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The use of artificial nests by weaver ants: A preliminary field observation

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ABSTRACT. Weaver ants (*Oecophylla* spp.) are managed in tropical plantations for their biocontrol of pests and to produce ant larvae as a food source. Main management objectives are to increase ant densities and colony longevity. As weaver ant nests are susceptible to harsh weather, rain storms may decimate populations or destroy colonies. The ants, however, show adaptive nesting behaviour, which may mitigate storm impact. This study tested whether *Oecophylla smaragdina* was willing to use plastic bottles as safe artificial nesting sites, and whether adoption of artificial nests was seasonally related to harsh weather. Bottles were used for nesting throughout the stormy rainy season in a pomelo plantation with an open canopy, whereas in a mango plantation with a denser canopy the ants, after initial colonisation, left the bottles again at the end of the rainy season, especially in the calmer part of the plantation. This suggests that exposure to harsh weather triggered the use of artificial nests. It was also found that ants preferred to nest in bottles covered with aluminum foil compared to transparent bottles. These findings document an opportunistic nesting behaviour of weaver ants and suggest that provision of artificial nests may become a future tool in their management.

Keywords: *Oecophylla smaragdina*, nesting behaviour, weaver ant management, biological control, entomophagy, ant farming, sustainable pest management

INTRODUCTION

Weaver ants (*Oecophylla* spp) are utilized for biological control of pest insects in tropical plantation crops (Van Mele 2008) and as a valuable harvestable resource for human and animal consumption (Rastogi 2011). At least twelve crop species have been shown to benefit from weaver ant attendance, as the ants are able to control more than 50 different pest species (Way & Khoo 1992; Peng & Christian 2006; Pierre & Idris 2013), and weaver ant larvae are sold for up to 16 USD (2010 prices) per kg, e.g. in Indonesia and Thailand (Césard 2004; Sribandit *et al.* 2008; Offenberg 2011). As the production of ant larvae can be harvested without detrimental effects on colony performance, double benefits can be derived from plantations because they simultaneously can utilize ants for biological control and harvest ant larvae for commercial markets (Offenberg & Wiwatwitaya 2010). Based on this commercial potential, weaver ants are increasingly being implemented in the management of tropical plantations and ant nurseries are being developed to provide farmers easy access to live queen-right colonies (M.G. Nielsen personal communication). In the light of an increasing commercial utilization of weaver ants, ways to augment and manage their populations are in focus for increased benefits and will thus be addressed in this study.

Weaver ant nests are made of living leaves that have been pulled together by the worker ants and subsequently have been fasten together with silk from their larvae to form the nest walls (Crozier *et al.* 2010). Such nests, however, are vulnerable to storms and heavy rain, as the accompanying physical forces may tear them apart (Peng *et al.* 2004). This is especially the case for nests built with leaves growing on different branches on a tree, as wind and rain may force branches apart, resulting in a broken nest. During the rainy season in Northeast Thailand and in Darwin, Northern Territory, Australia, broken nests have been observed after storms and workers have been seen struggling to pick up brood fallen to the ground (M.G. Nielsen and J. Offenberg, unpublished data). As what may be seen as an adaptation to this challenge, African weaver ants (*O. longinoda*) have been described to move their nests to the leeward side of their host trees as the monsoon changes direction on Zanzibar (Way 1954). In this way, they may be able to mitigate storm impact on their nests. A different nesting behaviour was observed during work in a mango plantation in Northeastern Thailand in 2006. At the beginning of the rainy season in April and May, a few cases were observed where weaver ants built their nests on the ground around the trunk of their host tree using wilted leaves found on the ground. These nests were used as a supplement to their canopy nests that were built under normal conditions (Fig. 1). Also I observed that the ants were building leaf nests in the canopy, but using a modified design where the leaves were woven to the tree trunk (Fig. 2) instead of being attached to other leaves. Lastly, I observed that the ants were utilizing plastic cups (used as feeding stations) attached to the tree trunks with steel wire (J. Offenberg unpublished data). In the latter case, the top opening of the cups was covered with silk and the interior used as a nest, holding brood and imago worker ants (Fig. 3). As these behaviours result in nests that are more stable and resistant to storm damage compared to normal nests hanging freely in the canopy, it may reflect an adaptation to the onset of harsh weather conditions – an adaptation that may save brood from being lost from nests and save resources to repair or replace broken nests.

Fig. 1. A weaver ant nest built on the ground around the trunk of the ants' mango host tree. The ants used wilted leaves collected on the ground as building material in contrast to living leaves normally used in canopy nests. This behaviour is unusual for otherwise canopy dwelling weaver ants. Photo taken April 16, 2006, by Joachim Offenberg.

Fig. 2. A weaver ant nest made from live leaves attached to the mango tree trunk instead of being attached to other leaves as under normal conditions. Note the white ant silk between the leaf and the trunk, used to "glue" the leaf to the trunk and seal the space. Photo was taken May 17, 2006, by Joachim Offenberg.

Fig. 3. A plastic cup (originally used as a feeding platform) attached to the trunk of a mango tree was colonized by weaver ants using it as a nest site. The cup opening was covered with weaver ant silk. The arrow shows how the ants secured the nest further by weaving it to the tree trunk with larval silk. Photo taken May 17, 2006, by Joachim Offenberg.

Based on these observations, in an experiment initiated during the following year´s rainy season, I tested whether weaver ants were willing to accept cheap and easily obtainable plastic bottles as artificial nests, and whether acceptance was related to season, to plantation site and to the penetration of solar radiation into the bottles.

MATERIALS AND METHODS

Experiments where artificial plastic bottles were mounted on weaver ant trees were conducted in one Thai mango plantation and one Thai pomelo plantation. The mango plantation comprised twelve-year-old trees of the variety Nam Dok Mai and was situated in the Wang Nam Khiaow District in Nakon Ratchasima Province, Northeast Thailand. The trees used in the experiment grew on a slope in the plantation, had well developed canopies and a spacing of 6 × 6 metres, allowing neighbouring canopies to almost touch each other. The pomelo plantation, situated in the Ban Thaen District of Chaiyaphum Province, Northeast Thailand, consisted of nine-year-old pomelo trees of the variety Tong Dee. The trees, which were smaller than the mango trees, grew in 11 rows on banks between water filled trenches, leaving open space between the rows. Thus, the pomelo trees were more exposed to weather conditions due to an open canopy in contrast to the almost closed canopy in the mango plantation. The upper part of Thailand, including Northeast Thailand, has a hot and dry summer season from February to May, a rainy Southwest monsoon season from May to October, and a cold winter Northeast monsoon season from October to February. In Northeast Thailand, the winter, summer and rainy season rainfalls are 72, 214 and 1086 mm a year^{-1}, respectively, with rainfall peaks in August and September. Thunderstorms occur from April to October, with a maximum frequency in May (Thai-Metereological-Department 2012).

In the mango plantation, artificial nests in the form of plastic bottles were mounted on 50 trees belonging to eight different weaver ant colonies in April 2007 and on 30 ant trees belonging to 13 different colonies in the pomelo plantation in May 2007. In the pomelo plantation, the bottles were lost from one tree during the experiment and the ants abandoned another tree, leaving 28 trees for subsequent analysis. On each tree, three different bottles were attached, each to a different main branch close to the main trunk in the middle of the tree (at similar height and exposure to solar radiation), with two pieces of steel wire (Ø = 0.7 mm) twisted around the bottle and the branch. Thus, a total of 150 bottles were used in the experiment in the mango plantation and a total of 84 bottles in the pomelo plantation. As a few data entries were lost during some of the surveys (due to the incompatibility of rain and ink), the N-values in some of the tests are lower than expected (N-values are provided for all the tests in the results section). The bottles were made from 600 ml plastic bottles used for drinking water, commercially available. Each set of three bottles consisted of one clear bottle without cover (allowing full solar radiation), one bottle covered with a yellow transparent plastic foil attached by transparent sticky tape (allowing partial solar radiation) and one bottle covered with non-transparent aluminum foil (allowing no solar radiation). After bottles were mounted to the trees, they were checked regularly to see if they had been colonized by weaver ants (defined as holding at least 20 worker ants inside) and, thus, functioned as artificial nests. Figure 4 shows an occupied transparent bottle. Bottles in the mango plantation were checked for the presence of ants in May, June and October 2007, and bottles in the pomelo plantation in June, August, September and October 2007.

At each survey, all bottles in the plantation were inspected, and for each bottle it was determined whether the bottle was occupied by ants or not. Occupancy of bottles was then compared between plantations, surveys (season), and treatments (the three different types of bottles) with G-tests (Sokal & Rohlf 1995). To reduce the number of significance tests (treatment by season by plantation), data from the three different treatments were pooled before analyzing the effect of plantation and season, and data from the different surveys were pooled before analyzing the effect of treatment.

In the mango plantation, where trees were arranged in straight lines by a row and a column number, there was a slope extending its highest point from the lowest row and column numbers of the trees to its lowest point at the highest row and column numbers. As both row and column numbers of the trees in the plantation were negatively correlated with occupancy (suggesting higher occupancy at the top of the slope) during all the three surveys (linear regressions; p-values ranging from < 0.0001 to 0.016 and R^2 ranging from 0.12 to 0.48), row and column number of each tree was added and the per cent of occupied bottles per tree was regressed on this number to test whether occupancy increased with elevation. This test was done with the statistical software JMP 9.0.0.

Fig. 4. A plastic bottle occupied by weaver ants during a pilot experiment. On the photo the bottle was mounted with sticky tape, however, bottles used in the reported experiment were mounted with wire. The close up shows the ants keeping brood in the artificial nest. Photos taken May 24, 2006, by Joachim Offenberg.

RESULTS

The overall percentage of bottles occupied by ants was 17.9 and 23.8 in the mango and pomelo plantation, respectively (G-test: $G = 3.3$; $P = 0.069$; $n = 793$), however, with differences between seasons and treatments.

Analyses where all three treatments were pooled: In June where a survey was conducted in both plantations there was no significant difference in occupancy between the plantations (G-test; $G = 2.09$; $P = 0.15$; $n = 236$), whereas in October significantly more bottles were occupied by ants in the pomelo plantation (G-test; $G = 17.20$; $P < 0.0001$; $n = 235$), since, in this survey, many of the bottles in the mango plantation had been abandoned by the ants, leaving only 4% occupied (Fig. 5). This is further illustrated by the significant decline in occupancy in mango from May and June to October (G-test: $G = 30.51$; $P < 0.0001$; $n = 448$), and the lack of a similar drop in pomelo (G-test: $G = 2.54$; $P = 0.28$; $n = 345$) (Fig. 5). Thus, occupancy declined in mango during the experiment, whereas occupation remained high in pomelo. In the mango plantation, the trees at the top of the slope had low row and column numbers and, accordingly, the trees at the lower part of the slope had high numbers. When the percentage of bottles occupied by ants per tree was linearly regressed on the sum of the tree row number and tree column number, a significant negative correlation was found for all the three surveys (Table 1 and Fig. 6 for the June survey), showing that occupancy was higher at the higher elevations in the plantation throughout the season. It should be noted, however, that R^2 declined in October (Table 1), as only few bottles were occupied at this time.

Analyses where data from the three surveys were pooled: In both the mango and pomelo plantation, there was a significant difference between treatments (G-tests: mango; $G= 33.0$, $P < 0.0001$; pomelo $G = 104.8$, $P < 0.0001$) with 7 and 18 times higher occupancy in bottles with aluminum foil compared to uncovered bottles, respectively (Fig. 7). Further, occupancy of bottles covered with the yellow semi-transparent foil was a significantly lower than occupancy of bottles covered with aluminum foil in pomelo (G-test: $G = 64.7$; $P < 0.0001$; $n =$

230), but this difference was much smaller and not significant in mango (G-test: $G = 1.95$; $P = 0.16$; $n = 300$)(Fig. 7). Thus, aluminum covered bottles were preferred for nesting in both plantations, but bottles with yellow foil only performed well in the mango plantation.

DISCUSSION

This study showed that *O. smaragdina* colonies readily accepted artificial nesting sites in the form of plastic bottles, at least during the study period from May to October, even when they had plenty of living leaves available for nest building on suitable host trees. Thus, artificial nests may be applied to support live ant colonies in plantations where the ants are managed for biocontrol and/or for ant larvae production.

Coincidental initial observations in the mango plantation in 2006 showed that at the onset of the rainy season ants built leaf nests attached to the trunks of their host trees and started to use various types of artificial nesting sites, e.g. plastic cups, plastic bottles and aluminum cans. Further, they were seen to nest on the ground, which is unusual, as their primary natural enemies usually are other ground nesting ants (Zerhusen & Rashid

Table 1. Linear regression statistics from the mango plantation showing the regression of the percent of bottles occupied per tree (including all three types of bottles) on the sum of the row and column number of each tree. A regression was made for each survey in the mango plantation.

Survey	Linear regression (y = % bottles occupied)	R^2	N (trees)	p
May	y = 63,1 - 1,4*row + column no.	0.34	50	< 0.0001
June	y = 67.1 - 1,4*row + column no	0.43	50	< 0.0001
October	y = 16.6 – 0.4*row + column no	0.18	50	0.0018

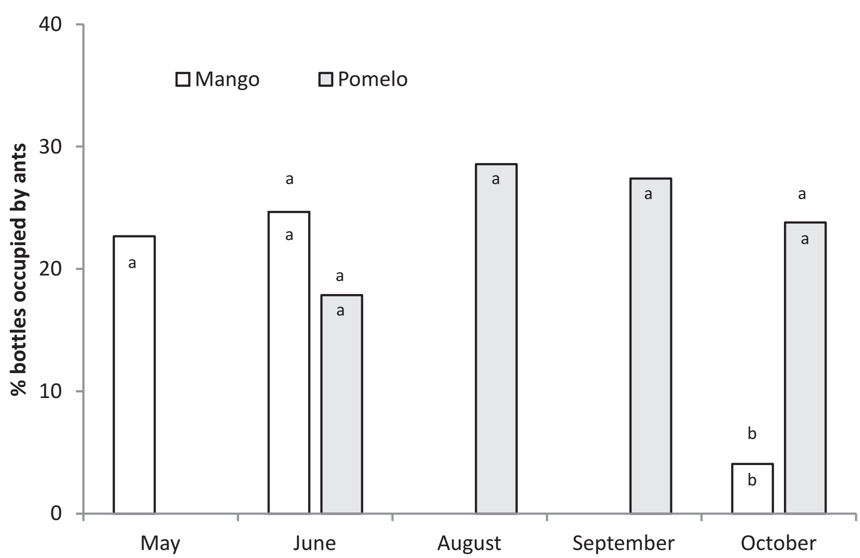

Fig. 5. Ant occupation of plastic bottles by month in the mango and pomelo plantation. Data include all the three different types of bottles used in the experiment. Bottles in mango were only surveyed in May, June and October, whereas bottles in pomelo were surveyed every month from June to October (N = 448 and 345 inspections in mango and pomelo, respectively). Different letters inside bars indicate significant differences (at the 5 % level) between months within each crop and letters outside bars indicate differences between crops within the same month.

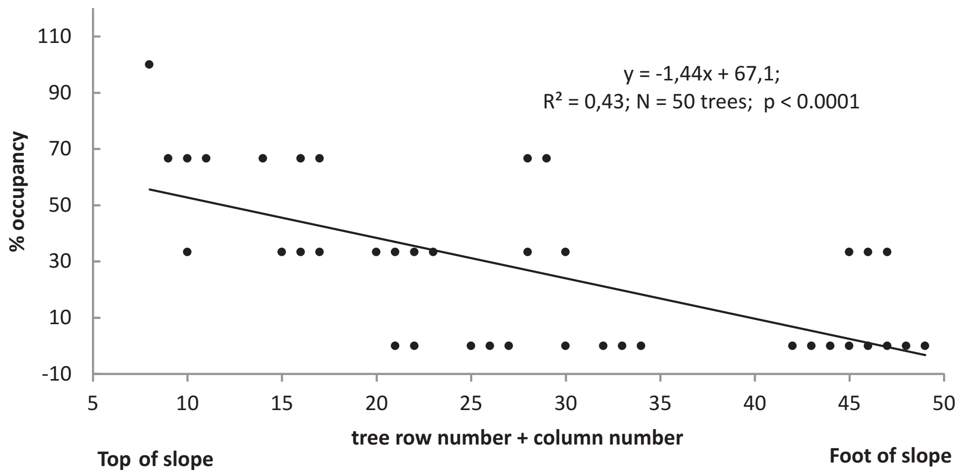

Fig. 6. The percentage of occupied bottles per mango tree by the sum of each tree´s row and column number. Data from all three types of bottles were included and only data from the June survey in the mango plantation is shown. Low numbers on the x-axis indicate trees at the top of the slope in the plantation, whereas high numbers indicate trees at the foot of the slope.

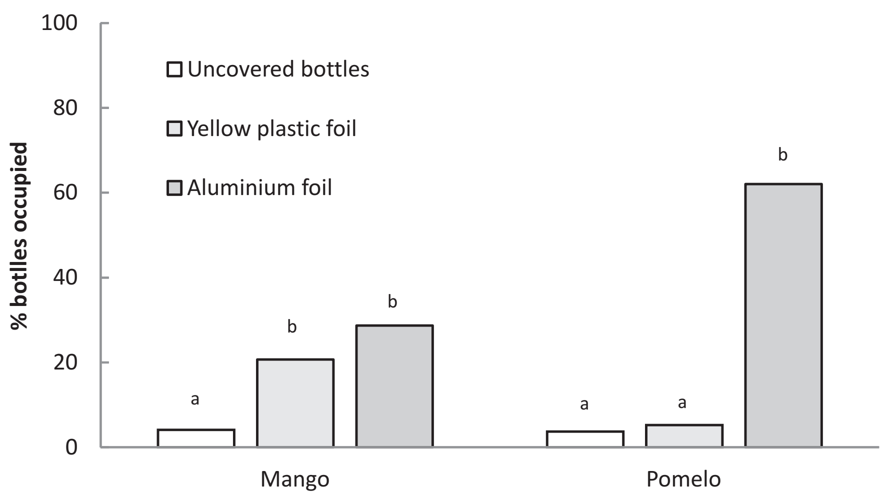

Fig. 7. Ant occupancy of bottles by bottle treatment in the mango and pomelo plantation. Uncovered bottles allow high solar radiation into the bottle, bottles covered in yellow plastic foil allow partial radiation, whereas aluminum covered bottles block for radiation. Data from all surveys are included in the diagram (N = 448 and 345 inspections in mango and pomelo, respectively). Different letters indicate significant differences (at the 5 % level) between treatments within each crop.

1992; Rapp & Salum 1995; Van Mele & Cuc 2003; Seguni *et al.* 2011). Common for these nests is their stability during stormy weather, as they are less exposed to wind and as they are not assembled with plant parts that may move independently under such conditions, as is the case with twigs belonging to different branches. The use of these types of nests may, therefore, be an adaptation to strong winds and/or rains. This is further supported, as the ants in the less exposed parts of the mango plantation at the foot of the hill moved out of the bottles at the end of the rainy season, whereas this was not the case in the more open pomelo plantation, where the ants remained in the bottles throughout the experiment (Fig. 5). Thus, the ants may prefer live leaves for nesting under optimal conditions; however, when exposed to harsh weather they may accept artificial nests as an alternative to unsecure leaf nests. As an alternative to this strategy, *O. longinoda* has been described to move their nesting sites to the lee side of their host trees when wind direction changes with the monsoon (Way 1954). As also this behaviour may result in nests that are less exposed to strong wind and rain, it seems likely that weaver ant nests in general are susceptible to storms and that the ants have evolved means to adapt to this risk.

An alternative explanation for the observed seasonality in nesting behaviour could be that weaver ants avoid leaf nests on mango during the onset of the rainy and stormy season, as at this time the mangoes shed part of their leaves without producing new leaf flush, which is their preferred building sites for new nests (Offenberg *et al.* 2006). Thus, during this season, new nests can only be placed on old foliage that is at risk of being shed. This hypothesis, however, does not explain why the ants used artificial nests in the pomelo plantation.

The occupancy of the three different types of bottles showed a clear preference for bottles with covers blocking solar radiation (Fig. 7). This may be caused by a preference for dark conditions where the ants may feel safer (Bartz & Hölldobler 1982) and/or because the ants avoid solar radiation, as it may increase the temperature in the bottle. In an open habitat with high solar radiation into the interior of the trees, the temperature in semitransparent yellow bottles may build up to intolerable levels[1], whereas this may not be the case in more shady canopies. This pattern was supported by the observed nesting behaviour, as the semitransparent yellow bottles were used much more frequently in the shady mango canopy compared to the open pomelo canopy, where almost only the non-transparent aluminum bottles were used for nesting (Fig. 7).

Regardless what triggers the nesting behaviour seen in this study, the results show that *O. smaragdina* have evolved an opportunistic nesting behaviour and are able to utilize options other than the live leaves on their host trees. Similar opportunism has been observed in the laboratory and the field where it is possible to keep *Oecophylla* spp. colonies in test tubes and other types of transparent vials in order to enable observations inside their nests (Hölldobler & Wilson 1978; Offenberg *et al.* 2012; E.M. Pierre, unpublished data). This plasticity in nesting behaviour may not only be utilized for scientific studies, but may also be exploited in plantations where weaver ants are used for biocontrol and/or for ant larvae harvest. First of all, if secure nesting options are offered during seasons with harsh weather, this may lead to fewer incidents of broken nests and, thus, higher survival of the larvae. In this way, managed weaver ant colonies may be augmented via a simple supply of cheap plastic bottles. Secondly, the provision of secure nesting options may increase the longevity of the weaver ant colonies, if the artificial nests are used by the maternal queen, and will reduce the risk of her being killed due to storm accidents (Peng *et al*. 2004). As each colony seems to be unable to replace its mated queen with a new one, colony longevity equal queen longevity (Way 1954; Peng *et al.* 1998, 2004). Longer colony survival can then lead to lower maintenance costs, as fewer colonies need to be replaced per year (Offenberg *et al.* 2013). Lastly, the acceptance of artificial nests may lead to a wider use of *Oecophylla* ants, if this habit will enable the ants to thrive on host plants with leaves that are not optimal for nest building or hosts that shed their leaves seasonally. Weaver ants are rarely seen nesting on e.g. papaya (*Carica papaya* Linnaeus); probably due to difficulties folding the large leaves of these plants (J. Offenberg unpublished data). If the ants live in artificial nests provided on these plants, then papaya may potentially be biologically protected by weaver ants in future biocontrol programmes. Similarly, host plants, e.g. neem (*Azadirachta indica* A. juss), that shed all leaves seasonally have been observed to be abandoned by weaver ants during dormancy and then become re-inhabited after the new flush develops (J. Offenberg, unpublished data). If artificial nests

1 *O. smaragdina* has been observed to die at temperatures above approximately 50°C (J. Offenberg, unpublished data).

can be utilized during periods without leaves, the ants may not need to abandon leaf shedding crop plants, which may again lead to more efficient biocontrol or lead to the utilization of such host species as a substratum for ant larvae production. Thus, the development and provisioning of artificial nesting options for weaver ants may broaden the scope of their use in agriculture.

To my knowledge this is the first study to show that weaver ants utilize artificial nesting sites in the field and that this behaviour may be exploited in weaver ant management. However, it should be noted that the study is preliminary and needs to be followed up by additional research to test the proposed hypotheses: (i) whether the origin of this behaviour is an adaptation to conditions with harsh weather and (ii) whether artificial nests do increase ant densities and/or colony longevity. Occupancy of artificial nests should ideally be followed for a minimum of one year in order to obtain more complete information on the seasonality of the use of artificial nests. Also, a design where open and closed canopies are compared within the same host tree species and site is needed to verify whether exposure to weather is triggering the use of artificial nests, or even better, an experiment where artificial wind and rain conditions are manipulated experimentally. Furthermore, in long term studies the potential positive effect of artificial nests needs to be confirmed by comparing the development of ant densities and colony longevity in colonies with and without access to artificial nests.

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