The Effect of the Prompt Removal of Inflorescence-Infected Plants and Early Debudding of Inflorescences on the Control of Xanthomonas Wilt of Banana

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Abstract

Xanthomonas wilt of banana, caused by *Xanthomonas campestris* pv. *musacearum*, is an important constraint to banana production in Uganda. Different strategies to control the disease were investigated in an attempt to identify those methods that could be used by small farmers in East Africa. The effect of removing pseudostems showing early and late symptoms of inflorescence infection on the spread of the disease in 'Kayinja' (syn. 'Pisang Awak', ABB genome) was studied. Suckers of 'Kayinja' did not become infected when pseudostems derived from the same mat were removed at an early stage of inflorescence infection. In addition, the results of experiments to determine the effectiveness of bagging and debudding inflorescences at different stages to prevent insect-borne infection are reported. This research was undertaken using 'Kayinja', mixed plantings of East African highland cultivars (AAA) and high-yielding exotic/improved cultivars in farmers' fields. 'Kayinja' was the most susceptible cultivar to floral infection, followed by the East African highland cultivars. Exotic/improved cultivars had the lowest number of infections. Lower numbers of floral infections may be attributed to the persistence of male flowers and bracts. No flower infection was observed on plants that were debudded immediately after the formation of the last cluster and on those that were bagged until the formation of the last cluster and debudded right after. However, plants that were bagged until the formation of the last hand, but not debudded, or debudded after 2 weeks or more, showed high levels of inflorescence infection. This indicates that insect-vector transmission occurs only via the male parts of the inflorescence. Prompt removal of the whole pseudostems showing symptoms of early inflorescence infection and early debudding are simple, cheap, easily applicable and highly effective methods for controlling Xanthomonas wilt. Results of a cost-benefit analysis of control options are discussed.

INTRODUCTION

Xanthomonas wilt of banana, caused by the bacterium *Xanthomonas campestris* pv. *musacearum*, was first detected in Uganda in 2001 (Tushemereirwe et al., 2003, 2004). The disease has since spread to 34 out of 56 districts. Previously found only in Ethiopia on banana (*Musa* spp.) and enset (*Ensete ventricosum*) (Yirgou and Bradbury, 1968, 1974), it is now known in the Democratic Republic of Congo (Ndungo and Kijana, 2004; Ndungo et al., 2004), Tanzania and Rwanda (Mgenzi et al., 2006), and has recently been reported in Kenya and Burundi (Anon., 2006). The fastest rate of spread has been observed in central Uganda where 'Kayinja' is widely cultivated. The bacterium causing Xanthomonas wilt enters the vascular system of the banana plant through wounds. Eventually, the entire plant wilts and dies. Because the pathogen attacks all banana cultivars, Xanthomonas wilt threatens food and income security in areas where it becomes endemic.

The disease can be observed on both flowering and non-flowering banana plants. The first visible symptom of a floral infection, caused by contaminated insect vectors alighting on unhealed wounds possibly resulting from flower and/or bract drop, is wilting of male bud bracts followed by drying of the rachis and premature fruit ripening. The bacterium spreads rapidly through the entire plant and bacteria-laden exudates and vascular sap provide the main source of inoculum for further spread between plants.

The disease is primarily disseminated by infected planting materials, insects and contaminated garden tools (Eden-Green, 2004). Control measures, including the total destruction of infected mats, use of disinfected farm tools, timely removal of male buds (debudding) and bagging of banana inflorescences to prevent vector transmission have been recommended based on their effectiveness in controlling other bacterial diseases of banana (Moko, bugtok and blood bacterial wilts), which have a similar epidemiology to Xanthomonas wilt (Turyagyenda et al., 2006). However, farmers in Uganda have not adopted the labour-intensive control method that calls for the destruction of infected mats and instead cut only the infected pseudostem from the mat. This option may not be effective, as the bacterium could have spread to the rhizome before removal. The objectives of this study were to assess the efficacy of the early removal of a pseudostem with an inflorescence infection to prevent spread to the whole mat and also to assess debudding and bagging as control measures to prevent insect-vector transmission of Xanthomonas wilt.

MATERIALS AND METHODS

All experiments were undertaken in farmers' fields in Zirobwe sub-county, Luwero district, Uganda, between March 2005 and July 2006. This area is located in Central Uganda at 0°39'N, 32°40'E and at 1115 m altitude. It has an average daily temperature of 25°C and a maximum temperature of 29°C. The climate is moist, moderately humid and with a mean annual rainfall of 1100 mm, which predominantly falls in two periods, March to May and September to November (Ssekiwoko et al., 2006).

Banana cultivars utilised in the experiment were 'Kayinja' (syn. 'Pisang Awak', ABB genome), a mixture of different matooke clones ('Nakamali', 'Nakitembe', 'Namaligga' and 'Nakabululu') (AAA genome, East African highland banana subgroup) and a mixture of exotic/improved high-yielding banana germplasm ('FHIA-17', 'FHIA-18', 'FHIA-23', 'FHIA-25', 'Yangambi Km 5', 'Burro Cemsa', '660K').

The practice of cutting the floral-infected plant from the mat was evaluated. Pseudostems with bunches at three different disease symptom stages, namely (1) wilting of male bud bracts, (2) drying of the rachis and (3) premature fruit ripening, were selected for this study. Plants with advanced symptoms, such as drying and rotting of fruits and wilting of the entire plant, were not included as it was considered that bacteria would most likely have reached the corm and attached suckers (Ssekiwoko et al., 2006). For each disease symptom stage, 50 pseudostems (one from each mat) were cut off at soil level and removed from the field.

To study the insect-transmitted infection and evaluate the effectiveness of debudding and bagging, six treatments were undertaken on mats of 'Kayinja'. These were: (1) debudding immediately after formation of the last hand on the bunch; (2) debudding two weeks after formation of the last hand; (3) debudding four weeks after formation of the last hand; (4) bagging the inflorescence at shooting until formation of the last hand; (5) bagging the inflorescence until the formation of the last hand followed by immediate debudding and (6) no bagging nor debudding (control). Only two of the treatments undertaken on 'Kayinja', namely (1) debudding immediately after formation of the last hand and (6) no bagging nor debudding (control) were carried out on the East African highland banana cultivars and the exotic/improved high-yielding banana cultivars. Debudding, bagging and control treatments were replicated five times on plots of 100 plants each.

Three months prior to the beginning of the experiments, all the diseased plants in the plots were removed to prevent results being confounded by delayed symptom expression. Plots were marked with coloured paints to differentiate between the treatments. Suckers attached to the mat were marked with paint and monitored for disease incidence. Deleafing or desuckering operations were not carried out on plants in experimental plots to prevent infections arising from contaminated tools.

An economic viability analysis was carried out by interviewing 17 farmers, who had provided land for the experiments, and by completing a pre-tested, structured questionnaire. In addition, information on labour costs incurred when using a particular control method, problems associated with each method and factors that might affect farmers' willingness to adopt each method were compiled. Descriptive statistics were generated using STATA.

RESULTS AND DISCUSSION

During the experimental period, heavy rains occurred in the months of March, April and May in 2005 and 2006. Rain enhances plant vigour, growth and inflorescence formation. For all treatments and cultivars, floral infections intensified during and immediately after the rainy season (Fig. 1).

The results of experiments on the effectiveness of the removal from the mat of pseudostems at different stages of inflorescence infection are presented in Table 1. No mats became infected when pseudostems were removed at the shrivelled-bract stage of inflorescence infection. Rhizome infection occurred in a few instances when the pseudostem was removed at the dried rachis stage. Mats from which pseudostems with bunches containing prematurely ripened fruit were cut had high numbers of infections in the attached suckers. This suggests that after the early shrivelled bract stage, the pathogen may have had time to invade the rhizome.

Ssekiwoko et al. (2006) reported that in pseudostems with shrivelled-bract symptoms, the pathogen was restricted to the upper parts of the true stem with 56% of the lower true stem free of bacteria. None of the pseudostems with shrivelled-bract symptoms had *Xanthomonas campestris* pv. *musacearum* in their rhizomes, leaf sheaths or attached suckers. Ssekiwoko et al. (2006) further reported that plants with decayed rachis, prematurely ripened fruit and whole bunch rotting/drying symptoms had bacteria at the base of the plant. They also reported that in plants showing advanced bunch symptoms, the bacterium had invaded the leaf sheaths, parts of the rhizome and attached suckers.

The results of the work reported here suggest that cutting inflorescence-infected pseudostems from the mat at an early stage of disease development, before spread to the rhizome, is an effective control measure. However, removing inflorescence-infected pseudostems with bunches showing a decayed rachis and/or premature fruit ripening symptoms may not be effective. It was concluded that pseudostem removal is effective if applied at an early stage of inflorescence infection, and this procedure was recommended to farmers as a control measure.

Sixty-eight percent of mats from which pseudostems with bunches with advanced disease symptoms were cut did not get infected (Table 1). This suggests that even removing inflorescence-infected pseudostems with advanced bunch symptoms may reduce overall Xanthomonas wilt incidence.

In the debudding and bagging experiments (Table 2), 'Kayinja' was more susceptible in the controls to floral infection than all other cultivars (Table 2). 'Kayinja' had the highest number of infected plants (180) followed by the East African highland banana cultivars (35). Exotic/improved cultivars had the lowest number of infections (33). The lower number of floral infections in the East African highland banana cultivars and exotic/improved may be attributed to the persistence of male flowers and bracts in some genotypes. Addis et al. (2004) reported that the persistent male bracts and flowers of 'Dwarf Cavendish' (AAA genome, Cavendish subgroup), which is very widely grown in western Ethiopia, could constitute a barrier to insect transmission.

The results of the experiments on the effectiveness of the different debudding and bagging control options (Table 2) indicate that debudding immediately after the last hand is formed on the bunch is effective in controlling inflorescence infections, as no plants in this treatment became infected. As would be expected, bagging combined with the above treatment also effectively controlled Xanthomonas wilt. However, bagging alone without debudding had a high number of floral infections (199) and was comparable to the control treatment (180). Disease levels were also similar to controls in those plants that were debudded 2 and 4 weeks after the formation of the last hand (Table 2). This suggests that the male flower wounds are the main avenues for infection and that only early debudding can effectively control Xanthomonas wilt. Another advantage of early debudding may be bigger and more evenly filled/sized fruits (Stover and Simmonds, 1987). Bagging until formation of the last hand and leaving the male bud intact is not effective in the control of Xanthomonas wilt. Early debudding using a forked stick is recommended for farmers.

The economic viability analysis revealed that 81% of the respondents preferred debudding over other methods to control insect-vector transmission. Debudding is not labour intensive and does not require additional expenses. Forked sticks recommended for debudding can be easily obtained. Destruction of infected mats was not preferred due to the costs of labour and tools (hoes were often broken when uprooting mats) needed to implement the recommendation.

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Literature Cited

Addis, T., Handoro, F. and Blomme, G. 2004. Bacterial wilt (*Xanthomonas campestris* pv. *musacearum*) on Enset and banana in Ethiopia. InfoMusa 13(2):44-45.

Anon. 2006. CRS/USAID/IITA Press Release. Bujumbura - October 31, 2006. Catholic Relief Services, Crop Crisis Control Project (C3P). http://www.reliefweb.int/library/documents/2006/crs-bdi-31oct.pdf.

Eden-Green, S. 2004. How can the advance of banana xanthomonas wilt be halted? InfoMusa 13(2):38-41.

Mgenzi, S.R.B., Muchunguzi, D., Mutagwaba, T., Mkondo, F. and Mohamed, R. 2006. An outbreak of banana bacterial wilt in Muleba district, Kagera region, Tanzania. Disease report, Maruku Agriculture Research and Development Institute Tanzania.

Ndungo, V. and Kijana, R. 2004. Diagnostic et stratégies pour la lutte durable contre la maladie des bananiers et bananier plantain dans la collectivité des Bashali, Territoire de Masisi, Province du Nord-Kivu, DRC. Goma, DRC, 26-29 January 2004.

Ndungo, V., Bakelana, K., Eden-Green, S. and Blomme, G. 2004. An outbreak of banana xanthomonas wilt (*Xanthomonas campestris* pv. *musacearum*) in the North Kivu province of the Democratic Republic of Congo. InfoMusa 13(2):43-44.

Ssekiwoko, F., Turyagyenda, L.F., Mukasa, H., Eden-Green, S. and Blomme, G. 2006. Systemicity of *Xanthomonas campestris* pv. *musacearum* in flower-infected banana plants. XVII ACORBAT International Meeting: Banana: A Sustainable Business. Joinville, Santa Catarina, Brazil, October 15-20, 2006. p.789-793.

Stover, R.H. and Simmonds, N.W. 1987. Bananas, 3rd ed. Longman, UK.

Turyagyenda, L.F., Blomme, G., Ssekiwoko, F., Mukasa, H. and Eden-Green, S.J. 2006. On-farm assessment of banana bacterial wilt control options. The 4th International Bacterial Wilt Symposium, Programme and Abstracts Book. The Lakeside Conference Centre, Central Science Laboratory, York, United Kingdom, 17-20 July 2006. p58.

Tushemereirwe, W., Kangire, A., Smith, J., Ssekiwoko, F., Nakyanzi, M., Kataama, D., Musiitwa, C. and Karyaija, R. 2003. An outbreak of bacterial wilt on banana in Uganda. InfoMusa 12(2):6-8.

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 Pathology 53:802.

Yirgou, D. and Bradbury, J.F. 1968. Bacterial wilt of Enset (*Ensete ventricosum*) incited by *Xanthomonas musacearum* sp. n. Phytopathology 58:111-112.
Yirgou, D. and Bradbury, J.F. 1974. A note on wilt of banana caused by the enset wilt organism *Xanthomonas musacearum*. East African Agricultural and Forestry Journal 40:111-114.

Tables

Table 1. Effectiveness of removing an inflorescence-infected pseudostem from the mat at various stages of symptom expression.

Disease symptom stage when removal occurred	Number of mats monitored	Number of mats infected
Shrivelling bracts	50	0
Drying rachis	50	5
Premature fruit ripening	50	16

Table 2. Effectiveness of Xanthomonas wilt-control treatments.

Cultivar/cultivar group	Treatment (500 plants per treatment)	No. of infected plants
'Kayinja'	Debudding immediately after formation of last cluster	0
	Debudding at 2 weeks after formation of last cluster	33
	Debudding at 4 weeks after formation of last cluster	97
	Bagging	199
	Bagging + debudding immediately after formation of last cluster	0
	Control (no treatment)	180
East African highland banana	Debudding immediately after formation of last cluster	0
	Control (no treatment)	35
Exotic/improved	Debudding immediately after formation of last cluster	0
	Control (no treatment)	33

Figures

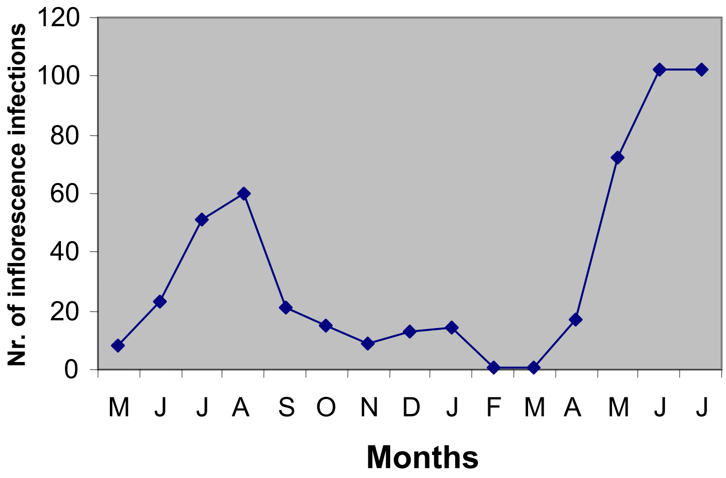

Fig. 1. Monthly inflorescence infections recorded in experimental plots from May 2005 to July 2006 showing increases after rainy seasons in March, April and May.