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ORIGINAL RESEARCH ARTICLE

Field response of three tephritid fruit flies to three food-based attractants and suppression of *Bactrocera zonata* (Saunders) using Mazoferm E802 + spinosad in a guava ecosystem in Sudan

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Abstract

Fruit flies of the genus *Bactrocera* are the most damaging pests of horticultural crops, leading to severe economic losses affecting the national income of various countries, especially Sudan. *Bactrocera dorsalis* (Hendel) and *Bactrocera zonata* (Saunders) were reported in Sudan in 2005 and 2012, respectively. Only the male annihilation technique (MAT) is applied in Sudan to manage the two *Bactrocera* species. Field experiments were conducted to evaluate the response of *B. dorsalis, B. zonata* and *Zeugodacus cucurbitae* to three food-based (Mazoferm, GF-120 and Torula yeast) attractants via McPhail traps at two sites in the Gezira State, Sudan. Another trial was undertaken to determine the effect of spot spraying Mazoferm + Spinosad on control *B. zonata*. The results showed that food-based attractants lured both sexes of the abovementioned fruit flies with specific attraction to females (74.5, 67.5 and 68.1% to Mazoferm E802, GF-120 and Torula yeast, respectively). At the first site, *B. zonata* responded in high numbers to Mazoferm E802, followed by Torula yeast and GF-120, while it responded equally to Mazoferm and Torula yeast at the second site. *B. dorsalis* responded positively to Mazoferm, followed by Torula yeast and GF-120, while *Z. cucurbitae* was attracted to Mazoferm E802, GF-120 and Torula. Spraying Mazoferm E802 + Spinosad significantly reduced the population of *B. zonata* (FTD) and suppressed the infestation level of guava fruits (fruit flies/kg of fruits) compared to those in unsprayed orchards. The spot bait application technique is an environmentally friendly approach that reduces fruit fly infestation levels, protects produce, decreases contamination and pollution and increases the income of poor farmers.

Keywords Peach fruit fly · Guava · Mazoferm · Spinosad

Introduction

Guava (*Psidium guajava* L.) belongs to the Myrtaceae family and is one of the most important tropical fruit trees in the world; this species is known to enrich the diet of hundreds of millions of people with high nutritive and health value (El Bulk et al. 1997; Morton 1987). In Sudan, guava is a popular fruit that represents a source of income for farmers throughout the year (Ali et al. 2014). Guava fruits are produced all over Sudan, and most are consumed locally (Mahmoud et al. 2020a, b). Due to its long fruiting period and softness, guava fruit is a highly preferred host for many insects and diseases, and among them are fruit flies (Mahmoud et al. 2020a, b).

Fruit flies are a group of insects belonging to the family Tephrtidae of the order Diptera with various genera of economic importance, including *Bactrocera, Ceratitis, Dacus* and *Zeugodacus* (Aluja and Norrbom 1999). In Sudan, different species, such as *C. capitata* (Wiedemann), *C. cosyra* (Walker), *C. quinaria*(Bezzi) and *Carpomya incomplete* (Becker), are indigenous fruit flies that negatively affect guava fruit, while *B. dorsalis* and *B. zonata* are alien invasive species introduced to the country during the last two decades (Salah et al. 2012; Mahmoud et al. 2020a, b).

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Sidahmed et al. (2017) also reported that the total number of adults of emerged fruit flies collected from guava fruits in the Alkadaro area, Khartoum State, was *B*. (*invadens*) *dorsalis*, *C. capitata*, *C. cosyra* and *C. quinaria*, with total numbers of 210.5, 170.3, 105.2 and 24.8 adults/kg of guava fruit, respectively.

The peach fruit fly *B. zonata* (Saunders) and the oriental fruit fly *B. dorsalis* are alien invasive pests of horticultural crops known to be native to Asia and harbor a wide range of host plants. These pests have been reported to attack more than 50 host plants, including guava, mango, peach, papaya, orange, grapefruit (edible hosts), jujube and ivy gourd (wild hosts) (Mahmoud et al. 2017; White and Elson-Harris (1994; Allwood et al. (1999).

was detected in central Sudan in 2011, and since it became the key fruit fly that displaced native species, it has competed strongly with the highly invasive *B. dorsalis*-infested Sudan in 2005 and spread to different states (Salah et al. 2012; Mahmoud et al. 2020a, b). The infestation level of *B. zonata* in the country reached 15% in mango orchards, while 10 Cite Reference. 0% loss was recorded in guava orchards (Mahmoud et al. 2016).

Fruit flies are subjected to strenuous efforts worldwide because of their ability to control vast invasions, high reproduction and severe damage (Ekesi and Tanga 2016). Stonehouse et al. (2002) mentioned that the effective methods used for controlling fruit flies include the bait application technique (BAT) and the male annihilation technique (MAT). Both BAT and MAT were controlled even on small- and medium-sized farms. Worldwide, protein baits mixed with insecticides, termed bait application technique (BAT), are among the main methods used for fruit fly control (Mangan and Moreno 2007; Manrakhan and Kotze 2011). Different types of protein hydrolysates baited in different types of traps or sprayed in combination with insecticides have been widely used since a century ago for monitoring and controlling fruit flies (Ekesi and Tanga 2016). Food-based attractants attract both sexes of fruit flies, but they are highly preferred by females because they are highly required for the development of ovaries and to increase egg maturity (Bateman and Morton 1981; Epsky and Heath 1998; Hull and Cribb 2001; Mazor et al. 1987; Robacker and Flath 1995; Robacker and Heath 1996). Other sources of protein, such as ammonia, which is released from human urine, chicken and duck feces, were found to be potential attractants for *Anastrepha* spp. (Hedström 1988) and three species of *Ceratitis*, four species of *Bactrocera* and two species of *Dacus* (Mahmoud et al. 2020a, b).

Mahmoud et al. (2012) reported that Nulure, Torula yeast, Mazoferm E802, human urine, water extracts of mango, guava, apple and grape attracted *B. dorsalis*, *C. cosyra*, *C. capitata*, *C. quinaria, Dacus ciliates* Loew, *D. vertebratus* Bezzi and *Z. cucurbitae*. Mazoferm E802 and Torula yeast were found to be more effective at attracting *B. dorsalis* and capturing more flies than did the standard Nulure (Ekesi et al. 2014).

The field control of fruit flies using GF-120 combined with Spinosad has been widely used for many years (Vayssie `res et al. 2009). Recently, a mixture of Mazoferm and Spinosad was found to be very effective at suppressing *B. (invadens) dorsalis* in mango fields in Kenya (Ekesi et al. 2014). The use of Spinosad, an insecticide derived from the metabolites of the soil bacterium *Saccharopolyspora spinosa*, has been shown to result in high mortality in different insect pests without affecting human health or natural conditions (Thompson et al. 2000).

Spatial distribution studies in Sudan revealed the movement of *B. zonata* southwards and eastwards, endangering the Republic of South Sudan, Ethiopia and Eretria, respectively; moreover, temporally, *B. zonata* was found throughout the year due to the availability of its host (Mahmoud et al. 2017; Zingore et al. 2020). Moreover, no studies have been conducted to evaluate the effectiveness of different food-based attractants for monitoring and suppressing *B. zonata* in Sudan.

Thus, this study was conducted to evaluate the field response of *Bactrocera* species, especially *B. zonata*, to three different food-based attractants, viz., Torula, Mazoferm E802 and GF-120, and to determine the effectiveness of Mazoferm in combination with the Spinosad in Lure and Kill technique for controlling alien invasive fruit flies in the guava ecosystem.

Materials and methods

Several studies evaluating the attractiveness of many synthetic food-based attractants using baited traps and partial spraying on fruit flies have been carried out in guava orchards distributed at two sites. All the experimental sites were located at Gezirat Elfil (14 26 56 4 N 33 29 8 52 E) and Fadasi (14 53 33 N 33 46 67 E) in the Gezira state, Sudan. The area of the experiment at each site was 0.5 hectares, and guava trees were the dominant species, with 6 m between each tree. Trees at both sites were irrigated from the Blue Nile River. No control measures were applied 6 months prior to the study.

The tested products and their dosages

The tested products used in the study were (1) Mazoferm® E820 (Corn Products International, Eldoret, Kenya) at 4% purity, (2) Torula Yeast® (International Technology, River Side, CA) at a rate of 3 pellets (4.78 g/pellet) per 1000 ml of water, (3) GF-120 (Dow Agro Sciences, Indianapolis, IN) at 18.2% purity, and (4) Spinosad (Tracer 4 EC; Dow Agro Sciences, Indianapolis, IN) at 100 g of active ingredient per hectare at an output volume of 5 L per hectare (50 ml per tree), and water was used as a control.

Baited trap trials

Three food-based attractants (Mazoferm E820, GF-120 and Torula yeast) and water (control) were used in the trap system to attract adult fruit flies in guava orchards distributed in the Gezirat Elfil and Fadasi areas. For each of the food-based attractants tested, water was placed in a McPhail trap (International Pheromone System (IPS) UK). In each trap, 3 g of borax (sodium borate) was added to preserve the caught flies.

Experimental design and assessment of the attractiveness of food attractants

A randomized complete block design (RCBD) was used for the two trials, which included 4 treatments (Mazoferm E820, GF-120, Torula yeast and water) and were replicated three times. The distance between blocks was 18 m, and the distance between treatments was 12 m. Traps were hung on trees 1.5-2 m above the ground. The trial was conducted for six consecutive weeks at each site during the winter of 2015. The attractants inside the traps were renewed weekly after cleaning, and their position was rotated sequentially.

The caught insects were preserved in vials in 70% alcohol and transferred to the laboratory. In the laboratory, insects were sorted, identified and sexed using a fruit fly pictorial key (Ekesi and Billah 2006), and the number assigned to each attractant was recorded.

Partial spraying trial

The effect of Mazoferm E802 combined with Spinosad on controlling fruit flies was evaluated for two consecutive fruiting seasons in the Fadasi area: November 2015–April 2016 and October 2016–January 2017. A half-hectare farm consisting of one hundred guava trees was treated with the combination of Mazoferm and Spinosad, and the same area with the same number of trees was selected for a distance of 1 km as the untreated one.

Monitoring population of fruit flies using traps

Before starting the partial spraying trial, a pre spray assessment of the population of fruit flies was conducted on 4 McPhail traps equipped with 15 g of Torula yeast (standard attractant) diluted in 300 ml of water. The traps were distributed 20 m apart from each other in the middle of each farm and were settled as described above, and the same procedure was applied after each spray to assess the ability of Mazoferm E802 + Spinosad to reduce the population of fruit flies.

Application of partial spraying

Mazoferm E802 + Spinosad bait spray was applied for eight consecutive weeks to the orchard, which was selected as the treatment group for two successive seasons, while the second orchard remained untreated (control). The Mazoferm E802 + Spinosad bait spray was applied as a spot application using a Knapsack sprayer to 1 m^2 of the canopy of every tree using a quadrate.

Data collection

Fruit flies that were caught in traps were collected and preserved in vials in 70% alcohol. Adult flies were sorted, sexed and recorded as fruit flies/traps/day. On the other hand, the level of infestation was assessed by the ambient amount of fruits collected from the trees and from the ground on the two farms. The collected fruits were weighed and kept on a ventilated container on the surface of 20 cm sterilized sand until the emergence of puparia. Emerged puparia were transferred to other containers on humidified sand until adult flies emerged; the plants were sorted, sexed, identified and recorded as fruit flies/kg of fruit.

Statistical analysis

The weekly data for each attractant were transformed using the formula.

($\sqrt{x}+1$). The results of all weeks of each treatment for each site were combined and subjected to ANOVA, and Tukey's test was applied to separate the means between different treatments, weeks and interactions between treatments and weeks.

For the fruit fly partial spraying trial, t test analysis (PROC TTEST) was conducted to determine the difference between the population of fruit flies, the level of infestation and the harvest loss (%) due to infestation by *B. zonata* for the treated and control orchards.

SAS computer-based statistical software was used to analyse the data of both trials (Kleinman and Horton, 2009).

Table 1 Mean of *Bactrocera zonata*/trap/day (± SE) attracted to Mazoferm, GF-120 and Torula yeast at guava orchard at Fadasi, Gezira State, Sudan (Combined analysis of six weeks)

Treatment	*B. zonata*/trap/day			% Females
	Males	Females	Total	
Mazoferm	6.1 ± 1.2 A (2.7)	12.5 ± 2.3 A (3.1)	18.6 ± 3.4 A (3.4)	67.2
GF-120	0.6 ± 0.2 C (1.8)	1.3 ± 0.2 C (2.0)	1.9 ± 0.4 C (2.2)	68.4
Torula Yeast	3.1 ± 0.6 B (2.3)	4.9 ± 0.7 B (2.9)	8.0 ± 1.3 B (2.8)	61.3
Control	0.1 (1.5) D	0.1 (1.5) D	0.1 (1.5) D	0
SE±	0.3	0.7	1.1	
C. V	12.8	13.2	11.9	
Pr > F week	< 0.0001	< 0.0001	< 0.0001	
Pr > F Treatment	< 0.0001	< 0.0001	< 0.0001	
Pr > F Week*Treatment	< 0.0001	< 0.0001	< 0.0001	

Numbers between brackets are transformed data and numbers with same letters are statistically same

SE = standard error

Table 2 Mean of *Bactrocera zonata*/trap/day (± SE) attracted to Mazoferm, GF-120 and Torula yeast at guava orchard at G.Elfil, Gezira State, Sudan (Combined analysis of six weeks)

Treatment	*B. zonata*/trap/day			% Females
	Males	Females	Total	
Mezofarm	0.3 ± 0.1 A (1.1)	0.9 ± 0.2 A (1.3)	1.1 ± 0.2 A (1.4)	81.8
GF-120	0.1 ± 0.03 B (1)	0.2 ± 0.1 B (1.1)	0.3 ± 01 B (1.1)	66.7
Torula Yeast	0.2 ± 0.1 A (1.1)	0.9 ± 0.1 A (1.4)	1.2 ± 0.2 A (1.5)	75
Control	0.0 (1) B	0.0 (1.0)B	0.0 (1.0)B	0
SE±	0.03	0.07	0.08	
C. V	7.5	13.7	14.6	
Pr > F Week	< 0.0001	< 0.0001	< 0.0001	
Pr > F Treatment	< 0.0001	< 0.0001	< 0.0001	
Pr > F Week*Treatment	< 0.0001	< 0.0001	< 0.0075	

Numbers between brackets are transformed data and numbers with same letters are statistically same. SE = standard error

Results

Evaluation of baited traps

Fadasi site

At the Fadasi site, the fruit fly *B. zonata* was the predominant species. Significant differences between the mean numbers of total daily catches of *B. zonata* flies per trap were recorded among the weeks (P > F Week < 0.0001) of treatment (P > F Treatment < 0.0001) and between the treatments and weeks (P > F Week*Treatment < 0.0001). The same trend of significance was also reported for females and males. All the traps equipped with the test products Mazoferm, Torula and GF-120 attracted a high percentage of females (61.3 to 68.4%) when compared with the traps equipped with water, which did not attract any fruit flies (Table 1).

The highest number of *B. zonata* was attracted to Mazoferm E802 (18.6 ± 3.4) adult flies/trap/day, followed by Torula yeast and GF-120 (8 ± 1.3 and 1.9 ± 0.4 flies/trap/day, respectively). It is very clear that Mazoferm E802 attracted more females (12.5) than males (6.1) to adults/trap/day.

G. Elfil site

At the G. Elfil site, the tested baits attracted *B. zonata*, *B. dorsalis* and *Z. cucurbitae* in different amounts.

B. Zonata Table 2 shows the results of the response of *B. zonata* to the tested attractants at this site. A significant difference was observed in the mean number of daily captures of the total number of *B. zonata* and for both sexes per trap among weeks, treatments and among the interactions between treatments and weeks P > F Treatment < 0.0001, P > F Week < 0.0001 and P > F Week*Treatment < 0.0075. The same number of *B. zonata* was attracted to both Torula and Mazoferm at 1.2 and 1.1, respectively, while GF-120 attracted the least number of 0.3 flies/trap/day (Table 2).

Mazoferm E802 and Torula yeast attracted the same number of males and same number of females. The percentages of captured females were 81.8, 75 and 66.7% for Mazoferm, Torula and GF-120, respectively.

B. dorsalis The results indicated that *B. dorsalis* responded positively to the test attractants, and there were significant differences in the number of fruit flies among the weeks (P > F week < 0.0001), treatments (P > F Treatment < 0.0001) and their interaction P > F week*Treatment < 0.0075. Mazofrm attracted the most *B. dorsalis*, followed by Torula yeast and G-F120, with 10.8, 4.4, and 1.6 flies/trap/day, respectively (Table 3). The same trend of attraction was observed for both females and males, and the percentages of females attracted to the three test attractants were 68.5, 68.2, and 56.3% for Mazoferm E802, Torula and GF-120, respectively (Table 3).

Z. cucurbitae This fruit fly was not found to infest guava or be reared out of guava fruit at all, but it was attracted to cucumber farms that were widely distributed around the farm of the study. *Z. cucurbitae* was positively related to the three test products, but its attraction to Mazoferm was

Table 3 Mean of *Bactrocera dorsalis and Zeugodacus cucurbitae/* trap/day (±SE) attracted to Mazoferm, GF-120 and Torula yeast at guava orchard at Gezirat Elfil, Gezira State, Sudan (Combined analysis of six weeks)

Treatment	*B. dorsalis/* trap/day			*Z. cucurbitae*/trap/day		
	Males	Females	Total	Males	Females	Total
Mezofarm	3.4 ±0.6 A (2)	7.4 ±1.1 A (2.2)	10.8±1.6 A (3.3)	1.1±0.2 A (1.4)	0.8±0.2 A (1.3)	1.9±0.4 A (1.6)
GF-120	0.7±0.2 C (1.3)	0.9±0.2 C (1.3)	1.6±0.4 C (1.5)	0.2±0.04B (1.1)	0.1±0.04B (1.1)	0.3±0.04 B (1.1)
Torula Yeast	1.4±0.2 B (1.5)	3.0±0.3 B (2)	4.4±0.5 B (2.3)	0.1±0.02 B (1.0)	0.1±0.02 B (1.0)	0.2±0.04 B (1.0)
Control	0.0 (1.0) D	0.0 (1.0) D	0.0 (1.0) D	0.0 (1.0) B	0.0 (1.0) B	0.0 (1.0) B
SE±	0.2	0.4	0.6	0.07	0.05	0.1
C. V	21.1	21.3	24.8	15.1	13.3	20.02
Pr>F week	<0.0007	<0.0001	<0.0001	0.1464	<0.0001	<0.01218
Pr>F Treatment	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.2843
Pr>F week*Treatment	<0.0028	<0.0075	<0.0075	0.4573	<0.3522	0.0075

Numbers between brackets are transformed data and numbers with same letters are statistically same

SE=standard error

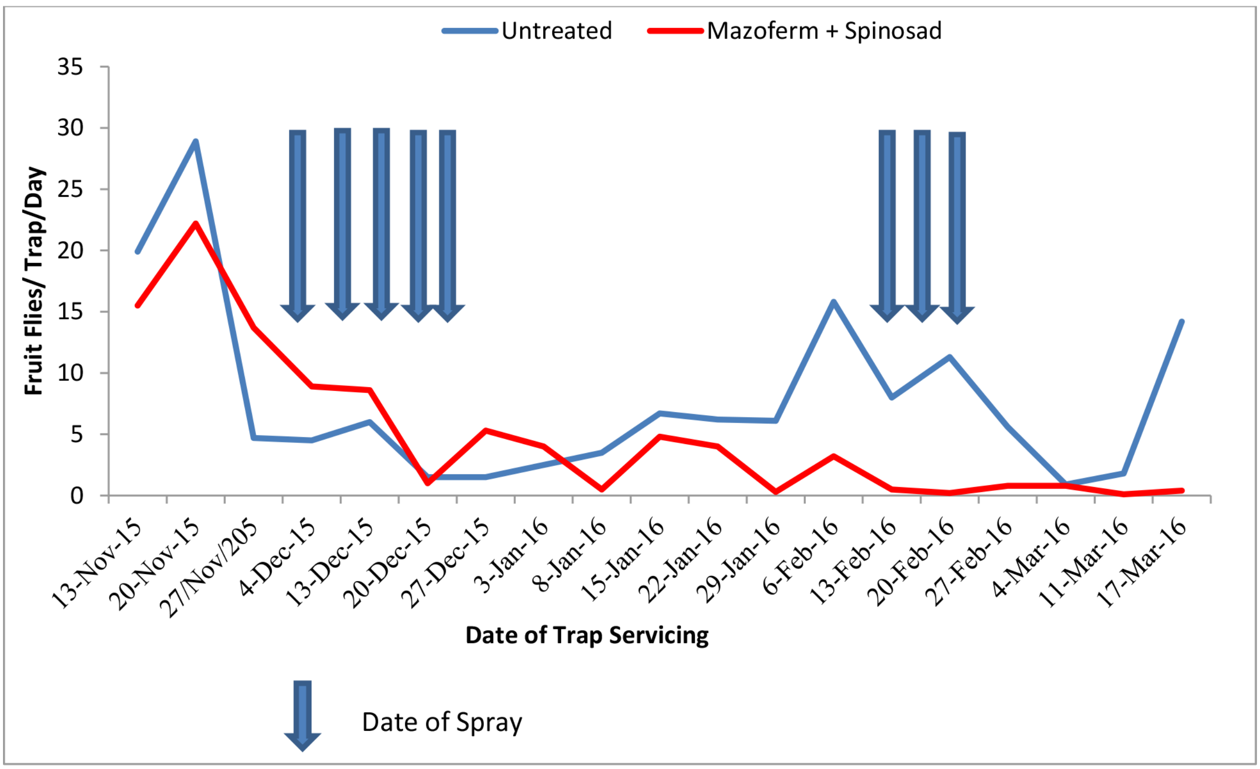

Fig. 1 Effect of Mazoferm+Spinosad on the population of *B. zonata* (FTD) on Guava orchard, Fadasi area, Gezira State, Sudan, November 2015–March 2016

greater than that to Torula and GF-120, which were significantly the same (Table 3).

Suppression trials

Effect of bait spray on the population of *B. Zonata*

In both harvesting seasons, the T test results revealed that the population of *B. zonata* was very low at the treatment site according to the application of Mazoferm E802+Spinosad compared to the untreated site, with probabilities P>T=0.0502 and P>T=0.0029 for the first and second harvesting seasons, respectively, at the 5% level.

Figure 1 shows the fluctuations in the population of *B. zonata* before and after the first season. The population was very high at the treated and control sites for counts before the application of Mazoferm E802 + Spinosad. The population of *B. zonata* decreased drastically at the treatment site, and the population decreased drastically after 5 sprays until it reached zero FTD. The population started to increase slightly before the application of the last three sprays, where the population decreased again to very low levels.

As presented in Fig. 2, the population of *B. zonata* in the second season decreased to very low numbers (zero) after the application of Mazoferm E802 + Spinosad at the treated site, while it fluctuated widely at the untreated sites.

Effect of bait spray on the level of infestation of guava by *B. Zonata*

A t test for the level of infestation revealed a significant difference between treated and untreated orchards (adult flies of *B. zonata*/kg of guava fruit) for the two consecutive seasons ($P > 0.0005$ and $P > 0.0049$, respectively). As indicated in Figs. 3 and 4, the number of adult flies/kg fruit on the untreated farm was greater than that on the treated farm for the two consecutive seasons. Mazoferm + Spinosad drastically decreased the infestation level on the treated farm.

Discussion

Fruit flies are polyphagous pests, and their control is very difficult unless there are integrated procedures (Vargas et al. 2015). Different management techniques are used worldwide to reduce the devastating effects of fruit flies (Billah and Wilson 2016). Field sanitation, the use of natural enemies, and the application of the male annihilation technique have been widely used for the suppression of tephritid fruit flies (Vargas et al. 2016). According to different studies by Gubara et al. (2009) and Sidahmed et al. (2014), only the male annihilation technique (MAT) is recommended for managing invasive *Bactrocera* species in Sudan.

Cornelius et al. (2000), Vargas et al. (2003), Mahmoud et al. (2012) and (Ekesi et al. 2014) reported that the most important factor affecting the attractiveness of fruit flies is the type of protein. As demonstrated in the results of this study, the tested food-based attractants (Mazoferm E802, GF-120 and Torula yeast) were found to potently attract both sexes of *B. zonata*, *B. dorsalis* and *Z. cucurbitae* at different levels according to the type of attractant. Mazoferm and Torula were more effective than GF-120 at trapping *B. zonata*, especially females, at the two study sites.

The high number of females attracted to the three protein hydrolysates in this study is in accordance with the findings of (Vargas et al. 2002), who reported the positive response of females of *C. capitata* to USB® yeast hydrolysate, Mazoferm® E802, Nu-Lure® Insect Bait, or

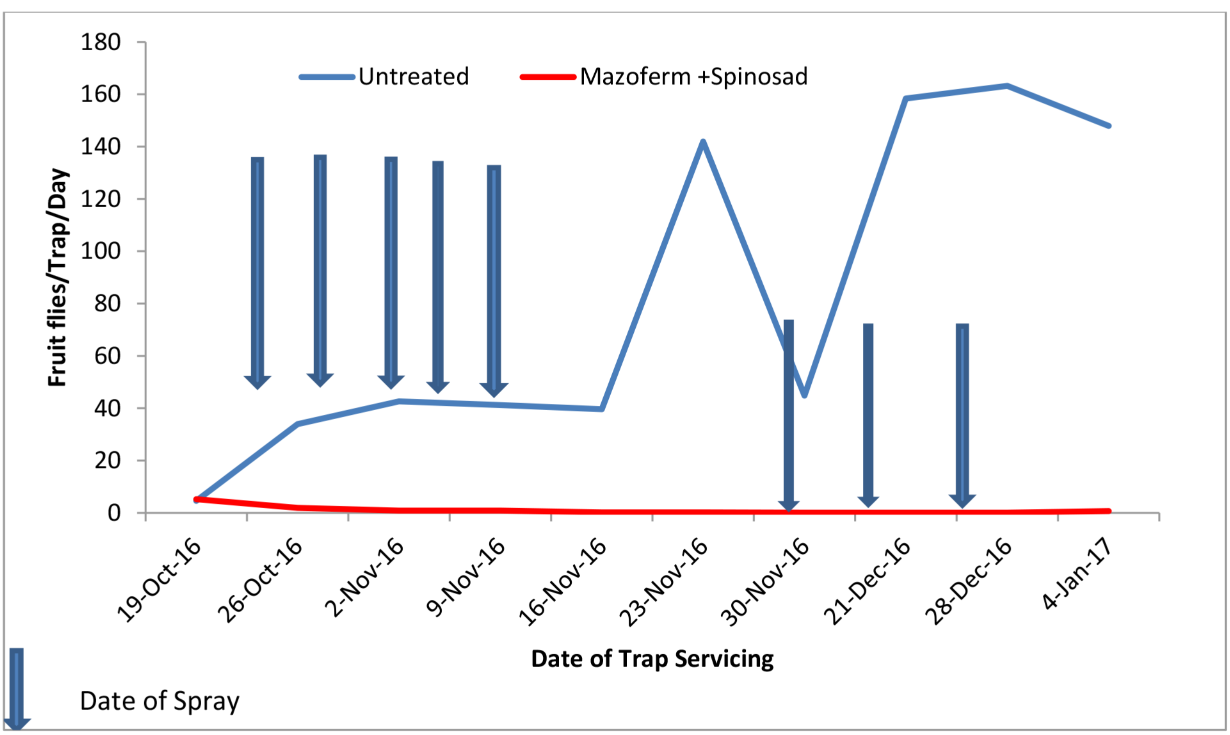

Fig. 2 Effect of Mazoferm + Spinosad on the population of *B. zonata* (FTD) on Guava orchard, Fadasi area, Gezira State, Sudan, (October 2016–January 2017)

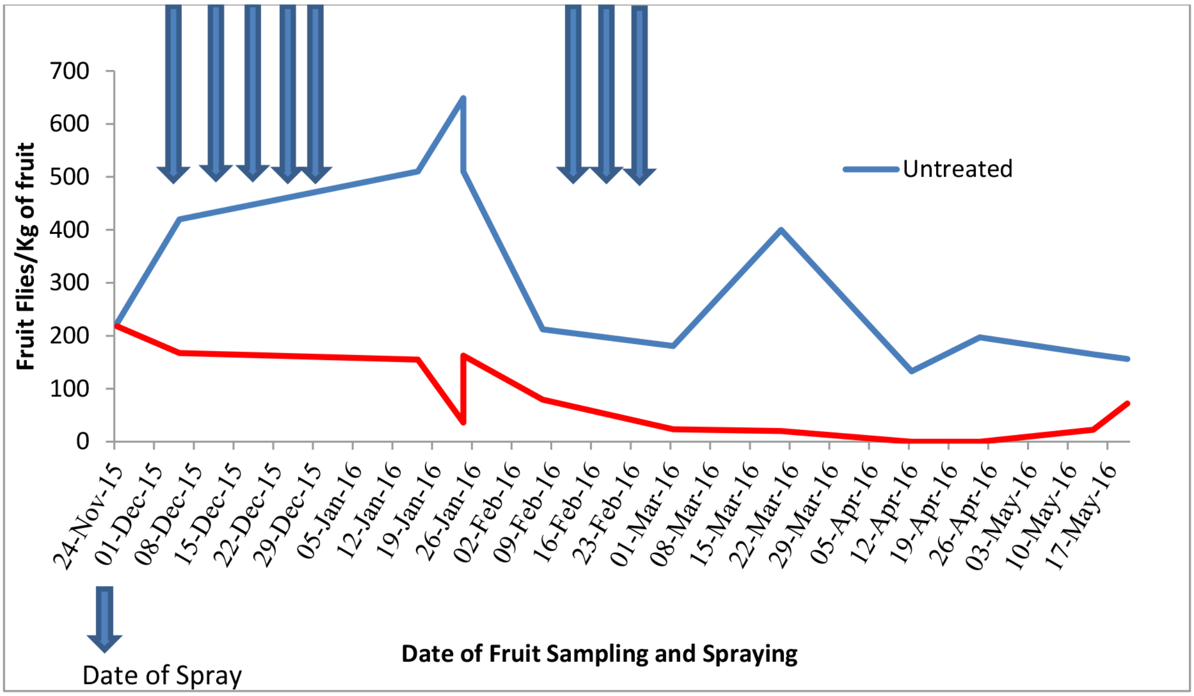

Fig. 3 Effect of Mazoferm + Spinosad on the infestation level of guava by *B. zonata* (Flies/kg of fruits), Fadasi area, Gezira State, Sudan, November 2015– March 2016

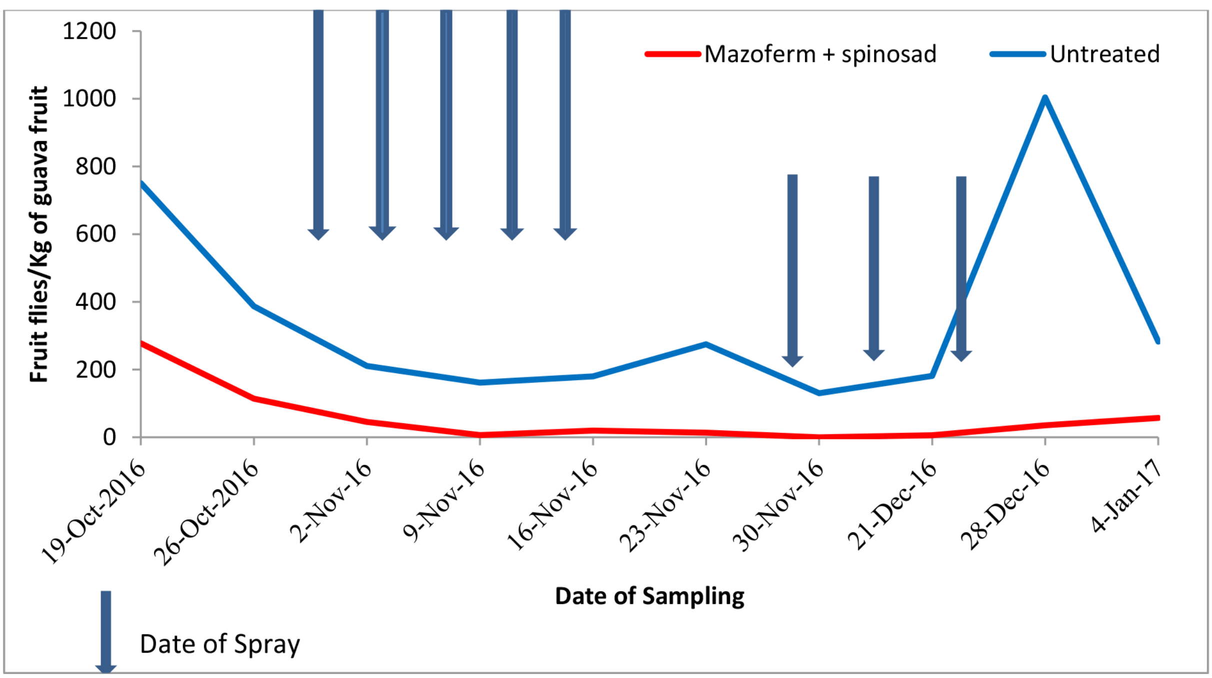

Fig. 4 Effect of Mazoferm + Spinosad on the infestation level of guava by *B. zonata* (Flies/kg of fruits), Fadasi area Gezira State, Sudan (October 2016–January 2017

Provesta® 621 autolyzed yeast extract. Additionally, the protein-starved females responded more strongly than the protein-fed females did.

Many authors have studied the attractiveness of different protein hydolystes to different species of fruit flies and demonstrated that most of the baits are highly attractive to fruit flies; however, due to the high price of most of them, Mazoferm is used because it is considered the least expensive (Moreno and Mangan 1995). With regard to its attractiveness Ekesi et al. (2014), Mazoferm has been used to control *B. dorsalis* in Africa, and from the results obtained, new invasive species *(B. zonata)* can be added to the list of fruit flies that are attracted to this fungus.

The attractiveness of the GF-120 in this study was very low compared with that of Mazoferm and Torula. The same result was obtained by (Mahmoud et al. 2012) when compared to Nulure, Torula and Mazoferm for trapping *B. dorsalis* and three species of *Ceratitis* in Sudan, even though fewer species were used to control other genera of fruit flies in different countries worldwide (McQuate et al. 2005; Revis et al. 2004; Vayssie `res et al. 2009).

Among the genera Anastrepha, Torula yeast is the most attractive protein hydrolysate used for monitoring different species of fruit flies (IAEA 2003), as do *Bactorcera, Ceratits* and *Dacus* (Mahmoud et al. 2012).

Torula yeast was found to be very effective at attracting *B. dorsalis* (Ekesi et al. 2014; Mahmoud et al. 2012), but due to its high price, it is recommended for use in trapping fruit flies. Protein bait sprays were first used to control *Rhagoletis* (Diptera: Tephritidae) flies in many years (Katsoyannos et al. 2000).

Little is known about the attraction of different species to the GF-120 Fruit Fly Bait (Dow Agro-Sciences, Indianapolis, Indiana) (Pelz et al. 2005, 2006; Yee and Chapman 2005).

Mazoferm (corn products) is an amino acid (autolyzed protein) bait that has been tested extensively against several Tephritids (Ekesi et al. 2014; Fabre et al. 2003; Peck and McQuate 2000; Vargas et al. 2002; Vargas and Prokopy 2006).

Yee (2006) reported that Mazoferm and Nulure significantly reduced larval infestations, while GF-120 and Spinosad alone did not significantly reduce larval infestations.

The results showing a reduction in the population of *B. zonata* due to the use of Mazoferm combined with Spinosad agree with those of (Vayssie `res et al. 2009), who reported a reduction in mango fruit infestation by *B. dorsalis* and *C. cosyra* to 89% when using GF-120 combined with Spinosad. Additionally, our findings are in parallel to the reduction in infestation to 59% (Ekesi et al. 2014).

Conclusion

The results of this study revealed the attractiveness of the three tested bait attractants to *B. zonata*, *B. dorsalis* and *Z. cucurbitae* when compared to water only. Among the attractants, Mazoferm demonstrated the highest attraction level to *B. zonata* and the other fruit flies. The spot application of Mazoferm E802 combined with spinosad reduced the population of fruit flies and was associated with a reduction in the infestation level of fruits. Based on the above results, Mazoferm E802 can be used as a costless bait attractant and can be sprayed in combination with Spinosad to control *B. zonata* via an area-wide management strategy to suppress fruit fly populations.

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Author contributions M.E.E.M: Conducted the field experiment and compiled and analysed the data; S.A.M., S.E. and F.M.K.: (Wrote the funding proposal and edited and reviewed the manuscript); M.I.B.: Participated in conducting the experiment, compiling the data and performing the statistical analysis.

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Data availability All the data and materials are available.

Declarations

Ethics approval and consent to participate This research does not need any ethical evidence because it deals with insect pests.

Consent for publication All **the** authors agree to publish this manuscript.

Competing interests The authors declare that there are no conflicts of interest.

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