

Monitoring wild silkmoth, *Gonometa postica* Walker, abundance, host plant diversity and distribution in Imba and Mumoni woodlands in Mwingi, Kenya

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SUMMARY

A survey of the abundance of larvae and pupae of *Gonometa postica* Walker and their host plants was undertaken in the long rainy season in 2006 at six sites in the Imba and Mumoni forests of Mwingi, eastern Kenya. One hundred trees of the primary host species of *G. postica* were sampled at each site, in addition to minor host species with *G. postica* pupae. The density of each tree species was calculated and the height, canopy, diameter and number of branches were measured. In order of decreasing abundance, the host plants in Imba forest were *Acacia tortilis*, *A. elatior* and *A. nilotica*, and in Mumoni forest, *A. tortilis*, *A. nilotica*, *A. mellifera* and *A. brevispica*. *A. elatior* had significantly more larvae than the other host plants in Imba. In Mumoni, *A. tortilis* and *A. mellifera* had significantly more larvae, followed by *A. nilotica* and *A. brevispica*. The minor host plants harbour significantly more pupae than the major host plants in the two forests. In general, Imba had a significantly higher abundance of larvae and pupae than Mumoni. Host plant species richness did not differ between the two forests, but their evenness was significantly higher in Imba than in Mumoni.

INTRODUCTION

In East Africa, as elsewhere in the world, there is increasing concern for biodiversity and its sustainable utilisation and conservation. Since some solutions lie in introducing economic incentives that integrate conservation with the economic development of the local people, a need exists to document some of the biological resources that can be used for both conservation and income generation

(Kioko *et al.* 1999, 2000; Raina and Kioko 2000; Raina *et al.* 2007).

The Imba (732 ha) and Mumoni (10,442 ha) forests are two of the five forest reserves of Mwingi District, eastern Kenya, that serve as major sources of fuelwood and poles for rural and urban markets (Abeele *et al.* 2005). The Mumoni hills provide an important water catchment for the local

population. These forests harbour significant biodiversity resources within a complex of thorn tree (*Acacia*, *Commiphora*) woodland communities (Kigomo 2001; Abeele et al. 2005; Kioko et al. 2007; Raina et al. 2007).

About 70% of the population in Mwingi District live below the poverty line (<US\$1 per day per person) (Office of the Vice-President and Ministry of Planning and National Development 1999; Rubyogo et al. 2005), with the poorest inhabitants residing in the driest divisions in the district (Office of the Vice-President and Ministry of Planning and National Development 2002). The forest resources have therefore degraded rapidly through unsustainable practices, such as charcoal burning (mostly *Acacia* spp.) as a means of survival (Raina et al. 2007). Through intervention of the International Centre of Insect Physiology and Ecology (ICIPE)'s Commercial Insects Programme (CIP) in 1996, communities adjacent to the Imba and Mumoni forests are now trained and are actively involved in beekeeping and wild sericulture on the *Acacia* species predominant in the area. A reversal in the degradation trend has taken place, as the forest has now regenerated through the conservation of bees, wild silkmoths and their host plant species (Raina and Kioko 2000; Kioko et al. 2007; Raina 2004; Raina et al. 2000, 2007).

This study seeks to quantify the abundance of *Gonometa postica* Walker larvae and pupae and the diversity, density and distribution of its host plants, so as to enhance the monitoring and conservation of the silkmoth and its host plant species in the Imba and Mumoni forests. Such monitoring is needed for assessment of the impact of the CIP, which aims to use honeybees and silkmoths for income generation, enhancement of livelihoods and biodiversity conservation in fragile ecosystems (Raina et al. 2007).

MATERIALS AND METHODS

Study sites

The study was carried out at six sites in the Imba and Mumoni woodlands of Mwingi District, eastern Kenya (Figure 1). The Imba forest included site 1 (0°51'S, 38°22'E), site 2 (0°50'S, 38°22'E) and site 3 (0°50'S, 38°23'E), and the Mumoni forest included site 1 (0°36'S, 38°1'E), site 2 (0°34'S, 38°2'E) and site 3 (0°32'S, 38°0'E). The sites were a minimum of

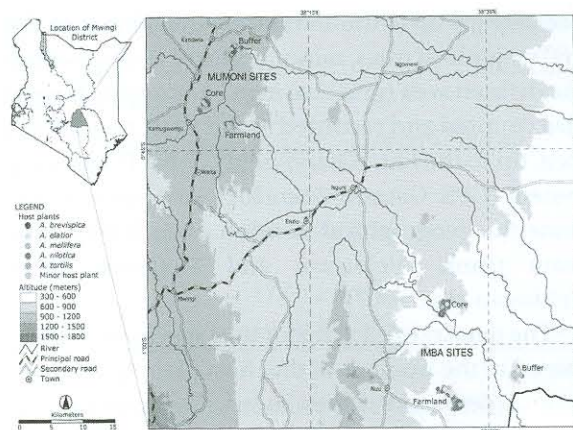


Figure 1 Map of Kenya showing *G. postica* host plant distributions in Mumoni and Imba forests of Mwingi

1 km apart, and were chosen systematically to reflect the different zones (farmland, buffer and core) of each forest, based on the available knowledge of the forest zonation of the Kenyan Forest Service; a minimum of 40 larvae or cocoons of *G. postica* was required for site selection.

Abundance of *G. postica* larvae and pupae and its host plant diversity, density and distribution

A survey of abundance of *G. postica* larvae, pupae and host plants was undertaken in the long rainy season in 2006. One hundred primary host trees of *G. postica* were sampled in each forest site by demarcating approximately the rectangular area incorporating these 100 trees (Veldtman et al. 2002, 2007). This was replicated three times in each forest. Each tree was thoroughly inspected, and the number of *G. postica* larvae or pupae (enclosed in a spun cocoon) seen were counted and recorded. The larvae observed were in the fourth, fifth and sixth instar stages. Those tree species where *G. postica* larvae were found actively feeding were considered primary or major host plants. Tree species in which pupae or *G. postica* final (sixth) instar larvae were found, and where no feeding was observed, were not used to determine host range, as these larvae may have moved there only for pupation. Thus, these trees were categorised as minor host (non-host) plant species (Veldtman 2004). Only trees taller than 1 m were included in the survey. The first host tree (called the START TREE) was chosen by finding at least one larva or pupa of *G. postica* on it. This tree was marked as 1 and the others followed

accordingly up to the 100th tree. In addition to the 100 major host trees, minor host tree species within the defined area (grid) having *G. postica* pupae were also counted and recorded as the 101st tree, 102nd tree, up to the last. A hand-held Global Positioning System (GPS: Garmin Geko 101) was used to determine the geographical position of each tree at its main trunk (Veldtman and McGeoch 2004; Veldtman et al. 2007).

The density of each major host species was determined as the number of that host plant species per unit or demarcated area in m². The area encompassing the 100 primary host trees differs according to site, due to differences in the tree canopies at the different sites. Host plant samples were pressed in newspaper and sent to the National Museums of Kenya in Nairobi for identification.

Host tree growth characteristics

Tree growth characteristics including plant height, canopy (width), trunk diameter (girth) and number of branches were measured for both major and minor host plants in each site. A visual estimate of the height of each tree was made to the nearest metre (m) (Veldtman 2004). The width of the tree canopy was measured with a measuring tape (100-m long surveyor's tape). The diameter at breast height (dbh) of each tree was measured and standardised at 1.3 m (Dallmeier 1992). Trees that had extensive branching below breast height had their diameter measured at the point just before they divided into branches. The number of branches emanating from the main tree trunk was counted and recorded.

Data analysis

Data on host plant abundance for *G. postica* were analysed to quantify the host plant diversity across the two forests. The Shannon diversity index (H') = $-\sum p_i \ln p_i$ was calculated, with p_i = the proportional abundance of the i th species ($p_i = n_i/N$), N = total abundance for all species sampled, and n_i = abundance for each species of host plant (Magurran 1988). The Shannon evenness (E) = $H' / \ln S$, was determined where S = the number of species sampled (Kempton 2002). A t test was used to compare diversity across the two forest sites.

Data on abundance of *G. postica* larvae and pupae, host plant characteristics (height, canopy size, girth and number of branches) and host

species density for the two forests were analysed using the analysis of variance (ANOVA) procedure of SAS. When ANOVA showed significance differences between means ($P < 0.05$), *post hoc* mean separation was conducted using the Student–Newman–Keul test (SAS Institute Inc. 2001). Data on the abundance of *G. postica* larvae and pupae were log transformed before analysis. Back-transformed means are presented.

RESULTS

Abundance of *G. postica* larvae and pupae and its host plant diversity, density and distribution

The major host plants of *G. postica* larvae included *Acacia tortilis* (Forssk.) Hayne (Mimosaceae), *A. elatior* Brenan and *A. nilotica* (L.) Del. in the Imba forest and *A. tortilis*, *A. nilotica*, *A. mellifera* (Vahl) Benth and *A. brevispica* Harms in the Mumoni forest. Minor host plants with non-feeding *G. postica* larvae and pupae in Imba forest included *Capparis tomentosa* Lam. (Capparidaceae), *Balanites aegyptiaca* (L.) Del. (Balanitaceae), *Acacia nubica* Benth (Mimosaceae), *Grewia tembensis* (Tiliaceae), *Solanum renschii* Vatke (Solanaceae), *Lawsonia inermis* L. (Lythraceae), *Acalypha* sp. (Euphorbiaceae), *Cordia sinensis* Lam. (Boraginaceae) and *Combretum aculeatum* Vent. (Combretaceae). *Capparis tomentosa*, *B. aegyptiaca*, *Adamsonia digitata* L. (Bombacaceae) and *Acacia ataxacantha* DC (Mimosaceae) were recorded as minor hosts in the Mumoni forest. *Balanites aegyptiaca* and *C. tomentosa* were common in both forests.

The density of the different major host plants differed between the two forests (Table 1). *A. tortilis* had a significantly ($df = 2$, $F = 5.03$, $P = 0.05$) higher density, followed by *A. elatior* and *A. nilotica* in the Imba forest. In Mumoni forest, *A. tortilis* had a significantly ($df = 3$, $F = 257.11$, $P < 0.0001$) higher density, followed by *A. nilotica*; densities of *A. mellifera* and *A. brevispica* were similar. The density of *A. tortilis* was significantly ($df = 1$, $F = 24.80$, $P = 0.008$) higher in Mumoni than Imba. The densities of *A. nilotica* were similar ($df = 1$, $F = 4.05$, $P = 0.110$) in both forests. *Acacia elatior* was recorded only in Imba forest, whereas *A. mellifera* and *A. brevispica* were recorded only in Mumoni (Table 1 and Figure 2).

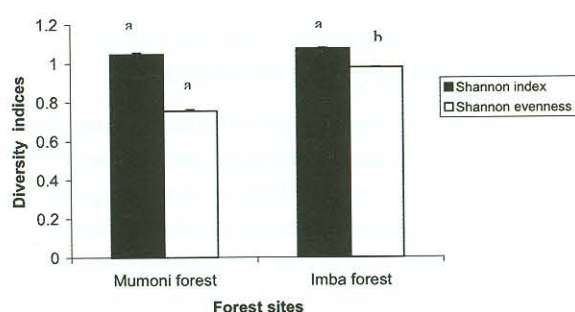
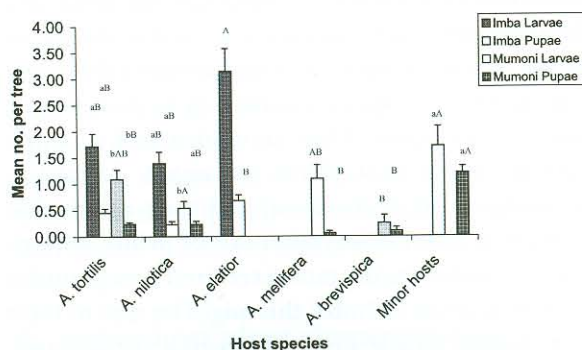
The abundance of *G. postica* larvae and pupae varied across the different host plant species within

Table 1 Host plant density of *G. postica* in Imba and Mumoni forests of Mwingi District Kenya during the long rainy season in 2006

Host species	Tree density \pm SE	
	Imba (Area sampled = $3204.60 \pm 623.89 \text{ m}^2$)	Mumoni (Area sampled = $2049.07 \pm 150.99 \text{ m}^2$)
<i>A. tortilis</i>	$42.67 \pm 3.71\text{bA}$	$61.67 \pm 0.88\text{aA}$
<i>A. nilotica</i>	$26.33 \pm 2.73\text{aB}$	$20.33 \pm 1.20\text{aB}$
<i>A. elatior</i>	$31.00 \pm 4.58\text{AB}$	–
<i>A. mellifera</i>	–	$11.00 \pm 2.31\text{C}$
<i>A. brevispica</i>	–	$10.50 \pm 0.50\text{C}$

– = species absent

Means within a column followed by the same capital, and within a row followed by the same lower case, letter(s) are not significantly different. ($P = 0.05$, SNK)

**Figure 2** *G. postica* host plant diversity indices in Mumoni and Imba forests of Mwingi during the long rainy season in 2006**Figure 3** Abundance of *G. postica* larvae and pupae on different host plants in Imba and Mumoni forests of Mwingi during the long rainy season in 2006

and between the two forests (Figure 3). In Imba, *A. elatior* had significantly ($df = 2$, $F = 8.62$, $P < 0.01$) higher densities of larvae than *A. tortilis* and *A. nilotica*. The abundance of larvae was significantly ($df = 3$, $F = 2.99$, $P < 0.05$) higher for *A. tortilis* and *A. mellifera*, followed by *A. nilotica* and *A. brevispica* in Mumoni. The number of larvae found on *A. tortilis* and *A. nilotica* was significantly ($df = 1$, $F = 8.23$,

$P < 0.01$; $df = 1$, $F = 11.45$, $P < 0.01$) higher in Imba than Mumoni. In Imba and Mumoni forests, pupal abundance was significantly ($df = 3$, $F = 13.67$, $P < 0.0001$; $df = 4$, $F = 14.11$, $P < 0.0001$) higher on the minor host plants than the other major host plants. The number of pupae on *A. tortilis* was significantly ($df = 1$, $F = 4.21$, $P < 0.05$) higher in Imba than Mumoni.

The host species richness did not differ between the two forests ($t_{cal} = 0.345$, $df = 140$, $P > 0.05$), but the evenness was higher in Imba forest than in Mumoni forest ($t_{cal} = 2.667$, $df = 140$, $P < 0.01$) (Figure 2). The *Acacia* species were mostly found in farmlands, buffer zones and at the base of the hills and lower slopes of the core zones in both forests (see altitudes of zones in Figure 1).

G. postica host plant characteristics

The heights of the host plants were not significantly different across species ($df = 4$, $F = 3.28$, $P > 0.05$) in Mumoni forest, whereas in Imba forest, *A. tortilis* and *A. elatior* were significantly ($df = 3$, $F = 17.34$, $P < 0.0001$) taller than *A. nilotica* and the minor hosts (Table 2). *A. tortilis* and *A. nilotica* were significantly ($df = 1$, $F = 17.97$, $P < 0.0001$; $df = 1$, $F = 20.88$, $P < 0.0001$) taller in Imba than Mumoni.

In Mumoni forest, *A. tortilis*, *A. nilotica*, *A. mellifera* and minor hosts had significantly ($df = 4$, $F = 6.25$, $P < 0.0001$) wider canopies than *A. brevispica*, whereas in Imba forest, the canopy width differed significantly ($df = 3$, $F = 14.32$, $P < 0.0001$) among all the host plant species. *A. tortilis* had the widest canopy, followed by *A. nilotica*, *A. elatior* and minor hosts.

In Mumoni forest, *A. tortilis* had significantly ($df = 4$, $F = 4.53$, $P < 0.01$) larger dbh than *A.*

Table 2 Growth parameters of host species of *G. postica* in Imba and Mumoni forests of Mwingi District Kenya during the long rainy season in 2006

Host species	Host tree growth parameters							
	Mean height (m) \pm SE		Mean canopy (m) \pm SE		DBH (m) \pm SE		Mean no. of branches \pm SE	
	Imba	Mumoni	Imba	Mumoni	Imba	Mumoni	Imba	Mumoni
<i>A. tortilis</i>	6.31 \pm 0.24aA	5.01 \pm 0.17 bA	6.87 \pm 0.30aA	4.58 \pm 0.16 bA	0.87 \pm 0.05aA	0.44 \pm 0.02bA	2.88 \pm 0.12aB	2.55 \pm 0.06bA
<i>A. nilotica</i>	4.49 \pm 0.13 aB	3.80 \pm 0.08bA	5.74 \pm 0.27aAB	5.05 \pm 0.20 aA	0.44 \pm 0.03aB	0.39 \pm 0.03aAB	2.33 \pm 0.07bC	3.03 \pm 0.16aA
<i>A. elatior</i>	6.27 \pm 0.26A	—	4.61 \pm 0.29B	—	0.39 \pm 0.03B	—	2.17 \pm 0.09C	—
<i>A. mellifera</i>	—	4.59 \pm 0.19A	—	4.12 \pm 0.34A	—	0.30 \pm 0.03AB	—	2.94 \pm 0.23A
<i>A. brevispica</i>	—	4.94 \pm 0.21A	—	2.57 \pm 0.37B	—	0.22 \pm 0.03B	—	3.10 \pm 0.41A
Minor hosts*	3.19 \pm 0.52aC	3.91 \pm 0.42aA	3.09 \pm 0.60aC	3.89 \pm 0.42aA	0.39 \pm 0.10aB	0.40 \pm 0.15aAB	3.50 \pm 0.47aA	3.10 \pm 0.59aA

— = species absent.

* = *C. tomentosa*, *B. aegyptiaca*, *G. tembensis*, *S. renschii*, *C. sinensis*, *L. inermis*, *Acalypha* sp., *A. digitata*, *A. nubica*, and *A. ataxacantha*.

Means within a column followed by the same capital, and within a row followed by the same lower case, letter(s) are not significantly different. ($P = 0.05$, SNK). DBH = diameter at breast height

nilotica, *A. mellifera* and minor hosts, which did not differ significantly in their dbh. *A. brevispica* had a significantly ($df = 4$, $F = 4.53$, $P < 0.01$) smaller dbh. In Imba, *A. tortilis* had a significantly ($df = 3$, $F = 24.8$, $P < 0.0001$) larger dbh than *A. nilotica*, *A. elatior* and minor hosts. The dbh of *A. tortilis* was significantly ($df = 1$, $F = 64.80$, $P < 0.0001$) larger in Imba than Mumoni.

The number of branches did not differ significantly ($df = 4$, $F = 1.12$, $P > 0.10$) among host plants in Mumoni, but in Imba, the minor hosts had significantly ($df = 3$, $F = 11.82$, $P < 0.0001$) more branches, followed by *A. tortilis*. *Acacia nilotica* and *A. elatior* had similar numbers of branches. In Imba, *A. tortilis* had significantly ($df = 1$, $F = 6.78$, $P < 0.05$) more branches than in Mumoni, whereas *A. nilotica* had significantly ($df = 1$, $F = 19.06$, $P < 0.0001$) more branches in Mumoni than Imba.

DISCUSSION

The conservation and monitoring of biological diversity has become an important issue, receiving national and international attention, and is regarded as essential to carrying out the directives of Articles 8, 9 and 10 of the Convention on Biological Diversity (CBD) (Noss 1991; Glowka *et al.* 1994; Teder *et al.* 2007). It is also an important element of ecosystem management and of an adaptive management approach (Everett *et al.* 1994; Gaines *et al.* 1999). By documenting the abundance of *G. postica* larvae and pupae and host plant diversity, density and distribution in the Imba and Mumoni forests of Mwingi, this study takes the first step to provide the baseline data necessary for future monitoring and conservation of these important woodlands.

G. postica abundance, and host plant diversity, density and distribution

Information on the relative abundance and distribution of *G. postica* and its host plants in East Africa is lacking (Ngoka *et al.* 2008) or is inadequate for proper management decisions on the conservation and sustainable utilisation of this important wild silkmoth and its host plant species (Kioko *et al.* 2000, 2007; Raina 2004; Raina *et al.* 2007). There is often a lack of basic data on the level and spatial distribution of biodiversity (Teder *et al.* 2007).

This study has identified *A. tortilis* as the most abundant host plant of *G. postica* in the Imba and Mumoni forests. Veldtman *et al.* (2002, 2007), in South Africa, identified *A. tortilis* as one of the dominant woody host species utilised by *G. postica* at six sites in their study. Thus, monitoring of *A. tortilis* and the other host plants (*A. elatior*, *A. nilotica*, *A. mellifera* and *A. brevispica*) and their sustainable utilisation and conservation are of prime importance. *A. elatior* was the most preferred host plant for *G. postica* larvae in Imba; this might be due to their distribution mostly along riverbanks, thereby providing fresh leaves and a favourable climate for survival of the larvae. Preliminary results for on-going work on the biology of *G. postica* larvae on different host plants in Imba show that pupae that developed from silkworms reared on *A. elatior* were significantly larger in size and weight than those raised on *A. nilotica* or *A. tortilis* (Fening *et al.* unpublished). *Acacia tortilis* was one of the most preferred hosts for larval development and the most abundant host species in the two forests. Thus, it must be given priority in conservation efforts, such as raising and planting this *Acacia* species in buffer zones of these forests.

Wilson *et al.* (1996) identified attributes of biodiversity that can be assessed at each level of ecological organisation. At the ecosystem level, richness, evenness and diversity of species, guilds and communities are important. At the species level, abundance, density and biomass of each species population may be of interest. This study has established that the relative densities of host species differed between the two forests examined. This might be the result of a combination of many factors, including human disturbance (Riswan and Hartanti 1995). For instance, local residents living adjacent to these forests used to cut these *Acacia* species for charcoal, and the intensity of tree cutting might vary from one forest to another. This may partly explain the unequal evenness in the host plant species diversity. The high evenness of the host species in Imba might explain why the larval and cocoon abundance was generally higher in Imba than in Mumoni.

As observed in the field, the *Acacia* species were predominantly found in farmlands, buffer zones and on the lower slopes of both hilly forests. Abeele *et al.* (2005) made a similar observation in the Mumoni hills, and concluded that *A. tortilis* and *A. mellifera* were among the main species of woody plants found on the lower slopes, but were absent on the upper elevations of the hills. Thus sustainable utilisation, monitoring and conservation efforts for the *Acacia* species utilised by *G. postica* must be focused within these areas, especially the buffer zones of these two forests, where most of the *Acacia* are located and experience more disturbance from the adjacent forest human communities due to their proximity and accessibility.

G. postica host plant characteristics

The measured growth characteristics of the host plants of *G. postica*, such as tree height, canopy size, diameter and number of branches, will now serve as baseline data to assess any change in the *Acacia* species composition within the same locations over time. This baseline data is crucial for monitoring (Wilson *et al.* 1996; Gaines *et al.* 1999) and making management plans for sustainable utilisation of the silkmoths, their host plants and biodiversity as a whole.

The finding that the sampled trees are relatively young to middle-aged suggests that most have developed as secondary vegetation, following

earlier encroachment and deforestation by people. The intervention by CIP, the Kenya Forest Service and Mwingi District Livestock Production Office in training communities adjacent to these two forests in beekeeping and wild silk farming on these *Acacia* species as an income-generation activity and for forest conservation has probably contributed to the regeneration of these *Acacia* species, which were previously over-exploited for charcoal (Abeele *et al.* 2005; Raina *et al.* 2007). These interventions through participatory forest management (PFM) are providing economic incentives to communities adjacent to both forests, will enhance forest conservation and are making some impact but will require constant monitoring. (Salehe 2005; Kioko *et al.* 2007).

A focus group discussion with farmers in the study area revealed rapid deterioration of the forests that were previously dominated by *Acacia* species. Burning of charcoal has now been drastically reduced and limited to domestic use, especially in the groups involved in beekeeping and wild silk farming. This was achieved by explaining to local people that preserving the *Acacia* species for their bees for foraging and also for raising the silkworms will provide more income than charcoal.

CONCLUSION

The initial phase in biodiversity surveys involves estimating diversity at one point in time and at one location. The second phase is estimating diversity at the same location at more than one time point in order to draw inferences on change (Wilson *et al.* 1996; Gaines *et al.* 1999). The present study provides baseline information necessary for future monitoring of *G. postica* population dynamics and host plant distribution at several spatial and temporal scales in the Imba and Mumoni forests of Mwingi. Such information will be used in the development of sound sustainable management plans aimed at conserving the wild silkmoth and its host species in these woodlands.

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