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Monitoring Mango Fruit Fly Dynamics, Assessing Species and Damage in central Zone of Tigray, Northern Ethiopia

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Fruit fly is newly introduced to Mereb-lekhe district which constraining the production and market quality of mango the major cash crop of the district. The current study was conducted to monitor fruit fly dynamics, identify the species and extent of fruit damage for effective management strategy. Semi-structured questionnaires were used to assess the status of mango fruit fly and the existing farmers management practices. Methyl eugenol pheromone trap were installed on randomly selected fruiting mango trees at a height of 1.5 meter above ground for two successive years 2019-2020 to monitor fruit fly dynamic. Fruit fly were reared in laboratory for identification and fruit loss were analyzed for each variety. The result indicated that according to 90%of the respondents fruit fly is the most challenging pest caused above 50% fruit loss. Eighty eight of the respondents proved fruit fly prefer the most familiar variety; apple mango than the local mango. Based on the trap catch's the highest fruit fly population was recorded during May, June, July 1693, 2977, 5128 fruit

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fly/trap/week respectively with the peak population in July (5128) fruit fly/trap/week. The number of fruit fly were increasing steadily from April to July and then begins to reduce from August. This coincides with the rainy season and fruit ripening stage of the fruit tree. In the rearing cages a total of 117 adult fruit fly were emerged from maggots in the collected samples of infested fruits. Adult fruit flies were differentiated into two species. Eighty five of them *Bactrocera dorsalis* and the rest 32 were Ceratites species. Bactrocera. dorsalis were the dominant species in the study area devastating both mango and guava fruits. The result indicated that fruit fly infestation was significantly higher on apple mango than kent and local variety of mango (56,26&18) % respectively. Apple mango were highly susceptible to *Bactrocera dorsalis* and the local fibrous mango were comparatively tolerant. The highest fruit yield loss was recorded on apple mango (36qt/ha) than the local variety (12qt/ha) This indicated that the producer loosed 108660ETB (Ethiopian birr) from a hectare of apple mango due to fruit fly. Fruit quality were highly affected by the pest a single pin hole on the peel of the fruit caused total market faller. The male annihilation (methyl eugenol) technology should registered in the country and made available in local markets to integrate with cultural practices for fruit fly management.

Keywords: Fruit fly; mango; population dynamics; Bactrocera dorsalis.

1. INTRODUCTION

Mango (*Mangifera indica* L.) 'a king of fruit' in the tropics and sub tropics [1] cultivated worldwide with leading production in India, China and Thailand [2]. Egypt, Nigeria and Kenaya were the highest mango producing countries in Africa [3]. In Ethiopia it grows abundantly in many parts of the country, (Oromia, Benshangul, Amhara, Gambela, Southern and Tigray,) regions [4]. Mango is the first major economic driver for farmers in Mereb-lekhe district central zone of Tigray where a number of actors along the value chain able to benefit [5]. Hence, the regional government of Tigray has constructed a dam, which has a capacity of irrigating more than 2000 hectares to improve the production and productivity of crops in the district most of it is covered by mango almost all farmers shift their production to mango [5]. Improved production system is introduced with selected and grafted mango varieties (apple mango, kent, kit and dado). Farmers adopt and practicing the grafting technology, Eg. MrsHaregu the owner of 12ha mango had her own mango nursery and sales grafted seedlings to farmers, NGOs and other stakeholders in the woreda [5].

The difficulty of this principal fruit production has been of national concern due to fruit flies and white mango scale [6]. Fruit flies (Diptera: Tephritidae) is the most destructive insect pests of fruit and vegetables [7,8]. There are about 4500 known species of fruit flies throughout the world, of these 200 are considered as pests and 70 species are agriculturally important pests [9,10]. The common fruit fly species in Ethiopia were *Ceratitis fasciventries*, *Ceratitis cosyra,* and *Bactrocera invadens* [11]. They cause enormous economic losses in every part of the world where fruits and vegetables are grown. There were early records of fruit fly species belonging to the Tephritidae particularly in the genus, *Ceratitis* and *Dacus* in Ethiopia [12]. In 2004, an invasive species, *Bactrocera invadens* Drew was reported from Ethiopia in high numbers in several fruit species across western and southern Ethiopia [13]. Female fruit flies puncture the pericarp and lay their eggs under the skin of mango fruit. Then, the eggs hatch into larvae which feed on the decaying flesh of the fruit. Infested fruits rot quickly causing considerable losses. In severe infestation, fruit fly can cause fruit damage up to 80% or even 100%, in mango producing areas when no control method is applied [14,15]. In addition to mango, fruit flies attack sweet orange, guava, apples, peach, papaya and many others. Due to their wide distribution, fast proliferation (rapid reproduction), polyphagous nature; they are difficult to control them using insecticides and caused a huge yield losses in fruit and vegetable crops [16,17,18,19]. The livelihood of rural community in the study areas is highly dependent on this fruit crop that extremely impacted with the losses. The impact of fruit fly on mango is not only direct loss of yield and increased control costs, but the local and export market demands are also lost due to fruit fly infestation [20]. The European Union countries and United States of America impose strict quarantine measures on importing fresh mango fruit. The detection of only one larva fruit fly at the entry port of a destination country leads to destruction of the entire mango consignment and a possible outright ban for the exporting country [21].

There are different types of IPM practices in many countries to control fruit flies. The combined use of different practices (MAT) male annihilation technique, population monitoring, spot application of food /protein bait, field sanitation and biological control (biopesticides, parasitoids and weaver ants) are effective in fruit fly management. Pierre [22] reported a reduction of fruit infestations of 80% was found for soil raking, 90% for the orchard sanitation. Similarly, reductions were 100% by MAT and 60% by BAT. Effectiveness was found to be 100% if MAT was combined with other cultural controls [23]. The ones that are used frequently were: male annihilation, "succes appat", bagging, and biological control (Badji & Vaughan, 2012); [22]. Male annihilation using methyl eugenol was effective in fruit fly management that captured 86.82% fruit flies in Cote d'Ivoire (Nidela, et. al., 2016).

However, there was no any studies made on fruit fly infestation, species identification, extent of damage and management options in Tigray region. Therefore, the current study was applied to assess the knowledge of farmers on mango fruit fly, population dynamics and peak activity of the pest, to investigate field infestation and extent of fruit damage by fruit flies on mango so as to schedule effective and timely control mechanisms.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The study was conducted in MerebLeke woreda, in the central zone of Tigray, northern Ethiopia during 2019-2020. MerebLeke woreda is found at the border of Ethio-Eritrea in the north. The woreda contains twenty-two kebeles and the administrative center is at Rama. From these kebeles Wedihazo, Hadushadi, Medhin, Birshiwa,may weini and Mihkan has common irrigation area known as Hamedo Irrigation scheme and the study was done in this scheme. It is located at about 1041 kms away from Addis Ababa and 67kms to the north of Aksum town, at 14^{o} 25'26" and 14^{o}18'48" N latitude, and 38^{o} 42'15" and 38^{o}48'30" E longitude with an altitude of 1390 m.a.s.l. It is found in semi-arid tropical belt of Ethiopia with "kola" agro climatic zone and the rainy season is mono - modal concentrated in one season from lateJune to early September receives from 400 - 600 mm of rain fall per annum. The mean minimum and maximum temperatures ranged from 13.33 ^{0}C to 33.71 ^{0}C, respectively. The soil texture is sandy clay loam textural class with bulk density of 1.72 gm cm^{-3}, very low in organic carbon (0.73%) with an alkaline pH of (8.2). The major crop production of the area is cereals, such as Sorghum, Finger Millet, Maize, ground nut as a pulse; Vegetables such as Onion, Tomato, Hot pepper, Sweet potato and fruits Mango, Citrus Papaya and Banana.

2.2 Field Survey and Assessment of Farmers Perception on Mango Fruit Fly

A field survey was conducted from June 2019 to July 2020 at Hamedo irrigation scheme in mango orchards to assess the status of mango fruit fly and the existing farmers practices on fruit fly management. Semi-structured questionnaires were used to determine the sample units. Five mango growing kebeles (Medhin,Wedihazo, Hadushadi, may weini and Mihkan) were selected. Based on their mango orchards. Fifty farmers having experience on mango production and owned fruiting mangos were selected and assessed their knowledge on mango fruit fly. Questions were asked relating to the awareness of fruit flies, the nature of damage, population dynamics, resistance and susceptible mango varieties,local market demands of the infested fruits, fruit losses caused by fruit flies and farmers management practices.Farmers knowledge or perception data on mango fruit fly was collected accordingly.

2.3 Population Dynamics Monitoring and Species Identification

Fruit fly dynamics were studied in Hamedo district mango orchards at Haregus mango farm and Axum Agricultural research station throughout the year during 2019/2020. Male annihilation technique using methyl eugenol trap were applied for monitoring the pest population. The trap was in the form of Bactrocera-Block which consists of a 5cm x 5cm wooden block impregnated with the attractant Methyl Eugenol and the contact insecticide Malathion. It was fixed on randomly selected fruiting mango tree at a height of 1.5 meters above ground [24]. Each trap (block) was used only for eight weeks then replaced with new once. Traps were visited and serviced at every week interval for two successive years 2019-2020. Each weekly captured fruit flies were counted and collected to the laboratory. Specimens were sorted, labeled, and preserved in 97% ethanol for species identification.

In addition to the trap collections; fruit flies were reared from infested fruits in laboratory to identify the species using identification keys. Fruit fly infested mango fruits were collected from Hamedo district and guava fruits from Enticho. A total of 40 infested mango fruits and 40 guava fruits were collected during the harvesting period and brought to the laboratory. The infested fruits were placed singly in plastic pots, with sandy soils at bottom for pupation and covered with muslin cloth tightly held with a rubber band. Pots were checked frequently for adult fruit flies emergence and the emerged fruit flies collected into bottle vials separately.Adult fruit flies collected by trapping and rearing were identified to species using appropriate manual for identification Plant Health Australia (2011). Specimens were sent to a fruit fly taxonomist for further confirmation.

2.4 Determination of Extent of Fruit Infestation and Fruit Yield Loss

To assess fruit fly infestation percentage and fruit damage in the mango orchards three commonly grown mango varieties were considered. Apple mango, kent and local mango were the most adapted and producing varieties in the area. Three mango orchards (research station, Haregus mango farm and farmers mango field) were taken for assessment. For each mango variety ten fruiting trees were randomly selected at each orchard. A total of thirty trees each variety were marked for inspection. Fifteen ripened fruits were randomly collected from each tree at peak harvesting time and visually inspected for any sign of infestation and separated in to “infested” or non-infested” categories. The two categories of fruits were separately counted and weighed. Percent damage was calculated as ratio of the weight of infested fruits to weight of the total fruits collected from marked tree. Fruit yield loss was estimated by using percent damaged fruit and fruit yield per hectare (tons). Monetary loss for the entire fruit orchards was estimated using the estimated market price during the study period.

2.5 Data Analysis

All collected qualitative data were analyzed using the descriptive analysis and quantitative data using ANOVA (SAS software) to test the differences in the ratio of damaged fruit among the mango varieties in each orchard. Differences were compared using statistical significance (LSD).

3. RESULTS AND DISCUSSION

The survey questionnaire result showedthat farmers produce different types of mango varieties apple mango, kent, dado and local or un grafted mango. Most of the respondents (75%) obtained the seedlings from office of agriculture and rural development fruit nursery at Rama. Questions in the questionnaire were targeted on finding information on pest problems commonly encountered by farmers in mango fruit production specific to their awareness on fruit flies.The majority of the respondents (89.9%) indicated that fruit flies were of major economic importance causing damage that can lead to the production of unmarketable fruits. The second in order of significance as a major pest to 64.3% respondents reported as powdery mildew. Respondents (80.5%) detected fruit flies by their nature of damage the pin hole on fruit peal and white maggots in the rotted fruits after dropping to the ground. But few farmers (5.6%) observed flies on mango fruits during ripening stage. Majority of respondents (65.7%) reported fruit flies as a common pests and increasing year to year. According to (82.8%) of the respondents fruit damage or fruit fly infestation was higher when fruit ripening stage coincides with rain fall (Table 1). Fruit fly caused above 50% fruit damage to 40% of respondents. Questions were asked to rate the level of infestation among mango varieties the local ungrafted fibrous fruit was comparatively tolerant to fruit flies than improved varieties (75%) and apple mango was highly susceptible or easily damaged by fruit flies (88.2%) of the respondents. The perceptions of farmers on market acceptance of infested fruits were almost the same they mentioned mango fruits with fruit fly symptoms have not any acceptance by the consumers and affected the market price of the whole produce which damaged economically the producers. In the local markets the demand of the crucial mango variety (apple mango) was reduced in an incident due to this pest consumers prefer the local fibrous fruit. Most of the respondents (55.6%) didn't used any management practice however (36.1%) used harvest before ripening to escape attacking by female fruit fly because there is no effective insecticide or control mechanism introduced in the area. The respondents (72.5%) of them recommend or demanded that effective insecticides and fruit fly traps to be available in the local markets.

Table 1. Farmers perception on mango fruit fly

S.No	Questioner	Variables	Respondents Perception %
1	Source of mango seedlings	Office of ARD	75
		NGO (REST&FAO)	20
		Private	5
2	Variety of mango planted	Apple mango	25
		Kent	17.5
		Mixed varieties (apple M, kent, dado & un grafted)	52.5
		Local (un grafted)	5
3	Productivity in qt per tree/year	1.5	52.8
		2	33.1
		3	13.9
4	Major diseases on mango	Powdery mildew	64.3
		Anthracnose	0
		No disease	35.7
5	Major insect pests damaging mango	Mango fruit fly	88.9
		Mango beetle	0
		Mango mealy bug	11.1
6	detection of fruit fly (symptoms)	Pin hole on fruit & fruit rot	80.5
		Flies seen on mango tree	5.6
		Not known	13.9
7	Fruit flies affect other fruits	Yes	11.1
		No	88.9
8	Pest (fruit fly) occurrences	Sporadic	20
		Yearly happened	65.7
		Not known	14.3
9	Pest prevalence	Increasing in this year	60
		Decreasing in this year	2.9
		The same	37.1
10	Fruit damage or infestation is higher	Ripening at rainy season	82.8
		Ripening at dry season	17.2
		The same at all	-
11	Fruit fly susceptible mango variety	Apple mango	88.2
		Kent	8.8
		Dado	3
		Local (un grafted)	-
12	Fruit fly tolerant mango variety	Apple mango	4.2
		Kent	8.3
		Dado	8.3
		Local (un grafted)	75
		No tolerant	4.2
13	Highly damaged fruit stage	Un ripened fruits	2.9
		Ripened fruits	88.2
		At all stage	8.9
14	Fruit yield loss due to mango fruit fly	1-25%	37.5
		26-50%	21.9
		Above 50%	40.6
15	Market demand of fruit fly infested fruits	Have no demand	88.3
		Have low price	11.8
16	Farmers management	Harvesting before ripening	36.1
		Using insecticides	8.3
		No management used	55.6
17	Farmers demand (question)	Training on the pest management	27.5
		Effective insecticides and traps be available	72.5

3.1 Population Dynamics, Monitoring and Species Identification

The result showed thatmango fruit fly appeared throughout the year in the study area while the population sizevaried with weather conditions and fruit ripening stage of mango. Based on the trap catch's the lower number of fruit flywas observed during January, February and March (43,61and 99) fruit fly/trap/week. The highest fruit fly population was recorded during May, June, July (1693, 2977, 5128) respectively with the peak population in July (5128) fruit fly/trap/week Table 2. In general the number of fruit fly were increasing steadily from April to July 2020 and then begins to reduce from August.This coincides with the rainy season and fruit ripening stage of the fruit tree. Similar results were discussed by Patel et al. [23], Bansode and Patel [25] maximum population of *Bactrocera Spp*. was recorded during April to July which coinciding with fruiting period of mangoand fly population increased with increasing temperature, relative humidity and rainfall. Sumathi et al. [26] also recorded the highest fruit fly catches 839.1fruit fly per trap during July while fruit fly population was low during January to April.

3.2 Fruit Fly Rearing and Identification

In the rearing cages a total of 117 adult fruit fly were emerged from maggots in therotted mango and guava fruits. Which are 56 from Rama and 61 from Enticho collections. Based on the morphological features the adult fruit flies were differentiated into two suspected species *Bactrocera dorsalis* and *Ceratitis sp*. *Bactrocera dorsalis* were the dominant species emerged from infested mangoand guava fruits collected from both sites. The morphological traits of *B.dorsalis* were clear wings, yellow stripes on the right and left side of the thorax, a dark T-shaped marking on the abdomen with the total length of the fly 8mm.where as the *Ceratitis sp*. had brown wing bands and shorter in length which was found only at Enticho infesting guavas. In addition to the reared fruit flies the captured flies (97670) from the trap have similar morphological treats with *B.dorsalis*. but *Ceratitis sp*. were not found in mango at Rama.

Table 2. Fruit fly dynamics and monitoring

s.no.	Month	Mean no. of fruit fly per trap per week
1	July-2019	978
2	August-2019	514
3	September-2019	462
4	October-2019	263
5	November-2019	110
6	December-2019	122
7	January-2020	43
8	February-2020	61
9	March-2020	99
10	April-2020	524
11	May-2020	1693
12	Jun-2020	2977
13	July-2020	5128
14	August-2020	2330

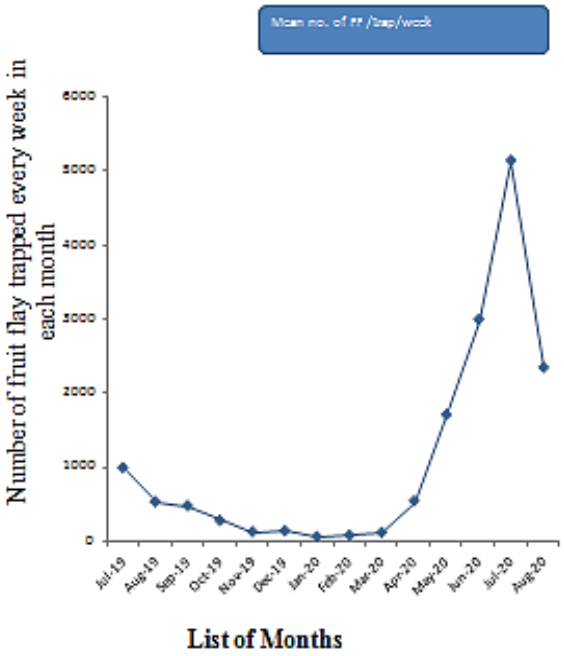

Table 3. Fruit fly rearing in laboratory for species identification

Fruit fly species	No. of emerged adult fruit flies from infested		Dominant %
	Mango (Rama)	Guava(Enticho)	
Bactrocera dorsalis	56	29	72.6
Ceratitis sp.	0	32	27.3

Fig. 1. Collection of fruit fly

3.3 Fruit Fly Infestation and Fruit Yield loss

The result indicated that fruit fly infestation was significantly higher on apple mango than kent and local varieties of mango. According the sample results out of 15 fruits eight of them were infested on apple mango (56.88%), where as four and three of them were infested on kent and local mango (26&18)%, respectively (Table 4.) as a result fruit damage was higher on apple mango. This indicated that apple mango is highly susceptible to fruit fly than the two varieties and the local un grafted mango is comparatively tolerant. Fruit quality were highly affected by the pest a single pin hole on the peel of the fruit caused total market faller. The highest fruit yield loss was recorded on apple mango (36qt/ha) than the local variety (12qt/ha) This indicated that the producer loosed 108660ETB (Ethiopian birr) from a hectare of apple mango due to fruit fly.

Table 4. Fruit fly infestation and fruit yield loss on different mango varieties

Mango Variety	Tot no. fruits	Wt of tot fruits	No. of inf fruits	Wt of inf fruits	Infestation% I	Damage %tage	Fruit yield qt/ha	Yield loss qt/hat/ha	Monetary loss ETB/ha
Apple mango	15	5.92^{a}	8^{a}	3.32^{a}	56.88^{a}	56.6^{a}	64	36.22^{a}	108660
kent	15	5.49^{b}	4^{b}	1.66^{b}	26.89^{b}	30.22^{b}	67	20.24^{b}	50599.10
Local	15	3.48^{c}	3^{b}	0.62^{b}	18.22^{b}	17.97^{b}	70	12.58^{b}	31450
LSD (0.05)	-	0.39	3.21	1.07	21	18.67		11.93	
R^2	-	98	89	93	89	91		90	
CV	-	3.49	27	25	27	23		22.86	

monetary loss was calculated yield loss qt/ha by the local market price of the fruit (apple mango=30birr/kg, kent and local ungrafted=25birr/kg)

4. CONCLUSION AND RECOMMENDATION

The distractive and invasive fruit fly sp (*Bactrocera dorsalis*) was highly infested and damaged mango and guava fruits in the study areas**.** The peak reproduction or infestation period wasmay-July which concedes withfruit ripening stage and rainy season.Apple mango were highly susceptible to B.dorsalisand the local un grafted mango were comparatively tolerant. The highest fruit yield loss was recorded on apple mango (36qt/ha) than the local variety (12qt/ha). This indicated that the producer loosed 108660ETB(Ethiopian birr) from a hectare of apple mango due to fruit fly.In current study the male annihilation (methyl eugenol) technology was the best option in reducing male fruit fly population specific to *B. dorsalis.*The technology should registered in the country and made available in local markets.Farmers should aware of the pest, harvest the fruit before ripening, field sanitation, used fruit fly traps and protein baits.Further studies on area wide fruit fly management, variety selection, agronomic manipulation (to make the tree fruiting in the dry season December-April) and different fruit fly baits is very important.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author (s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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