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EVALUATION OF TEF VARIETIES FOR RESISTANCE TO SHOOT FLY (*ATHERIGONA HYALINIPENNIS*) IN SILTE ZONE, SOUTHERN ETHIOPIA

Banchiamlak Nigussie Tefera, Wukiyanos Eredachew

Ethiopian Institute of Agricultural Research, Wondo Genet Agricultural Research Center, Wondo Genet, Ethiopia.

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ABSTRACT

Tef (*Eragrostis tef*) is one of the major cereal crops and the most important staple food crop of Ethiopia, where it originated and diversified. Tef shoot fly (*Atherigona hyalinipennis*) is one of the major pest problems in tef growing areas, causing more than 90% of panicle damage. The aim of the study was to evaluate shoot fly damage and incidence in various tef varieties for their tolerance. Ten tef varieties, including the local variety, were laid out in a randomized complete block design with three replications at the Sankura research site during the main cropping season. The results of the analysis revealed significant differences among genotypes for all tested parameters. The white head and shoot fly damage levels were higher in the Simada variety (WH = 4.11 and SDL= 1.94, respectively) than in the other varieties. The lowest number of white head and shoot fly damage levels were obtained from the Dukem (NWH = 2.11) and Bishoftu variety (SDL = 1.05). The Bora variety had a higher grain yield (GY = 3.20 kg/ha), whereas the lowest grain yield was obtained from the Simada variety (GY = 0.212 kg/ha). Tef damage (white-headed) due to tef shoot fly ranged from 1.05 to 1.94%. Thus, all the tef genotypes were grouped under the resistance category. However, the Bora variety, with low tef shoot fly infestation and higher grain yield than the other treatments, is recommended in tef growing areas of the study site.

Corresponding Author: Banchiamlak Nigussie Tefera

Email: titigonidae@yahoo.com

INTRODUCTION

Ethiopian tef (*Eragrostis tef* (Zucc.) belongs to the grass family Poaceae and comprises more than 350 species of the genus *Eragrostis*. Among these species, 54 are found in Ethiopia, and 14 are endemic to the country (Cufodontis, 1974). Tef is an endemic cereal crop of Ethiopia, and its major diversity is found only in Ethiopia. Ethiopia is the geographical center of origin and diversity of tef (Vavilov, 1951). The word 'Tef' is said to have probably originated from the Amharic word 'Tefa', which means 'lost' because of its small grain size.

Tef is an indigenous staple cereal crop of Ethiopia. Ethiopians are the first domesticators of Tef in the world since they are the center of origin and diversity for Tef (Seyfu, 1997). It accounts for approximately 23% of the grain crop area of land, which is more than any other major cereal, such as maize (16%), sorghum (14%), and wheat (13%) (CSA, 2008).

Tef can be grown from sea level up to 2,800 meters above sea level (masl) under various rainfall, temperature, and soil regimes. However, it requires an altitude of 1,800-2,100 masl, an annual rainfall of 750-850 mm, and a temperature range of 10-27°C for better performance. It is predominantly cultivated in sandy loam to black clay soils (Seyfu, 1997). Belg tef is primarily produced in Tigray, Amhara, Oromia, and the

Southern Nations, Nationalities, and Peoples region. The main tef-producing zones in the Southern Nations, Nationalities, and Peoples Regional State (SNNPR) are North Omo, Gurage, Hadiya, Kembata Tembaro, Alaba, and Keficho Shekicho (CSA, 2003).

Tef plays a significant role in Ethiopian agriculture, food, and trade sectors. Many Ethiopian farmers rely on tef production for their daily consumption. Therefore, Ethiopia has a great chance to ensure food security by boosting tef production and exporting. With numerous benefits (such as being gluten-free and having high nutritional values), tef could be the next super-grain, and injera could be the next super-food worldwide. Despite these facts, the yields of tef are low in Ethiopia and the Southern region due to different production problems. Lack of improved varieties, non-adoption of improved technologies, diseases, and pests are some of the most serious production constraints of tef in Ethiopia.

However, insect pests are significant contributors to considerable tef yield losses in Ethiopia. More than 40 insect species have been recorded in tef. Among these, the most important, although generally sporadic, include the tef grasshopper (*Ailopus longicornis*), tef shoot fly (various species), red tef worm, Wello bush cricket, termites, and black tef beetle (Assefa et al., 2013). Surveys conducted in Central Ethiopia (Debre Zeit, Mojo, Koka, Alem Tena, and Akaki), East Gojam (Yilmanadensa, Bahr Dar Zuria, and Adet Zuria), and the Tigray Region (Mehoni, Axum, and Wukro) have confirmed the widespread occurrence of tef shoot flies (DZARC, 2002; Mulatu et al., 2008).

The damage caused by the tef shoot fly species (*Atherigona hyalinipennis*) accounts for more than 90% of panicle damage (Sileshi, 1997). Yield losses reported in the East and Southwest Shewa Zone areas are either negative or less than 5%, mainly due to abundant rainfall. Factors that directly influence the types of prevailing pests and the extent of damage include geographical and seasonal variations in the amount and distribution of rainfall, temperature regimes, and other environmental factors, coupled with crop management practices adopted by farmers.

Therefore, the occurrence, incidence, infestation, and damage level of tef shoot fly should be surveyed in tef-growing areas of South Ethiopia. Screening Tef varieties for Shoot fly damage resistance is crucial. This can assist in developing more effective pest management options for regulating pest species. Thus, this study aims to evaluate shoot fly damage and incidence in various tef varieties and screen resistance variety.

MATERIALS AND METHODS

Description of the study area

This study was conducted in the Silte Zone, Southern Nations, Nationalities, and Peoples Region (SNNPR) of Ethiopia. The Silte zone is bordered on the south by the Halaba zone, on the west by Hadiya, on the north by Gurage zone, and on the east by East Shewa. Geographically, it lies between 38°3'25.812''E and 7°45'10.864''N. The field experiment was conducted at the Sankura research site during the 2022 main cropping season. The research station is located 17 km south of the Halaba Zone. The annual rainfall at the experimental site during the main cropping season was 613.92 mm. The mean average annual minimum and maximum temperatures were 12.16 and 26.78°C, respectively. The major crops grown in the Silte zone include maize, wheat, barley, tef, sorghum, beans, peas, potatoes, and Enset (CSA, 2009).

Experimental setup

The field experiment was laid out in a randomized complete block design with three replications. Nine recently released tef varieties were acquired from the Debre Zeit Agricultural Research Center (Table 1). A total of ten tef varieties, including the local check, were selected for the field experiment. Tef seeds were sown in the third week of August 2022 at the Silte Zone Sankura Woreda research site. Each variety was planted in ten plots with an area of 2 m × 2 m, spaced at 0.2 m inter-row spacing. Plots, blocks, and replications were spaced at 1 m, 0.5 m, and 1.5 m, respectively. All agronomic practices were uniformly applied to all treatments following the recommended guidelines.

The recommended seed rate of 10 kg/ha was utilized, with 1.2 g of seeds per plot hand-drilled in rows. Fertilizer rates of 60 kg N and 40 kg P_2O_5 per ha were applied based on the recommendations of urea and DAP (Seyfu, 1997). DAP was applied once at the time of sowing, while urea was applied once after germination. The initial urea application was carried out two weeks after seed germination, and the second split was applied two weeks after the first application. The crop was allowed to naturally face shoot fly infestation without implementing any control measures. Shoot fly damage was recorded for each variety during the trial. All other crop management practices were applied in accordance with the recommendations for tef production.

Table 1: List and description of experimental materials.

Sr. No.	Tef varieties	Variety description	Year of release	Area of adaptation		Seed color	Maturity days
				Altitude (masl)	RF (mm)		
1	Boset	Z-Cr-409 RIL 50d	2012	1200-1500	---	Very white	75-90
2	Bishoftu	DZ-Cr-497	2020	1700-2500	700-1200	White	94-110
3	Bora	DZ-Cr 453 RIL 120B	2019	---	---	White	---
4	Dukem	DZ-01-974	1995	1400-2400	150-700	Pale white	76-138
5	Ebba	DZ-Cr-458 RIL 18	2019	1700-2500	700-1200	very white	95-110
6	Kora	DZ-Cr-438 RIL 133B	2014	1700-2400	700-1200	Very White	110-117
7	Quncho	DZ-Cr-387 RIL355	2006	1500-2500	300-700	White	80-113
8	Simada	Z-Cr-285 RIL295	2009	Low to mid	300- 700	White	88
9	Tsedey	DZ-Cr-37	1984	1800-2700	500-1200	White	82-90
10	Local	---	---	---	---	---	---

Assessment of shoot fly damage

Shoot fly damage was assessed and visually rated on a scale of 1-9 (1=<10%; 2=11-20%;3=21-30%;4=31-40%;5=41-50%; 6=51-60%; 8=71-80%; and 9=>80% plants with deadhearts). The percentage of damage and the level of resistance were determined using a rating scale (Table 2). The overall resistance score was recorded on a 1-9 scale before harvesting (Sharma et al., 1992).

Table 2. Scale of shoot fly damage used for assessing resistance to tef varieties.

Damage	Rating scale	Degree of resistance
0	0	Highly resistant (HR)
1-5	1	Resistant (R)
6-10	3	Moderately resistant (MR)
11-15	5	Moderately susceptible (MS)
16-25	7	Susceptible (S)
>26	9	Highly susceptible (HS)

Data collection

Data on plant height (cm), spike length (cm), number of tillers, shoot fly incidence, total biomass (g), and grain yield (g) were collected as follows. Plant height (cm) was measured as the distance from the base of the stem of the main tiller to the tip of the panicle at maturity. Total biomass (g) was calculated by measuring the weight of all the harvestable areas, including tillers harvested at ground level. Grain yield (g) represents the weight of the grain yield for the entire harvestable area of the plot.

Data analysis

The collected data were subjected to analysis of variance (ANOVA) using SAS Software (Version 9.0). Mean separation was carried out using least Significant Difference (LSD) at 5% level of significance.

RESULTS

Plant height, panicle length and number of tillers

There was a highly significant difference (P<0.01) in plant height among varieties. Variety Kora had the highest plant height (PH=161.39 cm), while variety Simada had the lowest plant height (PH=85.11 cm) (Table 3). The variation in panicle length was also significant (P < 0.01) (Table 3). The panicle length ranged from 45.49 cm to 33.5 cm among varieties. The local variety had the longest panicle (PL=45.49 cm), while the Boset variety had the shortest panicle (PL=33.5 cm) (Table 3). The analysis of variance showed a significant difference among varieties in the total number of tillers at the Sankura research site. The number of tillers varied significantly (P < 0.01) among varieties. Tsedey variety had the highest number of productive tillers (NPT=7.72), and Quincho variety had the lowest number of tillers (NPT5.72).

Grain yield (kg/ha)

The analysis of variance indicated that the genotypic mean square values were significant for all the agronomic parameters recorded. In the present investigation, the yield in kg/ha was significantly different (P < 0.01). The variety Bora had the highest yield of 3.208 kg/ha, surpassing all the other varieties.

The variety Simada had the lowest grain yield in this experiment, producing only 0.212 kg/ha (Table 3). The grain yield in the tested tef varieties ranged from 0.212 kg/ha to 3.208 kg/ha.

Table 3. Mean performance of varieties for different agronomic traits.

Tef variety	Plant height (cm)	Panicle length (cm)	Number of tillers	Grain yield kg/ha
Bishoftu	106.00 ab	42.44 ace	6.94 ab	0.218 a
Boset	98.16 ab	33.5 b	7.16 ab	0.228 a
Bora	100.00 ab	39.5 ade	6.89 ab	3.208 b
Dukem	111.08 ab	41.6 ace	6.72 ab	0.228 a
Ebba	154.95 b	37.11 bde	6.66 ab	0.235 a
Kora	161.39 b	44.77 ac	6.55 ab	0.230 a
Qunicho	114.28 ab	43.83 ac	5.72 a	0.245 a
Simada	85.11 a	34.94 bd	6.66 ab	0.212 a
Tsedey	107.28 ab	43.83 ac	7.72 b	0.217 a
Local check	108.22 ab	45.49 c	6.16 ab	0.247 a
LSD (5%)	**67.9**	**5.83**	**1.6775**	**0.05**
CV	**34.5**	**8.34**	**14.5**	**14.76**

Means within a column followed by different letters are significantly different (P>0.05).

White head and shoofly damage

The analysis of variance indicated that there was a significant difference (P < 0.01) in the number of white heads among varieties (Table 4). The highest number of white heads was obtained from Simada variety (4.11), while the lowest was recorded for Dukem variety (2.11). The analysis of variance also indicated that there was a significant difference (P < 0.01) in shoot fly damage among varieties (Table 4). The highest shoot fly damage was recorded for Simada variety (1.94), compared to the other treatments. The lowest shoot fly damage was recorded for Bishoftu variety (1.05). The graph showed that the highest number of white heads was recorded for Simada, followed by Kora variety. The shoot fly damage was higher for Simada, followed by Quincho variety. However, the lowest number of white heads was observed for Bishoftu variety, followed by Kora variety (Figure 1).

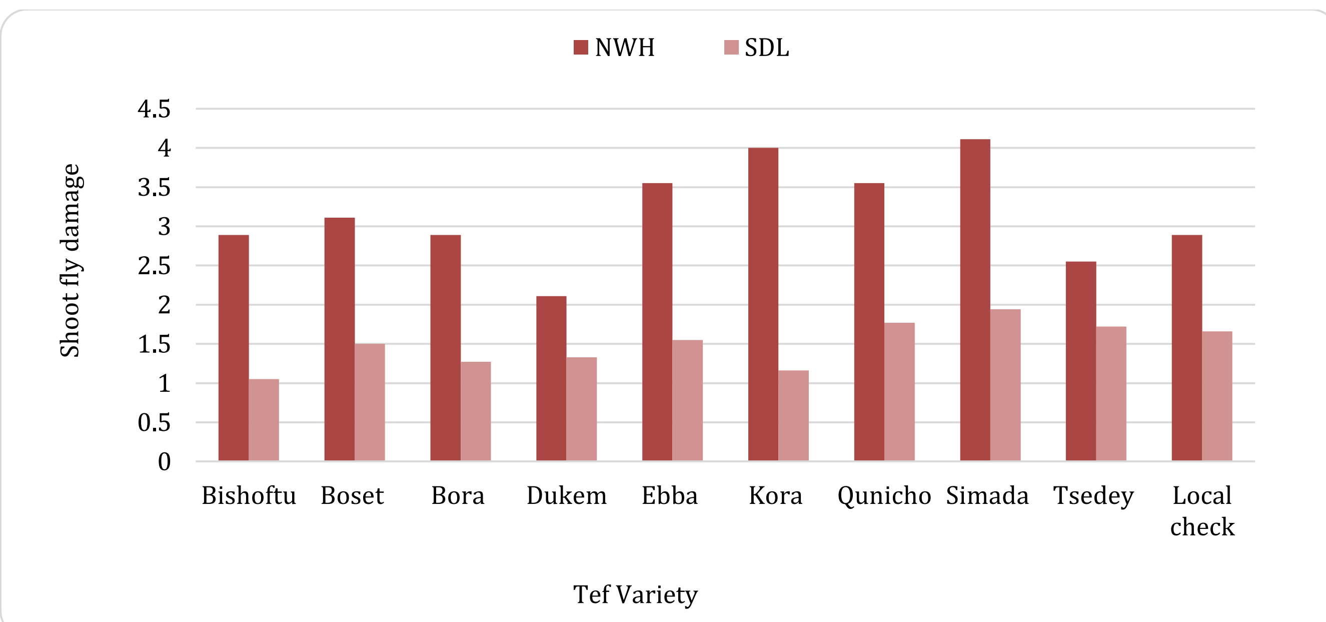

Figure 1. Mean of shoot fly white head and damage level.

Reaction of tef variety to shoot fly

The table below illustrates reaction of Tef genotype to the Tef shoot fly infestation (Table 4). All the Tef genotypes were grouped under resistance category. The field experiment was conducted under natural pest infestation and shoot fly infestation was low during the experiment.

Table 4. Reaction of tef varieties to tef shoot fly damage and resistance category.

Tef variety	Tef shoot fly damage		Resistance category
	Number of white heads	Shoot fly damage	
Bishoftu	2.89 ab	1.05 a	R
Boset	3.11 ab	1.50 ab	R
Bora	2.89 ab	1.27 ab	R
Dukem	2.11 ac	1.33 ab	R
Ebba	3.55 a	1.55 ab	R
Kora	4.00 a	1.16 ab	R
Quincho	3.55 a	1.77 ab	R
Simada	4.11 a	1.94 b	R
Tsedey	2.55 ac	1.72 ab	R
Local	2.89 ac	1.66 ab	R

R = resistance (Damage percent ranges 1-5%).

DISCUSSION

The damage caused by the tef shoot fly ranged from 1.05 to 1.94% in the current study. However, a previous study reported 6.96 to 37.60% damage in tef due to tef shoot fly infestation in the Tigray regional state (DZARC, 2002). In the present study, the highest shoot fly damage was recorded on the Simada variety, followed by the Quincho variety, compared to the other varieties. The lowest damage rate was recorded on the Bishoftu variety.

The grain yield was 0.212 kg/ha for the Simada variety and 3.208 kg/ha for the Bora variety. The grain yields of the varieties were almost the same, except for the Bora variety. This indicates that the shoot fly infestation and the shoot fly damage were low. In the current study, all the tested varieties were resistant to the shoot fly. Plant resistance to insect pests is known to be due to antibiosis, tolerance, and antixenosis (Abro et al., 2003). A previous study reported that late-sown tef was infested by the tef shoot fly, while early-sown tef was infested only if there was a dry spell (DZARC, 1983). However, in the present study, the infestation of the tef shoot fly was low even though the trial was sown late. There was good germination and production of tillers after sowing tef on the experimental trial field. Previous studies reported that inputs for tef production stimulated the appearance of the shoot fly (Corbeels et al., 2000; Berhane et al., 2015). Davies stated that shoot fly damage was greater when plant densities were low (Davies and Seshu Reddy, 1981).

CONCLUSION AND RECOMMENDATION

The damage caused by the tef shoot fly (white headed) ranged from 1.05 to 1.94%. As a result, the grain yield also varied from 0.212 to 3.208 kg/ha. The duration of the tef shoot fly infestation was determined between the beginning of August and the end of September. There was low infestation of tef shoot fly and the damage level was low during the present trial. However, the Bora variety, with low tef shoot fly infestation and higher grain yield than the other treatments, is recommended in the tef growing areas of the study area. The findings suggested the use of shoot fly resistant varieties such as Dukem, Bishoftu next to Bora for better yield performance in the study area.

The mechanism of resistance observed in the current study requires further investigation in order to reach at concrete conclusion. The tested varieties should be conducted for two consecutive years under field or greenhouse conditions by artificial infestation using fishmeal to increase the shoot fly infestation. This is due to the evaluation based on the damage percentage alone with low pest infestation cannot provide complete information on the resistance and susceptibility of the tef varieties to the tef shoot fly. Thus, considering both the damage percentage and the yield loss would be the accurate method for the categorization of varieties.

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AUTHOR'S CONTRIBUTIONS

The author planned and designed the studies, executed the experiments, collected and analyzed the data, wrote the manuscript and revised it.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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