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Major Tef Diseases in Ehtiopia and their Management

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1. Introduction

Tef is often considered as a relatively healthy crop since it suffers very little from epidemics of pests including diseases as compared to most other cereal crops grown in the country (Ketema, 1993, Assefa *et al*., 2011, Assefa and Chanyalew, 2018; Chanyalew *et al*., 2019). This has, amongst others, been due to the fact that the crop species being an indigenous ancient crop originated and domesticated in Ethiopia before the Semetic invasion of 4000-1000 BC (Ponti, 1978), it has co-evolved with the pathogens and other pests over the millennia of its cultivation (Badebo, 2013).

A comprehensive review of the pathological research on tef was made first by Amogne *et al*. (2001) and later on by Badebo (2013). The main objective of this topic is to give a summary of the body of knowledge, information, and innovation on tef diseases and their management in Ethiopia.

This study gives the body of knowledge and information available to date on the biology, distribution, significance, and management of the major diseases of tef in Ethiopia. To this effect, the fisrt section presents an inventory of the diseases so far known and recorded in tef in Ethiopia. The subsequent sections focus on description, symptoms, spore characters, yield losses and management options of five important tef diseases including tef rust (*Uromyces eragrostidis*), head smudge (*Helminthosporium miyakei*), smut sp., zonate eye spot (*Helminthosporium giganteum*), and damping-off. Accounts are also made of recently emerging diseases such as blast and smut. Finally, it is concluded by giving summarized highlights of the diseases and recommendations on the future directions for the management of the diseases.

2. Types of Tef Diseases

Tef is grown almost in all regions of the country as sole crop, mixed crop, relay crop, or in rotation with several types of crops in both *Belg* (short rainy season February to May) and *meher* (long rainy season June to September) seasons. It is also produced as irrigated crop in some areas. In these production systems, tef is infected by about 25 fungal diseases and three pathogenic nematodes (Bekele (1986), Amogne *et al*. (2001), (Table 1). The composition of the fungal species suggests that tef is attacked by different species at the seed, seedling, vegetative, and reproductive stages as well as stored grains. However, only few of these diseases occasionally cause economic yield losses.

Among the fungal diseases, zonate eye spot (*Helminthosporium giganteum*), smut, and leaf blast are recent records(Ashenafi *et. al*, 2018). In the past the fungus *Darluca filum* (B.V. ex Fr) Cast. (*Eudarluca caricis* (Biv). O. E Eriskss (teleomorph) was reported as causative agent of disease in tef; however, this fungus is a mycoparasite of cereal rust-fungi. Bacterial and viral diseases are not known in tef.

For tef rust (*Uromyces eragrostidis*), head smudge (*Helminthosporium miyakei*), smut sp., Damping off, and zonate eye spot (*Helminthosporium giganteum*) brief description symptoms and spore character and management options are given.

Table1. *List of tef diseases**

Pathogen	Diseases
Fungi	

Alternaria alternata (Fr.) Keissler S.I	Sooty mold
Alternaria sp.	Black tip of glume
Aposphaeria eragrostidis Cioc.& Castell.	Black tip of glume
Aspergillus flavus Link. Ex Fr	-
Cladosporium colocasiae Sawada	Sooty mold
Colletotricum graminicola (Ces.) G. W. Wilson (anamorph) *Syn. Glomerella garminicola* Politis *(teleomorph)*	Seedling blights of cereals
Coniosporium sp.	Sooty mold
Darluca filum (B.V ex Fr.) Cast *Eudarluca caricis* (Biv.) O. E. Erikss (teleomorph)	-
Drechslera bicolor (Mitra) Subr.& Jain state of *Cochliobolus bicolar* Paul & Parben	Damping off
Drechslera ellisii Danguch	Damping off
Drechslera poae (Baudis) Shoemaker	leaf spot & damping off
Dreschslera setariae (Savada) Subr. & Jain State of *Cochliobolus setariae* (Ito & Kurib)	Damping off
Drechslera ex Dustur	Damping off
Drechslera sp. very close to the *Drechslera* state of *Setosphaeria prolata* Lenconh. & Suggs but with slightly Morphologically different conidia -	Damping off
Entyloma oryzae H&P. Sydow	Leaf smut of rice
Epiccocum nigrum link	Damping off
Helmintosporium miyakei Nisikado (Syn. *Drechslera miyakei* (Nisik.))	Head smudge
Mycosphaerella eragrostidis Castell & Ciccar	Leaf blight
Penicillium brevicompactum Dicrekx	Leaf spot
Phoma depressitheca Rubak	Phoma leaf spot
Phoma sorghina	Phoma leaf spot
Phyllosticta sp.	Leaf spot
Septoria eragrostidis Castell	leaf spot
Tilletia baldratii Montemart	seed smut
Uromycesi eragrostidis Tracy	leaf rust
Helminthosporium gigantum	zonate eye spot
Nematodes	
Paratylenchus spp.	Root disease

*Compiled from Bekele (1986), Amogne *et al*. (2001), and Ashenafi *et al*. (2018)

2.1. Tef Leaf Rust (*Uromyces eragrostidis* Tracy)

Tef leaf rust is minor disease of tef that causes economic yield losses either in limited tef growing locations or seasons. It occasionally infects tef grown in locations with high temperature and late season rainfall. In such types of locations the disease usually occurs late in the season when the crop is at reproductive stage. At this growth stage, tef leaf rust infects lower older leaves and in most cases the flag leaf and the head remains uninfected, which might be attributed to the short infection period. Consequently, it does not cause economic yield losses. However, in late sown tef fields, if tef leaf rust disease occurs at or before joint stage, it causes economic yield losses and the disease symptoms found on leaf sheath, leaf, peduncle, panicle and spikelet. At both laboratory and field levels, the life cycle of tef rust and the environmental requirements for disease epidemics have not been studied.

2.1.1. Pathogen Biology

The fungus persists from season to season in alternative crops and also over winter as teliospores until the condition get conducive for the germination (Figure .1 d). The spore infects living hosts (Figure .1 a and b) and the fungus is obligate parasite in nature. Therefore, the fungus is almost exclusively air-borne. The pathogen can be transported by wind, human and animals from one place to another place.

2.1. 2. Disease symptoms

Tef leaf rust infects first the upper blade of lower older leaves and then the infection gradually advances upward to younger leaves. Tef leaf rust pustules are larger than those of wheat leaf rust and stripe rust. After the tef crop dried the spore changed in to teliospore or overwintering spore (Figure 1. d) They are, oval or elongated in shape with loose or torn epidermal tissue along the margins (Figure 1a). Pustules appear on the upper surfaces of leaf but sometimes can also appear on the lower surface of the leaf. Under severe condition leaf rust can attack all parts (stem, leaf-sheath, peduncle, panicle, spikelet), of the tef crop (Figure 1a and b). The urediniospores of *Uromyces eragrostidis* are reddish brown, elliptical to egg shaped (Figure 15.1c). The urediniospres of tef leaf rust remain 100% viable for four months when stored at five degree centigrade temperatures (5ºC) (5).(Degete Ashenafi 2018).

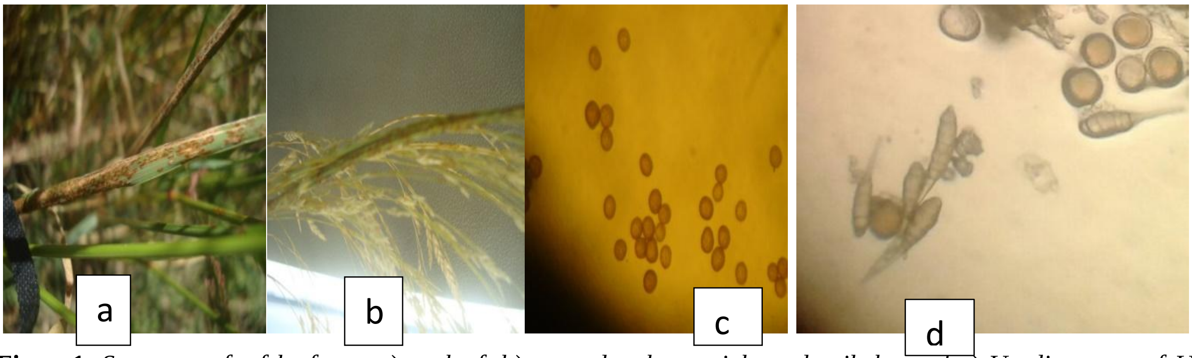

Figure1. *Symptom of tef leaf rust a) on leaf, b) on peduncle, panicle and spikelet and c) Urediospores of U. eragrostidis (10x40), d) Teliospore of U. eragrostidis*

The major cultivated cereal crops like maize, sorghum, barley, and wheat, and several weed species such as *Avena sativa*, *Lolium temulentum, Bracheria eruciformis, Hyperhenia rufa, Eleusine indica, Dinebra retroflexa, Andropogon* sp., *Sorghum halepense, Chloris gayana, and Pennisetum unisetum* are not host of tef leaf rust. However, except *Eragrostis curvula*, all other wild relatives of tef in the genus *Eragrostis* are infected by tef leaf rust. Moreover, *Anthericum angustifolium*, "Murri," and the perennial grass, *Cynodon dactylon* are host of tef rust, and because of their wider geographical distribution and abundance they might serve as reservoir of this disease during dry seasons.

2.1.3 Disease Assessment and Yield loss

Tef leaf rust disease is assessed using modified Cobb-scale where 0% = immune and 100% = completely susceptible (Peterson *et al*., 1948) and prevalence, incidence, and severity are calculated as follows:-

$$\text{Prevalence} = \frac{\text{Total number of surveyed fields}}{\text{total number of infected fields}} \; x\ 100$$

$$\text{Disease incidence} = \frac{\text{Total number of diseased plants}}{\text{Total number of diseased+healthy plants}} \; x100$$

$$\text{Disease severity} = \frac{\text{Infected plant parts}}{\text{Total plant parts}} \; x100$$

The amount of yield losses caused by tef leaf rust under farmers' field condition is not known. However, under on-station conditions tef yield losses vary between 10 and 24%. (DZARC, 2002). Wubit Dawit and Yeshi Adnew in 2010 also reported that tef leaf rust cause annual yield loss of 10-41%.

2.1. 4. Management Options

2.1.4.1. Cultural control

Early planting of tef is the cheapest and most viable technique to control tef leaf rust disease because the disease occurs late in the season. Late planting is also effective in reducing tef leaf rust occurrence although the yield penalty is high due to the absence of moisture to support plant growth. The use of early maturing varieties has a similar effect as early planting.

2.1.4..2. Chemical control

The use of fungicides should be carefully assessed since their effectiveness and economical uses usually depend on the level of resistance of the variety used; the growth stage of the crop at the onset of the disease; disease severity and inoculums build up, and prevailing weather conditions. When it is necessary to use fungicides, propiconazole 25 EC and Triadimefon 25 EC/wp can be used at the rate specified by the manufacturer (Dawit *et al*. 2005).

2.1.4..3. Genetic methods:

Planting relatively tolerant tef genotypes is another option. Few studies have shown that there is no complete resistance to tef leaf rust, which might be due to the co-evolution of the host and the pathogen. Screening more germplasm and understanding pathogen-host interaction are some of the areas for future studies.

2.2. Head Smudge (*Helminthosporium miyakei* Nisikado*)*

Head smudge of tef is common disease in warm-humid areas and can affect the yield and quality of tef. Head smudge incidence is high at valley bottoms near rivers and in fields bordered by shade trees. It is both seed and stubble-borne disease.

It infects the head and diseased heads have dark brown mycelia mat and spore (Figure 2a). The cultured diseased plant parts show pink color (Figure 2b). The conidia have four to five septa (Figure 2c). Preliminary studies have shown that some tef genotypes have complete resistance to head smudge; however, this requires confirmatory research.

2.2.1. Management of head smudge

Head smudge management options include use of tolerant genotypes; plowing under tef debris left in the field after harvesting; crop rotation; and use of disease free seed.

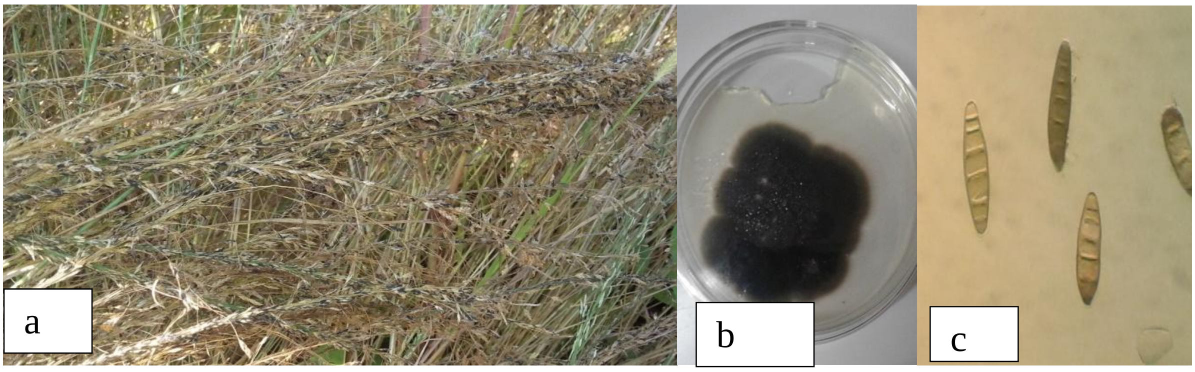

Figure2. *Head smudge symptom on matured tef head (a), cultured diseased plant parts (b) and Conidia (10 x 40) (c).*

2.3. Zonate Eye Spot (*Helminthosporium giganteum*)

Zonet eye spot was recently reported as fungal disease of tef. But it frequently occurs in cereal crops and is a common disease on tropical grasses. Early symptoms appears as numerous small grey-brown, ovals to circular spots on the upper side of green leaves. The centers of the spots soon fade, becoming light grey-to straw colored with distinct dark brown margins (Figure 15.3). The spots tend to remain small, but the tissues between the spots develop an unusual bleached appearance.

The fungus attacks plants that are growing rapidly from the seedling stage through heading; sporulation diminishes quickly after severe necrosis development. The disease is easily recognized by the zonate eye spots and the fungus by its large fruiting structure.

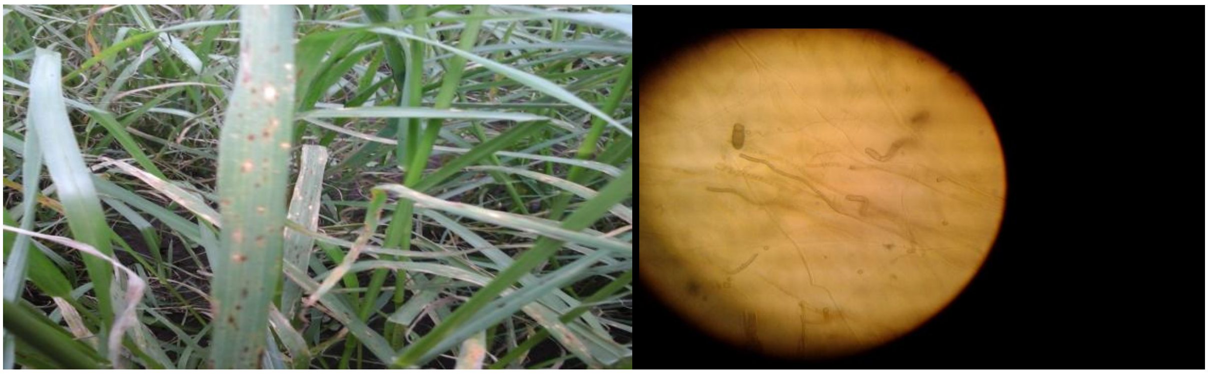

Figure3. *Zonate Eye Spot caused by H. giganteum*

2.4..Smut Spp Disease of Tef

The identity of smut disease has not been identified by authorized taxonomic. However, (16) has used the common name stinking smut. Figure 4.a. and 4.b. Show tef head infected by smut and spores, respectively. The infected spikelets contain masses of spores in place of grain. These spores are released before the normal grains mature, and they can be carried by wind and germinate on a suitable host.

In the smut spp of tef the smutted tef parts arise on plants that are already systemically colonized by the fungus. The embryos of the seeds are infected, so that the infection is repeated in the following season.

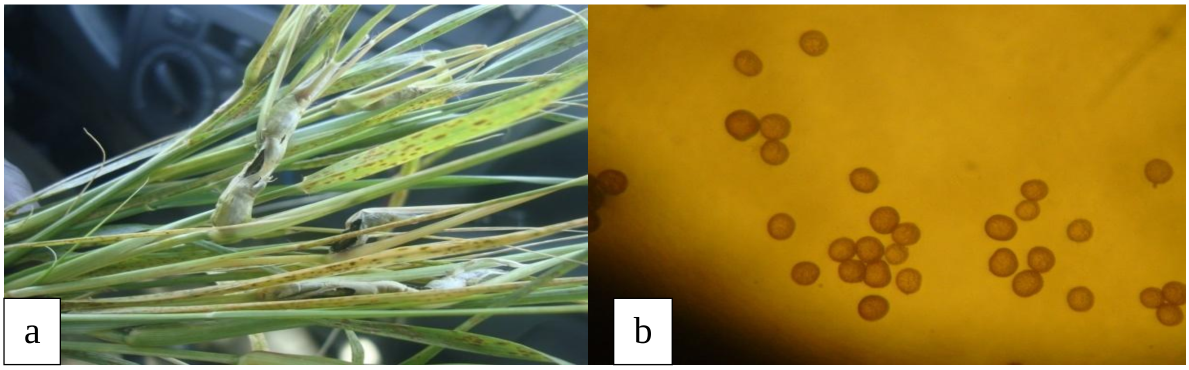

Figure4. *Diseased tef plants (a), and spores of smut spp (10 x 40) (b)*

2.4.1 Management of Smut disease

Smut spp management options include use of tolerant genotypes; crop rotation; and use of disease free seed.

2.5. Damping off (*Drechslera miyakei*)

Damping-off (Drechslera spp.) was observed at different localities in Shewa (around Ambo, Gedo and Debre Zeit), Wellega (Ardjo, Srey-Digfa), and Gojjam (around Debre Markos and Bahir Dar) (SPL, 1975-1979). The Conidia of *Drechslera miyakei* are found on infected seeds, seedlings, and roots. Infected seed rot and do not germinate, while infected seedlings have discolored coleoptile and roots. These seedlings die in about four weeks and the fungus sporulates on the dead tissue. On agar-medium *D. miyakei* develops small, circular, light-greenish gray colonies with abundant sporulation. The disease is effectively managed by using disease free seeds.

Damping-off is a seedling disease caused by a number of species in the genus Drechslera and by other pathogen species (Evmenenko, 1985c). The disease complex includes seed decay, and pre- and post-emergence damping-off. The disease usually occurs in patches of farmers' fields and the infection level was estimated to be from 40 to 50% (Gorshkov and Mekonnen, 1979). Due to the high tillering capacity of tef, however, significant yield reductions occur only when the severity was more than 40% (Evmenenko, 1985a). The percentage of damage to seedlings may reach up to 50% (Gorshkov and Mekonnen, 1979; Evmenenko 1985b). Identification of species in the genus Dreschslera that are attacking tef is difficult. To date, there has been only one failed attempt. Sixteen strains of Drechslera species from different locations in Ethiopia were used to assess the possibility of serologically distinguishing the different Drechslera species (Evmenenko, 1984c). Three species, D. miyakei, P. poae and D. selariae, with 20, 24 and 43 strains, respectively, were used to immunize rabbits to produce antisera. The results indicated that D. miyakei antiserum was similar to the antigens of the other Drechslera species and therefore this method was unable to separate them. One of the relatively better-known species, D. miyakei, was first observed on the wild Eragrostis pilosa in Japan (Nisikado, 1929) and on heads of tef in western Ethiopia (Castellani and Ciccarone, 1939). According to Awgechew and Mathur (1978), D. miyakei caused severe seed rot and seedling blight on tef. The release and dispersal of conidia of D. miyakei was studied (Evmenenko, 1982). Two spore traps with 20 slides in the experimental field and three spore traps with 20 slides in the production field o f the PPRC were used. The slides were replaced every 10 days with new ones. Each slide was examined under microscopc. During the observation, there were some periods specially favoring spore trapping and spore release from comdia; for instance, greater than 80% humidity favored abundant sporulation of the pathogen. Under natural conditions (17 to 20°c), the period from the beginning of conidia formation to their release is about 20 days. Another species, D. poae, was found to colonize not only the host (tel) tissues but also had high level of survival in the soil (Evmenenko, 1983a). The pathogen had also colonized other crops such as wheat, barley, sorghum and maize. This clearly indicates that the pathogen survives as a source of inoculum in infected seeds of tef both in the soil and in colonized plant tissues of other crops.

3. Summary and Conclusions

Tef is often considered as a relatively healthy crop since it suffers very little from epidemics of pests including diseases as compared to most other cereal crops grown in the country (Ketema, 1993, Assrfa *et al*., 2011, Assefa and Chanyalew, 2018; Chanyalew *et al*., 2019). Tef has co-evolved with the pathogens and other pests over the millennia of its cultivation (Badebo, 2013)..

Different studies in the past indicated that there is no tef germplasm that showed complete resistant for tef leaf rust. Diseases like tef leaf rust , head smudge, daming off, zonate eyespot and smut diseases are becoming very important diseases due to agronomic improvement of tef crops and climate change. Ashenafi *et al*., (2018) study showed that tef leaf rust and head smudge are widely distributed in farmer's field. Different management options can be used for the control of these diseases. Among all control options use of tolerant cultivars, crop rotation and planting disease free plants are the best methods. For tef leaf rust use of recommended fungicide is another option.

Further study on characterization and mapping of most of the tef germplasm and wild relatives are needed in the future to have relatively resistant or tolerant tef genotypes and wild relatives of tef.

Further study needed at both laboratory and field levels, to know the life cycle of tef rust, head smudge and the environmental requirements for diseases epidemics.

Further characterization and mapping of core tef germplasms are important to identify resistant or tolerant germplasm against head smudge disease.

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