Sustainable Agriculture Research; Vol. 6, No. 4; 2017
ISSN 1927-050X E-ISSN 1927-0518
Published by Canadian Center of Science and Education

Grower Perception of the Significance of Weaver Ants as a Fruit Fly Deterrent in Tanzanian Smallholder Mango Production

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Received: June 12, 2017 Accepted: July 11, 2017 Online Published: August 19, 2017

doi:10.5539/sar.v6n4p55 URL: https://doi.org/10.5539/sar.v6n4p55

Abstract

Managed populations of weaver ants in mango trees have been used successfully in Australia, SE Asia and parts of Western Africa to deter fruit flies from ovipositing in ripening fruits. The presence of indigenous weaver ants in mango trees of smallholder growers in Tanzania offers the possibility of exploiting them as an affordable, environmentally -friendly method to improve marketable fruit yield and quality. In a preliminary interview study in a mango-growing region of rural Tanzania, the farmers were not convinced of any beneficial, deterrent effect attributable to the indigenous weaver ants in their trees and were sceptical of any likely value as a biological control technique. Additionally, fruit fly infestation was not seen as a priority problem and subsequent enquiry and investigation showed that, fortuitously, traditional, local practices for storage and enhancing ripening prevented the development of a significant proportion of any deposited eggs. Subsequent field studies supported the grower perceptions as they recorded only an erratic and limited deterrent effect.

Keywords: mango, weaver ants, fruit flies, biological control

1. Introduction

Fruit flies are responsible for the economic loss of a significant proportion of the commercial and livelihood mango crop in Africa with fruit infestation ranging from 5% to 100% depending on climate, locality, mango variety and season (Lux, Ekesi, Dimbi, Mohamed & Billah, 2003; Niyibigira, Lada & Abdullah, 2003; Vayssiéres, Goergen, Lokossouy, Dossa & Akponon, 2009; Vayssières, Korie & Ayegnon, 2009; Vayssières et al. 2009). The fruit fly *Bactrocera dorsalis* (syn: *B. invadens*) is responsible for much as 70% of the damage recorded in Tanzania (Mwatawala, White, Maerere, Senkondo & De Meyer, 2004; Ekesi, Nderitu & Rwomushana, 2006; Ekesi, Billah, Nderitu, Lux & Rwomushana, 2009; Mwatawala, de Meyer, Makundi & Maerere, 2009; Badii, Billah, Afreh, Obeng & Nyarko, 2015) and is prevalent in the study area considered here. During the fruiting season (October to February) the fruit flies oviposit into the mango flesh (leaving a wound open to secondary infection) and the deposited eggs hatch into larvae as the fruit ripens. Local markets may tolerate a very limited number of hatched larvae in some fruits that can be used, in part, for juice production but**,** generally**,** infestation makes fruit unsaleable. Infested fruits are rejected by higher-value supply chains with zero tolerance applied by international export markets. In Eastern Africa some 80% of the mango production is by small-scale growers and is predominantly destined for local markets, and the generated income is important for the livelihood strategy of these growers (Association of Mango Growers (AMAGRO), 2011; Ekesi & Mohamed, 2011). Any control method that limits fruit fly infestation, even though it may not eradicate it, may offer a valuable, economic advantage to these smallholder growers, if the resource costs are compatible with their rural supply chain.

Managed populations of weaver ants (*Oecophylla smaragina* and *O. longinoda*) are reported to significantly reduce fruit fly infestation in mango plantations in Australia and Benin (Peng & Christian 2005a; Peng & Christian, 2006; Van Mele, Vayssieres, Van Tellingen & Vrolijks, 2007). The effect may be due to chemical deposits left by the ants on leaves and fruits (as yet unidentified) that can have a repellent effect on fruit flies (Adandonon, Vayssieres, Sinzogan & Van Mele, 2009; Van Mele, Vayssieres, Adandonon & Sinzogan, 2009;

Vayssieres, Sinzogan, Adandonon, Van Mele & Korie, 2013), together with anecdotal evidence suggesting that the visual sighting of ants by the flies can disturb oviposition.

In rural areas of Tanzania, *O. longinoda* ant colonies are commonplace in mango trees and a perception among smallholder growers of their role, if any, in reducing fruit fly infestation might be expected. If their perceptions were positive it might also be expected that these growers would be open to the improved development of weaver ant systems to protect them from fruit fly-related crop losses, as the ants are naturally-occuring and this type of biological control adds very little in terms of environmental or health risk (Offenberg, 2015; Van Mele et al., 2007). A challenge for the Tanzanian, small-scale growers is that, typically, they trade in a low-income led market, selling directly to low-income, retail customers or to intermediary traders (Kirkegaard, Offenberg, Msogoya & Grout, 2016; AMAGRO, 2011). Consequently, it would be necessary for the growers, commonly resource-limited, to gain sufficient, additional financial benefit to compensate for any increased inputs into management of weaver ant populations and their activities.

This study was undertaken to better understand the position and views of a community of smallholder growers and discover their perceptions, if any, of the effects of the indigenous populations of weaver ants on their fruit fly problems. The information was gathered by interview and discussion with growers, and pickers, over the harvesting season in two consecutive years. Direct field observations were also made to estimate the effect of the weaver ant populations on the frequency of fruit fly landings, and subsequent infestation of fruits.

2. Methods

2.1 Description of the Study Area

The study was carried out in and around the village of Kiroka, 20km from Morogoro in Tanzania (37.67E: 6.83S) where the predominant mango is an unimproved variety, known locally as'Dodo' (Griesbach, 2003) that is produced for the local wholesale and retail markets. It is an unimproved, poly-embryonic mango variety growing up to 20 m tall with fruit that is green and develops yellow patches as it ripens. The larger trees can produce several thousand fruits in a season. A major advantage of 'Dodo' is that it is resistant to anthracnose (Paull & Duarte, 2011) and tolerates transportation well and its disadvantages include susceptibility to powdery mildew (Ploetz & Freeman, 2009) and the size of the tree that can make harvesting difficult. This study focused exclusively on this variety.

2.2 Sampling Technique

Fifteen small-scale growers and 4 mango pickers (individual contractors hired to harvest fruits) were interviewed during the harvesting season (October to February) in 2012/13 and 2013/14. In total, 33 individual interviews were carried out. As the study focused on the condition of fruits at harvest, the contributions of growers and pickers to the study were considered to be analogous. Both growers and pickers were found using a snowball sampling technique (Galloway, 2005; Wright & Stein, 2005). In practice, the first grower was identified as he approached the principal investigator, out of curiosity, during the first visit to the village and the first picker identified as he walked through the village centre carrying mango-picking tools..

2.3 Interview Structure and Data Collection

The interviews were semi-structured (Wilson, 2014), with individual sessions lasting between 30 minutes and 2 hours. They were designed to collect information about the individual's knowledge of fruit flies, their experience of fruit losses and infestation level and their views on any observed effect of weaver ants on the mango crop. Prior to interview the growers were told that the aim of the study was to improve mango farming broadly, and not that there was a specific focus on fruit flies or weaver ants. During the interview process each grower was also asked to estimate the proportion of larvae–infested mango fruits they found, typically, in their harvested crop at the beginning, middle and end of the season (October –February).

Interviews were held in the growers homes, outdoors by their mango trees or in a local café and, when necessary, conducted in Swahili using an interpreter. The two interpreters employed had Swahili as a native language and were graduates in agricultural disciplines. The interviewee's responses were recorded or noted in detail, with permission, as the discussions progressed and the respondents were promised anonymity in any subsequent publications or presentations. It was also promised they would hear of the final outcome of the study, through one of the researchers based at Sokoine University of Agriculture, in Morogoro.

2.4 Field Studies to Assess Fruit Fly Activity and Fruit Infestation

To assess any deterrent effect of ants having walked over their surface, mature fruits were harvested, in January, from trees that had, or did not have, active ant colonies in the canopy. These fruits were kept in insect-proof cages in the laboratory for 1 week prior to assessment. The fruits from trees with weaver ant populations were caged with an active ant nest taken from one of the source trees trees to ensure that ant-generated, deterrent materials were maintained. Each afternoon, during the peak period for fruit fly activity (1500-1700h), the fruits were placed in open containers, adjacent to mango trees for 2h, each with a video camera suspended over it. The recordings were assessed to count the number of fruit flies landing on the fruits. The fruits from ant-colonised trees had 15 live ants added for the recording period to investigate possible visual deterrence. The container rims were treated with a barrier compound to prevent live ants from escaping. The data was examined by ANOVA with a significant probability level of $P < 0.05$.

To assess the level of infestation 20 mangoes were bought from each of 8 mango farmers at the village market. On the same day, 20 mangoes were harvested directly in each of 4 mango trees belonging to 4 different farmers. The mangoes were stored in an area free from fruit flies and when the fruits began to show signs of infestation or advanced ripening they were opened to check for infestation. The number of infested and non-infested mangoes was recorded.

3. Results

3.1 Recruitment

The snowball selection technique generated 15 growers (2 women and 13 men) ranging from 32 to 72 years old with farms from 0.1 to 3.2 ha. They harvested from 2 to 70 mango trees each season, the trees being from 7 to 25 m tall. The trees were not pruned, fertilised or irrigated. This population of interviewees reflected the diversity of the grower population in the study area.

The 4 mango pickers were male and ranged from 26 to 50 years old and only 1 of them also owned mango trees. Typically, each of them bought the entire production of individual trees from local growers, to harvest and sell in a manner of their choice.

3.2 Interviews with Mango Growers and Pickers

When asked about fly density around their trees, all but 1 grower acknowledged having seen fruit flies around their mango trees, specifically recognising the description of ‘yellow flies with wings pointing to the sides.’. The lone exception did not separate fruit flies from other types of fly, saying:

‘There are so many kind of flies but I don’t know what kind of flies are problematic’.

Of the remaining 14 growers, 7 believed that fruit flies caused the mangoes to rot:

‘They bite the mangoes while they are on the tree and this causes them to fall down and then they eat from those rotten mangoes. So the fruit flies are affecting the fruits in a way that makes the fruits rotten so they can eat them on the ground.’

Four of this group also connected fruit flies to the larvae found inside the fruits. The remaining 7 interviewees did not acknowledge any effect on the fruits, including the presence of larvae, that they would attribute directly to fruit flies. The consensus view of interviewees was that flower and early fruit drop were the largest production problems they faced and that losses due to fruit rot and larval infestation at the point of harvest were a lesser consideration. This view was supported whether or not the grower connected rot to fruit fly infestation.

Table 1. Grower estimates of the percentage of mango fruits with fruit fly infestation at the time of harvest (na: data not provided).

		Infested fruits (%) harvested at various times during the season		
Grower	Fruit stage at harvest	Early	Middle	Late
	Premature (PM)/Mature (M)			
1		na	na	10-20
2		1	1	1
3		0	0	0
5		0	na	80
6		0	0	15
7		0	na	15
	Mature/Softening (MS)			
8		5	15-20	30
9		3	100	0
10		15-20	15-20	15-20
11		5	10	15
12		0	10-15	20
13		10	na	40-50
14		30	50	75
15		25	70	95

Grower estimates of the proportion of mangoes that contained larvae at various times during a typical harvesting season are set out in Table 1. The responses are in two groups, the first including those growers who harvested fruits before they began to soften (the start of active ripening) and shortly before they reached their maximum size (pre-mature) or when fully expanded (mature). They claimed they did so to avoid fruit fly infestation, The second group includes the growers who harvested mature, softening fruits. They asserted that such fruits have a better flavour and fetch a better price.

'I harvest my mangoes at mature stage, not ripe, to avoid losses; but ripe mangoes fetch higher prices on the market'. When considering the season as a whole, the growers harvesting earlier experienced a mean of 9.1% of infested fruits whilst those harvesting actively ripening fruits had to endure a mean infestation of 22.4%.

The 4 mango pickers were familiar with the problem of fruit fly larvae in the fruits and 3 of them preferred to harvest at the PM or MH stages, at least in part to avoid fruit fly problems. Other reasons offered were that that PM and MH mangoes suffer less injury during transport and at these earlier stage of development a more uniform crop, with respect to overall quality, can be gathered at a single harvest.

'*The first harvest in the beginning of the season, few fruits are damages. At the end season that begins from January a lot of mangoes are damaged. It varies a lot; you can sometimes find 20, sometimes 30 out of a hundred.**'***

The fourth picker harvested ripe fruits for immediate, local sale and was less concerned with shelf life or transport.

Considering commercial loss i.e. fruit evidently infested to an unsaleable level, the pickers were agreed in their estimates of estimated of losses of 2.5 to 40.0 %, dependent upon season:

'*You can pack may be 150, or 180 or even 200 but you can find 60 or 50 mangoes are rotten.**'***

In the field evaluation of infestation there was considerable variation in levels between fruits from individual growers (9-12 in Fig.1), reflecting the situation apparent from Table 1. The mean infestation level for freshly-harvested mangoes was 8.3%, compared to 25.0% in the fruits bought in the local market (Fig 1)

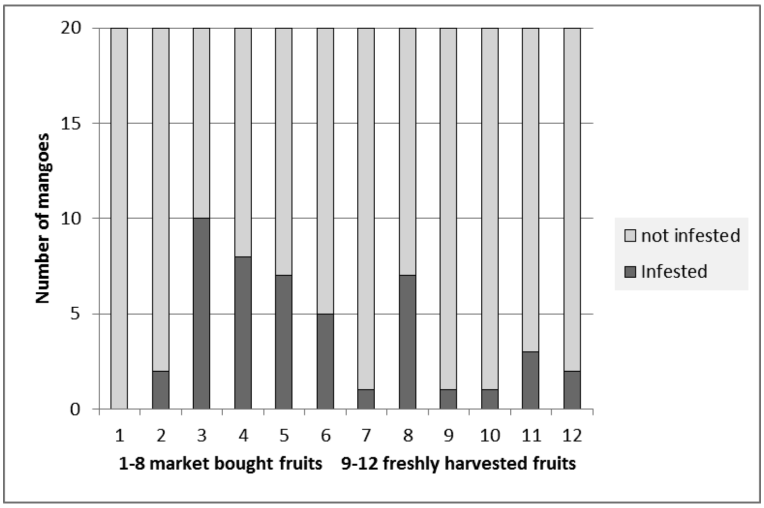

Figure 1. Number of mangoes infested *by Bactrocera dorsalis*. Samples 1-8 were bought at Kiroka market, and 9-12 harvested directly on local farms

Each of the growers was aware of weaver ants and 13 out of 15 had colonies in their mango trees. Nine of those with weaver ants claimed to dislike them as the ants would bite them during harvesting. Two of the 4 pickers also disliked the ants because of the bites they received when harvesting but the other 2 did not view this as a big problem.

The ants were also seen as associated with the presence of scale insects on a proportion of the fruits, which made them harder to sell and could lead to reduced prices. Three growers liked the ants for reasons that included keeping thieves and snakes away from the trees, with 1 speculating that they might increase fruit set, although he was not sure about it. The remaining grower with ants in his trees took a neutral position concerning their disadvantages or benefits.

Only three of the 13 growers with ant-infested trees believed they had a positive effect in reducing fruit fly infestation. These 3 had participated previously in a weaver ant seminar and one explained that after the seminar he had made observations and found fewer infested fruits in the trees with weaver ants compared to those without weaver ants, and he thought the difference was big. noted: A second member of the trio, referring to the fruits, said:

'When you climb the tree you see that those with many ants have no holes. Those without ants can have. If you separate the harvest you can see the weaver ants having an effect…It is a big difference '

However, 8 of the 13 growers whose trees held weaver ants did not see any such effect. One grower reported:

'Weaver ants cannot manage to avoid fruit flies to lay eggs into mangoes since weaver ants are building nests in the trees and stays there, also they walk in the branches of the trees while fruit flies are landing on mangoes and flies so I don't think if the weaver ant has an ability to avoiding fruit fly to laying eggs into the mango.'

The remaining 2 growers were uncertain about the presence of any effect and three of the pickers that were interviewed also did not think weaver ants had any effect on fruit fly infestation:

'There can be a tree with weaver ants having a lot of fruit flies also a tree without weaver ants can also have a lot of fruit flies.'

The fourth was unsure of the effect of weaver ants and noted that he could not recall any trees without ants.

3.3 Field observations of fruit fly landings

The video recordings of fruit fly landings showed no significant difference ($P< 0.05$) between fruits harvested from trees with or without weaver ant nests, and the presence of live ants did not appear to provide any additional deterrent effect (Table 2).

Table 2. Fruit fly landings on ripening fruit of the mango 'Dodo' over a 2h period. Data from two sets of observations are separated by /

Day	- ants	+ ants	-ants*
1	11/18	13/17	17
2	14/6	12/2	2
3	8/5	3/6	6
4	14/7	9/3	3
5	12/4	4/22	22
6	10/8	5/10	10
Mean ± SD	9.75 ±4.20	8.83 ±6.25	10.00 ±8.03

+ - ant nests in source trees,*live ants on the fruits during observation period

4. Discussion

The widespread scepticism in Kiroka concerning any positive impact of weaver ants on fruit fly activity, together with the view that any commercial impact of fruit flies was limited, would seem to make this aspect of biological control a poor candidate for adoption in the region.

Eleven of the 13 mango growers with ant-colonised trees and 3 of the 4 mango pickers interviewed did not believe that weaver ants had any effect on the fruit fly infestation level, which is comparable to a study in Guinea where none of 88 growers mentioned weaver ants as beneficial with respect to fruit flies (Van Mele, Camara & Vayssieres, 2009), and in Vietnam where only 2 of 93 growers mentioned the ants as beneficial (Van Mele, Cuc & Van Huis, 2001).

The attitudes of the Kiroka growers are likely to be influenced by the widespread, poor appreciation of the biological connection between fruit flies and larvae-infested mango fruits, with only 4 of the 15 participants in the study identifying this connection. This is in broad agreement with a study from Benin where only 10 from 40 growers not associated with the investigation knew of such a connection, whereas 11 of 15 growers more closely involved were aware of the link (Sinzogan, Van Mele & Vayssieres, 2008).

The lack of belief in weaver ants' as protection against fruit flies among the Kioroka growers and pickers was supported by the field observations as mangoes harvested from trees with a weaver ant colony were no less infested by fruit flies than those from trees without weaver ants (Fig. 1). Also, there was no significant difference in the number of fruit flies landing on mangoes from trees with or without weaver ant colonies (Table 2) reinforcing a similar,preliminary study in Kiroka that showed only a very marginal, deterrent effect of weaver ants on fruit fly landings (Kirkegaard et al., 2016). This contrasts with a number of studies from other locations with fruit flies in mango orchards in Australia and SE Asia successfully controlled when populations of weaver ants (*O. smaragdina*) were maintained in the trees (Peng & Christian, 2005a, b, 2006; Van Mele et al., 2001). Further, in Benin, (W Africa), the African weaver ant (*O. longinoda*) has been shown to have a similar effect (Van Mele et al., 2007).The question arises as to why the results are significantly less convincing on small-scale farms in Tanzania.

The explanation may involve properties of the mango variety 'Dodo', which may be described as 'unimproved' when compared to the highly selected varieties used to meet the requirements of the international market. If the deterrent effect of weaver ants relies on their herbivorous, damaging activity stimulating plant defence responses then the mango genotype may have a marked effect. For example, mango varieties containing relatively high amounts of phenolic acids, such as salicylic acid (a naturally-occurring plant defence compound), are reported to be less attractive to *B. dorsalis* (Verghese, Soumya, Shrivasshankar, Manivannan & Krishnamurthy, 2012) and applying salicylic acid to mango fruits makes them less attractive to gravid *B. dorsalis* and lowers the larval survival rate (Damodaram et al., 2015). It may be that the variety 'Dodo' considered in this study produces relatively little of such compounds in response to weaver ant colonization. The profile of emitted volatiles can be changed by breeding and it may be that improved varieties of mango, as used in commercial orchards, have an increased deterrent capability after insect damage (Mitchell, Brennan, Graham & Karley, 2016).

Relative ant abundance, influencing volatile compound concentration, may also be an issue if a chemical deterrent mechanism is at work, involving volatiles produced either by the plants, the ants, or both. No ant-produced deterrent has been identified to date. Trees of the 'Dodo' mango, as grown in Kiroka, are typically

7m tall when they first set fruits and can grow to 25m at maturity. With a very large canopy volume a similarly large density of ants may be required if a critical concentration of any volatile, repellent compounds is to be maintained. The ant population density in Kiroka was not actively managed by the growers, and in the mixed cropping systems of the region the ants are relatively widely dispersed owing to the range of food and habitat choices. This leads to relatively small colonies with population levels in many trees that may be too low for a deterrent effect to be apparent. To sustain population size. the weaver ants may need additional support, such as provision of additional food sources when the mangoes are not fruiting. Weaver ant densities can also be lower in Tanzania than Benin due to aggressive displacement by the Big-headed ant, *Pheidole megacephala* (Olotu, du Plessis, Seguni, Ekesi & Maniana, 2015).

Losses due to larval infestation in mango at harvest depend upon fruit maturity and timing within the mango season) (Mayamba, Nankinga, Isabirye & Akol, 2014; Vayssières, Korie & Ayegnon, 2009) The levels reported by Kirokan growers (Table 1) were broadly in line with those in Benin, where c.80% of interviewed growers believed they lost 20-45 per cent of their harvest to fruit fly infestation, with the remaining 20% estimating even higher losses (Sinzogan et al., 2008). An increasing population density of fruit flies as the season progresses may also be a contributory factor as illustrated by Vayssieres et al. (2015), who trapped almost no *B. invadens* at the beginning of the mango season, increasing to 35,000-55,000 flies per month at the season end.

The lack of enthusiasm for fruit fly control by weaver ants is supported by the widely agreed Kirokan growers view that the impact of fruit flies on their crop is of lesser importance than early fruit and flower drop. By contrast, 86 out of 100 growers in Guinea noting fruit flies as their biggest problem (Van Mele et al., 2009a). This diminished view of fruit flies as a pest is due, in part, to the common practice of harvesting mangoes at early maturity stage, with little or no flesh softening, when the fruits are less attractive to the flies (Mayamba et al., 2014). Fruit fly problems are also reduced as a consequence of local, postharvest practices that raise fruit temperatures to levels that are lethal to a significant proportion of deposited eggs and emerged larvae, limiting the development of infestation (Kirkegaard et al., 2016). These practices include respiration–generated heating when the fruits are stored in the baskets typically used for transport and the effects of limited-duration smoking commonly used to accelerate fruit ripening before sale.

The nature of the local supply chain is also a challenge to any development of weaver ant protective technology. As the growers supply a low-income chain (AMAGRO, 2011), selling to relatively low-income households, there is little opportunity to recover increased input cost. Consequently, enthusiasm for activities such as mango variety replacement to reduce canopy volume and ant population management are likely to be low. Replacing any significant number of trees of the current variety with another would not be popular due to direct cost, interrupted production and the possibility of low acceptance by local consumers. Ant population management , involving moving nests to colonise trees and providing food sources when the mangoes are not fruiting, would required additional labour and material resources and would be similarly unpopular. Fortuitously, existing postharvest practices related to packing for storage and transport and smoking to accelerate ripening reduce the effects of fruit fly infestation in mango to locally acceptable levels (Kirkegaard et al., 2016).

A key inference from this study is that any future attempt to develop fruit fly control in mango in developing rural communities, using weaver ants, should proceed with caution. The genotype and morphology of the trees and the sustained ant density are likely to be of significance and the economic context of mango production in the local economy must also be considered carefully.

Acknowledgments

This work was supported by the Danish Ministry of Foreign Affairs (DANIDA) under Grant 10-110 Life to Nina Kirkegaard. The authors wish to express their thanks to all those people in and around Kiroko who contributed so willingly and helpfully to the study. The time given by colleagues at Sokoine Agriculture University for discussions, advice and practical assistance is also gratefully acknowledged.

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