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Disease risk perception and diversity of management strategies by farmers: The case of anthracnose caused by *Colletotrichum gloeosporioides* on water yams (*Dioscorea alata*) in Guadeloupe

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ABSTRACT

Disease perception and adequate management practices are two essential issues faced by farmers, especially in the current context of climate change which may potentially increase disease risk. We investigated the diversity of water yam cropping systems in Guadeloupe through interviews, how producers and international yam research scientists perceived anthracnose, and how this perception correlated with farmers' risk management strategies. We found that disease perception by farmers is very close to perception by international yam experts, as both have the same perception of the hierarchy of factors translating into disease. Three different yam production strategies coexist at a local scale, where agronomic practices and socio-economic profiles are distinct and consistent with attitude toward anthracnose risk management. Six factors were perceived as decreasing the disease: associated crop species; crop rotation; staking; weeding; crop monitoring and varietal admixture. Yam producers raising crops more intensively were risk prone, while others usually sought practices to manage disease appearance and spread. Both cumulative risk and past anthracnose epidemic experiences translated into heavier reliance on chemicals. These results have practical implications for designing best yam crop management systems and control of yam anthracnose.

1. Introduction

World agriculture is facing important challenges: sustainably feeding an increasing world population while preventing environment degradation (Godfray et al., 2010; Tilman et al., 2002). Current practices to maximize crop productivity rely mainly on chemical and mechanical intensification and are incompatible with the objective of sustainability (Tilman, 1999). The appraisal about agricultural unsustainability (Meerman et al., 1996) brought a renewed interest about more extensive agricultural systems. They are often inspired from indigenous knowledge and agro-ecology (Swiderska et al., 2011; Altieri, 2004).

One of the steps toward food security is the control of crop antagonists (Strange and Scott, 2005), but agricultural intensification sometimes results into dominance of elite varieties at regional scales with potentially increased sensitivity to pathogens due to a narrower genetic base (Van de Wouw et al., 2010). Decline in landraces diversity is putting crop species at higher risks with regard to epidemics (Newton et al., 2009; Marshall, 1977), and climate change adds weather uncertainty which may further increase development of crop diseases (Ingram, 2011; Savary et al., 2011). Farmers are thus expected to produce food in a context of adverse conditions and increased disease risk (Bebber et al., 2014). A major issue pertaining to disease control is thus to understand disease perception by farmers, and to integrate these perceptions into the design of sustainable practices to prevent or reduce epidemics.

Agriculture in many regions still relies on traditional knowledge (Berkes et al., 2000), especially in the many orphan or neglected crop species worldwide. While we will not revisit the debate about farmer traditional knowledge in this study (we refer readers to Altieri (2002, 1999) for reviews), we will consider that agronomic practice is quite dynamic and naturally subject to variations and transitions (Nelson et al., 2001) because farmers are constantly experimenting with cropping systems. Farmers indeed choose crop management systems that best suit their individual experience,

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local conditions and goals toward a satisfactory productivity balance (Wood and Lenne, 1997). Generally, traditional crop systems rely on a great diversity of varieties with a broad genetic basis, and plants may be less prone to disease because of the lesser homogeneity compared to modern mono varietal crops. Plant diseases and epidemics are nevertheless a difficult issue and traditional knowledge does not always yield operational disease management practices, most probably because disease agents are sometimes perceived differently among farmers (Manu-Aduening et al., 2007) or perceived as less important compared to more easily recognized crop antagonists such as insect pests (Kiros-Meles and Abang, 2008; Obopile et al., 2008). When a disease is observed to correlate to external causes (e.g., climate events such as rains), disease management may evolve (e.g. Trutmann et al., 1996). and is usually dealing with preventive action upon the soil/climate correlates of disease (Sherwood, 1997; Trutmann et al., 1996). Some studies have also demonstrated that misattribution of disease symptoms could translate into inefficient actions and fail to prevent onset of epidemics (Kiros-Meles and Abang, 2008). Sometimes traditional disease management is preferred over recommendations by phytopathologists (Adam et al., 2015). Indeed, farmers usually know that agronomic practices could impact disease appearance and spread in their crops because they experience epidemics directly (Narayana, 2013). Understanding producers' perception of crop disease should thus address how farmers using traditional knowledge cope with disease risk, and whether diverse agronomic practices may increase disease control while taking into account farmers' perceptions. This could facilitate an innovation process toward more sustainable management of crop diseases.

In this study, we investigated how farmers perceived disease risk and coped with anthracnose epidemics on yams, and tested whether agricultural practices were associated with changes in reports of disease experienced by producers. We focused on Water Yam crop (*Dioscorea alata*, L.) and anthracnose disease caused by the generalist fungus *Colletotrichum gloeosporioides* (Penz.). Yam is the first food crop both in surface cultivated (450 ha) and regional production (6300 t) in Guadeloupe, despite high variability in productivity (Cornet et al., 2014). Its main disease, anthracnose, is characterized first by discrete necrotic lesions on the foliar apparatus eventually expanding and causing die-back of emerging stems, shoots and extensive defoliation. Depending on the onset of the disease, strong interference with tuber development may occur if plants are infected early during development, and this may result in dramatic yield losses (Winch et al., 1984). Whenever damages are limited, symptoms may be mistaken with those of the second most frequent pathogens on yams in the Caribbean –*Curvularia* species, but the latter never sustain epidemics resulting in complete crop wipeout. The disease is mostly found on *D. alata*, whose varieties demonstrate diverse resistance levels (Petro et al., 2011; Onyeka et al., 2006). Some cultural practices, such as removal of plant residues after harvest, mixed cropping, pruning or weeding out are known to decrease epidemics by *Colletotrichum* (Chowdhury and Rahim, 2009; Ripoche et al., 2008; Bedimo et al., 2007), while the traditional plantation distance generally falls within infectious dispersal range once these pathogens colonize fields (Penet et al., 2014). Because anthracnose still remains the most important threat to yam production in the Caribbean, a better understanding of the disease is needed to ensure more effective disease control (McDonald et al., 1998). The lack of accredited pesticides also enhances the threat for Water Yam cultivation.

In this paper, we explore three poles of disease perception and disease management and impact via cropping system: we first present a typology of Guadeloupean producers from a survey of farmers involved in yam production and then investigate perception of disease risk and how anthracnose disease impacts crop systems. We more specifically address the following questions: 1) crop management system diversity: is yam cropping system diverse and what are the components of cropping diversity? How many cropping strategies occur locally? 2) perception of anthracnose and risk factors: how do producers and scientists perceive anthracnose risk for specific agronomic practices? Are perceived risks correlated to disease experience? and 3) impact of disease experience on cropping systems: what was the impact of anthracnose experience on agronomic practices? Are there potential practices amenable to sustainable control of anthracnose and disease management?

2. Material and methods

2.1. Crop management system diversity and typology

2.1.1. Survey general characteristics

We designed a questionnaire about farmer socio-economic profile and agricultural practices with emphasis on management of *D. alata* varieties. The questionnaire was open at times or semi-structured and more constrained, depending on the questions. Seventy eight yam producers agreed to the interview and were surveyed, i.e., ca. 8% of the 1004 officially reported yam producers in Guadeloupe (DAAFG, 2010). We aimed to interview as many producers as possible within the planting season (February to April), so as to rely on actual cropping system reports, and thus interviewed every farmer that accepted to contribute to the study. Sampled farms were evenly distributed among the three main Guadeloupean islands where agriculture is economically relevant: Basse-Terre (22 farmers); Grande-Terre (42 farmers) and Marie-Galante, a usually less prospected area (14 farmers).

2.1.2. Yam producer typology

We used agronomical characteristics specific to the yam crop management system from the survey to delineate groups of producers within a typology. The typology was produced via a hierarchical classification method (Blazy et al., 2009) using XLSTAT software. Sixteen variables were used to produce the typology, 14 of which were categorical (associated crop species, cultivating yam on previously contaminated field, fertilization, irrigation, mulching, pesticide use, soil amendments, staking, tillage, tuber seed treatments, use of imported tuber seeds, weekly crop monitoring, yam as previous crop, and yam varietal admixture) and two were quantitative variables (number of yam plots and yam cultivated surface). In order to delineate homogenous groups of farms from our dataset, we used a two-step statistical treatment. We first transformed the data into non-correlated variables with a multiple correspondence analysis (MCA). Individuals were then grouped into specific farm types with Agglomerative Hierarchical Clustering (AHC) using input variables from the principal components of the MCA. This method already proved useful to categorize farms or farmer practices (e.g., Chopin et al., 2015; Blazy et al., 2009). The use of Euclidian distance as a dissimilarity index allows accounting for different multidimensional descriptive variables with a single index (Everitt et al., 2001). Individuals were then grouped minimizing dissimilarity. Pairs were aggregated with Ward's minimum-variance method (Ward, 1963), based on recurrent pooling of individuals by minimizing increase of total intra-class inertia. The result is a classification dendrogram with all individuals organized into groups. The resulting typology was determined by defining the truncature level in the dendrogram. Several truncature level trials aimed at defining the best tradeoff between farms' intergroup diversity and farms' intragroup variability. The resulting typology delineated three groups of producers (see Results) Section and we further explored how the typology related to 20 other agronomic