# Yield Losses of Crops Due to Plant Diseases in Ethiopia

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## Abstract

Crops are constantly affected by many diseases, among which rusts in wheat, blight in maize, coffee berry disease in coffee, late blight in potato and tomato, virus diseases in hot pepper and foot rot and viruses in citrus are some of the principal problems in Ethiopia. Yield loss records due to plant diseases are found in fragmented and scattered sources, although they are frequently referred in many reports of crop production to indicate their importance. At present, it is very difficult to evaluate the impact of plant diseases in crop production and take appropriate decisions, either at policy or farm management level. In this review article an attempt is made to compile the literature on yield losses due to diseases in Ethiopian crop production. The review also includes the importance of reliable and accurate loss data to facilitate decisions and provides yield levels of crops in relation to the developmental stages of crop production in Ethiopia, ie, primitive, actual, economic, attainable and theoretical levels. Besides, some useful and applicable options of loss assessment methods for different groups of plant diseases are briefly outlined. As a major section, yield loss records in cereals, pulses, oilseeds, vegetables, and some plantation crops are exhaustively summarized and discussed. Finally, crop-loss assessment program for the diseases not yet studied is proposed so that reliable and accurate data could be generated and the information obtained from this exercise is promptly disseminated to facilitate decisions from time to time.

## Introduction

Ethiopia is an agricultural country where more than 85% of its population is directly or indirectly engaged in agriculture (Teketel 1996). Crop production is a major enterprise that supports the majority of the people of which cereals, pulses, oilseeds, vegetables and many plantation crops are grown in the country's diverse agro-ecology (CSA 1998, 1999). For convenience, the yield loss data are, therefore, summarized in accordance with these commodities in the agro-ecologies they grow.

There were repeated questions to quantify yield losses of crops due to plant diseases under Ethiopian conditions and qualify the loss assessment methodology. In many conferences of the Crop Protection Society of Ethiopia, doubts have been expressed on the reliability of the existing loss figures and on the methodologies followed to generate these evidences. This is because, the importance of plant diseases is based on the yield losses they cause (Chiarappa 1971). Furthermore, there were also queries on how to organize a system to generate reliable and accurate loss data for the diverse cropping systems and agro-ecology so that appropriate decisions can be taken at various stages.

Reliable and accurate loss data are useful for governmental policy decisions in the areas of crop production and agricultural science programs of the country, economic decisions on farm and agro-industry levels, public and group decisions on environmental impacts of plant diseases, decisions on the resource utilization and development thereby assist the food security program of the country and determine plant protection needs of the country (Chiarappa 1971, 1981).

Loss information is very important to take decisions at different levels in a society (Zadoks 1981). At farm level, decision to effect control measure(s) requires knowledge of the magnitude of losses due to particular disease or group of diseases; while at government level reliable information on the level and trends of losses helps to develop agricultural inputs and allocate resources. Other objectives of generating loss data could serve the needs of individuals working in disease management in crop production where continuous sources of updated and useful information are essential. Periodic review like this one is, therefore, essential to update the information related to yield losses.

In the literature, although scattered, there are many estimates of losses due to diseases of many crops in Ethiopia (Tables 1,2,3,4, 5, 6). However, in many cases, realistic crop loss assessments have not been made due to many difficulties. These include (i) potential of a crop (USDA 1978), (ii) damage level of diseases (James 1974), (iii) the relationship of disease and yield levels (Habtu et al. 1997) and (iv) yield levels that depend on the level of agricultural development (Zadoks 1981). The question of relationship of disease and yield levels implies the need for assessment of losses in crop production.

The yield loss data reported in Ethiopia up to now indicate that loss is neither realistic nor accurate as in any places in the world (Chiarappa 1971, 1981). However, we thought that it is still important to review the available scattered data and suggest new methods to refine them for future works. Obviously, the place of plant diseases in Ethiopian agriculture is realized when reliable information on yield loss is available. On the other hand, many useful information on this topic are found in scattered literature in which it is difficult to understand the impact of diseases in Ethiopian agriculture. This paper attempts to (i) summarize the yield loss records of over 55 diseases of 26 crops in Ethiopia, (ii) give some options to quantify yield losses due to diseases with limited resources and manpower, (iii) provide organization of a crop loss program to periodically evaluate shifts of the losses in order to couple policy decisions to minimize them. The strength and shortcomings are also discussed to point out some principles on how to establish yield losses for different groups of pathogens and crop production systems.

## Relations of Loss Data with Yield Levels

Considering all aspects of crop production and agricultural development in the world, there are five stages of crop yield (primitive, actual, economic, attainable, and theoretical) that are characterized by specific features (Zadoks & Schein 1979, Zadoks 1981) thereby determine the definition, scope, application and type of losses caused by plant diseases. Each of this is briefly described with respect to magnitude and type of crop production systems in Ethiopia, because interpretations of yield losses differ in the different yield levels. Moreover, the evidence or data obtained in one yield level couldn't be applied to estimate the effects in the other yield level. This totally causes erroneous inference or decision that gives absolutely misleading ultimate results. Hence, we have catagorized crop production systems in Ethiopia into different yield levels so that we can properly determine and understand the yield loss data in each group.

### Primitive yield

Modern inputs (improved seeds, mechanized tillage, fertilizer, irrigation, crop protection, etc.) are not applied at this yield level. As calculated from CSA (1998, 1999), at present more than 5 million ha of land in Ethiopia gives this yield level. These include plots with landraces of different crops grown under traditional farming practices in the whole country. Hence, yield losses need to be produced under these situations in order to judge the impact of diseases in this situation. Over 90% of the yield loss data presented in this paper do not apply to this huge farming conditions. However, the countries' major production comes from this category. Actual crop protection profits are realized at this stage where loss is avoidable (Zadoks 1981) with minimum efforts. As far as food self sufficiency is considered, this production system is not encouraged and loss experiments are less emphasized.

### Actual yield

This is a crop yield that is obtained by certain level of modernization. The package program embarked at present in Ethiopia and many on-farm and demonstration plots managed by farmers and researchers jointly fall into this catagory. At this agricultural development level, partial or total use of inputs could always be adopted and actual crop protection is profitable with more efforts than traditional subsistence farming. At this stage, crop loss is avoidable and at present about 2.6 million ha of land produce a yield level of this kind in Ethiopia (CSA 1998, 1999). Some yield loss data given in this paper, somehow, apply to this category as they were obtained under situations of many agro-ecologies based on large production plots using several cultivars and years. Although this type of data dose not seem to exist in the litrature we reviewed, yellow rust of wheat (Eshetu 1985), wilt/root rot of lentil (Dereje 1986), bean antracnose (Tesfaye 1997), Coffee Berry Disease (Merdasa 1985) and sugar cane smut (Berhanu & Mengistu 1993) could fairly be used for this type of farming.

### Economic yield

At this agricultural development level, except skill and knowledge components, all the modern inputs are used and crops are well managed at economic justification. Crop production is always a profitable enterprise at this level of development and system. Some on-farm trials conducted by researchers at present fall in this category. It gives the highest return on investment. There is a potential profit from crop protection practices at this level. However, there is no yield loss data reported in this paper that is apropriate to this system except that of CBD (Merdasa 1985) due to high economic return from coffee. This yield loss requires data produced under conditions of many locations using several cultivars in large plots for several years that are verified for economic purposes.

### Attainable yield

All necessary inputs, skill and knowledge components of the farming system are applied. This may at times coincide with economic yield. All on-station field trials (yield, agronomic, soil, protection, verification, demonstration, etc) conducted by researches and those occupied by sugar cane plantations, some wheat, maize and cotton farms do give attainable yield in Ethiopia. A good portion of crop land, although difficult to estimate, gives this level of yields. All yield loss data reported here apply to this group and in this case the loss figure is high because the effect of diseases is magnified by agricultural inputs applied and uniformity of management practices. Crop loss is unavoidable at this level and crop protection may not be profitable unless judicious application of management practice is in effect and integrated disease management (IDM) is fully developed and applied.

### Theoretical yield

This is the upper limit of production calculated by crop physiologists. Equally spaced and well-managed trials conducted by physiologist could fall in this category. Crop loss is unavoidable and no profitable practice of crop protection is known so far for this type of system or practice.

## Interpretation of the Yield Loss Data

Crop losses signify the reduction in quantity and quality of produces while yield loss refers only to the loss in quantity of produce of an enterprise. Therefore, loss figure has to be carefully used without loosing the meaning and efficiency in communication (Chiarappa 1971, 1981). Yield loss of crops, the subject of this paper, differ in different levels of agricultural development (Tables 1-5). In Europe and North America, crop losses are the difference between attainable yield and actual yield that is produced with modernization of agricultural production (Zadoks & Schein 1979). But in Ethiopia and similar developing countries, losses are the difference between attainable and primitive yields. In these countries, although different and mixed farming conditions exist, traditional farming dominates where crop losses have to be reduced to obtain good harvest.

Interpretation of loss data is very important for practical reasons because disease management decisions require proper loss data for a particular yield level, which is the reflection of the production conditions. From the available loss data, disease management practices could not be invisaged for 5 million hectares of traditional farming conditions in Ethiopia. It can only be used for some 2.6 million hectares without precision. This is because, almost all the loss data reported here were generated under conditions that atleast includes (i) good land preparation, (ii) row planting or similar practices, (iii) high fertilizer application, (iv) clean crop or frequent weeding, harrowing and howing, (v) optimum seed rate and seeding date, etc. that differ from normal farmers production circumstances. Therefore, loss data should be qualified before use to take decisions at any level. We have to note here that the definition and application of loss data differs with the conditions it has been produced and for what type of yield levels we are using it.

It is expected that disease management practice with improved packages increase the yields of traditional farms than modernized ones because the difference is very large. Habtu et al. (1997) also discussed their result by emphasizing the impact of bean rust to be greater in the low input conditions than the higher management conditions which is in line of the above consideration.

Decrease of crop yields due to disease pressure is mostly apparent only in the primitive, actual and economic yield levels where these losses are avoidable and crop protection is actual and potential. In the attainable and theoretical yield levels, crop losses couldn't be avoided and crop production must couple with disease management to reduce crop losses at farm level (Zadoks & Schein 1979, Zadoks 1981).

## Methodologies Used to Generate Loss Data

Methodologies are among useful tools to qualify loss data. Most loss data reported were generated from field experiments designed to assess losses and estimation (reports of authorities) while some of them were obtained from survey results, chemical trials, and variety screening (Tables 1, 2, 3, 4, 5). Therefore, inorder to understand the level of precision, the methods used to generate the reported loss data are discussed with respect to disease types, farming practices, check plots, yield and disease measurement.

### Disease types

Loss assessments are easier for diseases such as root rot, wilt, head smuts, etc., where yield losses are equal or closer to disease intensity (severity) than foliar or systemic diseases. Bunt of wheat (Niemann et al. 1980), black root rot of faba bean (Dereje & Tesfaye 1994), wilt/root rot of lentil (Dereje 1986), root rot of haricot bean (Habtu 1981), wilt of enset (Lemma 1976) and sugar cane smut (Berhanu & Mengistu 1993) are among results that can immediately be used without much refrain for many different conditions. This is because, the loss data doesn't change much due to the nature of the diseases where the horizontal transport of the disease is generally very limited. However, foliar diseases such as rusts, mildews, blights, etc. are difficult to quantify and interprate loss data. Systemic diseases and many plant diseases with partal damage of stems, branches and underground parts are even more difficult to assess losses. Hence, data from such studies are treated cautiously.

### Farming practices

All loss data generated through field experiments are obtained from practices different from that of farmers'. They are produced under maximum care of researchers from plots with uniform cultivars/varieties, small size, dense and clean crop from weeds, fertilized, etc. that is far from farmers' traditional conditions. This difference challenges the loss data reported to date. Therefore, results of loss assessment trials should be verified under farmers circumstances in different agro-ecologies before use.

### Check plot

Check plots are important reference points to judge the results of experiments in science. Four check types are identified in our case. The first is healthy (protected) check which mostly were not completely free of infection or free of mixed infection in which case proper regression analysis was not used to estimate the yield for disease free plots. The second is checks of variety screening trial used to assess yield losses. It is obviously erroneous to attribute yield differences of two genotypes only to disease pressure where there are many other inherent differences. The third was check used in chemical (fungicide) trials for loss assessment. There are many differences between treated and untreated plots besides disease pressure that include differential application of systemic and non-sytemic fungicides, rate of fungicides, etc. The use of systemic chemicals for loss assessment is not accepted as most of these chemicals interfere with the metabolism of both the host and the pathogen. The fourth and the last is the check used in survey or inoculation trials. In these cases, the reference plots or plants are fairly those that are not diseased, hence are good checks to judge the yield losses although they may over estimate the disease compared to the natural incidence.

### Disease and yield measurements

Diseases mostly do not occur in uniform state at the same time, on the same plant grouth stage and at different places, hence produce varying effect on plants. Therefore, proper measurment of disease intensity and yield level at different conditions is crucial. Disease intensity is well understood if we use percentage figures. However, yield losses when expressed in percentages looses precision as the denominator and conditions of check plots mainly affect the ultimate result. Generally, measurements should be described well so that results could be utilized for practical purposes or to consider some disease management options.

## Options of Yield Loss Assessments

Yield losses are obtained by having at least two yield estimates; one which is diseased and the other which is disease-free that serves as check plot (Chiarappa 1971, 1981). But there are two difficulties here. In the first case one can't ensure epidemics by introducing inoculum if the disease does not occur in nature (Assefa et al. 1996, Habtu et al. 1997) and in the second case one cannot again produce a field which is completely free of disease by protecting one portion of the land (James 1974, Zadoks 1981, Dereje 2000). Generally it is difficult to ensure uniform epidemics by introducing inoculum or to control them by pesticide application although many of the global loss information depends on these methods (Chiarappa 1981). Nevertheless, if these methods are used cautiously, they produce the best result that facilitates decisions. Crop performance is influenced by many factors that further complicate the estimation of yield losses. Absence of disease, severity gradient in the field, an expected level of disease, many diseases occur together in the field, etc. are important occurrences in loss assessment endeavors (Chiarappa 1971, 1981). Because of these complications, employing the following methods could provide reliable and reasonably accurate loss estimations.

### Single plant/single tiller comparison method

This method is used when a plant community has diseased and healthy stems, tillers, branches etc. as components. For example wilt in plants, foot rot in cereals and pulses (Dereje 1993), eye spot (Eshetu & Yitbarek 1983) and take all in cereals, dying of trees, viruses in plants, head and cob rots, smuts, bunts, etc. can be measured precisely using this method (Chiarappa 1971, 1981).

### Small area comparison methods for patchy diseases

Root and foot rots are known examples in this group (Dereje 1986, 1993). Yield samples are obtained from the diseased portion of the land and from healthy patches. These two yield levels can be compared to indicate the yield losses. This is because, the same size of area could be obtained for diseased and healthy patches and can be harvested and measured for yield parameters (Eshetu & Yitbarek 1983).

### Half-field (on-farm) comparison method

All air-borne diseases with general type of infection such as rusts, mildews, blights, blotches, spots, etc. are assessed using this method (Dereje & Beniwal 1988, Tesfaye 1997).

### Chemical/Pesticide trial comparison method

This is possible only when protectant pesticides are used (James 1974). Most systemic ones interfere with metabolism of both the pathogen and the host (Dereje & Beniwal 1988, Dereje 2000) where yield of sprayed plots might be enhanced unnecessarily and give misleading result (James 1974). In this method, plots may receive different spray intervals or rate of chemical application to insure gradient of the disease where concomitant variation of disease and yield can be measured.

### Inoculation trial comparison

Any type of disease can be assessed by this method if most condition of crop growth are simulated (Assefa et al. 1996, Habtu et al. 1997). This method is useful in that different stages of the crop could be inoculated by a disease and useful data can be obtained like that of Assefa et al. (1996).

### Indirect "data" from authorities or marketing

For export commodities, this can provide good data but in some products where the marketing is unknown, it is difficult to utilize this method. But the reports of authorities are always there. In Ethiopia, coffee could be measured in this way since there are long term and organized marketing systems.

Yield loss data needs to be qualified in order to use them for decision making at any level. In Ethiopia, most yield losses are generated only at specific location or even they are estimates of specific cropping patterns, hence to use such data it needs precautions. One precaution is that evidence of field experiments should be more referred than mere guesses because these may mislead decisions.

## Ethiopian Yield Loss Reports

Since there is a diverse crop composition in the different agro-ecologies in Ethiopia, yield loss summary of crops viz. cereals, pulses, oilseeds, vegetables and some plantation crops are given for convenience. Most of the data are those either produced by field experiments as loss assessment trials or reliable estimates by surveys targeted to crop loss assessment.

### Cereals

Ethiopia devotes over 5.7 million hectares of land to cereals of which tef, maize, sorghum, wheat and barley are dominant crops (CSA 1998, 1999). Most inputs (fertilizer, improved seed, pesticides, etc) are used for maize, tef and wheat in which about 25% provide actual yield while 75% are produced without inputs and provide only primitive yield CSA (1998, 1999). This gives high opportunity for plant breeders to produce new (improved) technologies from time to time. The economic justification is that they produce impact simply because the difference between attainable and primitive yields are very high.

Yield loss information is mostly from field experiments in cereals except for tef (Table 1) where simple estimations were reported. This crop is unique to Ethiopia (Seifu 1997) and the yield loss data should be worked out here. Sorghum had been given also less emphasis and insufficient loss data is available for our conditions (Table 1). But, most diseases of barley, wheat and maize are well investigated and the yield losses are estimated from field trials and even some are from controlled environments. Estimation of yield losses due to wheat diseases were the highest (up to 96% for stripe rust). This may be due to several factors such as mechanized farming, use of fertilizer and pesticides. These conditions usually push yield losses up and most of these experiments are done in experiment stations where crops are managed more than normal crop production practices. This type of exaggerated figures may come from extra-ordinary management of the crops in small plots where large marginal or border effects dominate. In addition, stochastic errors may give such high loss data from small plots. Most field experiments conducted were also done using fungicides to control the disease. In large production fields, perfect control of the checks is impossible (James 1974, Dereje 2000). But yield loss data were produced by assuming that complete protection was assured (assumed as they were produced in small plots).

### Legumes

About one million hectares of land is devoted to legumes of which faba bean takes over 35% among the most important legumes (CSA 1998, 1999). Almost all important diseases of legumes had loss information for Ethiopian conditions (Table 2). Devastating diseases such as chocolate spot of faba bean may cause losses up to 61.2% on susceptible cultivars (Dereje & Beniwal 1988). In haricot bean, rust has the highest loss record of 67% (Habtu et al. 1997) and in lentil Ascochyta causes 71% yield loss (Mengistu & Nigussie 1994). Wilt causes up to 68% loss on lentil where a mean of 16.8% was recorded for Becho-Tefki basin (Dereje 1986). However loss records in legumes are mostly generated through field trials except for chickpea which are authoritative estimations. Zadoks (1981) considers authoritative estimations and records to be very useful for policy decisions since these experts have rich experience in the area. These figures are not so high as farmers do not use improved technology for legumes. More than 98% of the land devoted to legumes gives primitive yield at present. Even then, yield losses are recorded fairly low, which shows that there is low yield loss in legumes than in cereals.

## Oilseeds

Over 350 thousand hectares of land is devoted to oilseeds every year in Ethiopia. This is about 2.8% of the total cultivated land (CSA 1998, 1999). There are a few yield loss records in oilseeds (Table 3) although most were calculated from fungicide trials, survey and mere guesses. They are produced from indirect sources, except groundnut *Cercospora* which was well extensively investigated through field experiments (Geremew & Asfaw 1991).

In oilseeds, there is very low evidence of crop losses where most records are estimations as reported in conference papers. Generally, these are crops having very low yield losses due to diseases.

## Vegetables

Vegetables are sensitive to many diseases and demand more care than other crops such as oilseeds, legumes and cereals. Most diseases of vegetable crops such as potato, tomato, cabbage, onion and garlic are very devastating. For instance, late blight on potato, leaf spot on tomato and stem blight of pepper are serious diseases causing yield loss of 67, 67 and 88% respectively (Table 4). Like in oilseeds, yield losses on many diseases of this group of crops are generated from fungicide trials and are indirect information. As they are sensitive crops, and are perishable in nature, yield loss studies would have been more encouraged. Vegetable losses should have been more than what was reported in this review if post harvest losses were included.

## Plantation crops

For convenience, we have grouped many crops under plantation crops. Large area of land, over 450 thousand hectares, is devoted to these crops every year in Ethiopia (CSA 1998). Coffee, banana, enset, and citrus are some of the major crops in this group (CSA 1998, 1999). No much information is available concerning yield losses due to diseases except for coffee berry disease that have been well investigated and documented (Table 5). Coffee Berry Disease (CBD) has a national yield loss record of about 28% (Merdasa 1985)

Yield losses of crops due to plant diseases

Table 1. Yield losses of major cereal crops due to plant diseases in Ethiopia

| Host | Disease | Pathogen | Percent yield loss up to* | Method used | Reference |
|---|---|---|---|---|---|
| Tef | Head smudge | *Helminthasporium miyaki* | 50 | Estimation | Eshetu 1985 |
| | Rust | *Uromyces eragrostidis* | 25(30) | Estimation | Eshetu 1985, Seifu 1997 |
| | Damping-off | (Several) | 50 | Estimation | Eshetu 1985 |
| Barley | Scald | *Rhynchosporiwm secalis* | 67 | Field experiment | Eshetu 1985 |
| | Net blotch | *Helminthosporium teres* | 34 | Field experiment | Yitbarek & Wudneh 1985 |
| | Rust | *Puccinia hordi* | 23 | Field experiment | Getaneh 1998 |
| | Yellow rust | *Puccinia striiformis* | 22 | Estimation | Yitbarek et al. 1996 |
| | Eye-spot | *Pseudecercosporella sp.* | 9 | Survey results | Eshetu & Yitbarek 1983 |
| Wheat | Blotch | *Septoria spp.* | 82(25) | Field experiment | Niemann et al. 1980, Eshetu 1985 |
| | Yellow rust | *Puccinia striiformis* | 96 | Field experiment | Eshetu 1985 |
| | Leaf rust | *Puccinia recondita* | 75(27) | Field experiment | Eshetu 1985 |
| | Stem rust | *Puccinia graminis* | 52 | Field experiment | Eshetu 1985 |
| | Bunt | *Tilletia spp.* | 20(5) | Survey results | Eshetu 1985, Niemann et al. 1980 |
| | Eye-spot | *Psedocercosporella sp.* | 29 | Survey results | Eshetu & Yitbarek 1983 |
| | Leaf spot/on head | *Helminthosporium spp.* | 28 | Survey results | Eshetu 1985 |
| Sorghum | Smut | (Several) | 30 | Estimation | Teclemariam 1985 |
| Maize | Rust | *Puccinia sorgi* | 25(6) | Field experiment | Assefa & Tewabech 1992 |
| | Seeding diseases | (several) | 18 | Field experiment | Assefa & Tewabech 1992 |
| | Ear mold | (several) | 37 | Variety screening | Assefa & Tewabech 1992 |
| | Leaf blight | *Helminthosporium turcicum* | ·50 | Field experiment | Assefa et al. 1996 |

* *Values in parenthesis indicate national average*

Table 2. Yield losses of major food legume crops due to diseases in Ethiopian

| Host | Disease | Pathogen | Percent yield loss up to | Method used | Reference |
|---|---|---|---|---|---|
| Faba bean | Chocolate spot | *Botrytis fabae* | 61(23) | Field experiment | Dereje & Tesfaye 1994b |
| | Black root rot | *Fusarium solani* | 29 | Survey result | Dereje & Tesfaye 1994b |
| | Rust | *Uromyces viciae-fabae* | 21 | Field experiment | Dereje & Tesfaye 1994b, Habtu 1988 |
| | Foot rot | *Fusarium avenaceum* | 49 | Field experiment | Dereje 1993 |
| Field pea | Ascochyta blight | *Ascochyta spp.* | 53(31) | Field experiment | Dereje 2000 |
| | Powdery mildew | *Erysphe poligoni* | 38 | Field experiment | Dereje & Tesfaye 1994a |
| Chick pea | Stunt | *BWYV* | 30 | Estimation | Mengistu & Nigusie 1994 |
| | Wilt/root rot | (Several) | 30 | Estimation | Mengsitu & Nigusie 1994 |
| Lentil | Rust | *Uromyces viciae-fabae* | 25 | Field experiment | Mengistu & Nigusie 1994 |
| | Ascochyta blight | *Ascochyta fabae* | 71 | Fungicide trial | Mengistu & Nigusie 1994 |
| | Wilt/root rot | (Several) | 68(17) | Survey result | Dereje 1986 |
| Haricot bean | Rust | *Uromyces appendiculatus* | 85 | Field experiment | Habtu et al. 1997, 1998 |
| | Anthracnose | *Colletotrichum lendimuthianum* | 67 | Field experiment | Tesfaye 1997 |
| | Root rot | *Fusarium sp.* | 20 | Field experiment | Habtu 1981 |

Table 3. Yield losses of major oilseed crops due to diseases in Ethiopia.

| Host | Disease | Pathogen | Percent yield loss up to* | Method | Reference |
|---|---|---|---|---|---|
| Noug | Shoot hol | *Septoria guizotiae* | 10 | Fungicide trial | Yitbarek 1991 |
| Linseed | Wilt | *Fusarium oxysporium* | 30 | Survey result | Dereje unpublished |
| Rape seed | Leaf spot | *Alternaria alterniarae* | 14 | Fungicide trial | Yitbarek 1991 |
| | Black leg | *Leptosphaerea maculans* | 62 | Variety screening | Yitbarek unpublished |
| Groundnut | Leaf spot | *Cercospora personata.* | 65 | Field experiment | Geremew & Asfaw 1991 |
| | Seed rot | *Aspergillus spp.* | 15 | Survey result | Geremew & Asfaw 1991 |
| Sunflower | Downy mildew | *Plasmopara halistedii* | 63 | Estimation | Teclemariam & Tsehay 1987, Mesfin 1991 |
| | Head rot | *Sclerotinia sclerotiorum* | 30 | Estimation | |

** Values in parenthesis indicate national average*

Table 4. Yield losses of major vegetables due to diseases in Ethiopia

| Host | Disease | Pathogen | Percent yield loss up to* | Method used | Reference |
|---|---|---|---|---|---|
| Potato | Late blight | *Phytophthora infestans* | 67(30) | Field experiment | Bekele & Yaynu 1995 |
| Grarlic | Bulb rot | *Corticium rolfsii* | 48 | Estimation | Mengisut 1992 |
| Onion | Purple blotch | *Alternaria porri* | 38 | Fungicide trial | Tesfaye & Habtu 1985 |
| Tomato | Leaf spot | *Septoria sp.* | 67 | Fungicide trial | Tesfaye & Habtu 1985 |
| Pepper | Bleaching | (Several) | 18(20) | Survey result | Girma 1987, Tesfaye & Habtu 1985 |
| | Stem blight | *Phytophthora sp.* | 88 | Fungicide trial | Tesfaye & Habtu 1985 |
| Cabbage | Black rot | (?) | 35 | Inoculation | Temam & Tarekegn 1993 |

* Values in parenthesis indicate national average

Table 5. Yield losses of some plantation crops due to plant diseases in Ethiopia

| Host | Disease | Pathogen | Percent yield loss up to* | Method used | Reference |
|---|---|---|---|---|---|
| Banana | Burrowing nematode | *Radopholus similis* | 14 | Chemical trial | Lemma 1992 |
| Enset | Wilt | *Xanthomonas musisiarum* | 15 | Estimation | Lemma 1976 |
| Coffee | Coffee berry disease | *Colletotrichum cafeanum* | 81(18) | Fungicide trial | Merdasa 1985, Anonymous 1982 |
| | Coffee wilt | *Gribberrela xylarioides* | 9 | Estimation | Merdasa 1985 |
| Kenaf | Root knot nematode | *Meloidogyne spp.* | 29 | Field experiment | Asfaw & Mesfin 1985, Asfaw 1985 |
| Sugar cane | Smut | *Ustilago scitaminea* | 6 | Survey result | Berhanu & Mengistu 1993 |

Values in parenthesis indicate national average

## General conclusions on yield loss records

The yield loss records in different crops due to diseases are from field experiments in small plots, survey results, indirect evidence from chemical and variety screening trials, and authority estimations. Data generated in these ways may have enough precision to serve many purposes. On the other hand, those data generated through field experiments of large fields for more than one year in several agro-ecologies can be subjected to different types of analyses using different models to predict crop loss that serve decisions at various levels. Measurement of disease/crop loss relationships has practical application and has to be reliable and easy. Two models, single point and multiple piont, could be used by considering the nature of disease development. Single point model considers one disease record at a particular crop growth stage to predict crop loss while multiple point models consider several diseases measures to pridict crop loss. For this the crop loss program suggested in the following section could be useful.

## Suggested Crop-Loss Assessment Program

Reliable and accurate data on crop losses due to diseases are useful for (i) economic decisions on the farm level and agricultural industries, (ii) governmental policy decisions in the areas of agricultural production and agricultural science programs, (iii) public and group decisions on environmental impacts of diseases (iv) decisions on resource utilization and development thereby assist the food security program of the country and (v) determine plant protection needs (Chiarappa 1971, 1981).

Therefore, this important data base at national level could be obtained only through sound **crop-loss assessment program** that provide prices or accurate and up-to date crop loss data to facilitate decisions and setting prices. In Ethiopia, a crop-loss assessment program should be considered to generate reliable data on the diverse disease problems of crops grown in the different agro- ecologies of the country. The main objectives of the loss program could be suggested as follows.

**Step-1**: Establish crop disease problems from which loss data can be beneficial. This review clearly shows the gap and helps to analyze the situation and suggests methods to assess the losses.

**Step-2**: Develop evaluation procedures and models to quantify crop losses due to diseases for the vast agro-ecological areas of the country.

**Step-3:** Develop accurate and practical techniques of measuring disease intensity in plants and estimating crop losses (yield, quality, economic value, etc.) that facilitate decisions. The existing literature on disease-loss measuring and estimations need to be evaluated and revised to erect procedures and refine information. When not available, research on improved techniques should be carried out.

**Step-4**: Testing and evaluating methods, techniques and models that are essential for natural field conditions. To use these methods in practice necessitate vast training program at different levels. Hence, provide training for all involved in crop loss programs (different institutions and regions)

**Step-5:** Acquisition of reliable and accurate crop loss data every three or four years at national or regional levels which is the actual process of quantity losses.

**Step-6** Information dissemination should be the ultimate goal of the crop loss program through publications and conferences.

The proposed crop loss program can be launched with other research programs undergoing and may need only some funding. The available infrastructure (human resource, research facility, distribution of research centers in different agro-ecology, etc) could be quite enough at the moment. Implementation should be well planned ahead of time and execution need to be done in coordination.

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