6 The big giveaway

Farmers and biological constraints

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Introduction

It is estimated that the countries of Southern Africa need to increase food production by 2% or more per year to feed present and future populations (FAO, 2011). One of the most effective means of achieving this goal is through the reduction of losses due to pests and diseases.

The amount of food lost during production and postharvest due to the activity of pests and diseases has been estimated to be as high as 60% (Oerke et al., 1994; Oerke and Dehne, 2004; Savary et al., 2019).

Biotic constraints in Southern African agriculture are numerous and include insects, mites, fungal pathogens, viruses, bacteria, nematodes, rodents, birds and weeds. Please note that the term “pest” will be used in this chapter as a catch-all term for all these detrimental organisms.

These pests are major limiting factors to food production in Southern Africa, where small family farms of < 2 ha produce crops under largely rainfed conditions, with poor access to basic agronomic inputs, and often under climatic stress conditions. Even in the Southern African countries where larger size family and commercial farms predominate, and where sound agronomic practices and pest management systems are in place, crop loss due to biotic constraints is ever present.

According to the authors – “there is no such thing as a healthy plant in nature”. All plants are under constant attack by one or more pests, both in the field from planting up until harvest and then in storage.

Pest damage to crop plants in the field and to stored food produce are to a major degree responsible for periodic hunger and for dependency on food imports, and in some cases food aid. Small family farms in rural communities are not producing at levels that ensure sufficient short- and long-term food availability. This is especially true at specific times of the year, when drought conditions exist or when there are major pest outbreaks. These small farms, however, do have the potential to produce healthier and thereby higher yielding crops. In this chapter we will demonstrate: 1) the massive losses farmers incur due to pests; 2) the impact of inadequate pest management on crop yield; 3) the losses caused by postharvest pests; and 4) the threat of invasive pests.

We will conclude by underscoring the need for new or improved agricultural policy and associated processes to make plant protection technologies available to small- and medium-size farmers.

The magnitude of crop loss

A number of key studies have demonstrated the enormous amounts of yield lost to pests in Africa and around the world on a wide range of crops (Oerke et al., 1994; Tefera, 2012; Sikora et al., 2018; Savary et al., 2019).

To demonstrate the devastation these biotic stressors have on crop production in Southern Africa, we compared maize and tomato yields in Southern African countries with that of the world average (Table 6.1).

The differences in yield between the world average and Southern Africa, with only a few exceptions, are enormous. The major Southern African maize producing countries harvest only 37.4% of the world average. For tomatoes, a similar discrepancy was found with a yield of 45.3%. This means the countries of Southern Africa are greatly underproducing many food crops when compared to other regions of the world. These differences in yield are even more pronounced if the crop yields in the Republic of South Africa, which is subjected to similar climatic conditions, are used for comparison. Yield reductions of at least 50% for maize and 80% for tomatoes are evident in most of the other countries in the region. These results illustrate the large potential existing in

Table 6.1 Production of maize and tomato in ten countries of Southern Africa (average 2015–2017)

Region/ Country	Maize			Tomatoes		
	Area [1000 ha]	Yield [kg/ha]	Production [1000 t]	Area [1000 ha]	Yield [kg/ha]	Production [1000 t]
World	194,328.3	5,637	1,095,689.8	4,836.4	37,169	179,770.3
Africa	38,987.3	1,975	77,080.6	1,292.6	16,787	21,685.2
Southern Africa, total	10,663.5	2,106	22,459.3	69.0	22,895	1,580.6
– relative to world	5.5	37.4	2.0	1.4	61.6	0.9
– relative to Africa	27.4	106.6	29.1	5.3	136.4	7.3
Angola	2,098.7	1,087	2,271.1	6.0	2,703	16.2
Botswana	43.3	223	9.2	0.1	53,997	5.7
Lesotho	102.2	722	85.8	–	–	–
Madagascar	180.3	1,714	308.9	4.9	8,527	41.8
Malawi	1,691.9	1,693	2,870.0	24.4	19,863	485.6
Mozambique	1,676.2	883	1,484.4	0.7	13,386	9.8
Namibia	31.9	1,958	62.4	1.5	6,090	9.4
South Africa	2,409.4	4,716	11,517.8	7.8	75,353	584.7
Zambia	1,151.8	2,676	3,032.6	2.6	9,782	25.7
Zimbabwe	1,275.8	626	802.5	3.7	7,020	25.9

Source: FAO (2019)

the region to produce higher yields when appropriate agronomic practices and pest management are adopted.

Crop production with and without pest management

In Figure 6.1, we present what is estimated to be maximum production potential for maize (large circle), maize production with pest management (middle circle) and production without integrated pest management (small circle) on a global scale.

The estimates provided in Figure 6.1 were extrapolated from data collected from large farms as well as university and industrial experimental fields (Oerke et al., 1994). Regardless of the source of the data, it is clear that under good agronomic conditions the lack of adequate pest management leads to significantly high crop loss as seen by the large differences between the middle and small circles.

With the exception of a few countries in Southern Africa, the small circle probably best represents the current situation with regard to the level of production and the degree of pest damage to maize on most small farms. In fact, the level of losses is probably even higher. These are farms characterized by inadequate agronomic inputs and ineffective pest management. Similar negative production estimates for other crops grown in the region under similar agronomic conditions and without pest management are to be expected.

Figure 6.1 Estimated production potential for maize (large circle); production with good agronomic practices and pest management (centre circle) and production with good agronomy but without plant protection (smallest circle)

Source: Data for production worldwide and by region for the period 2002–04; data from Oerke (2006)

The giveaway

The differences in production presented in the previous table and figure are what we call the farmer's *giveaway*, with pests being the primary recipients. In the end, farmers are attempting to produce food for human consumption, but a large proportion of their yield ends up being given away for consumption by pests. This unwanted *giveaway* is the result of 1) lack of knowledge of the presence and/or importance of the pests and how to manage them, 2) insufficient access to pest management inputs and 3) poor access to extension information on pest management.

The fact that the majority of family farmers in Southern Africa are giving away vast amounts of yield to pests is catastrophic. This is especially true when one considers the serious food shortages and poor nutritional status that affects people in the region.

Conversely, larger family farms and commercial farming enterprises in some countries in Southern Africa – those who have a stronger financial basis and access to modern agronomic and pest management inputs – seem to be less affected by pests.

Crop-specific losses

The overall loss potential due to major pests in different crops around the world was evaluated by Oerke et al. (1994) and Oerke and Dehne (2004). The actual amount of loss, i.e., losses despite the use of modern integrated crop protection practices were estimated for wheat, rice, maize, barley, potatoes, soybeans, sugar beet and cotton for the period from 1996–1998 on a regional basis for 17 regions. Actual losses were estimated at 35%, 39% and 40% for maize, potatoes and rice, respectively.

In a recent study, yield losses for 137 pest species on wheat, rice, maize, potato and soybean worldwide were estimated at different hotspots around the world including sub-Saharan Africa (Savary et al., 2019). Their survey showed that in Southern Africa average loss and the range of losses for different crops were wheat 21.5% (10.1–28.1%), rice 30.0% (24.6–40.9%), maize 22.5% (19.5–41.1%), potato 17.2% (8.1–21.0%) and soybean 21.4% (11.0–32.4%). The greatest losses were detected in food-deficit regions with fast-growing populations.

On a worldwide basis, weeds had the most severe impact on yield (32%) followed by animal pests and then pathogens at 18 and 15%, respectively. Added together the total loss due to these major pests is over 60%. Weeds are a farmer's worst enemy, with smallholder farmers, mainly women, spending 50–70% of their total labour time hand weeding (Gianessi and Williams, 2011).

Pest damage chain

The amount of yield lost to pests is complex in that farmers are constantly confronted with a series of losses caused by the simultaneous occurrence of pests along the food chain from sowing until harvest and thereafter in storage (Figure 6.2). Pests seldom if ever come packaged alone.

Figure 6.2 The yield loss chain, illustrating the biotic and abiotic constraints that may affect crops during the crop cycle from before seedling emergence up to storage

Source: Adapted from Harris and Lindblad, 1976

At every stage of crop production, from the field to the marketplace, a certain percentage of yield is slashed off by one or more pests acting singly or in consortium, resulting in cumulative damage that exceeds that caused by any single pest acting alone. A simplified chain of events affecting plant health could include: 1) fungal and viral contamination of seed in storage for planting; 2) ever present soil-borne weeds, fungal pathogens and nematodes; 3) fungal spores distributed by wind; 4) highly mobile below- and above-ground insects; 5) insect vectors of disease causing organisms; and 6) birds and rodents.

Depending on 1) initial pest density; 2) pest complex; 3) susceptibility of the crop variety; 4) climatic conditions; 5) the nutritional status of the plant; and 6) quality of storage silos, the pest damage chain can and does result in very high accumulated losses, as shown in Figure 6.1.

Postharvest losses

Pest damage does not stop at harvest but continues during postharvest storage when the grain is fed upon by insects and rodents and is further degraded through the activity of fungal molds.

Insect damage during postharvest storage can be extensive and is usually the results of poor methods of exclusion from storage bins (see Chapter 13) and when no pest control is applied. Two major examples are the larger grain borer (*Prostephanus truncatus*) and the maize weevil (*Sitophilus zeamais*), which can cause losses of up to 65 and 80% respectively (Boxall, 2002; Muatinte and Van den Berg, 2018).

In addition, postharvest losses can occur at different stages, from harvest to the marketing process itself (Tefera, 2012) (Figure 6.3). At this time, for example, pests reduce the quality of horticultural products such as fruits and vegetables in storage and even during transport to markets.

A major unseen enemy that directly affects consumer health is the molds that cause indirect damage and quality loss due to contamination of grain in storage bins (Bandyopadhyay et al., 2016; Savary et al., 2019; Akello et al., Chapter 21 in this volume). A number of fungi infect maize and other grains as well as vegetables and contribute to both quantitative as well as qualitative loss in food value and a decrease in market value.

These fungal molds are responsible for the formation of toxins (Fandohan et al., 2005) that are highly toxic to humans and livestock (see Chapter 21 in this volume). Aflatoxins are responsible for stunting in children, cancer in adults and negative effects on livestock health. These fungal molds infect maize, groundnut and other crops in Southern Africa and produce aflatoxins in food stuffs at concentrations far above the WHO recommended standards. The presence of these toxins in many cases would lead to 100% loss in many countries of the world where aflatoxin levels are monitored and thresholds enforced.

Figure 6.3 Graphic presentation of the degree of losses caused by storage pests which take place during the harvest and other grain handling processes

Source: Own representation, modified from Boxall, 2002; Muatinte and Van den Berg, 2018; Tefera, 2012

Figure 6.4 Regional differences in the overall efficacy of crop protection practices in 11 crops (barley, cotton, maize, oilseed rape, peanuts, potatoes, rice, soybean, sugar beet, tomatoes and wheat); calculations are based on loss estimates between 2002–2004

Source: Own representation

Distortions in the effectiveness of pest management

To make matters worse, there are strong regional differences in the efficacy of plant protection practices applied in the region (Figure 6.4). The effectiveness of pest management in West, East and Southern Africa, for example, is significantly below the worldwide average measured over 11 crops (Oerke and Dehne, 2004).

This discrepancy in control efficacy between regions is probably due to 1) a lack of awareness of the cause of damage; 2) improper selection and/or access to plant protection products; 3) ineffective application procedures; and 4) poor access to extension service knowledge support systems.

The unwanted guests

The threat of introduction of invasive pests represents another major challenge to food production. A recent review by Sileshi et al. (2019) reported that 16 current alien invasive insect and mite pests have invaded new areas in Africa. These pests will, over time, spread to countries in Southern Africa, where they will cause significant crop damage (Muatinte and Van den Berg, 2018). Unless suitable measures of quarantine are in place to prevent the introduction and

spread of alien invasive species, crop damage cannot be avoided (CABI, 2019). Unfortunately, the often understaffed and poorly funded phytosanitary programmes in Southern African countries leads to enhanced spread of invasive pests in the region.

Five destructive invasive species which threaten agricultural production and food security in East and Southern Africa were discussed by Pratt et al. (2017). The estimated economic impacts of these five invasive species on maize cultivated in production systems with beans and tomato caused combined annual

Table 6.2 List of important invasive pest species, their host crops and estimated economic impact

<i>Invasive pest</i>	<i>Major hosts</i>	<i>Regions affected</i>	<i>Estimated losses</i>
Spotted stem borer <i>Chilo partellus</i>	Maize and sorghum	East Africa, 1920s. (Now East and Southern Africa)	US\$450 million/yr Smallholder losses
Maize Lethal Necrosis Disease (MLND)	Maize, sorghum, millet and some grasses	Kenya in 2011. (Now Tanzania, Uganda and Rwanda)	US\$350 million/yr Smallholder losses
Weed species <i>Parthenium hysterophorus</i>	Grasses in pastures, maize	Southern Africa	US\$82 million/yr
Leaf miner <i>Liriomyza trifolii</i>	Horticultural crops, vegetable, affects marketability	Most of East and Southern Africa	Total fruit losses Farm closures
South American tomato leaf miner <i>Tuta absoluta</i>	Vegetables, affects marketability	Tunisia, 2007. Most of East and Southern Africa	US\$791.5 million
Fall Armyworm <i>Spodoptera frugiperda</i>	Attacks 350 plant species incl. maize, sorghum, millet, rice, groundnut, vegetables	West Africa, 2016. All of SSA	Maize 20.6 million t/yr in 12 countries 53% of production, US\$6.2 billion
Panama fungal wilt disease <i>Fusarium oxysporum</i> Race 4	Banana – Cavendish	Mozambique, 2017	Total crop loss
Fruit fly <i>Bactrocera invadens</i>	Horticultural crops, Mango, avocado	Kenya, Mozambique, Tanzania, Uganda	60% fresh fruit loss Negative local and export impact
<i>Liberibacter asiaticus</i> (Asian greening disease) Transmitted by the psyllid <i>Diaphorina citri</i>	Citrus	Ethiopia, Tanzania, Kenya, Réunion and Mauritius.	Millions of trees destroyed in the Americas

Sources: CABI, 2019; Mahuku et al., 2015; Rubaba et al., 2017; Kiruwa et al., 2016; Goergen et al., 2011; Viljoen, 2019

losses of US\$0.9–1.1 billion. They estimated future annual losses over the next five–ten years at US\$1.0–1.2 billion and indicated that it could be much higher.

Conclusions

Biotic stresses in the form of a wide array of pest organisms are a major constraint to food production. Losses in yield of food crops in the region are far more serious than that of the world average. These pests impact yield from seeding to postharvest storage and indicate a major lack of pest management at farm level. These pests are responsible for food insecurity in many countries during years affected by low levels of production (e.g., drought), between crops and harvests (hunger-season) but also over longer periods of time due to chronic underproduction.

These losses are manageable with proper pest management as discussed in a number of chapters in this volume. In many cases small family farmers are not familiar with pests and diseases, cannot access this type of information or the inputs to control these pest organisms are too expensive, which leads to immense losses.

By reversing the food *giveaway*, Southern Africa could produce enough food to reduce food insecurity until at least 2050 and beyond by using currently available pest management technologies to reduce pest-induced losses in all crops through improved: 1) integrated pest management programmes (IPM) supported by extension programmes; 2) crop breeding for resistance to biotic and abiotic stresses and seed distribution programmes; 3) improved postharvest storage technology; 4) food toxin management; and 5) improved phytosanitary services (all outlined in the chapters in this volume).

It is imperative that government policies are put in place that improve small- and medium-size farmer access to pest management systems as well as the other inputs of modern agriculture. A significant improvement in extension services and their information technological knowledge dissemination systems also is needed.

Intensification of crop production without addressing pest management will have disastrous effects in terms of food security and is probably economically irrational and ecologically irresponsible.

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