



Infestation and Yield Losses Due to Sesame Webworm (*Antigastra catalaunalis*, (Duponchel) on Different Sesame Varieties in Western Tigray, Northern Ethiopia

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Authors' contributions

This work was carried out in collaboration between both authors. Author ZG designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author FA managed the analyses of the study. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JAERI/2020/v21i330134

Editor(s):

(1) Dr. Ozdal Gokdal, Adnan Menderes University and Çine Vocational School, Turkey.

Reviewers:

(1) M. Indar Pramudi, Lambung Mangkurat University, Indonesia.

(2) O. Adeleye Adeoluwa, Obafemi Awolowo University, Nigeria.

Complete Peer review History: <http://www.sdiarticle4.com/review-history/55403>

Received 12 January 2020

Accepted 17 March 2020

Published 13 April 2020

Original Research Article

ABSTRACT

Sesame (*Sesamum indicum* L.) is the most important oilseed crop in Ethiopia. It is basically grown during the summer season in different regions of the country and produced mainly in the northern and northwestern lowlands of Ethiopia. The production of sesame is low because of insect pests such as sesame webworm, sesame seed bug and gall midge. Among these pests, sesame webworm is one of the most important insect pests and it attacks the crop at all growth stages and causes a significant yield loss. Therefore, the present study was aimed to assess the infestation and avoidable yield losses of sesame due to sesame webworm on different released sesame varieties at field conditions. A field experiment was conducted to assess the infestation and yield losses with respective cost-benefit of nine released sesame varieties to sesame webworm in paired plots (treated with Diazinon 60% EC and untreated) in RCBD with three replications in 2016 production year. There was a significant difference ($p < 0.001$) between the protected and unprotected plots of each variety in leaf, flower and capsule injury. Protection of sesame from the webworm with insecticide effectively reduced leaf (0.02%), flower (<2%) and pod (<1%) damage to

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very low levels, On the other hand, the unprotected sesame had high levels of infestation. The highest capsule injury was recorded on BaHa-Necho (9.68%) and varieties Adi, Setit-2 and Borkena sustained <5% capsule injury. Grain yield was also increased significantly ($p < 0.001$) in the protected plots of the nine varieties as compared to their corresponding unprotected plots. Maximum yield was obtained from Setit-2, Setit-1, Humera-1 and Higher in both treated and untreated plots. The highest avoidable yield losses were obtained from Adi, Gonder-1, BaHa-Necho, and BaHa-Zeyit with respective cost-benefit ratio 2.27, 2.02, 2.12 and 2.03. Therefore integration of sowing the varieties Setit-2, Setit-1, Humera-1 and Hirhir and spraying with Diazinon 60 EC, at a rate of one liter per hectare at 2, 4 and 6 weeks after crop emergence (WAE) has potential to reduce the yield losses of sesame due to sesame webworm infestation and to increase yield of sesame.

Keywords: Webworm; sesame; variety; capsule injury; infestation; severity.

1. INTRODUCTION

Sesame (*Sesamum indicum* L.) is grown during the summer season in different regions of the country. Sesame is the most important oilseed crop in Ethiopia and grows well in the lowland areas of Tigray, Amhara, Benshangul Gumuz, Oromiya, Somalia and in some areas of Southern Nations Nationalities and Peoples regions. Sesame is Ethiopia's single largest exported oilseed and, important in foreign exchange generation. About 95 percent of exports are in the form of unprocessed seeds, leaving an opportunity for value-addition before export [1] for value-addition before export [1]. Tigray region covers about 36% of the total production of sesame in Ethiopia [2]. Western zone is the main sesame production area with large commercial farms and many small-scale farmers. According to the Zonal Offices of Agriculture, the western zone of Tigray from the total of 582,030.8 ha agricultural land about 395040 ha was covered by Sesame yearly. In the study area; sesame is called white gold. Humera - type sesame is well known for its uniformity, white color, large size, aroma, sweet taste, and these characteristics make it suitable for use in the local and international market [1]. Sesame is a good source of income in this area. Sesame is grown mainly for its attractive domestic and international prices in this area. The production of sesame is constrained by a large number of insect pests. Sesame webworm (*A. catalaunalis*), sesame seed bug (*Elasmolomus sordidus*), gall midge (*Asphondylia sesami*) are the most important insects pests that affect the production of sesame during its different growing stages [3], of these insects sesame webworm is the most serious one accounting for approximately 90% of yield losses [4]. Generally, webworms can cause yield losses of between 25 and 35% and a

critical period for control action is the flowering stage. Nevertheless, the webworm injured capsule may inflict up to 100% seed loss [5]. However, losses in yield are many variables depending upon the pest reaction of different varieties and season in Tikamgarh, India [6]. The level of infestation and yield losses of sesame due to sesame webworm in the study area was not studied. So, the present study aimed to identifying the infestation and yield losses of sesame due to sesame webworm on different sesame varieties in Western Tigray.

2. MATERIALS AND METHODS

2.1 Description of the Experimental Site

The experiment was conducted at the Humera Agricultural Research Center and Dansha (Kebabo) area during the main growing season of 2016 (Fig. 1). Humera is located 600 km west of Mekelle at an altitude of 604 m.a.s.l and at 14°06'N latitude and 38°31'E longitude. The agro-ecology of the region is hot to warm semiarid plain sub-agro-ecology. The maximum temperature varies from 33°C in May to 42°C in April while minimum temperature varies from 17.5°C in August to 22.5°C in July. The annual rainfall ranges from 400-650 mm which lasts from June to September. The dominant soil type of Humera Agricultural Research Center is chromic vertisol black in color characterized by very deep clay texture [7]. While the second location Dansha (Kebabo) is located at about 1439 km far from Addis Ababa via the Mekelle road and 135 km south of Humera. It is located at geographic coordinate 25°12'16" N latitude and 15°10'23" E longitude and an altitude of 690 m.a.s.l. The mean annual temperature is 28.7°C and it has vertisol soil type. The average annual rainfall varies from 850-1400 mm [8].

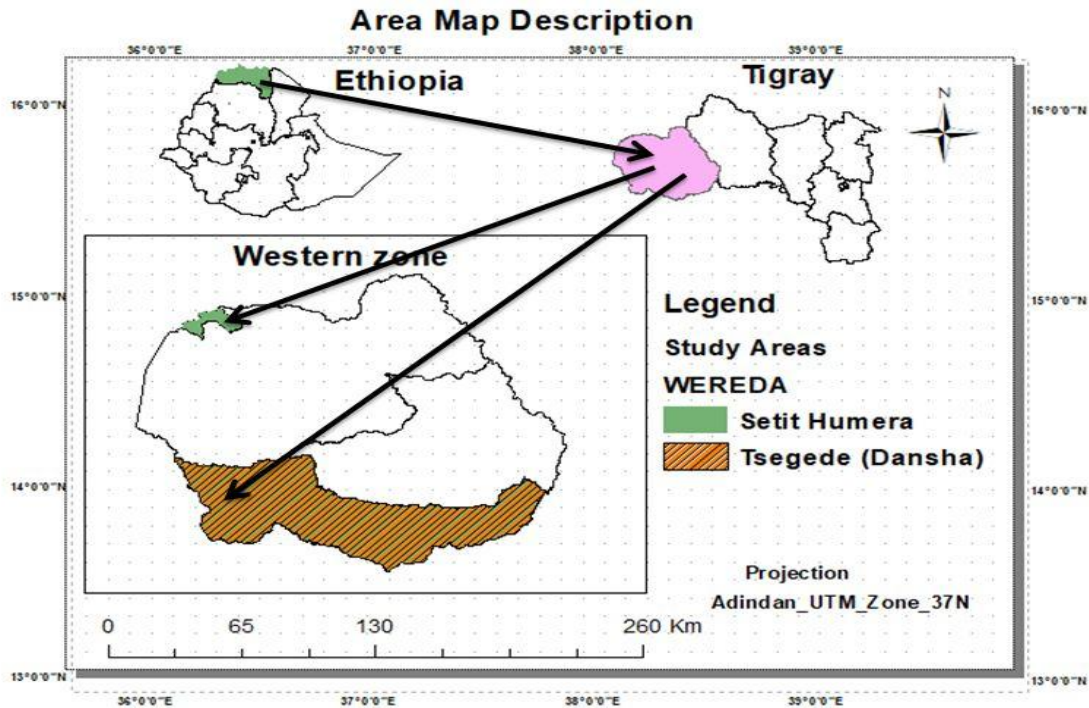


Fig. 1. Map of the study area

2.2 Experimental Design and Field Management

The nine varieties (Setit-1, Humera-1, Setit-2, Hirhir (local), Adi, Gonder-1, Borkena, BaHa-Necho, and BaHa-Zeyit) were planted at the two research sites to evaluate the yield loss due to sesame webworm. The experiment was laid down in a randomized complete block design (RCBD) with three replications. The experimental plot area was 10 m² having 5 rows each and 5 m long. The spacing of 40 cm between rows and 10 cm between plants was used. The varieties were sown in paired plots. One set of the experiment received foliar sprays of the insecticide Diazinon 60 EC, at a rate of one liter per hectare at 2, 4 and 6 weeks after crop emergence (WAE) depending on the infestation levels of the insect pest while the other set of the experiment was left untreated (unsprayed). The drift of insecticide sprays was controlled by shielding the unprotected treatments with plastic barriers.

2.3 Data Collected

Observations were made at weekly intervals. For this purpose, five plants were selected randomly from each plot and tagged. The damage of

Sesame webworm was recorded from the leaves, flowers and capsule of the plant parts. The data's such as number of injured leaves /plant, number of injured flower per plant and number of injured capsules per plant were also recorded from the randomly selected five plants and finally mean of the five plants were taken for each parameter. Yield data was taken from the three central rows of the plot and converted into hectares. The recommended crop management practices were followed by uniformly for all plots. Observation of leaf, flower and pod injuries were recorded at a weekly interval starting two weeks after emergence from the five selected plants per replication and 15 plants per variety. Severity was calculated at each developmental stage of the crop using the formulas indicated below.

2.4 Severity

Severity is the size of the damage on leaves, flowers and capsules of the sesame plant. It was calculated by the proportion of the total number of infested leaves, flowers and capsules of five plants per total leaves, flowers and capsules of the plant-based on the following formulas as described by [9].

$$\begin{aligned} \text{Percent leaf/flower/pod injury} \\ = (\text{Number of injured leaf} \\ \text{/flower/pod}) \\ /(\text{Total Number of leaf} \\ \text{/flower)/pod}) \times 100 \end{aligned}$$

2.5 Economic Importance (Avoidable Yield Loss) Due to Sesame Webworm

The yield data (kg/ha) was recorded from insecticide treated and untreated plots of the experiment and determine the economic importance of sesame webworm (*A. catalaunalis*). Then after the difference between the weight of seed yield (kg/ha) in treated and untreated plots was calculated. The percent losses or percentage of increase in yield of treated plots over the untreated plots was calculated based on of a formula by [10] as given below:

$$\begin{aligned} \text{Percent increase in yield} \\ = (X1 - X2)/X1 \times 100\% \end{aligned}$$

Where X1 is the mean yield in treated plots

X2 is the mean yield in untreated plots

Gross income was calculated by multiplying the yield difference (kg/ha) between the mean yield in treated plots and untreated plots of all treatments with the actual price of sesame per kilogram. Management cost (cost of chemical and spray only) was calculated but the other production costs were considered similar for all the treated and untreated experiments. Then net income was also calculated by subtracting the management cost from the gross income. Finally, the economic analysis of yield data of all the treatments and cost-benefit ratio (C: B) was calculated with the following formula used by [11].

$$\text{Cost - benefit Ratio} = \frac{\text{Net income}}{\text{Manabement cost}}$$

The cost-benefit analysis was made using the partial budget method [12]; by including costs of seeds, agronomic practices were uniform for all the treated and untreated experiment and costs of labor, insecticide and spray equipment were taken based on the price in the locality. The costs and benefit ratio were calculated per hectare basis and ten percent of the yield was deducted from the total grain yield since farmers in the area were assumed to obtain 90% of experimental yield.

2.6 Statistical Data Analysis

The field experimental data were subjected to ANOVA using SAS software 9.2 versions and means comparisons were made using Tukey's test at a 5% probability level.

3. RESULTS AND DISCUSSION

3.1 Infestation Level of Sesame Webworm on Sesame Varieties in Western Tigray

There was a significant difference ($p < 0.001$) between the protected and unprotected plots of each variety in leaf, flower and capsule injury (Table 1). Protection of sesame from the webworm with insecticide effectively reduced leaf (0.02%), flower (<2%) and pod (<1%) damage to very low levels (Table 1), On the other hand, the unprotected sesame had high levels of infestation. The damage at leaf stage on all the varieties was low (<3%) with the highest record on variety Adi and the lowest on Setit-1. The flower injury on different sesame varieties ranged from 7% to 9% and capsule injury from 4% to 10%. The highest capsule injury was recorded on BaHa-Necho (9.68%) and varieties Adi, Setit-2 and Borkena sustained <5% capsule injury.

3.2 Grain Yield of Different Sesame Varieties in Western Tigray

The over location combined analysis of varieties not treated with insecticides showed that there was a highly significant variation ($p < 0.0001$) in grain yield. Among the nine sesame varieties the highest grain yield was recorded from Setit-2 (918.28 kg ha⁻¹), Setit-1 (855.25 kg ha⁻¹) and Humera-1 (765.56 kg ha⁻¹) followed by the local check (753.25 kg ha⁻¹) which were significantly different from the remaining varieties, whereas very low grain yield was recorded from BaHa-zeyit (321.42 kg ha⁻¹), Borkena (387.61 kg ha⁻¹), BaHa-Necho (382.50 kg ha⁻¹), Gonder-1 (456.39 kg ha⁻¹) and Adi (510.22 kg ha⁻¹) (Table 2). There was also a significant difference ($p < 0.001$) between the protected and unprotected plots of each variety in grain yield. Protection of sesame webworm with insecticide reduced the grain yield losses, and leaf, flower and capsule injuries. Maximum grain yield was recorded on insecticide-treated sesame by spinosad (8.22 q ha-1) followed by indoxacarb (8.18 q ha-1), acephate (7.85 q ha-1) and carbaryl (7.59 q ha-1) and these chemicals were best in enhancing the yield of sesame in Jobner, Rajasthan [13].

Table 1. Percent leaf, flower and capsule injury due to sesame webworm on different sesame varieties in Western Tigray

Variety name	Leaf injury (%)			Flower injury (%)			Capsule injury (%)		
	Protected	Unprotected	Sig	Protected	Unprotected	Sig	Protected	Unprotected	Sig
Adi	0.05 ^d	2.94 ^a	s	1.03 ^{cd}	8.86 ^a	s	0.43 ^f	3.70 ^d	s
BaHa-Necho	0.17 ^a	2.28 ^{bcd}	s	1.27 ^{bcd}	9.38 ^a	s	0.87 ^{ab}	9.68 ^a	s
BaHa-zeyit	0.10 ^b	2.33 ^{bc}	s	1.45 ^b	8.68 ^a	s	0.67 ^{cd}	7.82 ^{bc}	s
Borkena	0.05 ^d	1.37 ^f	s	1.93 ^a	8.36 ^a	s	0.54 ^{def}	4.83 ^d	s
Gonder-1	0.09 ^{bc}	2.56 ^{ab}	s	1.35 ^{bc}	8.44 ^a	s	0.99 ^a	8.90 ^{ab}	s
Hirhir (Local)	0.10 ^b	1.91 ^{cde}	s	1.34 ^{bc}	7.37 ^a	s	0.74 ^{bc}	4.96 ^d	s
Humera-1	0.07 ^{cd}	2.37 ^b	s	1.44 ^b	7.89 ^a	s	0.97 ^a	6.84 ^c	s
Setit-1	0.09 ^b	1.58 ^{ef}	s	1.25 ^{bcd}	8.32 ^a	s	0.62 ^{cde}	6.84 ^c	s
Setit-2	0.09 ^{bc}	1.90 ^{de}	s	0.95 ^d	6.91 ^a	s	0.47 ^{ef}	4.69 ^d	s
LOC	***	***	***	***	***	***	***	***	***
VAR	***	***	***	***	NS	***	***	***	***
LOC* VAR	***	***	***	***	NS	***	***	***	***
L.S.D(±)	0.02	0.43	0.33	0.34	2.62	2.08	0.19	1.45	1.14
Grand mean	0.09	2.14	1.11	1.34	8.25	4.8	0.69	6.47	3.59
CV (%)	13.64	10.51	14.1	13.43	16.63	20.74	14.02	11.73	15.18

Means followed by the same letter(s) within a column are not significantly different at 5% level of significance, Sig= significant difference between the protected and unprotected, S= significant, LOC= location, VAR= variety, LSD= least significance difference, CV (%) = coefficient of variation

Table 2. Grain yield of the protected and unprotected sesame varieties in Western Tigray

Variety name	Grain Yield (kg/ha)		
	Protected	Unprotected	Sig
Adi	755.42 ^b	510.22 ^c	s
BaHa-Necho	616.28 ^{bc}	382.50 ^{cd}	s
BaHa-zeyit	548.69 ^c	321.42 ^d	s
Borkena	548.67 ^c	387.61 ^{cd}	s
Gonder-1	683.09 ^{bc}	456.39 ^{cd}	s
Hirhir (Local)	970.20 ^a	753.25 ^b	s
Humera-1	976.42 ^a	765.56 ^{ab}	s
Setit-1	1070.58 ^a	855.25 ^{ab}	s
Setit-2	1111.89 ^a	918.28 ^a	s

Variety name	Grain Yield (kg/ha)		
	Protected	Unprotected	Sig
LOC	***	***	***
VAR	***	***	***
LOC* VAR	***	***	***
L.S.D(±)	183.53	161.53	205.32
Grand mean	809.03	594.50	733.74
CV (%)	11.87	14.22	13.38

Means followed by the same letter(s) within a column are not significantly different at 5% level of significance, Sig= significant difference between the protected and unprotected, S= significant, LOC= location, VAR= variety, LSD= least significance difference, CV (%) = coefficient of variation

Table 1. Mean farmers adjusted grain yield, mean avoidable loss, net profit and, C: B ratio on different varieties of sesame in Western Tigray

Variety name	Mean adjusted yield(kg/ha)			Mean (%) avoidable losses	Cost of chemical & spray (birr/ha)	Gross income (birr/ha)	Net profit (birr/ha)	C: B ratio
	Protected	Un protected	Increased yield					
Adi	679.88	459.20	220.68	32.46	1350	4413.60	3063.60	2.27
BaHa-Necho	554.65	344.25	210.40	37.93	1350	4208.04	2858.04	2.12
BaHa-zeyit	493.82	289.28	204.54	41.42	1350	4090.86	2740.86	2.03
Borkena	493.80	348.85	144.95	29.35	1350	2899.08	1549.08	1.15
Gonder-1	614.78	410.75	204.03	33.19	1350	4080.60	2730.60	2.02
Hirhir(Local)	873.18	677.93	195.26	22.36	1350	3905.10	2555.10	1.89
Humera-1	878.78	689.00	189.77	21.60	1350	3795.48	2445.48	1.81
Setit-1	963.52	769.73	193.79	20.11	1350	3875.94	2525.94	1.87
Setit-2	1000.70	826.45	174.25	17.41	1350	3484.98	2134.98	1.58
Mean	728.13	535.05	193.08	26.52	1350	3861.52	2511.52	1.86

Note: Mean farmers adjusted yield (harvested grain yield kg/ha * 10%), Price of Sesame seed=20 Birr/kg, Cost of labor=100 Birr/day/labor, Cost of Diazinon 60 EC=250 Birr/liter, 2 Labors, and 1 liter Diazinon 60 EC being required for 1 hectare for a single spray, Total of 6 labors and 3 liters of Diazinon 60 EC were used, Other variable costs were the same for all the treatments, BCR = Net income/Management cost

3.3 Grain Yield Losses

The combined analysis of variance across the two locations revealed that the grain yield was also increased significantly in the protected plots of the nine varieties as compared to their corresponding unprotected plots. In the protected plots the highest yield was observed from Setit-2 (1000.70 kg ha⁻¹), Setit-1 (963.52 kg ha⁻¹), Humera-1 (878.78 kg ha⁻¹) and Hirhir (873.18 kg ha⁻¹) followed by Adi (679.88 kg ha⁻¹) whereas the lowest was recorded from Borkena (493.82 kg ha⁻¹), BaHa-Zeyit (493.82 kg ha⁻¹) and BaHa-Necho (554.65 kg ha⁻¹) (Table 3). In the unprotected plots, the highest yield was recorded similarly on Setit-2 (826.45 kg ha⁻¹), Setit-1 (769.73 kg ha⁻¹), Humera-1 (689.00 kg ha⁻¹) and Hirhir (677.93 kg ha⁻¹) while the lowest yield was from BaHa-Zeyit (289.28 kg ha⁻¹), BaHa-Necho (344.25 kg ha⁻¹), Borkena (348.85 kg ha⁻¹) and Gonder-1 (410.75 kg ha⁻¹).

Avoidable yield losses in different varieties varied from 17.41 to 41.42% (Table 3). The highest grain yield losses of sesame were recorded on BaHa-Zeyit, BaHa-Necho, and Gonder-1 while the lowest was in Setit-2, Hirhir, Setit-1 and Humera-1 (Table 3). The higher losses in grain yield of sesame recorded on these varieties could be due to the high leaf, flower and capsule injury by sesame webworm as compared to the other varieties. Varying levels of yield losses on sesame by the sesame webworm have been reported from different studies; [14] 18.3 to 22.9% in Tikamgarh, [15] 27.47%, [16] 57.60%, [17] 82.90%, and [18] 90.10%. In the current study, the highest loss was recorded on the varieties BaHa-Zeyit (41.42%) and BaHa-Necho (37.93%).

The highest net profit was obtained from Adi (3063.60), BaHa-Necho (2858.04), BaHa-Zeyit (2740.86) and Gonder-1 (2730.60) with cost-benefit ratio of 2.27, 2.12, 2.03 and 2.02 whereas the least was obtained from Borkena (1549.08), Setit-2 (2134.98), Humera-1 (2445.48), Setit-1 (2525.94) and Hirhir (2555.10) with a respective cost-benefit ratio of 1.15, 1.58, 2.81, 2.87 and 2.89.

The infestation of sesame webworm (leaves, flowers and capsules injury) was effectively controlled in all the nine varieties with three foliar sprays of Diazinon 60% EC at the rate of 1 liter/ha. The grain yield of all the tested varieties was also significantly higher in the plots treated

with Diazinon 60% EC which reduced the leaf, flower and capsule injury. This result is in line with [19,20] who reported that control of *A. catalaunalis* with two applications of dimethoate 40% applied at a rate of 2 l/ha at 2 and 4 weeks after sesame germination. Effective control and increased yield were reported with the use of endosulfan [21,19,18,13], Cypercal P720EC [22]. Yield losses of sesame caused by major insect pests were 36.56% when Carbaryl 0.2% sprays at 35 and 50 days after crop emergence [23]. Many studies have shown that insecticide applications reduce sesame webworm populations. Spraying of Endosulfan 35 EC at 0.07% reduced sesame webworm by 32.14% [24]. The need-based application of Lambda-cyhalothrin and spinosad are better than other insecticides to be effective [25]. A recent study reported a high-level reduction of sesame webworm population by spinosad (70.10%), indoxacarb (65.28%), carbaryl (60.95%) and acephate (60.35%). Neem seed kernel extracts at 5% Neem leaf extracts at 2%, Neem oil at 2%, and Nimbecidine at 0.15% were found to be effective on sesame webworm [24,13].

4. CONCLUSION AND RECOMMENDATION

Grain yields were significantly higher in the protected plots of the nine tested sesame varieties as compared to their corresponding unprotected ones. The highest farmers adjusted grain yield was obtained from Setit-2, Setit-1, Humera-1 and Hirhir in both the protected and unprotected plots. The avoidable grain yield of the varieties varied from 17.41 to 41.42% and the highest avoidable losses were obtained from varieties; Adi, Gonder-1, BaHa-Necho and BaHa-Zeyit with the respective cost-benefit ratio of 2.27, 2.02, 2.12, and 2.03, respectively. Therefore integration of sowing the varieties Setit-2, Setit-1, Humera-1, and Hirhir and sprayed with Diazinon 60 EC, at a rate of one liter per hectare at 2, 4, and 6 weeks after crop emergence (WAE) has potential to reduce the yield losses of sesame due to sesame webworm and to increase yield of sesame.

ACKNOWLEDGEMENT

The author expresses his thanks to Tigray Agricultural Research Institute (TARI), Humera Agricultural Research Center (HUARC) and Sesame Business Network (SBN) for their financial support.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
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