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Pests of Belg and Irrigated Tef (*Eragrostis tef*) in the Amhara Region, Ethiopia

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በበልግ ዝናብ እና በመስኖ የሚመረት ጤፍን ስለሚያጠቁ ፀረ-ሰብሎች ማንነት መሠረታዊ መረጃ ለማመንጨት በ 2008 እና በ 2009 ዓም በአምስት ዞኖች ቅኝት ተካሄደ፡፡ የአረም ናሙና የተወሰደው 50 ሳሜ በ 50 ሳሜ በሆኑ አራት ካሬዎች ሲሆን በእያንዳንዱ ካሬ ውስጥ የነበሩ የአረም ተክሎች ብዛት እና የዝርያ ማንነት በመመዝገብ ነበር፡፡ የተባይ እና የበሽታ ናሙና የተወሰደው ደግሞ ሙሉውን ማሳ በዓይን በመመልከት እና የተባዩን እና የበሽታውን ምልክት በመለየት የጉዳቱን መጠን በመገመት ነበር፡፡ የጤፍ ግንጫፍ ዝንብ ፣ የበቆሎ ክሽክሽ እና ማንነቱ ያልተለየ ግንድ ቦርቧሪ ተባይ በበልግ ዝናብ እና በመስኖ የሚለማ ጤፍን ያጠቃሉ፡፡ እነዚህ ተባዮች የጤፍ ተክል ላይ የሚያደርሱት የጉዳት መጠን ዝቅተኛ ሲሆን እስከ 10 በመቶ ሊደርስ ይችላል፡፡ ሁለት የጤፍ በሽታዎች ማለትም የጤፍ ዋግ እና ገሳሽ በተወሰኑ የጤፍ ማሳዎች ብቻ ተገኝተዋል፡፡ የተለያዩ የወፍ ዝርያዎች ጤፍን ያጠቃሉ፡፡ በ 14 ቤተሰብ ውስጥ የሚመደቡ ከ 22 የሚበልጡ የአረም ዝርያዎች በሁለቱም ዓመት ተመዝግበዋል፡፡ በ 2008 ዓም እንግጫ፣ የጥጃ ሥጋ፣ ቅንጨ አረም፣ የውሻ ጎመን እና የምኝ ፍቅር በብዛት የተገኙ የአረም ዝርያዎች ሲሆኑ፤ በ 2009 ዓም ደግሞ የውሻ ስንደዶ፣ ቅንጨ አረም እና ነጭ ለባሽ በብዛት የተገኙ የአረም ዝርያዎች ነበሩ፡፡ ስርጭቱ በምስራቅ፣ ደቡብ ምዕራብ እና ምዕራብ ሸዋ ዞኖች ብቻ የተወሰነው ጋሻ ነቃይ አረም ቁንጮ በተዘራ አንድ ማሳ ውስጥ ብቻ ተመዝግቧል፡፡

Abstract

*Field surveys were conducted in 2016 and 2017 belg season to generate baseline information on the type of pests prevailing in Belg and irrigated tef. The survey was conducted in five zones. Weeds were sampled in four 50 cm x 50 cm quadrats and the number of individual weed plants were counted and identified to species level in situ. Insect pests and diseases were determined by visual search for damages done by insects or symptoms of diseases throughout the field. Tef shoot flies (***Atherigona** *spp.), maize aphid (***Rhopalosiphum padi***) and unidentified stalk borer infested tef. But the severity of damage caused by these insect pests was trace to 10%. Tef rust (***Uromyces eragrostidis***) and* **Sclerotium** *sp. were prevalent in limited tef fields. Tef is also attacked by different bird species. More than 22 weed species in more than 14 families were recorded throughout the surveyed areas. The two families Poaceae and Compositae accounted for the larger proportion of weed species. In the 2016 season* **Cyperus spp**., **Portulaca oleracea, Parthenium hysterophorus, Amaranthus hybridus** *and* **Xanthium strumarium**, *in decreasing order, were the most abundant weed species, whereas in the 2017 season* **Setaria pumila, Eragrostis cilianensis, P. hysterophorus** *and* **Argemone ochroleuca,** *in decreasing order, were abundant weed species. Field bindweed,* **Convolvulus arvensis**, *which is found only in East, Southwest, and West Shewa Zones, was found in one field sown to Quncho.*

Introduction

Belg tef (*Eragrostis tef*) is produced, in decreasing order, in the Southern, Nations, Nationalities and Peoples, Oromia, Amhara, and Tigray regions. In the Amhara region, it is produced in the Belg season (February to August) as rain-fed and irrigated crop mainly in North and South Wello Zones and in limited areas in North Shewa and South Gondar Zones. Thus, in the 2016 season, more than 170,000 households have grown belg tef on an area of 25,718 ha with an average yield of one ton per hectare (CSA, 2018).

In the main season, although the numbers of diseases and insect pests recorded on tef are many (Kebebew *et al.*, 2011), it has no major disease and insect pest problem. However, the tef rust (*Uromyces eragrostidis*) and several *Atherigona* spp. (Diptera: Muscidae) among diseases and insect pests, respectively, occasionally cause economical yield loss in certain localities (Abate *et al.*, 2017). On the other hand, weeds are one of the major yield limiting factors in all areas where tef is grown. Tef's vulnerability to weeds is due to its shallow root system and slender stem with narrow leaves (Birhanu and Tesema, 1984). This renders weed control one of the major management components of the tef production.

It is apparent that geographical and seasonal variations in amount and distribution of rainfall, temperature regimes and other environmental factors along with crop management practices practiced by farmers have direct effect on the type of pests prevailing and the associated degree of damage inflicted by them. However, in belg season, which is characterized by short and erratic rainfall, the pest species that attack tef are not known i.e. it is not known if the belg season pest problems are similar with that of the main season tef pest problems. Alternatively, it is not known if the belg tef is serving as green bridge for pests that cause occasional damage on the main season tef crop. Besides, in the past five to six decades different tef technologies were generated and transferred to farmers to tackle the production constraints in the main season tef production. Identifying the pest problems of belg and irrigated tef can help to make informed decision as to whether pest management technologies developed for the main season tef crop are applicable or not for managing pests in the belg season or irrigated conditions.

In recent years, other than the movement of grains for food or market, transport of "improved seeds" and other planting materials and even straw within a region or from region to region has tremendously increased. On the other hand, there is no internal quarantine system in place to restrict the spread of pests from one region to the other. Therefore, determining the pests of a crop in general in a particular season will enable to detect newly introduced pests *via* seeds and planting materials that have not been properly cleaned. Moreover, in the past there have not been studies carried out to survey and document pests associated with belg and irrigated tef. Therefore, the objective of this study was to generate baseline information on the type of pests prevailing in belg and irrigated tef. The information will be useful to prioritize the pest problems that require future research and/or extension activities destined for belg and irrigated tef production improvement.

Materials and Methods

The survey was conducted for two consecutive seasons, in the second and third weeks of April 2016 and first and second weeks of June 2017, in North Shewa Zone (between Debre Sina and Shewa Robit), South Wello Zone, North Wello Zone, South Gondar Zone (Woreta, Addis Zemen and Hamusit areas) and West Gojam Zone (Koga irrigation area). Since spatial distributions of rain-fed or irrigated tef fields were erratic, stopovers were made as tef fields were encountered and the selected field was inspected for the presence of diseases, insect pests, and weeds. To sample weeds, four 50 cm x 50 cm quadrats were taken in square or rectangular fashion across a field and within the quadrant; the number of individual weed plants were counted and identified to species level *in situ*. When the weed species was unknown, pictures were taken for comparative identification. The relative frequency, relative field uniformity, relative mean field density, and the relative abundance for species were calculated as described by Thomas (1985). The relative frequency indicates the number of fields in which a species occurred; relative field uniformity indicates the number of quadrats in which a species occurred and relative mean field density measures the number of individuals of a species per unit area.

Insect pests and diseases were determined by visual search for damages done by insects or symptoms of diseases throughout the field. The insect pest and the disease type were identified *in situ* and the severity of damage they caused was visually scored. Whenever farmers were found working in their field, they were asked about the type of pests that they rank as most important.

Result and Discussion

Production system

In each season, 25 tef fields were surveyed to detect the type of pests prevalent in rain-fed or irrigated tef. In 2016 and 2017 seasons, 50% and 72% of the surveyed fields, respectively, were rain-fed and the remaining fields were irrigated tef. In rain fed tef production, tef fields were interspersed among the mung bean fields and their size was very small to about a quarter of a hectare. The majority fields had sparse population and the phenological stage of the crop varies within – and among – fields. Tef was intercropped rarely with maize, sorghum or Noug (*Guizotia abyssinica*). Moreover, most tef fields were sown to mixed type landraces.

Irrigated tef was grown around Shewa Robit, Efeson (Ataye), Jari, Kobo, Afrike (west of Weldia town), Gumara, and Dera Hamusit (Yiazeb Got). In these areas, tef was grown in rotation with vegetables mainly onions. Although the irrigation method used to irrigate tef was flooding, there was difference between zones in the way water is applied within the field. Moreover, the majority of irrigated tef fields, particularly in Gumara and Dera Hamusit, and fields sown to tef landraces had very dense population per unit area, whereas fields sown to improved varieties had optimum population. In Kobo-Girana, irrigated tef fields were sown to Boset, but according to informants and field observations, although the performance was excellent, it shatters in the field before harvest. Therefore, it is necessary to optimize all agronomic practices including selecting varieties suitable for irrigated production system.

Insects, diseases, and weeds were pests of tef. However, compared to diseases and insect pests, weeds were more important both in irrigated and rain-fed tef fields.

Insect pests

In both survey seasons, tef was infested by tef shoot flies, although the severity was trace to 10%. According to farmers, the insect is more problematic during the main season than the belg or irrigated condition. In 2017, tef shoot fly was the most prevalent insect pest, and this fly infested 48% of the fields. Out of the fields that were infested by tef shoot fly, 58% of them had incidence/ severity of trace level, while the remaining 42% had 1 to 5% damaged plants. In different localities, the damage symptom of shoot fly is known by different names as *Bih*, *Moles*, *Burh*, and *Kussus*, which suggests that the damage is widespread and perhaps indicates the existence of the shoot fly for many years in the surveyed area. In the main season, two groups of shoot flies are known to attack tef (Sileshi, 1997). Several species of the tiny chloropid flies, in the Family Chloropidae, infest tef from three to six leaf stage, while the *Atherigona* spp., in the Family Muscidae, and *Delia* sp., in the Family Anthomyiidae, infest tef from tillering (stem elongation) to heading stage. Among the *Atherigona* spp., the *A. hyalinipennis* van Emden is widely distributed in the eastern, central and northern (Axum area) Ethiopia (Sileshi, 1997; Chekole Niguse and Tebkew Damte, unpublished report). The species *A. longifolia* is found in Adet area and central Ethiopia, while *A. lineata ugandae* and *Delia flavibasis* are prevalent in central Ethiopia. Therefore, it is speculated that the shoot fly species, which attack belg and irrigated tef between tillering and heading stage, is *A. hyalinipennis*. Moreover, the sparse tef plant population in rain-fed belg tef might be due to the attack of chloropid flies at early seedling establishment stage. Therefore, it is recommended to undertake surveys at early seedling establishment stage to detect if the tiny chloropid flies are occurring and causing seedling loss.

Maize aphid (*Rhopalosiphum padi*) and other aphid species also infested Tef rarely. Other than the shoot flies and aphids, in 2016 season, at Kobo-Girana and Koga, unidentified stalk borer (probably Hymenopteran insect) infested experimental irrigated tef fields and it was more prevalent in red headed tef genotypes than white headed ones. It bores one or multiple small round holes along the stem. Stems of stalk borer infested tef had shorter inter-nodes and produces more tiller than the normal tef. They had head with very short peduncles, pedicels, and panicles, which results in broom head (fig. 1). Sometimes the head fails to exert from the flag leaf. However, in the 2017 season, the tef stalk borer occurred in 20% of the surveyed fields with trace level of incidence/severity. The insect was rarely found on matured tef. The altitudinal distribution of this insect ranges from 1500 m to 2500 m. Moreover, in 2017 off-season, a single plant with similar symptom of stalk borer damage was found in experimental tef plants grown in a glass-house at Debre Zeit Agricultural Research Center. It was not possible to recover adult insects from stalk borer infested plants probably because the sampling time was not appropriate. A similar damage symptom caused by *Eurytomocharis eragrostidis* (Hymenoptera: Eurytomidae) on tef, *Eragrostis cilianensis* (All) Lutati, *E. erosa* (Scribn), and *E. poaeoides* Beauv. Ex

Roem and Schult) and other grass species is known in tef growing areas in the USA (McDaniel and Boe, 1990).

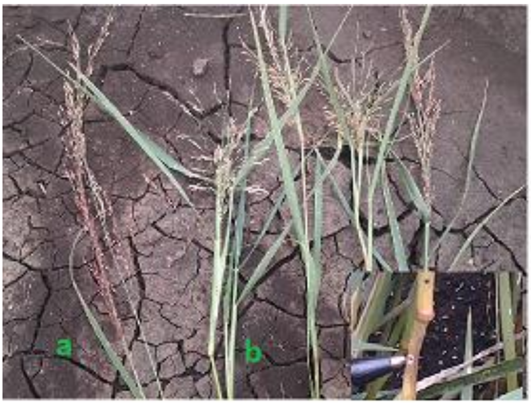

Fig. 1. Tef head showing healthy (a) and deformed (b) due to unidentified stalk borer. The inset (bottom right) shows entrance or exit hole made by the stalk borer

Diseases

In the 2016 season, except the occurrence of tef rust (*Uromyces eragrostidis*) in a field in Dera Hamusit District, the remaining tef fields in all surveyed areas were free from diseases. The incidence as well as the severity of tef rust was very low. In 2017, 52% of the surveyed tef fields were free of diseases; while 32%, 12% and 4% of them were infected by tef leaf rust, tef leaf rust and *Sclerotium* sp., and *Sclerotium* sp. alone, respectively. Of the fields that were invaded by tef leaf rust, 62.5% had incidence level of trace, whereas the rest 37.5% of the fields had very high incidence and severity level. Thus, one field each in Jara, Aloma, and Afrike had tef rust incidence of 85% with severity of 50%, 45% incidence with severity of 25% and 15% incidence with 3% severity, respectively. Compared to the 2016 belg season, the area covered by rain-fed tef and the proportion of tef leaf rust infected tef fields were greater in 2017 probably the 2017 season was wetter than the preceding season. Moreover, the spatial distribution of tef rust was limited to irrigated fields that were situated along riverbanks than those fields that are away from the riverbanks. This might be ascribed to the high relative humidity (free moisture) requirement for rust spore germination and invasion of host tissues. In the future, it might be necessary to undertake pathogenicity test to determine if the tef leaf rust race in belg and irrigated tef is different from the main season race. *Sclerotium* sp., which was characterized by white mycelium with round shaped but variable size sclerotia, was the other disease found in 2017 season both in rain-fed and irrigated tef fields with incidence/ severity of $\leq$ 1%.

Birds

In some areas, such as Kobo-Girana plane, different bird species severely attacked tef (fig 2). Farmers use slings to get rid of birds from their fields. Tef yield losses due to birds would be very high if control measures were not practiced. Birds attack belg and irrigated tef because there are no other cereals and grass species that grow and ripen during the belg season. Moreover, since farmers grow early and medium maturing tef genotypes in contiguous plots of land, bird attack is extended for longer period. Therefore, encouraging farmers to grow uniformly maturing groups of tef will help to shorten the time period during which tef is exposed to attack by birds. Moreover, in the Rift Valley of Ethiopia, chemicals such as Methiocarb have been recommended to repel birds from sorghum (Bruggers *et al.,* 1981).

Fig 2. Flock of birds attacking irrigated tef in Kobo-Girana Valley

Weeds

Irrigated and rain-fed tef was infested by annual and/or perennial broad leaved and grass weed species (Tables 1 and 2). In both seasons, nearly all the farmers had hand weeded their tef fields, but they did not use herbicides. In 2016 season, only two irrigated tef fields in Efeson (Ataye) area were sprayed with herbicides. In 2016, more than 31 weed species in 16 Families were recorded across the surveyed areas. The family Compositae (19.4%), Poaceae 16.1%, Polygonaceae (9.7%), Solanaceae (9.7%), Euphorbiaceae (6.5%) and Leguminosae (6.5%) comprised of 67.7% of the weed species (Table 1). Similarly, in 2017 season, more than 22 species in 14 Families were prevalent in both irrigated and belg rain tef fields. The two families Poaceae (31.82%) and Compositae (13.64%) accounted for the larger proportion of weed species (Table 2). *Cyperus* spp., *Portulaca oleracea, Parthenium hysterophorus, Amaranthus hybridus* and *Xanthium strumarium,* in decreasing order, were the most abundant weed species in the 2016 season. Even though *Cynodon nlemfuensis* and *Echinocloa colona* had very high mean field density (number of individuals per m^2), they had very low values of relative field density, relative frequency and relative field uniformity. It means out of the total number of fields surveyed and quadrats examined, only small proportion of fields and quadrats, probably which were not weeded, were infested by these two weed species. Consequently, they had large number of individual plants per unit area.

Table 1. Species composition and abundance of weed flora in irrigated and belg rain tef in 2016

Family	Species	Lifecycle *	Mean field density (Number per M²)	Relative frequency (%)	Relative field uniformity (%)	Relative field density (%)	Relative abundance (%)
Amaranthaceae	*Amaranthus hybridus*	A	11.72	7.64	8.15	7.56	23.34
Capparidaceae	*Gynandropsis gynandra*	A	9.67	2.08	2.81	1.75	6.65
Chenopodiaceae	*Chenopodium spp.*	A	1.00	1.39	0.56	0.12	2.07
Commelinaceae	*Commelina benghalensis*	A/P	5.00	1.39	1.40	0.60	3.40
Asteraceae (Compositae)	*Bidens pilosa*	A	6.00	1.39	1.12	0.73	3.24
	Gnaphalium unionis	A/p	5.00	0.69	0.84	0.30	1.84
	Guizotia scabra	A	1.00	0.69	0.28	0.06	1.04
	Launaea cornuta	P	4.17	4.17	3.09	1.51	8.77
	Parthenium hysterophorus	P	10.62	9.03	10.96	8.34	28.33
	Sonchus asper	A	9.25	2.78	2.81	2.24	7.82
	Xanthium strumarium	A	5.86	9.72	8.99	4.96	23.67
Cruciferae	*Erucastrum arabicum*	A	1.75	2.78	2.25	0.42	5.45
Cyperaceae	*Cyperus spp.*	P	24.06	11.11	12.64	23.28	47.03
Euphorbiaceae	*Euphorbia heterophylla*	A	6.00	0.69	0.84	0.36	1.90
	Euphorbia hirta	A/P	4.50	1.39	1.40	0.54	3.34
Leguminosae	*Medicago polymorpha*	A	3.00	3.47	2.25	0.91	6.63
	Trifolium rueppelliuanum	A	1.00	1.39	0.56	0.12	2.07
Papaveraceae	*Argemone ochroleuca*	A	3.67	2.08	2.25	0.67	5.00
Plantaginaceae	*Plantago lanceolata*	B	1.00	1.39	0.56	0.12	2.07
Poaceae	*Brachiaria eruciformis*	A	7.25	2.78	2.53	1.75	7.06
	Cynodon nlemfuensis	P	52.00	0.69	1.12	3.14	4.96
	Digitaria spp	A/P	15.29	4.86	5.34	6.47	16.67
	Dinebra retroflexa	A	4.00	1.39	0.84	0.48	2.72
	Echinocloa colona	A	36.25	2.78	3.65	8.77	15.20
Polygonaceae	*Oxygonum sinuatum*	A	5.67	2.08	2.25	1.03	5.36
	Polygonum nepalense	A	5.67	2.08	2.25	1.03	5.36
	Rumex bequartii	P	5.00	2.08	1.97	0.91	4.96
Portulacaceae	*Portulaca oleracea*	A	27.27	7.64	8.43	18.14	34.20
Solanaceae	*Datura stramonium*	A	8.20	3.47	3.93	2.48	9.88
	Nicandra physalodes	A	2.67	2.08	1.69	0.48	4.25
	Solanum nigrum	A	3.00	1.39	1.12	0.36	2.88

**A=annual, B=biennial and P= perennial*

In 2017, *Setaria pumila*, *Eragrostis cilianensis, P. hysterophorus* and *Argemone ochroleuca,* in decreasing order, were abundant than the other weed species. Similar to the preceding season, relative field density contributed more to the abundance value than relative frequency and relative field uniformity. It means that few fields or part of a field was not weeded. *A. ochroleuca*, was more abundant in 2017 than in 2016 season. This weed species is late season weed and the difference in abundance is attributed to the time of surveying. Field bind weed, *Convolvulus arvensis (*Convolvulaceae) was found in one field sown to Quncho in a place called Aloma (Altitude 2060 m, 11°27'8.62" N and 39°68'0.89" E). According to the farmer, the weed was introduced to his farm in 2015 with the relief seed he received from non-governmental organization. This weed species was inadvertently introduced to Ethiopia with lentil seed in the 1980s and it has now invaded East Shewa, Southwest Shewa, and West Shewa Zones, which are main sources of improved tef seeds. Besides, Ethiopia has no internal quarantine system to limit the introduction of new pests from one region to the other. This case suggests the need to implement stringent internal quarantine system to restrict the spread of pests with seeds and straw.

Table 2 . Species composition and abundance of weed flora in irrigated and belg rain tef in 2017

Family	Species	Lifecycle*	Mean field density (Number per m^2	Relative frequency (%)	Relative field uniformity (%)	Relative field density (%)	Relative abundance (%)
Amaranthaceae	*Amaranthus hybridus*	A	6.03	3.90	5.24	6.63	15.78
Chenopodiaceae	*Chenopodium spp.*	A	0.77	2.23	1.50	0.85	4.58
Commelinaceae	*Commelina benghalensis*	A/P	1.01	2.23	1.87	1.11	5.21
Convolvulaceae	*Convolvulus arvensis*	P	-	-	-	-	-
Asteraceae (Compositae)	*Bidens pilosa*	A	4.50	5.57	5.62	4.95	16.14
	Guizotia scabra	A	2.49	3.90	3.75	2.73	10.38
	Parthenium hysterophorus	P	7.56	6.13	7.12	8.32	21.56
	Xanthium strumarium	P	3.49	3.62	2.81	3.84	10.27
Cruciferae	*Erucastrum arabicum*	A	2.98	5.29	4.87	3.28	13.44
Cyperaceae	*Cyperus rotundus*	P	2.68	5.29	4.87	2.94	13.11
Euphorbiaceae	*Euphorbia hirta*	A/P	0.52	1.39	0.94	0.58	2.91
Papaveraceae	*Argemone ochroleuca*	A	6.53	5.85	5.43	7.19	18.47
Plantaginaceae	*Plantago lanceolata*	B	3.53	5.29	4.49	3.89	13.67
Poaceae	*Brachiaria eruciformis*	A	3.99	5.29	5.43	4.39	15.11
	Cynodon dactylon	P	3.26	4.74	4.31	3.58	12.63
	Digitaria abyssinica	P	4.90	5.29	6.37	5.40	17.06
	Echinocloa colona	A	3.00	3.34	3.56	3.30	10.20
	Eragrostis cilianensis	A	9.75	6.13	8.43	10.73	25.29
	Setaria pumila	A	14.90	6.13	10.11	16.39	32.63
	Snowdenia polystachya	A	3.44	5.29	4.12	3.78	13.20
Polygonaceae	*Polygonum nepalense*	A	1.87	3.62	2.62	2.05	8.30
Portulacaceae	*Portulaca oleracea*	A	0.83	2.51	1.87	0.91	5.29
Solanaceae	*Nicandra physalodes*	A	1.10	2.79	1.87	1.22	5.87

Eighteen weed species in different Families occurred in both seasons, while 13 weed species, which were prevalent in 2016, were not detected in 2017. Similarly four weed species, which were not prevalent in 2016 season, occurred only in 2017. Moreover, except *P. hysterophorus* which was relatively abundant in both seasons, species that were abundant in 2016 season were less abundant in 2017 and species that were more abundant in 2017 were less abundant or even absent in 2016. This variation in abundance, frequency of occurrence, and proportion of areas infested by a species is attributed to the effect of altitude, edaphic factors, season and crop management methods practiced by farmers (Hyvönen and Salonen, 2002; Fried *et al.,* 2008; Pal *et al.,* 2013). The results of these surveys did not show the potential weed diversity, species richness and abundance because the surveys were conducted after the farmers had exercised weed control measures.

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