith, J.J. 2004. First report of *Xanthomonas campestris* pv. *musacearum* on banana in Uganda. Plant Path. 53:802-802.
Tushemereirwe, W., Kangire, A., Smith, J., Ssekiwoko, F., Nakyanzi, M., Kataama, D., Musiitwa, C. and Karyeija, R. 2003. An outbreak of bacterial wilt on banana in Uganda. InfoMusa 12:6-8.

Tables

Table 1. Insect families from where *Xanthomonas campestris* pv. *musacearum* was isolated after visiting infected bananas.

Family	Common name	Abundance
Apinae	Stingless bees	***
Drosophilidae	Fruit flies	**
Apidae	Honey bee	*
Chloropidae	Grass flies	**

* = less abundant; ** = abundant; *** = very abundant.
Modified from Tinzaara et al., 2006.

Table 2. Information dissemination channels on Xanthomonas wilt of banana in Rwanda, Tanzania and Uganda.

Communication channel	Rwanda	Tanzania	Uganda
Radios	***	***	***
Television	*	*	*
Documentary/drama	**	**	**
Newspapers and newsletters	**	**	**
Leaflets/pamphlets/posters/manual	***	***	***
Phone text messaging	*	*	**
Local leaders	***	***	**
Community based organization	*	***	***
Participatory development communication			***
Training/seminars/workshops	***	***	***

* = less effective; ** = effective; *** = very effective.
Source: Tinzaara et al., 2009.