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# Integrated pest management of tef shoot fly (*Atherigona hyalinipennis*) and tef leaf rust (*Uromyces eragrostidis*) in Ethiopia

**Midekesa Chala Mamo**

Ethiopian Institute of Agricultural Research, Ambo Agricultural Research Center, P.O.BOX, 37, Ambo, Ethiopia

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**This review paper gives an overview of major tef pests in Ethiopia. A number of diseases and pests are known to attack tef, but only a few are of economic importance, mostly in specific localities and production years. Among the diseases, leaf rust (Uromyces eragrostidis), head smudge (Helminthosporiummiyakei) and damping off (Drechslera spp. and Epicoccumnigrum) are the most important. Low plant densities and early sowing reduce the damage caused by leaf rust and damping off, respectively. Breeding for resistance has not been carried out because of limited genetic variation in resistance and the sporadic nature and environmental specificity of the diseases. Insect pests known to attack germinating tef seeds and seedlings include the tef shoot fly (Atherigona hyalinipennis), Wollo bush-cricket (Decticoidesbrevipennis), the red tef worm (Mentaxya ignicollis), grasshoppers, ants and termites. The black tef beetle (ErlangeriusNiger) attacks the inflorescence. Appropriate management methods need to be developed for major pests including diseases (especially leaf rust, head smudge and others) and insect pests (e.g. shoot fly, red tef worm, Wello Bush cricket and others). Integrated pest management (IPM) is the best combination of cultural, biological and chemical measures to manage diseases, insects, weeds and other pests. The goal of IPM programs is to maintain pest damage at economically acceptable levels while protecting the environment and human health.**

**Keywords:** control method, integrated pest management, Shoot fly, tef rust

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## INTRODUCTION

Tef (Eragrostis tef) is one of the major cereal crop and stable food crop of Ethiopia where it originated and diversified. It is originated in northern Ethiopia, where it is widely cultivated. Details of its domestication are unknown, but it may predate the introduction of wheat and barley to the region. Tef is perhaps descended from the closely related wild *Eragrostis pilosa* (L.) which is a tetraploid ($2n = 40$) annual like tef, and which has a cosmopolitan distribution. Grain cultivation of tef has been confined mainly to Ethiopia and to some extent the highlands of Eritrea. It is also grown in northern Kenya. Small-scale commercial tef production takes place in

South Africa, the United States, Canada, Australia, Europe (the Netherlands) and Yemen. Tef is grown as a forage grass, for instance in South Africa, Morocco, Australia, India and Pakistan (Midekesa et al., 2014).

Tef is an important staple cereal crop in Ethiopia occupying the largest (28%) acreage of cereals in the country.In 2016/2017 tef was annually cultivated on 15350.57 ha in Ethiopia, which is about 30% of the total acreage of cereals in the country. With an average annual production of *2,642,570.64* t of grain, tef constitutes 22% of the annual cereal grain production in Ethiopia (CSA, 2017).The crop harbors several useful traits both for farmers and consumers. Some of these beneficial traits are: the plant is tolerant to extreme environmental conditions, the seeds are not attacked by storage pests; and the seeds are gluten-free and hence considered as a healthy food. In Ethiopia tef straw is used as forage, especially during the dry season. Mixed with clay it is used as plastering material for local houses and to make bricks, stoves, granaries, beds and pottery. Outside Ethiopia tef is mainly grown for hay (e.g. in South Africa) and as green fodder (e.g. in Morocco and India). Despite all these importance in the Ethiopian agriculture, the major bottlenecks constraining tef production are low yield of landraces under widespread cultivation, susceptibility to lodging and lack of basic knowledge concerning the genetic control of agronomic traits (Kebebew *et al*, 2013). The main causes for the low yield of tef are; biotic factors such as diseases, insects, weeds and unimproved seeds abiotic factors such as poor soil fertility and moisture scarcity, lack of proper crop and soil management practices and socio-economic factors such as lack of access to credit system and market information.

The population of Africa will double in the next 33 years to reach 2.5 billion by 2050. Although roughly 60% of the continent's population is engaged in agriculture, the produce from this sector cannot feed its citizens. Hence, in 2013 alone, Africa imported 56.5 million tons of wheat, maize, and soybean at the cost of 18.8 billion USD. Although crops cultivated in Africa play a vital role in their contribution to Food Security, they produce inferior yields compared to those in other parts of the world. For instance, the average cereal yield in Africa is only 1.6 t·ha-1 compared to the global 3.9 t·ha-1. Low productivity in Africa is also related to poor soil fertility and scarce moisture, as well as a variety of insect pests, diseases, and weeds (Zerihun T, 2017).

According to the Food and Agriculture Organization (FAO) of the United Nations IPM means considering all available pest control techniques and other measures that discourage the development of pest populations, while minimizing risks to human health and the environment. For farmers, IPM is the best combination of cultural, biological and chemical measures to manage diseases, insects, weeds and other pests. It takes into account all relevant control tactics and methods that are locally available, evaluating their potential cost-electiveness. IPM is a flexible system that makes good use of local resources and the latest research, technology, knowledge and experience. Ultimately, IPM is a site-specific strategy for managing pests in the most cost-effective, environmentally sound and socially acceptable way. Implementation of IPM lies with farmers, who adopt practices they view as practical and valuable to their activities (Goodell, G., 1984).

Factors contributing to low tef yields are drought, low soil fertility, soil erosion, poor crop management practices, insect pests and weeds. Insect pests are among the major factors causing low yield. Shoot fly (*Atherigona* spp.), Wello bush cricket (*Decticoidesbrevipennis* Ragge) and Red tef worm (*Mentaxya ignicollis*(Walker)) are the most important insect pests of tef (Hein B, 1989). Of the above mentioned insect pests, damage by shoot fly infestation is becoming a serious problem in tef production.

## Major insect and disease pest of Tef in Ethiopia

Major pests of Tef including diseases (leaf rust, head smudge and others), weeds (broad-leaved as well as grass weeds) and insect pests (e.g. shoot fly, red tef worm, Wello Bush cricket and others). In tef, only few insect pests are considered as a major threat to tef productivity. More than 40 insect pest species have been recorded on tef. Of these, tef grasshopper (Aiolopus longicornis), tef shoot fly (different species), tef red worm (Mentaxya ignicollis), Wello bush cricket (Decticoidesbrevipennis Rag.), termites (Macrotermessubhyalinus and Odontotermes sp.) and perhaps the tef black beetle (Erlangerius Niger) are sporadically important insect pests in various tef growing areas. Hence, these insect pests cause different levels of yield losses in tef (Tebkew D, 2013).

## Tef shoot fly (Atherigona hyalinipennis)

Tef shoot fly is a serious pest of tef grown on black clay soils (Mideksa et al, 2014). The status of shoofly as major pest of tef was reported in five regional state of the country (Tadesse, 1987.)

**Figure 1** Tef shoot fly

**Figure 2**. Red Tef Worm

## Species composition

According to Sileshi 1997, the species assemblage of tef shoot fly in Haramaya area include *Elachipterasimplicipes* Becker, *Melanochaeta vulgaris* (Adams), *Oscinellanartschukiana* Beschovsky, *O. acuticornis* Becker and *Rhopalopterum*sp. in the family Chloropidae and *Atherigona hyalinipennis* and *Atherigona* sp. in the family Muscidae. The Chloropidae flies infest tef starting from crop germination and dominate up to the three leaf stage (but they occur in combination with Muscidae flies in the other crop stages), whereas the Muscidae flies occur starting from the three leaf stage and dominate between the heading and maturity of the crop. The period when the shoot flies are active is influenced by the type of the crop and weather condition. For instance, the adults of *A. hyalinipennis* are abundant in tef fields from August to September, whereas the adults of *E. simplicipes*and *M. vulgaris* are active in sorghum fields from August to October and June to September, respectively (Sileshi, 1994, 1997).

## Biology of shoot fly (Atherigona hyalinipennis)

Eggs are laid singly (rarely up to four) on the leaf sheath at the base of the seedling or on the soil. The larva, the destructive stage of shoot fly, requires about two weeks reaching pupal stage. The average incubation period of eggs, developmental periods of larvae and pupae of *A. hyalinipennis* were 3.0, 12.7 and 9.6 days respectively, and the total life cycle was completed in less than a month in the laboratory. After hatching, the larva bores into the stem, cut the growing shoot and feeds on the rotting tissue (Sileshi, 1997).

## Geographical distribution

Surveys conducted in Central Ethiopia (Debre Zeit, Mojo, Koka, AlemTena and Akaki), East Gojam (Yilmanadensa, Bahr Dar Zuria and AdetZuria) and Tigray Region (Mehoni, Axum and Wukro) confirmed the wide occurrence of tef shoot fly (DZARC, 2002; Bayeh*et al.,* 2008). Depending on the season, the level of tef seedling infestation ranged from 2 to 4% in Central Ethiopia, 3 to 10% in East Gojam and 7 to 37% in Tigray. According to Bayeh*et al.* (2009), this fly is considered as a pest of tef in Asgori, Teji and Tulu Bolo areas of Southwest Shewa Zone and Ginchi area of West Shewa Zone, but not in Guder and Ambo areas of the same Zone. Bayeh, 2004 study result show also the Entomology of Tef 179 incidence of shoot fly in GubaLafto, Habru, Sirinka and Ziquala areas of North Wollo Zone ranged from 5 to 6% at seedling and 2 to 5% at heading stage.

## Yield losses by shoot fly

Sileshi (1997) asserted that *A. hyalinipennis* alone causes more than 90% of panicle damage. The yield losses reported in areas where the rainfall is abundant (e.g. East and Southwest Shewa Zones) was negative or less than 5%. Similarly, in Gojam area tef shoot fly does not cause yield losses (AARC, 2002). On the other hand, in Tigray Region where precipitation is low and the soil is degraded (Tesfaye and Zenebe, 1998), the tef shoot fly causes greater yield losses than in the other tef growing areas. At Haramaya, tef is sown after sorghum and the shoot fly population that built-up on sorghum might have caused severe damage (378 to 522 kg ha-1) (Sileshi, 1997).

## Management Tactics of Tef Shoot Fly

### Biological method (Natural enemies)

Biological control basically means, "The utilization of any living organism for the control of insect-pest, diseases and weeds". This means use of any biotic agents for minimizing the pest population either directly or indirectly. Biological control of insect-pests is gaining recognition as an essential component of successful IPM. Classical biological control involves deliberate and natural establishment of natural enemies in areas where they did not previously occur. In addition to deliberate introduction of biocontrol agents, proper attention needs to be given for conservation and augmentation of natural enemies that already exist in an area. This should be treated as important as many insect predators are much more susceptible to insecticides than the pests they attack. Biological control agents for insect pests are available in nature abundantly and work against crop pests naturally called as Natural Control. According to Sileshi (1997), 7 to 19% of *A. hyalinipennis* larvae are parasitized by *Neotrichoporoides nyemitawus* (Rohwer) (Hymenoptera: Eulophidae). Moreover, the parasitoid *Bobekia sp.* (Braconidae: Hymenoptera) parasitizes 3% of the pupae of this fly species.

### Cultural method

As citied by Tekabe *et al* 2004, the incidence of tef shoot fly around Debre Zeit, in Central Ethiopia, is primarily governed by the rainfall distribution. During the normal growing season, late sown tef is infested by the tef shoot fly, while early sown tef is infested only if there is dry spell. On the contrary, in Mekele area, northern Ethiopia, sowing tef in early- to mid-July favors the incidence of tef shoot fly than sowing in August; however, grain yield of early sown tef was greater than late sown ones (Tesfaye and Zenebe, 1998; Bayeh*et al*., 2008). Both the damage due to tef shoot fly and grain yield of tef increased until third week of July and decreased thereafter (Abraham and Adane, 1995). Regarding control measures, except in Tigray Region where farmers use late planting, repeated plowing, soil compaction and insecticides, farmers in other part of the country do not apply any control measures against shoot fly (DZARC, 2002; Bayeh*et al*., 2008). According to Corbeels*et al*. (2000), the application of manure predisposes the crop to infestation by the tef shoot fly. In general, dead hearts were more prevalent in fertile parts than in the waterlogged or less fertile parts of the tef field (Tesfaye and Zenebe, 1998).

### Chemical method

Chemical crop protection products (pesticides) are biologically active chemicals that control a range of insect and vertebrate pests, diseases and weeds. They are often the most cost-effective way of controlling infestations as part of an IPM strategy. As Ademe *et al*. 2016 chlorpyrifos-ethyl (1.5 L ha-1) and lambda cyhalothrin (0.4 L ha-1) was recommended for the management of tef shoot fly. The control of tef shoot fly using chemical and cultural practices has been attempted earlier to some extent. However they were not adequate to minimize the density of shoot fly and thereby alleviating the yield loss caused by the pest. Mideksa *et al* 2015 evaluate bio-pesticide and compare the infestation level of shoot flies on row planting and traditional broadcasting system of tef crop. Botanical and entomopathogenic fungi were effective to reduce tef shoot flies population infesting tef crops. Among tested botanicals, Nicotiana spp. (local var.) was effective in reducing tef shoot flies after application of three days. Entomopathogenic fungi B. bassiana (PPRC-6) was effective in reducing tef shoot flies population after application of ten days in both row planting and broadcasting sowing methods.

## Tef rust (Uromyces eragrostidis)

Teff is relatively free of plant diseases when compared to other cereal crops. Among the diseases, tef rust (Uromyces eragrostidis), head smudge (Helminthosporiummiyakei), damping-off (Drechslerspp) and helminthosporium leaf spot (Helminthosporiumspp) are occasionally important (Ayele et al., 2008). In Ethiopia, in locales where humilities are high, rusts and head smuts are important diseases.


**Figure 3.** Tef leaf rust

### Management method of tef leaf rust (Uromyces eragrostidis)

### Chemical control (Fungicide against tef rust)

Ayele *et al*., 2008 study at Bishoftu result show, the level of rust incidence on *propiconazole* treated tef was significantly lower than the one treated with *triadimefon*. Although it was not statistically significant, reduced rust infection was coupled with more grain yield production. In another experiment, however, agronomic traits of tef were not affected by tef rust; rather only crude protein content of the grain was affected (DZARC, 2002, 2003; Ayele *et al*., 2008). Thus, fungicide sprayed tef had the highest crude protein content than unsprayed tef.

### Cultural control

Effect of sowing date on tef rust studied at Debre Zeit shows, planting tef between the third week of July and first week of August exposes tef to relatively higher tef rust pressure than planting during mid-August (DZARC, 2002). However, in terms of grain yield earlier planted tef out yields late planted ones. Since yield is the ultimate measure of the effectiveness of a control measure, early planting is recommended to avoid yield penalty. Sowing early maturing tef varieties in the third week of July and first week of August will enable them to evade tef rust infection (Woubit and Yeshi, 2005).

### Host resistance control

Study on tef resistance to tef rust using About 2000 tef accessions and 5000 mutants developed by radiating the tef variety Magna (or DZ-01-196) with 700 gy gamma-ray were evaluated at Debre Zeit Agricultural Research Center (DZARC, 2002; Woubit and Yeshi,2005). In this evaluation, complete resistance to tef rust was not found. Moreover, the majority of the accessions and all mutant lines were susceptible to tef rust (had large uredia without Chlorosis). However, there were quantitative differences among Pathology of Tef 195 genotypes, and 22 tef genotypes exhibited relatively lower rust severity when compared to the rest. Rust severity showed increasing trend when tef is grown under optimum conditions (space planting), and only six entries showed severity below 30%. The highest rust severity was noted on KayeyMuri (80S) followed by Magna (DZ-01-196, 60S). This result indicated that tef rust could be economically important under optimum management conditions.

The absence of complete resistance in tef to tef rust could be due to the co-evolution of the host and the pathogen. Since tef is a crop species native to Ethiopia, the major genes might have gradually been depleted through selection and probably tef varieties with minor genes (residual resistance) co-existed with the pathogen. It is interesting to raise a question that "if tef is susceptible to tef rust as revealed in many field screenings, why has the disease not reached epidemic level in tef fields under natural infection?" One assumption is that tef resistance to rust is conferred by polygenes (Kebebew *et al*., 2011), which is more durable than resistance conferred by mono- or oligo- genes. The second assumption is that the screening methodology followed to screen tef accessions to rust disease is unable to detect subtle differences among the test entries.

## Host range of tef rust

Wild relatives of tef, cultivated cereal crops, forage grasses and grass weeds were evaluated under glasshouse condition to determine if some of these plant species are hosts of tef rust (DZARC, 2002; Sewalem, 2004). *Eragrostis curvula,* among the wild relatives of tef, and wheat, sorghum and barley, among the tested cultivated cereal crops, were non-host for tef rust. On the other hand, the perennial sedge, *Cynodondactylon*was infected by tef rust and because of its wider geographical distribution and abundance *C. dactylon*might serve as reservoir of this disease during dry seasons (Sewalem, 2004; Ayele *et al*., 2008).

## CONCLUSION

Tef is an important staple cereal crop in Ethiopia occupying the largest (28%) acreage of cereals in the country. Factors contributing to low tef yields are drought, low soil fertility, soil erosion, poor crop management practices, insect pests and weeds. In tef, only few insect and disease pests are considered as a major threat to tef productivity. Shoot fly, red tef worm, Wello Bush cricket and termites are important insect pests in various tef growing areas in Ethiopia. Among these Shoot fly is a serious pest of tef grown on black clay soils which alone causes more than 90% of panicle damage. The bulk of the research work on tef insect pest management was on insecticides and the best period of controlling tef shoot fly using insecticide is before the adults lay their eggs and/or before the larvae bore and enter into the stem of tef. Other aspects of pest management such as cultural control (sowing date, seed rate, fertilizer rate, host plant resistance and the likes), natural enemies and ecological areas were not investigated. Tef is reported to be less affected by diseases under the current farmers' practices in Ethiopia; however, diseases like tef rust and head smudge are considered to be relatively important. The importance of tef rust might increase with change of agronomic practices such as row planting. Appropriate management methods need to be developed for major pests including diseases (especially leaf rust, head smudge and others) and insect pests (e.g. shoot fly, red tef worm, Wello Bush cricket and others). IPM is a systematic plan which brings together different pest-control tactics into one program. It reduces the emphasis on pesticides by including cultural, biological, genetic, physical, regulatory and mechanical control. Since there was no complete resistance against the insect and diseases pest, emphasis on tef pests' research should be given to integrated pest management (IPM) where two or more of the control measures could be integrated for sustainable pest management.

In general, future research on tef entomology and pathology needs to focus on the following main area: i)main periodic monitoring and surveying of tef pests in order to determine shifts in pest status: ii) exploration of indigenous farmers' insect pest management practices and knowledge; iii)continuing screening and testing of new insecticides for major tef pests; iv)identifying and assessing the effectiveness of natural enemies of insect and disease pests of tef; v) evaluating cultural control methods; and vi)developing integrated insect pest management options.

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