Crop Protection 84 (2016) 132–140

Contents lists available at ScienceDirect

Crop Protection

journal homepage: www.elsevier.com/locate/cropro

The distribution and incidence of banana Fusarium wilt in subsistence farming systems in east and central Africa

Patrick Karangwa [a, b, *], Guy Blomme [c, 1], Fenton Beed [d, 2], Celestin Niyongere [e], Altus Viljoen [a]

[a] Department of Plant Pathology, University of Stellenbosch, Private Bag X1, Matieland 7602, South Africa
[b] Research Department, Rwanda Agriculture Board, P.O. Box 5016 Kigali, Rwanda
[c] Bioversity International Uganda Office, P.O. Box 24384, Kampala, Uganda
[d] International Institute of Tropical Agriculture (IITA) – Regional Hub, Mikocheni B, P.O. Box 34441, Dar es Salaam, Tanzania
[e] Institut des Sciences Agronomiques du Burundi, P.O. Box 795, Bujumbura, Burundi

ARTICLE INFO

Article history:
Received 17 March 2015
Received in revised form
1 March 2016
Accepted 2 March 2016

Keywords:
Chi squared test
Fusarium wilt
Incidence
GIS
Subsistence farming

ABSTRACT

Bananas (*Musa* spp.) are major staple and cash crops in the Great Lakes region of Africa. Yet, banana yields in this region are among the lowest in the world due to a wide range of abiotic, biotic and socio-economic causes. Cropping systems which could contribute to soil fertility replenishment, pest and disease suppression and climate change mitigation might improve banana yields and contribute to uplifting the livelihoods of millions of people in the region. In this context, a survey was conducted over two seasons in banana-based subsistence farming systems in Rwanda, Burundi, north-western Tanzania (Kagera and Kigoma regions) and eastern Democratic Republic of Congo (South Kivu province), to investigate the distribution and incidence of banana Fusarium wilt as related to cropping systems, edapho-climatic and socio-economic factors. Banana Fusarium wilt incidence was found generally high in the region, 54.1% of all farms had disease incidence higher than 40%, with Tanzania having the highest number of farms with high disease incidence (63.6%). Statistical analysis (chi-squared test of association) and GIS mapping, by layering Fusarium wilt incidence over selected predictor maps, showed that disease incidence was lower in farms growing cultivar mixtures ($p < 0.01$) and at higher altitudes (>1600masl) ($p < 0.05$), and a significant association of Fusarium wilt and farm age was observed whereby disease incidence was highest in farms aged between 10 and 30 years ($p < 0.05$). Additionally, this study reports for the first time the occurrence of *Fusarium oxysporum* f. sp. *cubense* race 2 in Rwanda and Burundi, and suggests that strategies for banana Fusarium wilt management in east and central Africa should include raising farmers' awareness on pathogen spread mechanisms and enhancing their access to disease-free planting materials.

1. Introduction

Bananas and plantains (*Musa* spp.) are among the most important crops grown in the eastern and central part of Africa (ECA) which comprises the countries of Rwanda, Burundi, Uganda, Tanzania and the Democratic Republic of Congo (DRC, North and South Kivu provinces). In this part of the region which is commonly known as the Great Lakes region of Africa, bananas per capita consumption is the highest in the world and they constitute the main source of income for millions of people (Karamura et al., 1999; Lynam, 2000; Rutherford, 2001). However, banana yields are among the lowest in the world (http://faostat3.fao.org) due to wide range of abiotic, biotic and socio-economic causes (van Asten et al., 2005; Wairegi et al., 2010; Swennen et al., 2013).

Rwanda, Burundi and Uganda have some of the highest population growth rates in the world, and consequently represent three of the five most densely populated countries in mainland Africa (United Nations, 2007). In addition, this region has one of the highest rural population densities in Africa (Stock, 2004; Place

* Corresponding author. Research Department, Rwanda Agriculture Board, P.O. Box 5016 Kigali, Rwanda.
E-mail address: patrick.karangwa1@gmail.com (P. Karangwa).
[1] Present address: Bioversity International, Addis Office, c/o ILRI, P.O. Box 5689, Addis Ababa, Ethiopia.
[2] Present address: AVRDC – The World Vegetable Center, P.O. Box 1010 (Kasetsart), Bangkok 10903, Thailand.

http://dx.doi.org/10.1016/j.cropro.2016.03.003
0261-2194/

et al., 2006). The vast majority of ECA's population live in rural areas, where their livelihoods are mostly based on low input subsistence agriculture, putting severe pressure on soil fertility (Stock, 2004; Place et al., 2006).

Soil fertility decline is a major cause of low and declining agricultural productivity in ECA and sub-Saharan Africa in general (Sanchez et al., 1997; Okalebo et al., 2007; Bationo et al., 2012). Most soils are highly weathered, with Ferralsols, Acrisols and Nitisols being the most commonly found soil types (Eledu et al., 2004; Okalebo et al., 2007; Bationo et al., 2012). Furthermore, many soils in the region have been found to be extremely acid, with high aluminium toxicity and significant phosphorus and nitrogen deficiencies (Matungulu, 2011). Such soils are not suitable for banana production, as they require heavy fertilization and liming to mitigate soil acidity (Robinson and Sauco, 2010). African subsistence farmers are deterred from fertilizer use due to its high cost, despite awareness of their potential benefit to crop production (Bekunda et al., 2010; Bationo et al., 2012). In parts of Africa where land availability is not yet a major constraint, farmers resort to agricultural systems such as shifting cultivation and fallowing (Stock, 2004; Okalebo et al., 2007; Bekunda et al., 2010). These ancient subsistence agricultural systems allow exhausted land to rebuild soil fertility and were widely practiced across sub-Saharan Africa until the fast-growing human population forced continuous land cultivation (Okalebo et al., 2007).

Increasing land scarcity due to population growth compelled farmers to develop the subsistence production practice of intercropping and growing cultivar mixtures. With these practices farmers strive to produce a range of staple crops for household consumption and income generation on limited land (Stock, 2004; Robinson and Sauco, 2010). Besides land use efficiency, some intercropping systems might contribute to soil fertility improvement and/or suppression of pests and diseases, and might also contribute to yield improvement through atmospheric nitrogen fixation, reduction of evapotranspiration, suppression of weeds and/or improvement of soil nutrient availability to plants by regulation of soil pH (Sanchez, 1995; Zuo et al., 2000; Enyi, 2008; Ouma, 2009; Zhang et al., 2013). Intercropping systems are thought to contribute to disease suppression through a variety of mechanisms, including alteration of vector dispersal, changes in moisture and the host's morphology and physiology, as well as pathogen inhibition (Boudreau, 2013). While a reduction in disease severity has been reported in some intercropping systems, an increase has been reported in others (Summer et al., 1981; Dordas, 2008).

Among the most common intercropping systems found in ECA are banana-bean and banana-coffee intercropping (Oduol and Aluma, 1990; Wartmann and Sengoba, 1993; Rutherford and Kangire, 1998; Ouma, 2009; van Asten et al., 2011). There is limited published information on the effects of farmers' practices such as intercropping, the use of cultivar mixtures, mulching and planting material sourcing on banana pest and disease intensity in subsistence farming systems of ECA. However, studies in China have shown that intercropping and rotating banana with Chinese chive (*Allium* spp) result in a significant reduction of banana Fusarium wilt (Zhang, Wang et al., 2013), and a reduction in disease severity of banana leaf spot in cultivar mixtures has been reported in Brazil (Gonçalves et al., 2008).

The use of cultivar mixtures is recognized among crop diversification strategies for disease control (Mundt, 2002). However, there is a paucity of published scientific literature in this area, and effectiveness of cultivar mixtures on disease reduction has been mostly reported for specialized, polycyclic, wind-dispersed foliar diseases of cereals (Smithson and Lenne, 1996; Cox et al., 2004). Nonetheless, disease reduction in cultivar mixtures has been reported for *Fusarium* spp. and *Septoria nodorum* of wheat (Manthey and Fehrmann, 1993), while no reduction of *Fusarium oxysporum* f. sp.*radicis-betae* incidence was observed in fields of cultivar mixtures of sugar beet (Harveson and Rush, 2002).

Low-cost disease suppression and soil fertility replenishing systems may significantly benefit subsistence farmers who cannot afford fertilizers and pesticides to improve productivity. In the current study, a survey was conducted in four countries of ECA for on-farm evaluation of the incidence of banana Fusarium wilt, as related to farmers' practices (intercropping, mulching, planting material sourcing and movement), cultivars, age of plantation, edapho-climatic factors (soil types, altitude/temperature) and human population density. Although banana Fusarium wilt is not considered the most important production constraint of banana in the ECA region because east African highland bananas (EAHB), the major staple grown in the region, are resistant to Foc race 1, the disease is the major deterrent to initiatives for intensive production of susceptible bananas used for export and delivery to local breweries. Banana Fusarium wilt is caused by the fungus *Fusarium oxysporum* f. sp. *cubense* (E.F. Smith) W.C. Snyder & H.N. Hansen (Foc), whose spores (chlamydospores) can survive in the soil for decades without banana as the host (Ploetz and Pegg, 2000). The disease is introduced into new areas mainly by the movement of planting material (Ploetz and Pegg, 2000; Blomme et al., 2013). No effective control options exist, besides the use of resistant cultivars or planting disease-free planting material in disease-free soils (Ploetz and Pegg, 2000; Ploetz, 2006). Studies on the distribution and propagation of Fusarium wilt within the subsistence banana farming areas in the ECA region could contribute to better understanding disease development and epidemiology and to the development of cost-effective and sustainable management strategies.

2. Materials and methods

2.1. The study area and survey methodology

The area surveyed included the countries of Rwanda and Burundi, eastern DRC (South Kivu province) and north-western Tanzania (Kagera and Kigoma regions). This area has some distinct geographic features compared to the rest of the continent, the main one being the western Rift Valley, running along the border between DRC and Rwanda and Burundi, which is part of the long Afro-Arabian rift system extending from Turkey to Mozambique (Baker et al., 1972; Stock, 2004), and which includes lakes after which the region is called the Great Lakes region. The region's landscape consists mostly of highlands and valleys. The mean annual temperature is 19.2 °C while the mean annual precipitation ranges from 978 mm in eastern Rwanda to 1566 mm in DRC South Kivu province (Hijmans et al., 2005).

Surveys were conducted in the study area in 2009 (June, November and December) and 2010 (May, June and July) (Table 1). Rwanda and Burundi were the most extensively surveyed. The survey covered all Rwandan provinces, with the southern and eastern provinces the most surveyed (41 farms from all 15 districts of these two provinces). In Burundi, the survey covered 14 of the 17 provinces of the country (except Karuzi, Mwaro and Cankuzo). In Tanzania, the survey covered all districts of the Kagera region except Kyerwa and Muleba, and in Kigoma region only the district of Kibondo was surveyed. DRC's South Kivu province was the least extensively surveyed, due to limited road access and security concerns; the survey covered two of the eight territories of the province, i.e. Kabale and Walungu.

Over 100 banana farms were surveyed, but Fusarium incidence was recorded in 85 farms across the region (Table 1). The location of each farm was recorded using a GPS device and farmers were interviewed regarding disease history (date when the disease was