Tropical Crop Pests and Diseases in a Climate Change Setting—A Few Examples

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Chapter 6
Tropical Crop Pests and Diseases in a Climate Change Setting—A Few Examples

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Abstract Climate change alters the behaviour of pests and their distribution. There is a genuine risk that pest and disease pressure will increase as a result of environmental and agrosystem disturbances. This is a concern for all agricultural stakeholders, especially in temperate countries where introductions of new pests, diseases and weeds abound. The list of introductions in Europe is getting ever longer, with the onset of disturbing phenomena that are a real threat to food security. The impact of climate change on pest populations and their natural enemies in the tropics is even harder and more complicated to grasp—changes in pest status, introductions, dramatic development of diseases or insect populations and extension of their ranges are being observed. Based on examples of insects and diseases affecting a few tropical agrosystems, we discuss the impact of climate change on these pests and propose new agroecological protection strategies while promoting the conservation of natural regulation services to sustainably reduce pest and disease risks.

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6.1 Background

Since the advent of agriculture, diseases and pests have affected agricultural production worldwide, sometimes causing substantial yield losses. Changes in climatic conditions increase these losses, while threatening food security and farmers' livelihoods. Developing countries are highly dependent on agriculture and hence especially vulnerable to changes in pest status. Hundreds of millions of smallholders depend solely on agriculture for their livelihoods. In recent decades, pest control has been heavily reliant on pesticide treatments, which can have adverse effects on humans and the environment, especially rural communities that do not always have access to proper treatment and protection equipment. Climate change can also have an impact on food safety by, for instance, creating favourable conditions for the contamination of stored produce by fungi that produce mycotoxins which are harmful to human health—this concerns foods such as groundnuts, wheat, maize, rice and coffee.

There is evidence that climate change alters the distribution of plant pests and pathogens, but it is hard to predict all of its effects. Changes in temperature, humidity and atmospheric gas concentrations can modify plant, fungus and insect growth and renewal rates, therefore disturbing biological and chemical interactions between pests, their natural enemies and hosts. This is particularly true in tropical environments where geophysical features (no climatic breaks in pest cycles) and biological features (high biodiversity, very complex community networks and substantial biotic constraints) are conducive to pest outbreaks or quick changes in their status. Climate change is, however, only one of a number of components of what is now called global change, which also includes the large-scale increase in material and commercial trade as well as human modification of natural environments. Climate change is a complex phenomenon, so it is hard to separate and identify the role of the different components that have a bioecological impact and modify pest pressure on agrosystems. Based on a few examples of tropical crop pests of economic importance, we describe the phenomena observed in association with climate change and potential solutions to mitigate the impact and reduce the pest pressure.

6.2 Impact on the Epidemiology of Coffee and Cocoa Diseases

6.2.1 Coffee Rust

Rust is one of the most serious fungal diseases affecting *Coffea arabica* and a major epidemic has been developing in recent years in Latin America. The impact of coffee rust varies depending on the fruit load on coffee trees (Avelino et al. 1991), temperature, rainfall, humidity, cultivar, treatments and landscape configuration

(Avelino et al. 1991, 2012). The factors determining recent rust epidemics in Central America are economic, but climatic factors are also strongly suspected in light of the unusual severity of the epidemics. Several meteorological anomalies (temperature, rainfall, sunshine duration) were noted over the 2008–2013 period, which was crippled by major epidemics. The mean annual temperature in 2012 in the region was close to the average for the 1981–2010 period, but very little variability was observed. Low temperatures which hamper rust development are less frequent. Epidemics are now occurring in highland regions where high quality coffee is grown and where rust outbreaks seldom occurred in the past.

Several options are being investigated. The dissemination of resistant plant material seems to be one of the most promising solutions, but coffee is a tree crop and it takes many years to replace an orchard. Moreover, several resistance traits developed in genetic improvement programmes have turned out to be relatively unsustainable, with resistance breakdown appearing after a few years. It would therefore be preferable to promote quantitative resistance (horizontal), which is generally more sustainable than monogenic resistance. Genetic strategies cannot solely overcome the spread of rust epidemics—agroecological management strategies against the parasite complex (including the coffee berry borer which we will discuss hereafter) should also be developed. Gaining insight into dispersion and development phenomena according to the landscape setting and cropping conditions is thus essential (Avelino et al. 2012). Efficient management of shading, appropriate pruning, fertilization tailored to fruit load and soil conditions, and timely fungicide applications could reduce the rust pressure and incidence in coffee orchards, while also delaying resistance breakdown after the resistant material has been planted. Coffee genetic improvement studies (Chap. 7) aimed at obtaining healthy, more resistant and resilient plants are complementary to the agronomic approaches presented here.

6.2.2 Cacao Swollen Shoot Virus—Climate Change, Deforestation or Both?

The cacao swollen shoot virus disease (CSSVD) is causing heavy production losses in West African cocoa plantations (Fig. 6.1). The virus alters the physiological functioning of cocoa trees, ultimately killing them within a relatively short period (6 months–3 years). As cocoa trees are native to the Amazon Basin and the virus was initially only present in Africa, a switch in host from an African plant to cocoa occurred. Is the progress of this epidemic due to climate change? Several hypotheses have been put forward, but deforestation of cocoa growing areas in Côte d'Ivoire is the most common explanation. This vector-borne disease is transmitted by several mealybug species and differs markedly from coffee leaf rust. Deforestation could have led to a rise in their populations on cocoa trees. Moreover, the virus strains detected in Côte d'Ivoire are new strains that have not been found in former outbreak

Fig. 6.1 Cacao swollen shoot virus disease, Soubré, Côte d'Ivoire (© C. Cilas/CIRAD)

areas in Côte d'Ivoire, Ghana or Togo (Kouakou et al. 2012). The dramatic increase in CSSVD therefore seems to be due to the transmission of new strains derived from other plants in Côte d'Ivoire as a result of global changes induced by deforestation, which is also disrupting climatic conditions in the vicinity.

6.3 Lepidopteran Stem-Borers and Other Insect Pests of Sugarcane—Biological Control Disturbances, Expansion of Infested Areas

Chilo sacchariphagus (Fig. 6.2) and *Eldana saccharina* are two lepidopteran stem-borer pests that have a major economic impact by causing significant sugar and biomass losses in sugarcane crops (Goebel and Way 2009). Biological control is one of the most common strategies used to manage these pests. Tiny *Trichogramma* parasitoid wasps attack lepidopteran eggs and are among their natural enemies, thus

Fig. 6.2 A *Chilo sacchariphagus* stem borer larval caterpillar on a sugarcane stalk (© R. Goebel/CIRAD)

playing a key role in regulating natural stem borer populations. A decline in natural *Trichogramma* parasitism has been noted in some countries and several factors have been advanced to explain this situation, e.g. chemical treatments, cane field burning (still carried out in many African countries), or the occurrence of acute recurrent droughts. This has led to a scarcity of resources and shelters for *Trichogramma* that are naturally present or released via biological control operations, thus hindering their maintenance and survival in the agrosystem. *Trichogramma* wasps live on external plant parts and are hence very sensitive to temperature variations, whereas stem borers are endophytic, living inside sugarcane stalks, therefore benefiting from more buffered living conditions (Goebel et al. 2010).

A change in the status of these pests and an extension in their distribution have been observed. A study carried out in South Africa showed that there is a good chance that the sugarcane stem-borer, *Chilo sacchariphagus*, which is already present in other southern African countries (Malawi, Mozambique, Zimbabwe), will infect ‘cooler’ sugarcane growing areas in South Africa due to the overall increase in temperatures in this country (Bezuidenhout et al. 2008). Agricultural areas in the highlands of Réunion, where the cool temperatures still hamper colonization by lepidopteran stem-borers, could also be increasingly affected by infestations. Such changes in status may be further illustrated by the infestation and rapid adaptation of the sugarcane thrips, *Fulmekiola serrata*, in South Africa (Way et al. 2010), and very recently by *Sipha flava* aphids. These aphids can transmit yellow leaf syndrome, a serious sugarcane disease that could have a major impact on the South African sugar industry.

6.4 Changes in the Helicoverpa Armigera Population Dynamics in Cotton Fields

Helicoverpa armigera is a lepidopteran cotton pest in West Africa. The life cycle of this species is closely linked with the climatic conditions and it may undergo up to 10 generations a year under tropical climates. The length of each stage during the life cycle depends on the environmental conditions (resource availability, rainfall and temperature). The caterpillar enters diapause when the conditions are unfavourable (resource availability, rainfall and temperature), which lengthens the cycle and reduces the number of generations.

In northern Benin, during infestation peaks in cotton plots, it was reported that the pest abundance was dependent on the extent of heterogeneity of host plants (cotton, maize, tomato, sorghum) in the landscape around the plots (Tsafack 2014). This heterogeneity is dependent on the cropping calendar, which in turn is closely related to variations in temperature and rainfall. The prevailing hypothesis is that the agricultural landscape around cotton plots could include more or fewer host plants for these pests depending on the temperature and rainfall variation patterns (drought, flooding).

6.5 Coffee Berry Borer—A Spreading Pest

The coffee berry borer, *Hypothenemus hampei*, is a tiny beetle (1 mm) and the main coffee insect pest throughout the world. This pest of African origin has an impact on the production output of most of the 20 million coffee growers worldwide, resulting in global losses that are estimated at $500 million a year (Vega et al. 2003).

Pesticides are not very effective in controlling this beetle since it spends most of its life cycle within coffee berries. Good cropping practices such as limiting shade, pruning coffee trees and harvesting all berries, can reduce infestations to an economically acceptable level (Damon 2000). An attractant-baited coffee berry borer trap developed by CIRAD and marketed under the trade name BROCAP® has proven effective when combined with these practices (Dufour and Frérot 2008). Biological control operations using African hymenopteran parasitoids have been under way in Latin America since the 1980s. Three species, i.e. *Prorops nasuta*, *Cephalonomia stephanoderis* (Bethylidae) and *Phymastichus coffea* (Eulophidae), have been introduced on a large scale, but with limited results so far.

Coffea arabica cropping conditions (above 1300 m elevation) do not seem to suit coffee berry borers, which are scarce in areas above 1500 m, likely because the temperatures are too low. Global warming could foster the spread of this pest into more highland areas, therefore jeopardizing highland *Coffea arabica* production, which is generally renowned for its quality. One study revealed that complete coffee berry borer development is only possible between 20 and 30 °C (Jaramillo et al. 2009) and that this pest could develop in areas where it was previously absent, such as the Jimma region in Ethiopia where coffee is mainly cropped in the highlands. The coffee berry borer was detected for the first time in 1928 in Kenya (Waller et al. 2007), a country that shares its northern border with Ethiopia. It is now found at several locations in southern Ethiopia (Mendesil et al. 2004). Models predict an increase in the coffee berry borer range in most East African coffee producing countries over the next 50 years (Jaramillo et al. 2011).

Rainfall has an indirect influence on the coffee berry borer population dynamics because coffee flowering and fruit set are dependent on the rainfall regime. Rainfall partially determines the number of berries available for coffee berry borer infestation during the year. During extreme dry seasons, coffee berries ripen simultaneously and a shortage period that is detrimental to this pest occurs after the coffee harvest. In the reverse situation, coffee berries are available year round, which is favourable for the beetle. A change in the rainfall regime, as already observed in some regions worldwide, could therefore cause differences in infestation levels of coffee berry borers and change their seasonal patterns.

The failure of successive parasitoid-based biological control campaigns in Latin America has yet to be explained. The climatic conditions in regions where these parasitoids have been introduced could be partly responsible for this situation. One reason put forward to explain the effects of temperature increases on pest abundance is the disruption of trophic systems involving crop plants, pest insects and their natural enemies. Hymenopteran parasitoids at the top of the trophic system are particularly affected by climate change (Hance et al. 2007). Global warming could thus be upsetting pest/natural enemy trophic balances by reducing the ability of natural enemies to curb pest outbreaks (Harrington et al. 2001). Regarding the coffee berry borer, a rise in temperature could affect the regulation of this pest by these parasitoids and challenge biological strategies to control it. Many signals indicate that the global impact of coffee berry borers on coffee production—highland *Coffea arabica* production in East Africa or coffee produced by smallholders worldwide—could increase as a result of global warming.

6.6 How to Cope with Climate Change and Provide New Pest Control Solutions

Climate change leads to ecosystem disturbances at all trophic levels and modifies interactions between different biological and ecological communities, including crop plants, natural habitats, aboveground biodiversity and soil (Fig. 6.3).

Cropping systems must now be tailored to these disturbances by modifying farming practices, including landscape features. Some local farming practices worsen climate change on a global scale, but incentive measures are available to foster changes in these practices and they should be applied. Because of the risk of the spread of pests beyond the current limits of their distribution due to the combined effect of trade globalization and climate change, it is essential to strengthen export crop management measures and the implementation of preventive measures in areas that have so far been unaffected. An effective biosecurity plan should be set up, including increased border surveillance, regular warnings, trapping networks and information exchange between different neighbouring countries. Australia is a leader in this area given its high drought susceptibility and constant exposure to insects and diseases from neighbouring tropical countries, such as Indonesia and Papua New Guinea (Goebel and Sallam 2011).

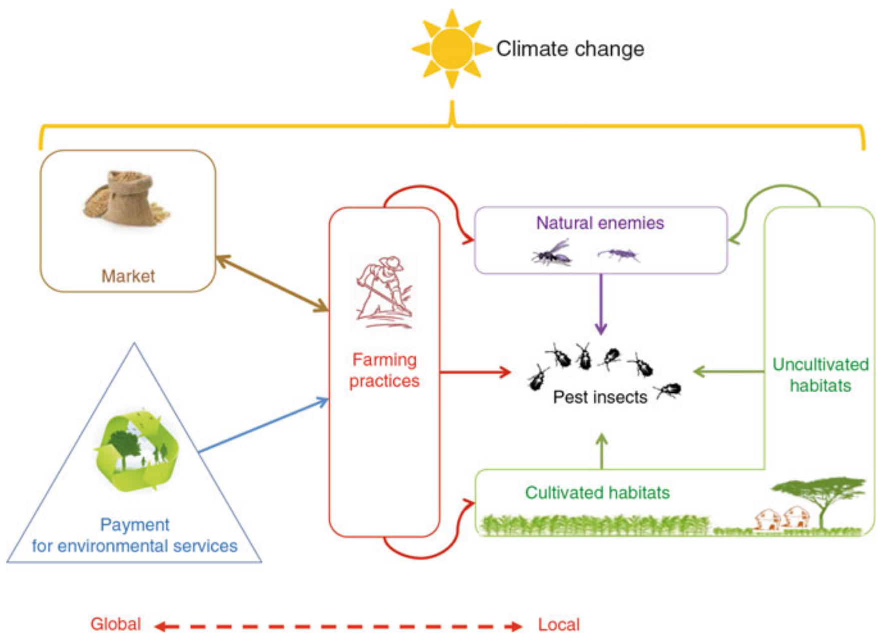

Fig. 6.3 All relationships to consider in an agrosystem under the pressure of climate change: pests and their natural enemies, link with noncultivated areas, cropping practices as well as economic and political settings on different scales (markets, especially export markets, public environmental policies), which can impact agricultural practices

The research priorities should focus on:

- local management of pest and disease risks aggravated by climate change in order to adapt cropping systems to their effects;
- adaptation of crop protection strategies to not increase the risk of climate change on a global scale;
- forecasting and prevention of the introduction of tropical pests and their establishment in more temperate areas once they become potentially invasive or emerging as a result of climate change.

This type of research is currently underway and some promising results have prompted us to continue on this path. In a study carried out in Madagascar, an improvement in the water balance and a reduction in evapotranspiration via conservation agriculture contributed to reducing the impact of blast disease in upland rice crops (Sester et al. 2013). Maintaining plant cover in rice crop fields also enables a reduction in crop losses due to pests by enhancing the local biodiversity (above- and below-ground) while reducing the use of inputs with a high carbon footprint. Coffee pest management could be facilitated via associations of coffee with other trees (Tscharntke et al. 2011). Such agroforestry practices for coffee have been adopted by most coffee smallholders in the world because these associated trees provide shade necessary to achieve a good balance between productivity and sustainability on plantations without systematic use of irrigation or fertilizers (Chap. 16). These practices should nevertheless be carefully designed because intense shade conditions could be conducive to coffee berry borer development (see above and Vega et al. 2009). But the introduction of shade trees could also be effective for maintaining the air temperature in plantations below that favourable for pest development, especially in highland regions. Moreover, shading could hamper sudden temperature changes, which are detrimental to the biological balance of agrosystems, thus contributing to the agroecological regulation of pests (Verchot et al. 2007). Ecological services can therefore be preserved while mitigating the impact of the climate on biodiversity. Moreover, it is essential to find novel ways to design cropping systems that will provide efficient pest protection through ecological processes.

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