Research Article

Received: 6 July 2012 Revised: 2 October 2012 Accepted article published: 29 October 2012 Published online in Wiley Online Library:

(wileyonlinelibrary.com) DOI 10.1002/ps.3451

Efficacy of the African weaver ant *Oecophylla longinoda* (Hymenoptera: Formicidae) in the control of *Helopeltis* spp. (Hemiptera: Miridae) and *Pseudotheraptus wayi* (Hemiptera: Coreidae) in cashew crop in Tanzania

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Abstract

BACKGROUND: Cashew, *Anacardium occidentale*, is an economically important cash crop for more than 300 000 rural households in Tanzania. Its production is, however, severely constrained by infestation by sap-sucking insects such as *Helopeltis anacardii*, *H. schoutedeni* and *Pseudotheraptus wayi*. The African weaver ant, *Oecophylla longinoda*, is an effective biocontrol agent of hemipteran pests in coconuts in Tanzania, but its efficacy in the control of *Helopeltis* spp. and *P. wayi* in Tanzanian cashew has not been investigated so far. The aim of this study was therefore to evaluate the efficacy of *O. longinoda* in the management of these insect pests in the cashew crop at different sites of the Coast region of Tanzania.

RESULTS: Colonisation levels of *O. longinoda*, expressed as weaver ant trails, varied from 57.1 to 60.6% and from 58.3 to 67.5% in 2010 and 2011 respectively. The mean number of leaf nests per tree varied from five to eight nests in 2010 and from five to nine nests in 2011. There was a negative correlation between numbers of nests and pest damage. *Oecophylla longinoda*-colonised cashew trees had the lowest shoot damage by *Helopeltis* spp. of 4.8 and 7.5% in 2010 and 2011, respectively, as opposed to uncolonised cashew trees with 36 and 30% in 2010 and 2011 respectively. Similarly, nut damage by *P. wayi* was lowest in *O. longinoda*-colonised trees, with only 2.4 and 6.2% in 2010 and 2011 as opposed to uncolonised trees with 26 and 21%.

CONCLUSION: *Oecophylla longinoda* is an effective biocontrol agent of the sap-sucking pests of cashew in the Coast region of Tanzania and should be considered as an important component of IPM.

Keywords: biocontrol agent; cashew; colonisation; *Oecophylla longinoda*; sap-sucking pests

1 INTRODUCTION

Cashew trees, *Anacardium occidentale* Linnaeus (Sapindales: Anacardiaceae), are grown in many tropical countries. They have a long history of cultivation in Central and South America, South-East Asia, India, Australia and tropical Central Africa.[1] The cashew was introduced from Central and South America to different parts of the world in the sixteenth century.[2] The crop was introduced by the Portuguese for afforestation and control of soil erosion along the coastal areas of Tanzania, Kenya, Mozambique and Nigeria.[2,3] The crop is widely believed to have remained in the coastal areas mainly as a subsistence crop for local communities until it gained economic importance after World War II.[4] Cashew nut is the main cash crop and the leading source of income for over 300 000 households, grown on 400 000 ha, with 40 million trees, mainly in south-eastern Tanzania.[4] In 2006, cashew nut accounted for 10% of the total value of foreign exchange earning in Tanzania and represented $US 54.1 million.[4]

The production of cashew nut is being constrained by numerous insect pests, including sap-sucking insect pests, of which the mirid bugs *Helopeltis anacardii* Miller and *Helopeltis schoutedeni* Reuter (Hemiptera: Miridae) and the coreid bug *Pseudotheraptus wayi* Brown (Hemiptera: Coreidae) are the most important in Tanzania.[5−7] *Helopeltis* spp. attack leaves and stalks of the vegetative and flowering shoots. All tissues above the feeding location of these insects die, and, if an attack comes early in the growing season, each affected branch produces no leaves or flowers and fruits for the year (Stathers TE, unpublished). The sites of attack are marked by angular lesions due to injection

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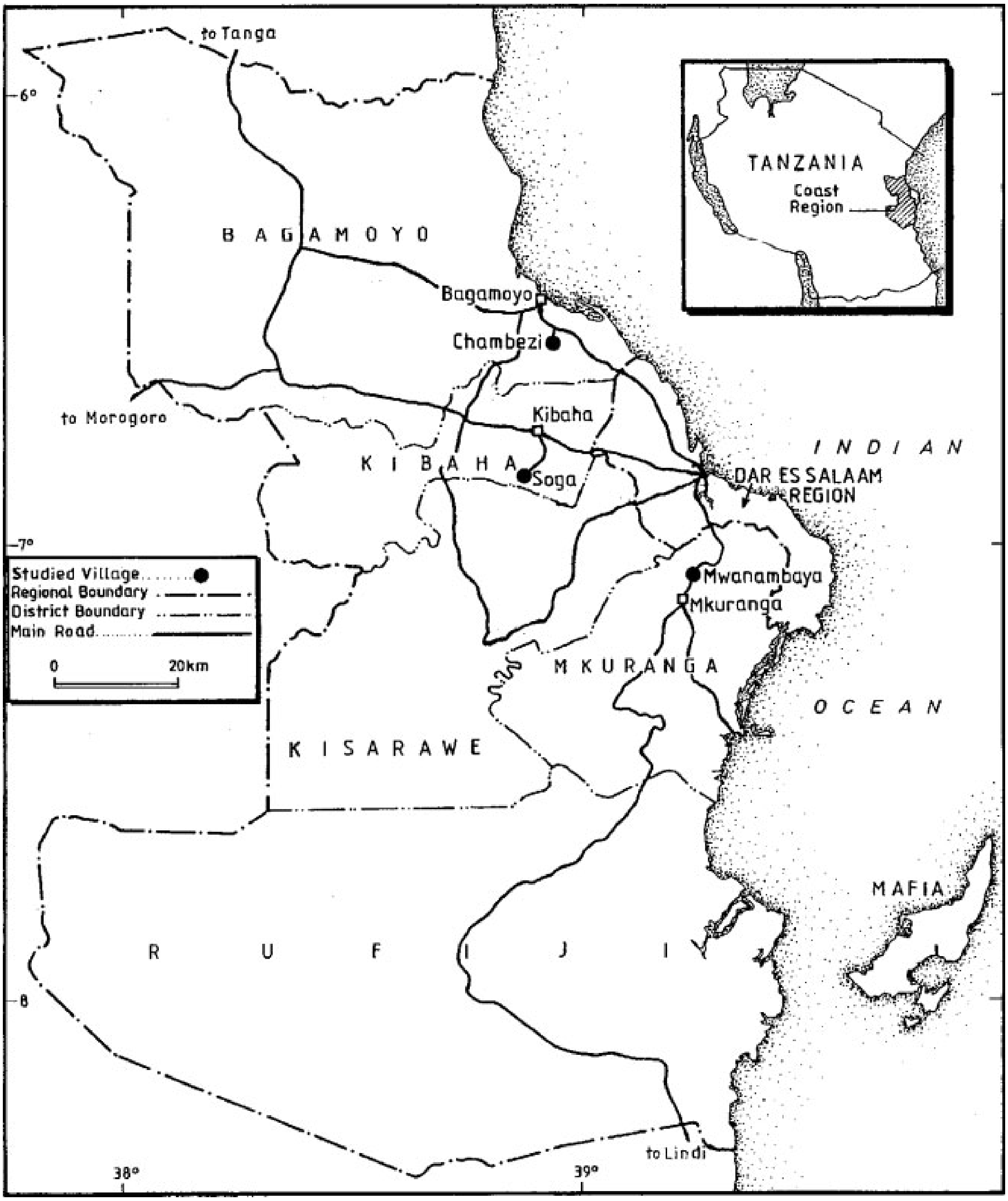

Figure 1. Location of the study sites in Bagamoyo, Kibaha and Mkuranga districts, Coast region, Tanzania.

of toxic saliva into the stalks of the tender shoots. Secondary infection by fungi may cause dieback of the shoots,[6] which is characterised by withering of the shoots, generally starting from the tips and later advancing downwards to the main floral shoots and leaves (Stathers TE, unpublished). *Pseudotheraptus wayi* feeds on developing nuts, causing them to shrivel, dry and blacken before they are shed. A characteristic sunken spot develops at the site of puncture, and mature kernels show black, sunken spots (Stathers TE, unpublished).[7] The increase in sap-sucking pest populations coincides with the main growth period of the tree crop, which begins shortly after the end of the long rainy season (Stathers TE, unpublished).[8] Damage by these sap-sucking insects can vary between years and localities.[5,7]

The main management strategy largely relies on calendar-based applications of insecticides, namely lambda cyhalothrin (Karate 5EC) and trifloxistrobine (Flint 50WG), which are applied during flowering.[9] Although this can reduce insect pest damage significantly, disadvantages, apart from the cost of synthetic chemical insecticides, can also be numerous. These include a reduction in natural enemies and potential pollinators, increased insect resistance to pesticides, environmental pollution and negative effects on the health of the farmers, who often lack the necessary protective gear.[10] There is a need, therefore, to develop an ecologically sustainable and economically viable integrated pest management (IPM) strategy for control of these key pests. Weaver ants, *Oecophylla smaragdina* Fabricius (Hymenoptera: Formicidae), are used as biocontrol agents in cashew and mango orchards in Australia.[11,12] The African weaver ant (AWA), *Oecophylla longinoda* Latreille (Hymenoptera: Formicidae), has already been used to control *P. wayi* in coconut in East Africa,[8,13,14] cashew

Table 1. Mean colonisation level expressed as number of leaf nests and weaver ant trails per tree in the three production areas

			Mean number (X ± SD) of leaf nests per tree			
2010	Aug	Sep	Oct	Nov	Dec	Range
Bagamoyo	5.2 (3.8)	5.7 (4.3)	5.7 (3.7)	5.5 (3.2)	6.1 (3.1)	0.9
Kibaha	6.4 (4.1)	6.9 (4.8)	6.9 (5.9)	7.4 (6.5)	8.3 (6.9)	1.9
Mkuranga	6.4 (4.3)	6.1 (3.3)	6.3 (3.1)	6.4 (3.2)	5.9 (3.4)	0.5
			$F_{8,288} = 0.395$, $P = 0.923$			
2011	Aug	Sep	Oct	Nov	Dec	Range
Bagamoyo	7.7 (5.3)	7.0 (5.3)	8.1 (5.1)	7.7 (5.9)	8.0 (5.3)	1.1
Kibaha	5.5 (3.4)	6.1 (3.4)	6.3 (2.9)	4.6 (3.7)	6.3 (3.9)	1.7
Mkuranga	8.4 (5.6)	9.3 (6.0)	8.0 (5.3)	8.1 (5.2)	8.7 (4.9)	1.3
			$F_{8,288} = 1.33$, $P = 0.227$			
			Mean percentage (X ± SD) colonisation level of weaver trails per tree			
2010	Aug	Sep	Oct	Nov	Oct	Range
Bagamoyo	55.8 (24.2)	54.6 (22.8)	58.2 (25.9)	57.5 (21.9)	59.4 (16.1)	4.8
Kibaha	61.7 (29.0)	58.8 (27.2)	59.6 (30.7)	56.0 (24.5)	58.5 (24.4)	5.7
Mkuranga	59.6 (20.8)	54.6 (24.8)	60 (18.3)	64.7 (21.8)	64.2 (24.3)	5.1
			$F_{8,228} = 0.388$, $P = 0.926$			
2011	Aug	Sep	Oct	Nov	Oct	Range
Bagamoyo	67.8 (18.6)	62.8 (24.5)	61.9 (25.7)	60.6 (21.6)	64.7 (24.3)	7.2
Kibaha	50.0 (24.8)	54.4 (20.4)	57.5 (19.3)	55.8 (23.4)	60.8 (24.1)	10.8
Mkuranga	66.6 (23.2)	69.6 (23.1)	65.4 (27.7)	67.3 (28.3)	68.5 (29.8)	4.2
			$F_{8,288} = 1.270$, $P = 0.260$			

pests [*H. schoutedeni*, *Pseudotheraptus devastans* Distant and *Anoplocnemis curvipes* Fabricius (Hemiptera: Coreidae)] in Ghana[15] and fruit flies [*Ceratitis* spp. and *Bactrocera invadens* (Diptera: Tephritidae)] in mango in Benin.[16] The aim of this study was therefore to evaluate the potential of AWA in the control of *Helopeltis* spp. and *P. wayi* in cashew trees in Tanzania.

2 MATERIALS AND METHODS

2.1 Experimental sites

Experiments were conducted in cashew fields at Bagamoyo (06° 49.3′ S, 38° 54.8′ E, 53.43 masl), Kibaha (06° 33.4′ S, 38° 54.7′ E, 150.57 masl) and Mkuranga (07° 3.5′ S, 39° 15′ E, 90.53 masl) in the Coast region of Tanzania (Fig. 1). The data were collected monthly for two cashew production seasons from August to December 2010 and 2011. The average annual rainfall of the region is 1000 mm. The cashew fields were approximately 8, 5 and 3 ha at Bagamoyo, Kibaha and Mkuranga respectively. The cashew trees in Bagamoyo and Kibaha were 12 years old and planted in 22 and 18 rows respectively. The plantations consisted of cashew trees planted in monoculture, and the majority of the trees were well separated from each other. The cashew trees at Mkuranga were 15 years old and were irregularly intercropped with mango, coconut and citrus trees.

2.2 Colonisation levels of O. *longinoda*

Mean AWA colonisation level per tree was determined during the flushing shoot and flower initiation period, which coincided with high incidence of the sap-sucking pests. Forty cashew trees were selected randomly per site. The random selection was stratified, with 20 trees colonised and 20 trees non-colonised by AWA. Foraging AWA on main branches and leaf nests in the trees were used as indicators of colonisation by AWA. Hydramethylon ant bait (AMDRO) was additionally applied at a rate of 3 g tree^{-1} on AWA-colonised trees to control *Pheidole megacephala* Fabricius (Hymenoptera: Formicidae), an inimical ant to AWA, to ensure a high and stable colonisation level of AWA. The level of AWA colonisation was measured in two ways: (a) the number of nests per tree; (b) the percentage of main branches with AWA trails. More than ten weaver ants walking along a main branch was recorded as one weaver ant trail. Between one and ten weaver ants along the main branch was recorded as 0.5 weaver ant trail.[17]

The percentage of AWA trails on main branches (i), the mean percentage of AWA trails on occupied trees in the field (ii) and the average number of nests per AWA-occupied tree (iii) were calculated:

i (Number of main branches with weaver ant trail in tree)/(number of main branches in tree) × 100.
ii The mean weaver ant colonisation level, based on trails per field, was calculated as the average of weaver ant colonisation.
iii The mean number of nests on AWA-occupied trees per field was calculated as the sum of all nests counted per 20 trees.

2.3 Shoot and nut damage

An assessment of damage to flushing shoots and young nuts by *Helopeltis* spp. and *P. wayi*, respectively, was conducted on each of the selected cashew trees. A 1 m^2 quadrat was placed over the shoots approximately 1 m above the tree base, the flushing shoots and nuts within each quadrat were carefully inspected and the numbers of shoots and nuts damaged were recorded separately. A leaf was treated as 'damaged' if more than 30% of its surface showed signs of damage.[18] Leaves with less than 30% damage were classified as 'not damaged'. Five tender leaves per shoot were inspected, and, if any one of these leaves was affected, the shoot was treated as damaged.

Two quadrats were used to assess damage per tree. One quadrat was placed at the southern, sunny side, and the other at the northern, shady side of the tree. The position of the quadrat

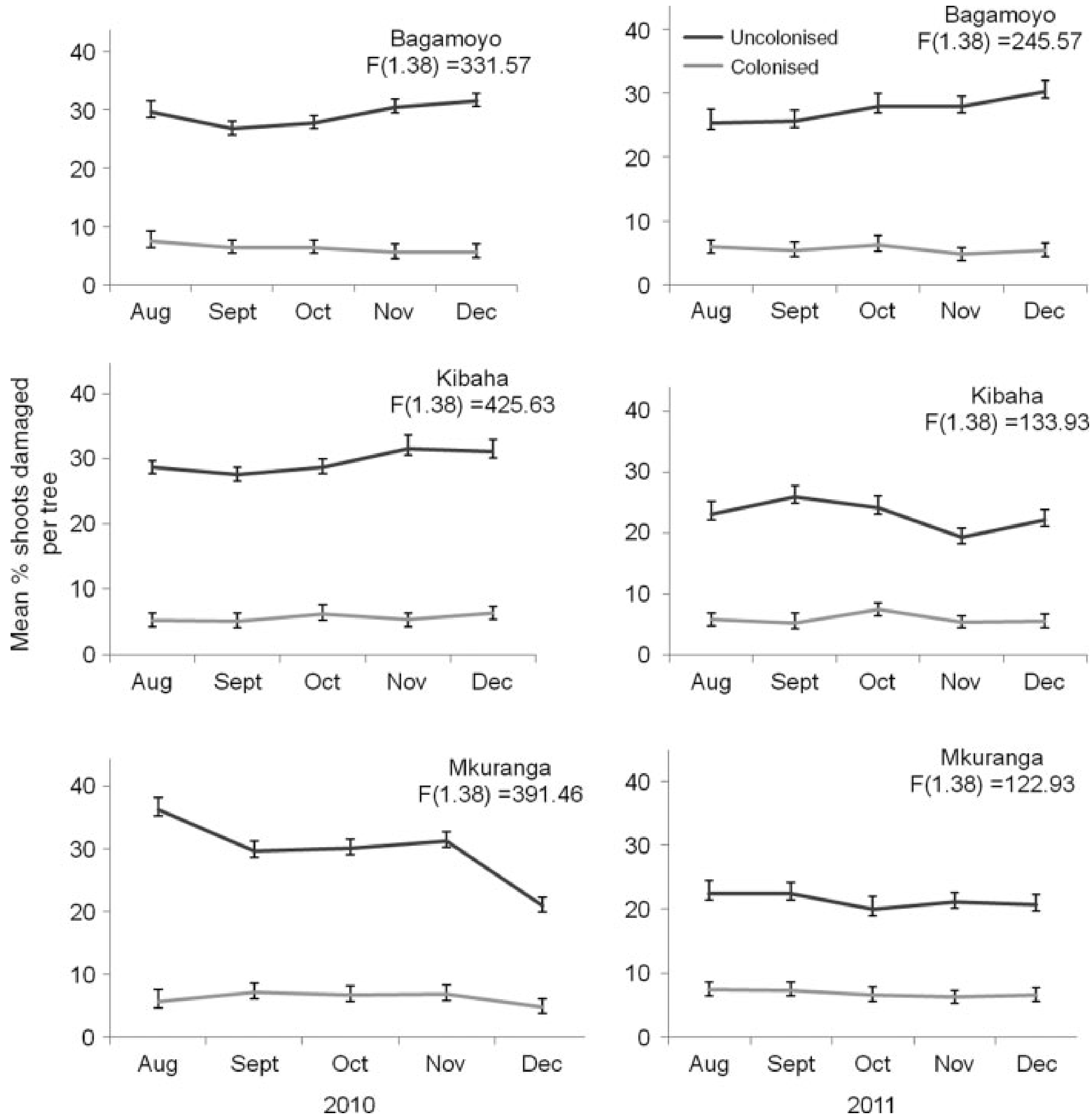

Figure 2. Shoot damage by *Helopeltis* spp. during 2010 and 2011 cashew production seasons in *Oecophylla longinoda*-colonised and uncolonised trees in the three cashew production areas. Bars indicate SE.

was maintained throughout the study. Evaluation of damage to tender shoots and young nuts by the sap-sucking pests was done monthly.

The percentage of shoots damaged per quadrat was calculated as follows:

i (Total number of damaged shoots per quadrat)/(total number of shoots counted within quadrat) × 100.
ii The percentage of shoots damaged per tree was calculated as the average of the percentage of shoots damaged in the two quadrats.

A similar procedure was also used to calculate the percentage of damaged nuts per tree.

2.4 Data analysis

Damage to flushing shoots and young nuts, expressed as a percentage, was arcsine transformed before analysis. The data were analysed using STATISTICA v.10 (Stasoft, Inc., Tulsa, OK). Repeated-measures ANOVA was used to analyse percentage damaged shoots and nuts over time. Bonferroni correction was used to adjust for multiple mean comparisons. It is the most common way to control the familywise error rate.[19] The Durbin–Watson test was used to determine the correlation between numbers of AWA nests and pest damage.

3 RESULTS

3.1 Colonisation levels of *O. longinoda*

Colonisation levels of AWA, expressed as weaver ant trails on the main branches, were similar at the three sites during the 2010 and 2011 cashew production seasons ($P = 0.926$ and $P = 0.260$ respectively) (Table 1). Mean colonisation levels ranged between 57.1 and 60.6% in 2010 and between 58.3 and 67.5% in 2011. A total of 1898 and 2182 leaf nests were counted in the 2010 and 2011 cashew production seasons respectively. The mean numbers of leaf nests per tree were similar at the three sites in both 2010 (P

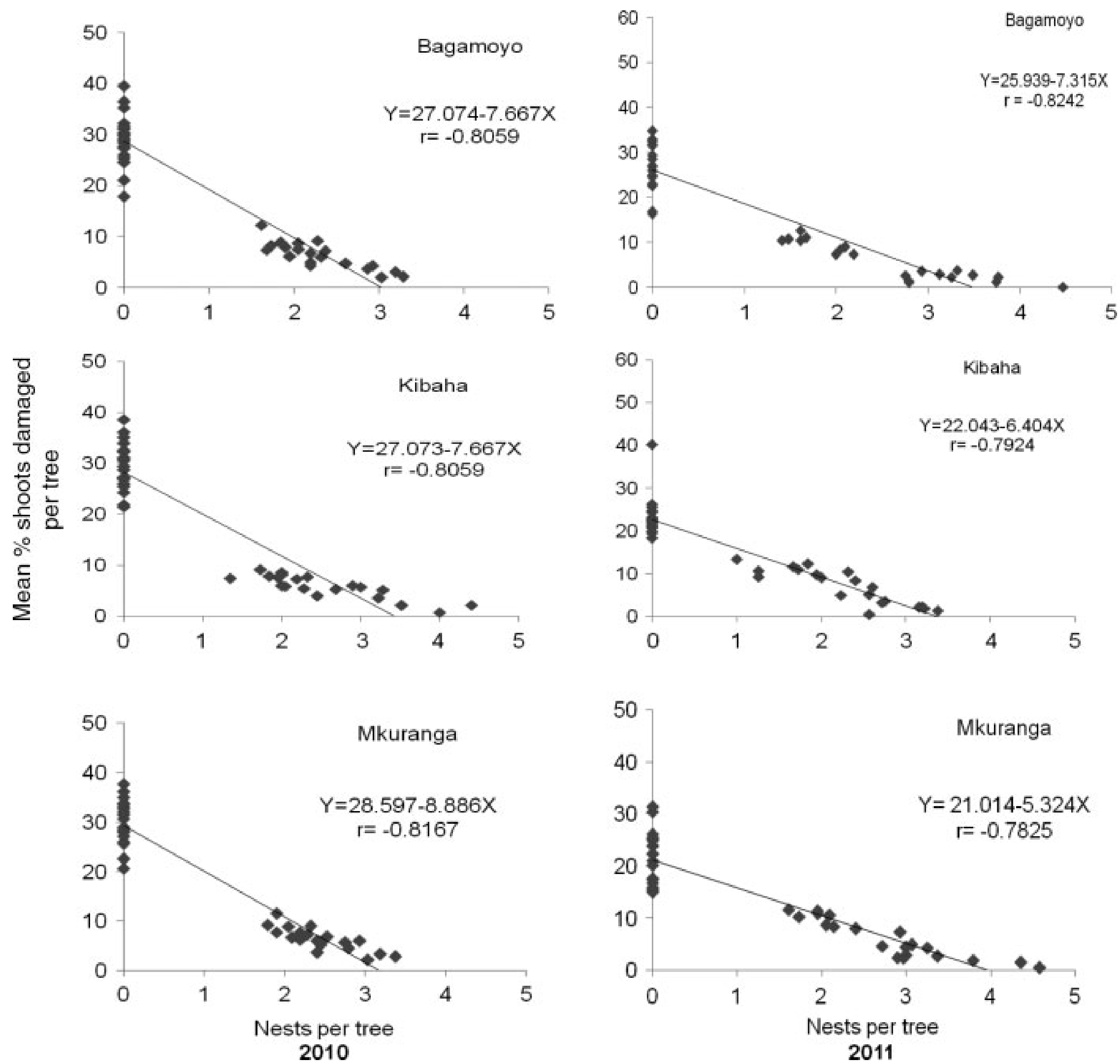

Figure 3. Relationship between numbers of *Oecophylla longinoda* nests and shoot damage by *Helopeltis* spp. during the 2010 and 2011 cashew production seasons. Correlation coefficient indicates a negative correlation (Y = intercept, X = slope, r = correlation coefficient).

= 0.923) and 2011 ($P = 0.227$), ranging from five to eight nests and from five to nine nests during 2010 and 2011 cashew production seasons respectively (Table 1).

3.2 Shoot and nut damage

The shoot damage levels were between 4.8 and 11.74% in the colonised trees (Fig. 2) and between 19.29 and 36.26% in the uncolonised trees (Fig. 3) during both seasons. The mean percentage of shoot damage was therefore significantly lower in AWA-colonised trees than in uncolonised trees at all three localities over the two seasons ($F_{8,228} = 2.554$, $P = 0.009$). However, the mean percentage of shoot damage in the AWA-colonised trees was not significant between 2010 and 2011 cashew production seasons ($F_{4,228}$) = 0.463, $P = 0.763$). A similar trend was also observed in trees that were not colonised by AWA over the two seasons ($F_{4,228}$) = 1.808, $P = 0.125$).

Seasonally, the incidence of shoot damage at Mkuranga differed significantly from that at Bagamoyo and Kibaha, but the latter two did not differ from each other at $P < 0.05$ (Bonferroni correction). No differences were recorded in incidence of shoots damaged between any of the sites during 2011 ($F_{8,228} = 1.778$, $P = 0.0823$).

There was a negative correlation between numbers of AWA nests and shoot damage caused by *Helopeltis* spp. during both 2010 and 2011 cashew production seasons (Fig. 3).

There was also a significant difference between mean percentage of nuts damaged by *P. wayi* in AWA-colonised and uncolonised trees at all three sites ($F_{6,228} = 2.606$, $P = 0.017$). The incidence of nut damage in these trees at these sites was also similar during both 2010 and 2011 ($F_{3,228} = 1.734$, $P = 0.159$). The mean percentage nut damage per tree ranged between 17 and 21% and between 16 and 26% in uncolonised trees in 2010 and 2011 respectively (Fig. 4). The mean percentage of nuts damaged in cashew trees colonised by AWA did not differ significantly over time between the three sites during both 2010 and 2011 cashew production seasons ($F_{2,228} = 0.907$, $P = 0.437$). The mean percentage damage per tree in the AWA-colonised trees ranged between 4.1 and 5.7% and between 2.4 and 6.2% during the 2010 and 2011 seasons respectively (Fig. 4). Nut damage was therefore significantly lower in AWA-colonised than in uncolonised trees during both 2010 and 2011 cashew production seasons at all three localities ($P = 0.017$) (Bonferroni correction) (Fig. 4). There was also a negative correlation between numbers of AWA nests and nut

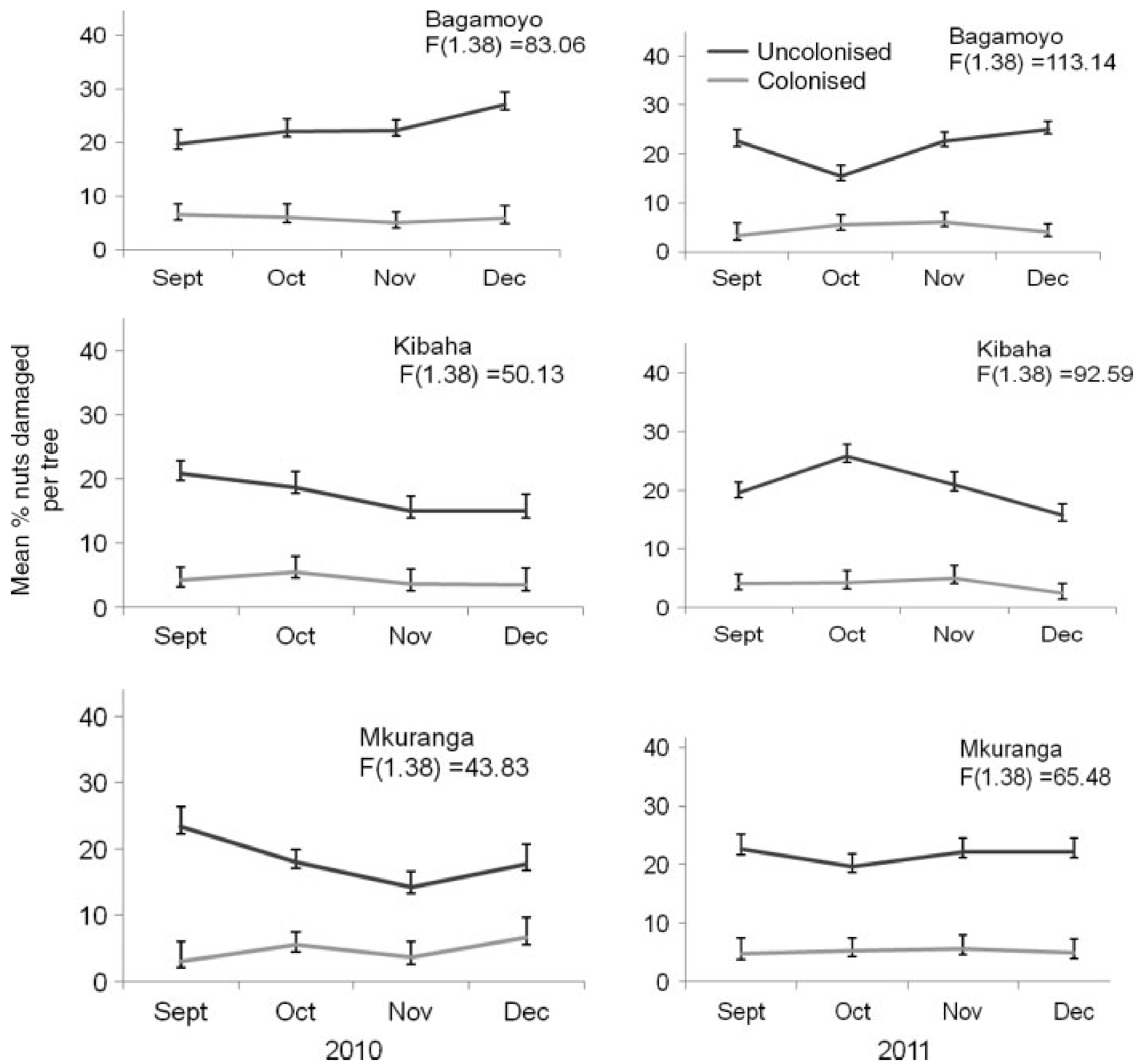

Figure 4. Nut damage by *Pseudotheraptus wayi* during 2010 and 2011 cashew production seasons in *Oecophylla longinoda*-colonised and uncolonised trees in the three cashew production areas. Bars indicate SE.

damage caused by *P. wayi* during both 2010 and 2011 cashew production seasons (Fig. 5). An increase in numbers of AWA nests resulted in a reduction in nut damage caused by *P. wayi*.

4 DISCUSSION

High colonisation levels of AWA were recorded at the three sites during both 2010 and 2011. This could partly be attributed to the application of hydramethylon ant bait (Amdro), which was applied to control the inimical ant, *P. megacephala*. The use of hydramethylon has proven to be a successful method in controlling this ant species on coconut farms,[8,13,14] thus improving the effectiveness of AWA in controlling sap-sucking pests because it does not spend energy on defending its territory.[14] The high colonisation levels of cashew trees by AWA can also possibly be ascribed to the presence of large numbers of insect symbionts (trophobionts) such as the scale insect, *Coccus hesperidum* Linnaeus (Homoptera: Coccidae), and the red tea bug, *Hilda patruelis* Stål (Homoptera: Tettigometridae) (Olotu M, personal observation), which have been reported to be closely associated with AWA on cashew trees (Stathers TE, unpublished).[15] A prerequisite is, however, that the host plant should be able to support associated Homoptera from which the ant can obtain honeydew for food.[15,20]

AWA was effective in controlling the key sap-sucking pests *Helopeltis* spp. and *P. wayi* in the Tanzanian cashew crop in terms of a reduction in flushing shoot and nut damage respectively. Similar results were reported in tree crops in West Africa.[15,16,21] A negative correlation between numbers of AWA nests and pest damage was reported in cashew crops in Ghana[15] and mango fruit fly damage in Benin.[16] As *Helopeltis* spp. and *P. wayi* are low-density pests (Stathers TE, unpublished), assessments of damaged shoots and nuts are therefore a more reliable way to determine their pest status in cashew fields than to monitor pest numbers. Field monitoring at the three sites for 2 years showed that in AWA-colonised trees the shoot damage by *Helopeltis* spp. was significant lower than in uncolonised trees. A similar trend was also observed in nut damage caused by *P. wayi*. The reduction in pest damage in AWA-colonised trees might be due to the ability of AWA to prey on sap-sucking pests on cashew. Similar observations were recorded in coconuts in East Africa[13,22] and in cashew in West Africa.[15] The aggressive behaviour of AWA experienced by farmers as a nuisance during harvesting is not a serious matter, as

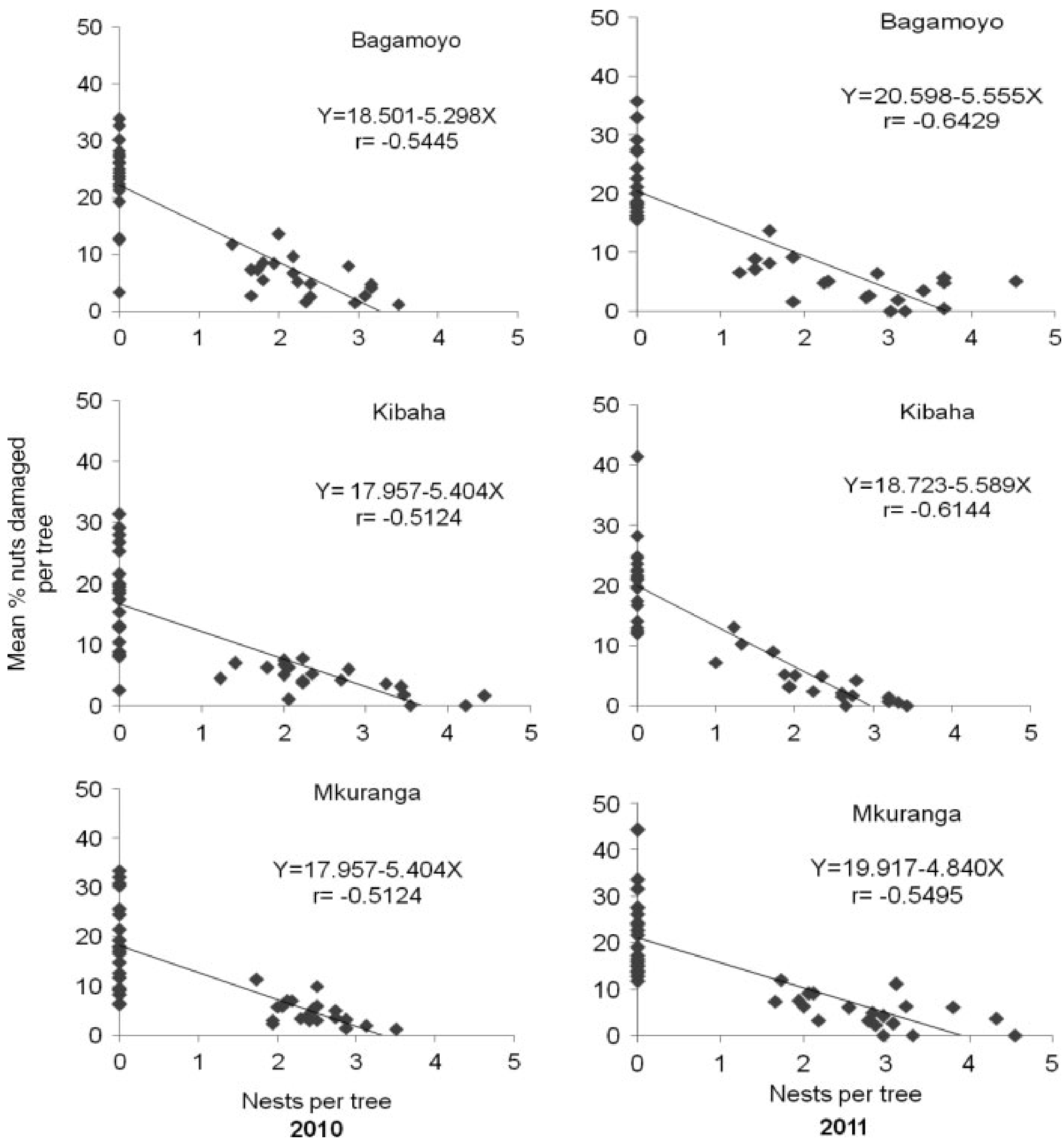

Figure 5. Relationship between numbers of *Oecophylla longinoda* nests and nut damage by *Pseudotheraptus wayi* during the 2010 and 2011 cashew production seasons. Correlation coefficient indicates a negative correlation (Y = intercept, X = slope, r = correlation coefficient).

farmers collect cashew that have naturally dropped to the ground (Stathers, unpublished).[15]

5 CONCLUSIONS

Oecophylla longinoda effectively controls sap-sucking pests in cashew in Tanzania. Fewer shoots and nuts were damaged in the trees colonised by AWA compared with the uncolonised trees. In practice, biocontrol is currently considered by farmers to be insignificant in the control of the sap-sucking pests in cashew (Olotu M, personal observation). As a result, large-scale producers rely on chemical pesticides, which is environmentally unsustainable. However, this study showed AWA to be an effective biocontrol agent for the sap-sucking pests in cashew fields in Tanzania. It should therefore be included as an important part of an IPM system for the control of the sap-sucking pests in cashew production and may even replace the use of pesticides.

ACKNOWLEDGEMENTS

The authors acknowledge the financial support of the Federal Ministry for Economic Cooperation and Development and the German Academic Exchange Service (DAAD), Germany. They thank the International Centre of Insect Physiology and Ecology (*icipe*), the African Regional Postgraduate Programme in Insect Sciences (ARPPIS) and Mikocheni Agricultural Research Institute (MARI) for overall assistance during this study. They also thank J Ambrosy, M George, S Mgema, V Nyange, B Mruma, C Materu and G Mwingira for their technical assistance. Grateful thanks also to Mr and Mrs Ponzi, B Myogopa, H Bakari and M Chimela for providing field sites and farm facilities.

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