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Effect of Parasitoids' Exit and Predators' Ingress Holes on Silk Yield of the African Wild Silkmoth, *Gonometa Postica* Walker (Lepidoptera: Lasiocampidae)

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Wild silkmoths can be utilised sustainably in the production of silk as an income for resource-poor rural communities. However, attack by parasitoids and predators affect the quality of cocoons and quantity of raw silk produced. A laboratory experiment was undertaken to quantify the effect of parasitoids' (dipteran and hymenopteran) and predators' (ants) exit and ingress holes, respectively, on silk production. The mean number of shells required to produce fifty grams of raw silk was highest with cocoons parasitised by a dipteran and lowest with unattacked cocoons (but with moths already emerged). Degumming loss was highest in parasitised and lowest in unttacked cocoons, but both were not different from cocoons predated by ants. Shell weight was highest in unattacked cocoons, followed by hymenopteran-parasitised and predated cocoons, with the dipteran parasitized ones being the least. Single cocoon weight was greater in hymenopteran-parasitised and predated cocoons than the dipteran-parasitised and unattacked cocoons. Shell ratio or raw silk, floss and yarn weights were higher in unattacked than parasitised and predated cocoons. The total loss in raw silk attributable to attack by parasitoids and predators ranged between 17.4~31.2%. The results offer baseline information for assessment of economic losses in wild silk farming due to parasitoids and predators in the field.

Key words: Wild silkmoth, *Gonometa postica*, Parasitoids, Predators, Exit and ingress holes, Shell ratio, Raw silk yield.

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Introduction

Wild silkmoth farming can provide an alternative income to poor farmers in Africa and elsewhere in the world through the sales of silk cocoons that can be processed into yarns for the production of fabrics (Cumming, 2007; Kioko *et al*., 2000; Peigler, 1993; Raina *et al*., 2007; Zethner *et al*., 2009). The wild silkmoth, *Gonometa postica* Walker (Lepidoptera: Lasiocampidae) is known to produce silk of high quality comparable to that of the domesticated silkmoth *Bombyx mori* L. (Lepidoptera: Bombycidae) (Akai *et al*., 1997; Nel, 2007).

Among the constraints associated with wild silkmoth farming are attack by parasitoids, predators, birds, and diseases (Hartland-Rowe, 1992; Kioko, 1998; Ngoka, 2003). For example, exit and ingress holes produced in *G. postica* cocoons by parasitoids and predators, respectively, are reported to affect the quality of cocoons and raw silk yield (Fening *et al*., 2009; Veldtman *et al*., 2002) but to which extent is not known. Thus, the objective of this study was to assess the impact of dipteran and hymenopteran parasitoids, and of predatory ants on raw silk yield. This information will be useful for assessment of economic losses in silk yield due to parasitoids and predators in the field.

Materials and methods

Experimental site

The experiment was carried out at the International Centre

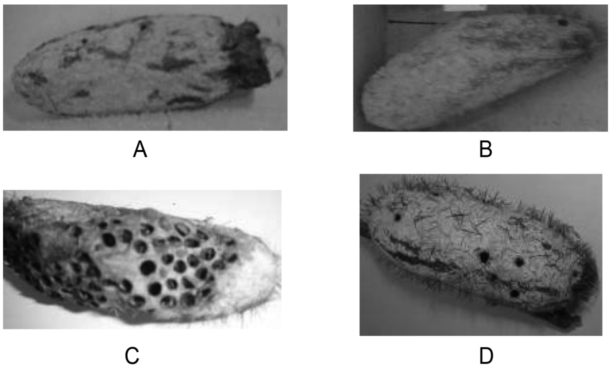

Fig. 1. Different types of *G. postica* female cocoons utilised for the silk loss assessment. A) Unattacked *G. postica* cocoon. B) Hymenopteran-parasitised *G. postica* cocoon. C) Dipteran parasitized *G. postica* cocoon. D) Ant predated cocoon.

of Insect Physiology and Ecology (ICIPE), Nairobi, Kenya from November to December, 2008. *Gonometa postica* cocoons used in this experiment were collected from Imba and Mumoni woodlands during the long rainy season of April to May 2007.

Post harvest processing of cocoons

The cocoons of *G. postica* collected from both woodlands were mixed and sorted according to sex and whether they were parasitized, predated upon, or unattacked (i.e. unattacked by parasitoids or predators but moth had emerged) (Fig. 1). As most of the parasitised cocoons were females, only female cocoons were used in this experiment. The parasitised cocoons were further sorted according to the order of the parasitoid, that had attacked the cocoon i.e., dipterans (mainly *Palexorista* sp.) and hymenopteran [i.e. *Goryphus* sp. *Eurytoma tolidepepra* Delvare, *Brachymeria* nr. *Albicrus* Klug, and *Pimpla* (*Apechtis*) sp.]; earlier work by Fening *et al.* (2009) identified them as the predominant larval-pupal parasitoids.

The exit holes left in *G. postica* cocoons are characteristic to each species of parasitoid, thus they were used for their identification (Fening, 2008; Veldtman *et al.*, 2004). This was further verified with the specimen that emerged in the laboratory. The hymenopteran parasitoids were identified by Gerard Delvare of the Agricultural Research Centre for International Development (CIRAD), France. The identification of the dipteran parasitoid was carried out at the Biosystematics Unit of ICIPE.

All cocoons were cut and cleaned of any pupal remains using a scalpel to obtain the shell weight. Prior to that, the cocoon weight of individual cocoons were measured with an electronic balance for the estimation of the shell ratio or raw silk which is defined as the ratio of the average shell weight to the average single cocoon weight and expressed as a percentage (Vishuprasad, 2004). The cocoon weight is the average weight of a cocoon, whereas the shell (cocoon minus pupa) weight is the average of the single shell weight.

After cutting and cleaning, fifty grams of each cocoons lot; unattacked, parasitized by hymenopterans, parasitized by dipterans and predated upon were separately put into a boiling cage ($14 \times 14 \times 14$ cm) made of wire (mesh size, 2 mm) and together boiled in a solution of 55 g of sodium carbonate in 11 L distilled water in a covered 15 L pan for 1 hour. The concentration of the sodium carbonate (5 g per Litre) was according to the procedures by Arami *et al.* (2007) and Rajkhowa *et al.* (2000). The material-to-liquor ratio, MLR [cocoons weight (150 g): volume of treatment solution (11 L)] for each boiling was 1 : 73. The total volume of solvent was 11L for each boiling to ensure that all the cages were fully submerged. Each treatment was replicated four times.

After boiling for the required time, cocoons were removed from each cage separately and rinsed in distilled water to remove the degumming solution. Thereafter, they were submerged in a solution of 50 ml of star soft detergent in 1 L of distilled water for 3 minutes to soften the threads. Each treatment of degummed cocoons was suspended in the shade for the water to drift off. They were dried in an electronic oven (Memmert 854 Schwabach, Germany) at 95°C (Arami *et al.*, 2007) overnight till a constant weight was obtained in the morning. The dried degummed cocoons were reweighed with an electronic balance for estimation of the percentage sericin loss after degumming (Arami *et al.*, 2007).

After drying, the degummed cocoons were deflossed by hand. The floss was spun into yarns using a locally manufactured spinning wheel (diameter 50 cm) controlled by hand and powered by foot paddling. The weight of each floss and spun yarn was taken with an electronic balance. The floss was kept in tight polythene bags to prevent absorption of moisture. The weight of each floss was confirmed with the original floss weight before spinning. Where there was a gain in weight, the sample was dried to the original weight in an electronic oven before spinning.

Data analysis

Data on cocoon counts, single cocoon weight, shell weight, shell ratio and degumming loss percentage, floss and spun yarn weights were analysed using the analysis of variance (ANOVA) procedure of SAS. The significance level was set at $P < 0.05$. *A post-hoc* mean separation was conducted using the Student Newman-Keul test (SAS Institute Inc., 2005). Data on counts and percentages were log (x+1) and arcsine square root transformed, respectively, before analysis. Back-transformed means are presented.

Table 1. Quality parameters of shells boiled with sodium carbonate for an hour for different treatments of female *G. postica* cocoons means within a row followed by the same letter (s) are not significantly different. ($P < 0.05$, SNK).

Quality parameter	Type of shell				df, *F*, *P*
	Unattacked	Dipteran parasitised[1)]	Hymenopteran parasitised[2)]	Predated[3)]	
No. of shells per 50 g	36.33±0.88C	53.00±2.89A	44.00±0.58B	46.33±1.76B	3, 18.19, 0.0006
Single cocoon weight (g)	1.85±0.16B	2.06±0.03B	2.68±0.06A	2.65±0.13A	3, 15.09, 0.0012
Shell weight (g)	1.38±0.03A	0.95±0.05C	1.14±0.01B	1.08±0.04B	3, 23.23, 0.0003
Shell ratio (%)	75.35±4.90A	46.13±2.31B	42.45±0.93B	41.05±2.11B	3, 22.48, 0.0003
Degumming loss (%)	36.93±4.00B	46.89±0.23A	48.33±0.36A	43.36±0.75AB	3, 6.27, 0.0170
Floss weight (g)	23.29±1.04A	19.22±0.16B	17.62±0.61B	18.57±0.75B	3, 12.19, 0.0024
Spun yarn weight (g)	20.75±0.41A	15.45±0.72B	15.20±0.54B	14.32±0.87B	3, 19.65, 0.0005

[1)] *Palexorista* sp., [2)] *Goryphus* sp. *E. tolidepepra*, *Brachymeria* nr. *albicrus*, *Pimpla* (*Apechtis*) sp., [3)] formicid ants.

Results and discussion

The mean number of shells required to make fifty grams of raw silk was significantly higher with cocoons parasitised by dipterans, followed by hymenopterans, ant-predated, and unattacked cocoons (Table 1). The shell weight was highest in unattacked cocoons, followed by hymenopteran-parasitised and predated cocoons, with the dipteran parasitized cocoons being the least. Single cocoon weight was greater in hymenopteran-parasitised and predated cocoons than the dipteran-parasitised and unattacked cocoons.

The degumming loss was higher in parasitized than unattacked cocoons, but both were not significantly different from predated cocoons (Table 1). The higher degumming loss in parasitized *G. postica* cocoons compared to unattacked cocoons suggests that exit holes left in the cocoons offered a larger surface area for the boiling liquid to act upon, thereby removing more sericin than in the unattacked cocoons. Unattacked cocoons produced significantly higher shell ratio, floss and yarn weights than the parasitised and predated cocoons. Thus, parasitized and predated cocoons generated more waste in terms of losses due to degumming, deflossing and spinning, and produced less amount of yarn.

Cocoon quality contributes to about 80% of the raw silk quality (Shimazaki, 1964; Vishuprasad, 2004). Several factors contribute to the quality and yield of cocoons, among them the weight of cocoons, the integrity of cocoons (unattacked or attacked by natural enemies, or exit holes created by moths), degumming loss and the age of cocoons (Anon, 1996; Fening, 2008; Sonwalkar, 1993; Veldtman *et al*., 2002). Furthermore, the shell weight and shell ratio are considered as important attributes determining approximately the amount of obtainable raw silk (Gaviria *et al*., 2006; Vishuprasad, 2004). The shell ratio offers an estimation of the amount of raw silk present in each cocoon. Therefore, the higher the shell ratio, the better is the quality of the cocoon. In the current study, the unattacked cocoons were of a much better quality than the parasitised and predated cocoons, and the total loss in raw silk attributable to attack by parasitoids and predators ranged between 17.4~31.2%.

As parasitism and predation affect quality and quantity of silk produced, the semi-captive technique (Mbahin *et al*., 2010; Ngoka *et al*., 2008), which allows rearing of the larvae within a protective net sleeve attached to the host plant should be considered in order to maximize quantity and quality of silk produced. This study offers baseline information necessary for assessing partly the economic loss due to attack of *G. postica* cocoons by parasitoids and predators in the field.

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