

Semi-captive rearing of the African wild silkmoth *Gonometa postica* (Lepidoptera: Lasiocampidae) on an indigenous and a non-indigenous host plant in Kenya

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Abstract. The life cycle of the African wild silkmoth *Gonometa postica* Walker was studied between September 2000 and September 2001 in the Uasin Gishu District of western Kenya with *Acacia mearnsii* de Wild and *Acacia hockii* de Wild as host plants. The initial population of *G. postica* was set up from healthy live pupae in cocoons collected from host plants in the study area. Oviposition was carried out in net sleeves and small plastic cages. Moth emergence and oviposition were bimodal, occurring between September and October 2000 and between March and April 2001, respectively. Larvae were reared in semi-captivity by using net sleeves on the branches of the two host plants. Larvae passed through six developmental instars. The pupal stage lasted from December to February during the short rains and from June to September during the long rains. Moth fecundity in the net sleeves was higher than that of those kept in plastic cages and fewer eggs hatched in the plastic cages compared with the net sleeves. Larvae reared on *A. mearnsii* had a shorter developmental period compared with those reared on *A. hockii*. Male larvae spun cocoons earlier than females but moths of both sexes emerged simultaneously. Sexual dimorphism was exhibited in both pupal and adult stages, females being larger and heavier than males. The importance of the semi-captive rearing technique for sustainable utilization of wild silkmoths for mass production of cocoons is discussed.

Key words: African wild silkmoth, *Gonometa postica*, semi-captive rearing, life cycle, *Acacia hockii*, *Acacia mearnsii*

Introduction

The larvae of the African wild silkmoth *Gonometa postica* Walker (Lepidoptera: Lasiocampidae) feed mainly on African *Acacia* and *Brachystegia* spp. (both Fabaceae) (Hartland-Rowe, 1992; Kioko *et al.*, 2000; Veldtman *et al.*, 2002). In 24 h, the silkworm larvae spin silken cocoons in which they pupate.

In Kenya, *G. postica* has been recorded in Kamaguti in Uasin Gishu District, Nguni in the Mwingi District, and in Wote and Sultan Hamud in the Makueni District (Fig. 1). The distribution of *G. postica* in other parts of East Africa has not been documented although older records indicate that *Gonometa* spp. exist in the region (Okelo, 1972; Kioko *et al.*, 2000; Raina, 2000).

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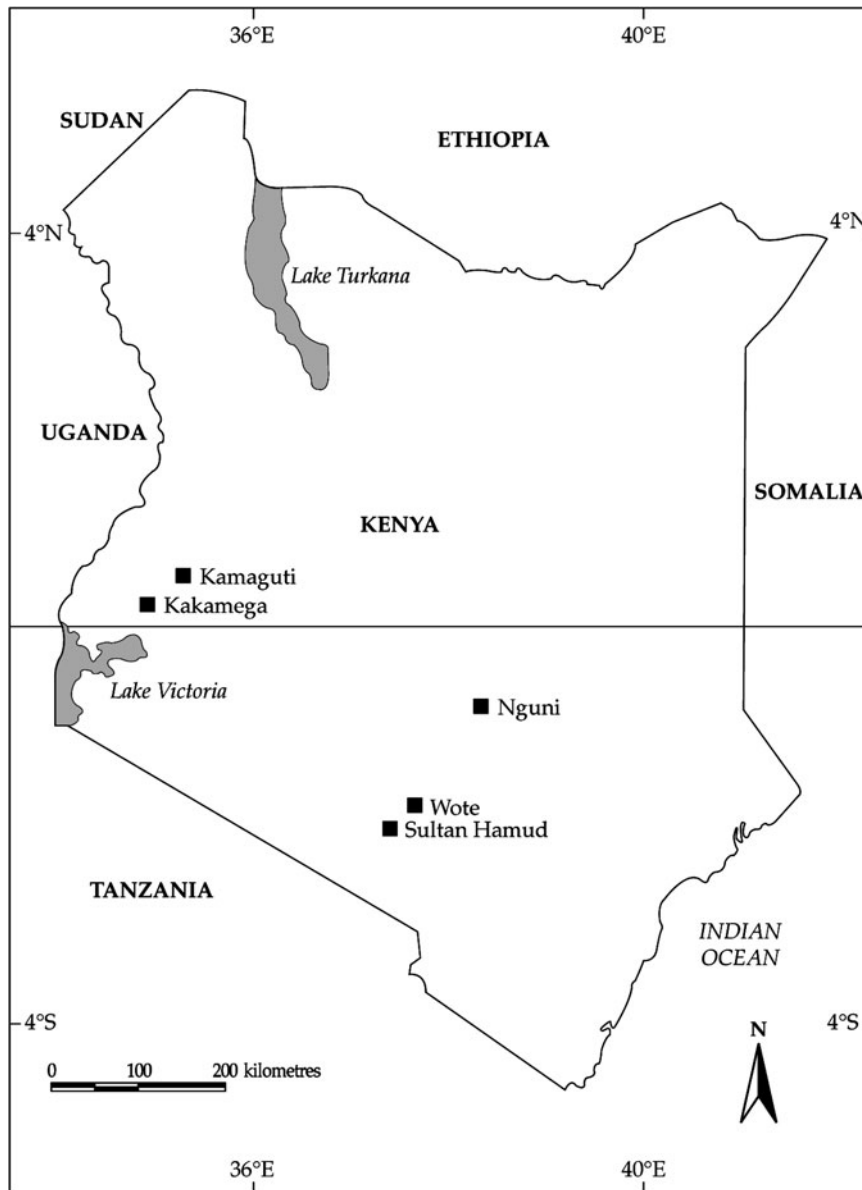


Fig. 1. Sites in Kenya where *Gonometa postica* was surveyed (Source: Kioko *et al.*, 2000)

In Nguni, *G. postica* has been reported to have two generations in a year. The first generation occurs between the months of March and September, while the second generation begins in October and ends in March (Kioko *et al.*, 2000; Kioko *et al.*, 2007). *Gonometa postica* has two generations per year in southern Africa, one with and another without diapause (Hartland-Rowe, 1992; Veldtman *et al.*, 2004). In East Africa, *G. podocarpi* Aurivillius was noted to have two distinct generations in a year and was observed as a defoliator of conifers and many dicotyledons (Okelo, 1972). Having two generations in a year is of advantage to farmers since it allows them to have two harvests of cocoons per year.

Gonometa postica lays eggs on various substrates and thus possesses a potential for wild silk production. Very little is known about the behaviour, abundance and distribution of *Gonometa* spp. (Chikwenhere, 1992; Hartland-Rowe, 1992; Veldtman *et al.*, 2007). Current utilization strategies of *G. postica* and *Gonometa rufobrunnea* Aurivillius in southern Africa consist solely of harvesting empty pupal cocoons from natural populations (Veldtman *et al.*, 2002; Veldtman, 2004; Veldtman *et al.*, 2007). Generally, *Gonometa* spp. are difficult to rear artificially. Previous attempts to rear *G. rufobrunnea* in captivity were unsuccessful (Hartland-Rowe, 1992). Studies in the Mwingi District of eastern Kenya showed that

semi-captivity rearing of *Gonometa* spp. is possible through the use of net sleeve cages on tree branches (Raina, 2000). The use of net sleeves greatly reduces losses due to parasitism and predation as they act as mechanical barriers to natural enemies of the moths (Kioko, 1998; Raina, 2000). Protecting especially young larvae with net sleeves and releasing them at their final instar has the potential to increase survival chances and to build up sustainable populations in the field, which can be utilized for mass production of cocoons.

The objective of this study was to initiate wild silkworm rearing techniques, which will reduce silkworm losses due to natural enemies and thus increase their productivity. In the indigenous forests of East Africa, the biodiversity of wild silkmoths is diminishing along with their habitats (Raina, 2004). Hence, preserving and utilizing these silkmoths for the production of silk fibres using semi-captive rearing strategies will generate income for farmers, as well as conserve threatened natural forests.

Materials and methods

Study site

The developmental cycle of *G. postica* was studied in the vicinity of Kamaguti (0°55'N, 35°37'E, see Fig. 1), in the Uasin Gishu District of western Kenya between September 2000 and September 2001. The area had been selected following a previous survey on diversity of silkmoths in which *Acacia mearnsii* de Wild and *A. hockii* de Wild were found to be the main host plants of *G. postica* (Kioko *et al.*, 2000, Fig. 1). The exotic *A. mearnsii* was previously introduced in the region to harness tannin and its invasiveness in the District has been kept under control by human settlements, clearing of land for agricultural purposes and its use as source of fuel and building materials.

Gonometa postica initial population stock

The initial population of *G. postica* was set up from healthy pupae in cocoons collected from host plants in the study area. The cocoons were enclosed in 2 × 2 × 2 m net sleeve cages for the moths to emerge. Enclosed in each cage was a naturally growing short-trimmed *A. mearnsii* tree to provide a point of attachment for the emerging moths. The cocoons were attached with strings to the tree branches for the moths to emerge freely.

Oviposition and incubation period

Freshly emerged female and male moths were isolated in pairs from the breeding stock and placed in net sleeves or small plastic cages. The small plastic

cages, measuring 10 × 9 × 5 cm, were made of hardened polythene with 2.5 × 0.2 cm perforations. The net sleeves measured 58 × 88 × 125 cm with mesh of 0.1 cm diameter. The net sleeves were tied onto a branch of a mature *A. mearnsii* tree with leaves before placing the paired moths inside for mating and oviposition. Paired moths were also placed in the plastic cages and transferred into a house to study egg laying and egg incubation period in an indoor set-up. Thirty-five paired moths were used in each set-up. A hydrothermograph was kept in the house and another one near the net sleeves to record humidity and temperature continuously on a daily basis. The average of the highest and lowest peaks of the daily humidity and temperature was calculated as the mean in each set-up. Eggs laid were marked daily to determine the incubation period in both experimental set-ups. The number of viable eggs produced by a female moth was defined as the fertility, while fecundity was a measure of the total egg production, the latter comprising of the number of eggs deposited by the live moth plus the mature eggs present in the oviduct after the death of the female (Klomp, 1966; Southwood, 1968).

Larval developmental period

The *G. postica* larvae hatching from the net sleeves or plastic cages were transferred to rearing net sleeves tied onto branches with fresh leaves of *A. mearnsii* or *A. hockii* trees. The net sleeves had a maximum holding capacity of up to 50 silkworms at their final instar. The larvae were reared on those food plants till they spun cocoons. The period between the hatching and the spinning date was recorded as the larval period. Each treatment (host plants) was replicated 10 times with 10 silkworms per net sleeve.

The larval period on the two food plants was determined and compared to identify the food plant that could be recommended for wild silk cocoon production in the study area. The number of instars was determined by observing larval exuviae and head capsule cast-offs after each moult. The number was further confirmed by measuring the length and width of head capsules under a stereomicroscope with an eyepiece calibrated with a stage micrometer to show any gradual increment.

Pupal developmental period

Larvae formed silken cocoons at the end of the larval period. The newly formed (about 24 h old) cocoons were marked daily. The harvesting was done seven days after spinning to allow the silken cocoons to become dry and the larvae to transform into pupae. After harvesting, the cocoons were kept under field conditions in an enclosed net sleeve until moth emergence. The time between spinning and emerging

date was recorded as the pupal developmental period. A sample size of 200 cocoons was randomly selected for males and females to determine sexual dimorphism by weight, length and width. An electronic balance (Mettler PJ360, Switzerland) was used to weigh each cocoon mass. Cocoon size (length and width) and moth wing length were measured by vernier calipers (0–15 cm, 0–6 in).

Statistical analysis

The data were analysed using analysis of variance (PROC GLM, SAS Institute, 2000) and in case of significant *F*-values, followed by independent *t*-tests at $\alpha = 0.05$.

Results

Egg incubation period

The moths' oviposition was bimodal. The eggs were laid randomly in clusters in the small plastic cages and net sleeves on the host plant branches and leaves. The first *G. postica* oviposition season was observed between October and November and the second one between March and April (Table 1). In both the seasons, the incubation period was significantly shorter in the plastic cages than in the net sleeves. The incubation period between seasons did not differ significantly in the net sleeves but in the plastic cages, with a significantly shorter duration in the first compared with the second season (Table 1).

There was no significant difference in temperature between the two experimental set-ups but between the seasons, the first season having a higher mean temperature than the second one. Mean relative humidity varied significantly between the two set-ups in both seasons, with the highest being recorded in the net sleeves during the second season (Table 1).

Larval development

The *G. postica* larvae fed normally on both *A. hockii* and *A. mearnsii*. In total, six instars were observed.

The head capsule (cast after each moult) measurement revealed a gradual increment from the first to the sixth instar (Fig. 2).

Gonometa postica larvae were gregarious up to the end of the third instar. They showed colour variations between the first and the second instar. The first instar was black with a single white stripe across the thorax. After the first moult to the spinning stage, larvae acquired a mixture of white and black hairs with much longer hairs on the lateral sides. Larvae were also equipped with sharp black and brown pointed setae that snapped off when they pierced the human skin, causing irritation. With $99.15 (\pm 4.95 \text{ SE})$ and $72.75 (\pm 1.83)$ days, respectively, mean larval developmental period significantly ($P < 0.05$) differed between *A. hockii* and *A. mearnsii*.

Pupal development

In the pupal stage, the *G. postica* pupa is enclosed in a tough light brown silk cocoon that is compact and has setae on the outer surface that can also cause urticaria in humans. Cocoon length and weight varied between the sexes. Mean weight and length of female and male cocoons were significantly different between the sexes (Table 2). The mean pupal period was significantly different between the two sexes during the two seasons, with a longer second than first pupal period in both sexes (i.e. first pupal period (December 2000 to February 2001): Males 52.79 ± 1.89 days vs females 48.43 ± 0.99 days; second pupal period (June to September 2001): 65.15 ± 6.97 and 72.42 ± 4.49 days for females and males, respectively). Although the males started spinning a few days earlier than the females, all moths emerged simultaneously.

Adult period

Gonometa postica showed a very distinct sexual dimorphism, with larger females than males. With $8.93 \text{ cm} (\pm 0.32 \text{ SE})$, females had significantly longer

Table 1. Egg incubation period of *Gonometa postica* during October–November 2000 (season 1) and the March–April 2001 (season 2) in Uasin Gishu district

Design	First season (Oct/Nov)			Second season (Mar/Apr)		
	Incubation period (days) (mean \pm SE)	Temperature ($^{\circ}\text{C}$) (mean \pm SE)	Relative humidity (%) (mean \pm SE)	Incubation period (days) (mean \pm SE)	Temperature ($^{\circ}\text{C}$) (mean \pm SE)	Relative humidity (%) (mean \pm SE)
Plastic cages	$13.65 \pm 0.28\text{aA}$	$23.33 \pm 0.51\text{aA}$	$64.82 \pm 2.7\text{aA}$	$15.03 \pm 0.42\text{aB}$	$21.92 \pm 0.76\text{aB}$	$64.97 \pm 4.03\text{aA}$
Net sleeves	$17.77 \pm 0.35\text{bA}$	$23.6 \pm 1.07\text{aA}$	$63.38 \pm 3.63\text{bA}$	$18.41 \pm 0.63\text{bA}$	$21.76 \pm 1.24\text{aB}$	$67.3 \pm 5.75\text{bB}$

Means followed by the same lower case letters in the same column and upper case letters in the same row are not significantly different (*t*-test $\alpha = 0.05$).

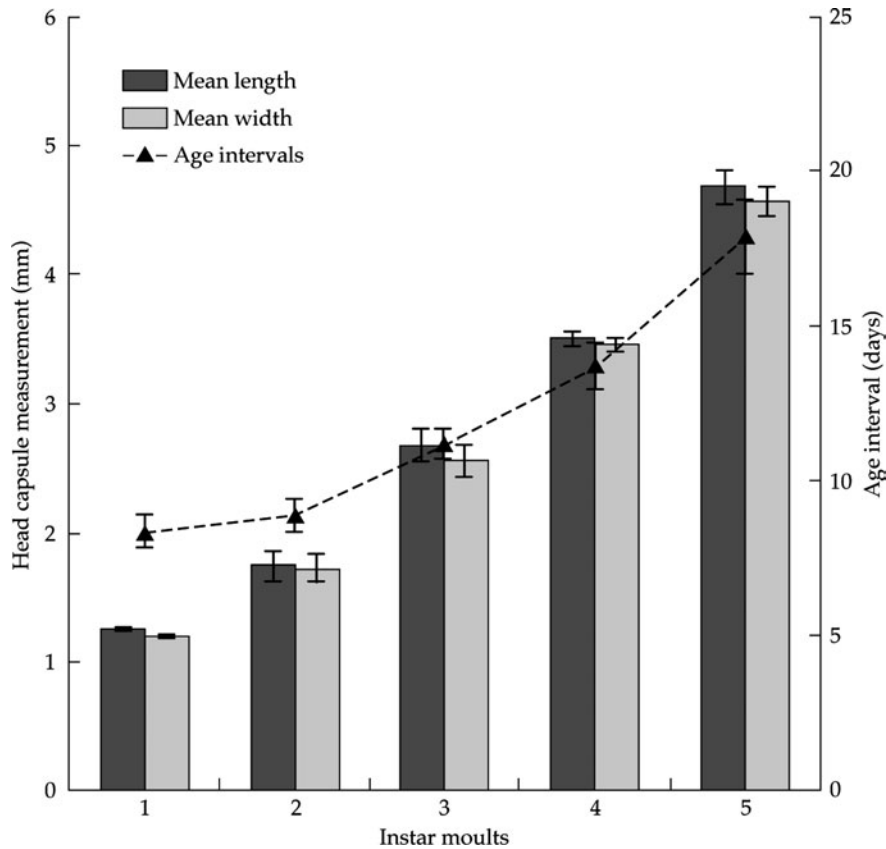


Fig. 2. Head capsules mean (SE) length and width (mm) of developing *Gonometta postica* larvae collected between instars after moulting during semi-captive rearing trials

mean wing length compared with 5.0 cm (± 0.21 SE) in males ($P < 0.05$).

Data on mean percentage fertility, infertility and fecundity for the first season are provided only from the net sleeve design (Table 3) because the first generation population was too low for testing both experimental set-ups. The moths in the net sleeves had higher fertility compared with those in the plastic cages in the second season. However, the fertility of the moths kept in the net sleeves was also much higher during the second season compared with the first season (Table 3).

Table 2. Mean weight, length and width of male and female cocoons of *Gonometta postica*

Variable	Males	Females
Weight	2.32 \pm 2.21a	5.75 \pm 0.26b
Length	3.42 \pm 0.09a	4.36 \pm 0.11b
Width	1.13 \pm 0.03a	1.53 \pm 0.05a

Means followed by the same letter in the same row are not significantly different (t -test $\alpha = 0.05$).

Discussion

Egg incubation period

Eggs laid and incubated in the net sleeve set-up took a longer period to hatch in comparison with those kept in the plastic cages, which could be attributed to temperature and humidity variations evidenced especially between the two seasons. It was noted that temperatures were higher during the first season, with shorter egg incubation period recorded in comparison with the second season. The recorded incubation period in the plastic cage set-up compares well with previous studies in the Mwingi District of eastern Kenya, which had shown *G. postica* eggs to have an incubation period of 11.3 \pm 0.1 days in an outdoor environment (Kioko, 1998; Kioko *et al.*, 2007). The highest percentage fertilization was recorded in the net sleeve set-up, probably due to the larger mating space in the net sleeves in comparison with the smaller-sized plastic cages. Our findings that *G. postica* moths have the ability to lay eggs in enclosed ventilated plastic cages and net sleeves corroborate results from earlier studies by Okelo (1972) and Kioko (1998)

Table 3. Mean fertility, infertility and fecundity of the female adult *Gonometa postica* moths in net sleeve and plastic cages in two seasons; October–November 2000 and March–April 2001

Design/Season	Mean fertility percentage	Mean infertility percentage	Mean fecundity percentage
Season 1: November–October 2000			
Net sleeves	52.43 ± 1.08A	47.57 ± 2.94A	319.34 ± 22.99A
Season 2: March–April 2001			
Net sleeves	80.59 ± 4.29aB	19.41 ± 0.87aB	338.86 ± 24.28aB
Plastic cages	48.35 ± 2.16b	51.65 ± 1.23b	293.65 ± 22.28b

Means followed by the same lower and upper case letters in the same column are not significantly different (*t*-test $\alpha = 0.05$).

who reported that *Gonometa* spp. in Kenya may not be host-specific with regard to substrates when ovipositing. This concurs with Hartland-Rowe (1992) who reported that *G. rufobrunnea* in northern Botswana does not usually lay eggs on its food plant *Colophospermum mopane* Kirk ex Berth (Fabaceae), but on thin grass stems or other herbage beneath bushes, although sometimes it chooses to lay on *C. mopane* leaves. This characteristic behaviour in African wild silkmoths can be exploited to enhance the laboratory egg production with the aim to reduce egg parasitism.

Larval development

The larvae reared on the indigenous *A. hockii* had a longer developmental period compared with those reared on the exotic *A. mearnsii*. Since the larva is the only feeding stage, this developmental difference could be due to the effect of host plant leaves, which was not covered in this study. In Kamaguti, *A. mearnsii* could be recommended for wild silk rearing because it was noted to maintain green leaves throughout the year unlike *A. hockii*. *Acacia mearnsii* is also popularly known as a source of nectar and pollen for bees, timber and tannin products; therefore, conserving the host plant for wild silkworm rearing would have additional benefits for both biodiversity conservation and the livelihoods of the communities in this already transformed area of Kenya.

The developmental period of the silkworm larvae at Kamaguti was longer in comparison with those reported in a previous study in the locality of Nguni, Mwingi District, eastern Kenya (2°12'S, 38°16'E) (Kioko, 1998). With 53.5 ± 6.2 days *G. postica* larvae have a shorter developmental period. This indicates that the prevailing climate of an area has an impact on the development of wild silkmoths. Thus, this study supports the hypothesis that climate conditions and not latitudinal position influence the size of cocoons in *Gonometa* spp. (Veldtman, 2004).

The entire larval stage had five moults, hence six instars. Observation of exuviae was the most

dependable method to determine instars, since it was possible to observe the various changes in a stadium very closely until ecdysis occurred. The head capsule measurements confirmed the six larval instars in *G. postica*. Ashiru (1988) recommended the direct observation of exuviae as the most reliable method to determine the number of larval instars in *Anaphhe venata* (Butler) (Lepidoptera: Notodontidae). Head capsule measurements are useful when the larval stage is not known, but such measurements might not be accurate as an instar determinant method when growth of larvae is not uniform (Fox *et al.*, 1972; Schmidt *et al.*, 1977; Ashiru, 1988).

Pupal development

There was a variation in the pupal periods during different seasons of the year. The longest pupal period occurred between June and September 2001, while the shortest was recorded between December 2000 and February 2001. Males start spinning earlier than females, but all moths emerge simultaneously during the breeding season. This explains why males seem to take a longer pupal period than the females in each of the two seasons. The longer pupal period coincides with the cooler months of June–July and the dry spell between August and mid-October in the study area in Kenya. In South Africa, *G. postica* undergoes pupation in early autumn (March to April) for a second generation, which undergoes diapause, with the existing pupae of the first generation emerging the following spring (Hartland-Rowe, 1992; Veldtman *et al.*, 2004).

There was variation within the sexes in the cocoon size. The sexual dimorphism exhibited in the pupal and adult stages allows accurate field identification and separation of the sexes during the breeding period. Previous studies in the Mwingi District of Kenya on *G. postica* reported significant differences in the size of male and female cocoons as well as in adult moths (Kioko *et al.*, 1999, 2000; Raina, 2000). Sexual dimorphism exhibited by *G. postica* cocoons with regard to weight and length

in this study concurs with the recent work by Veldtman *et al.* (2002) in South Africa. Veldtman *et al.* (2002) reported that cocoon length generally explained more of the variations in occupied cocoon mass than width, but together length and width explained 11–18% of the variation in mass than length alone.

Gonometa postica generations

Our study revealed two distinct generations of *G. postica* per year in the study area. The two generations coincide well with the onset of the long (March to July) and short (October to December) rainy seasons, allowing a synchronization between larval growth period and larval food availability. The dry season in East Africa occurs between January to mid-March and August to mid-October, during which we observed *G. postica* going into diapause. In the Mwingi District of eastern Kenya, Kioko *et al.* (2000) also observed two generations (with diapause) of *G. postica* per year. Yet in South Africa, Veldtman (2004) observed an intermediate generation of *G. postica* in mid-summer (December to January), with pupation occurring in early autumn (March to April). This suggests two generations of *G. postica* per year in South Africa, one with diapause and another one without it (Veldtman, 2004; Veldtman *et al.*, 2004). Sinha and Chaudhuri (1992) reported a close relationship between rain and the emergence phenology of the tasar silkmoth, *Antheraea mylitta* (Drury) (Lepidoptera: Saturniidae). The natural environment signals its developmental fate and regulates the whole mechanism by which partial synchrony is achieved. Furthermore, the appearance of suitable food for the establishment of young larvae on host plants with abundant leaves during the rainy season also provides optimum conditions for the silkmoths. From a production point of view, having two generations of *G. postica* per year is advantageous to farmers since this allows them to obtain two cocoon harvests a year and an increase in silk production (Raina, 2000).

Conclusions

This study illustrates for the first time that captive rearing of *G. postica* with the aim of supplying wild silk is a viable practice for sustainable utilization of this moth species. The fecundity observed for *G. postica* concurs well with fecundity for other species currently being utilized for wild silk production. For instance, in *A. paphia* (Moore), Nayak *et al.* (1994) reported 334.64 ± 20.51 as maximum egg production per silkmoth and 216.23 ± 12.67 as the lowest. Since in our study the highest fecundity was recorded in moths kept

in net sleeves, this would be ideal for mass production of eggs. The net sleeve method would also reduce egg loss due to parasitism. Raina (2000) reported 84% mortality of *G. postica* larvae due to parasitoids, predators and other factors, but the incidence of parasitism was reduced by 35 to 55% through the use of net sleeves. *Gonometa* spp. parasitoids and predators have been recorded in southern and in East Africa and parasitism remains one of the major challenges faced by wild silk production (Hartland-Rowe, 1992; Raina, 2000; Veldtman *et al.*, 2004; Kioko *et al.*, 2007). The successful use of net sleeve cages in the present study, both as an oviposition and rearing method for *G. postica* larvae, illustrates that they can be utilized as an effective wild silkmoth farming technique to reduce parasitism.

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References

- Ashiru M. O. (1988) Determination of the number of instars of the silk worm *Anaphe venata* Butler (Lepidoptera: Notodontidae). *Insect Science and Its Application* 9, 405–410.
- Chikwenhere G. P. (1992) Distribution and abundance of the African silkmoth (*Gonometa rufobrunnea*) in Matebeleland Province of Zimbabwe. *Zimbabwe Journal of Agricultural Research* 29, 133–137.
- Fox R. C., Anderson S. C., Garner S. C. and Walker A. L. (1972) Larval head capsules of the Nantucket pine moth. *Annals of the Entomological Society of America* 65, 513–514.
- Hartland-Rowe R. (1992) The biology of the wild silkmoth *Gonometa rufobrunnea* Aurivillius (Lasiocampidae) in north eastern Botswana, with some comments on its potential as a source of wild silk. *Botswana Notes and Records* 24, 123–133.
- Kioko E. N. (1998) Biodiversity of the wild silkmoths (Lepidoptera) and their potential for silk production in East Africa. PhD thesis, Kenyatta University, Nairobi.
- Kioko E. N., Raina S. K. and Mueke J. M. (1999) Conservation of the African wild silkmoths for economic incentives to rural communities of the

- Kakamega forest in Kenya. *International Journal of Wild Silkmooths and Silk* 4, 1–5.
- Kioko E. N., Raina S. K. and Mueke J. M. (2000) Survey on diversity of wild silkmooth species in East Africa. *East Africa Journal of Science* 2, 1–6.
- Kioko E. N., Raina S. K., Fening K. O., Ngoka B. M. and Mbahin N. (2007) Harnessing wild silkmooth biodiversity for environmental conservation and income generation, pp. 151–154. In *Development of Sericulture and Apiculture Products for the Poor in Fragile Ecosystems Using the Value Chain Approach* (Edited by S. K. Raina, E. M. Muli, E. K. Nguku and E. Kioko). Proceedings of the Trainers' Course and IVth International Workshop on the Conservation and Utilization of Commercial Insects, 14 November to 8 December 2006. ISBN 9290641916. ICIPE Science Press, Nairobi.
- Klomp H. (1966) The dynamics of the pine looper, *Bupalus piniarius* L. *Advances in Ecological Research* 3, 207–307.
- Nayak B. K., Dash A. K., Mishra C. S. K., Nayak U. K., Dash M. C. and Prabhakar D. R. (1994) Innovation of technology for commercial rearing of Indian wild tasar silk insect, godamodal ecorace of *Antheraea paphia* Linn. (Lepidoptera: Saturniidae). *International Journal of Wild Silkmooths and Silk* 1, 75–79.
- Okelo O. (1972) Life history studies of *Gonometa podocarp* Aurivillius (Lepidoptera: Lasiocampidae) in East Africa. *Ohio Journal of Science* 72, 301–303.
- Raina S. K. (2000) *The Economics of Apiculture and Sericulture Modules for Income Generation in Africa*. IBRA Press, Cardiff. 57 pp.
- Raina S. K. (2004) *Commercial Insects: A Practical Guide for Raising and Utilising Silkmooths and Honey Bees in Africa*. Volumes 1–3. Three books published in 7 languages (English, French, Kiswahili, Spanish, Luganda, Arabic and Amharic). Raina S.K. (Compiler); Overholt K. (Ed., English); Jones H.R. (Overall Ed., International Bee Research Association, UK). (173 pp.). ISBN 0860982467 English, French, Swahili; (183 pp.) ISBN 086098241 English, Spanish, Lugandan; (192 pp.) ISBN 0860982475 English, Arabic, Amharic. ICIPE Science Press, Nairobi.
- Schmidt F. H., Campbell R. K. and Trotter S. J. Jr (1977) Errors in determining instar number through head capsule measurements of a Lepidoptera – a laboratory study and critique. *Annals of the Entomological Society of America* 24, 451–466.
- Sinha A. K. and Chaudhuri A. (1992) Factors influencing the phenology of different broods of tropical tasar silk moth, *Antheraea mylitta* Drury (Lepidoptera: Saturniidae) in relation to its emergence and post-emergence. *Environment and Ecology* 10, 952–958.
- Southwood T. R. E. (1968) *Ecological Methods with Particular Reference to the Study of Insect Populations*. Methuen, London. 391 pp.
- SAS Institute Inc. (2000) *SAS Users Guide*. Version 6. Statistical Analysis System Institute Inc., Cary, North Carolina.
- Veldtman R. (2004) The ecology of southern African wild silkmooths (*Gonometa* species, Lepidoptera: Lasiocampidae): consequences for their sustainable use. PhD dissertation, University of Pretoria, Pretoria.
- Veldtman R., McGeoch M. A. and Scholtz C. H. (2002) Variability in pupal size in southern African wild silkmooths: implications for sustainable harvesting. *African Entomology* 10, 127–136.
- Veldtman R., McGeoch M. A. and Scholtz C. H. (2004) Parasitoids of southern Africa: wild silkmooths (Lepidoptera). *African Entomology* 12, 117–122.
- Veldtman R., McGeoch M. A. and Scholtz C. H. (2007) Fine-scale abundance and distribution of wild silkmooth pupae. *Bulletin of Entomological Research* 97, 15–27.