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Effectiveness of a biological control agent *Palexorista gilvoides* in controlling *Gonometa podorcarpi* in conifer plantations of Uganda

P. Kiwuso[1], R. Tumuhimbise[3], S. Sempala[1], R. Kakayi[1], R. Gwokyalya[1], V. Namuyanja[1], D. Mukwasibwe[1] and W. Mafabi[2]

[1]National Forestry Resources Research Institute P. O. Box 1752, Kampala, Uganda
[2]National Forest Authority P. O. Box 70863, Kampala, Uganda
[3]National Agricultural Research Laboratories (NARL), Kawanda, Uganda

Author for correspondence: Kiwusopeter@yahoo.com

Abstract

Widespread defoliation of plantation forests by insect pests causes economic losses worldwide. Successful pest outbreak management requires knowledge of effective pest management options. Currently, such knowledge is inadequate for *Gonometa podocarpi* an indigenous pest that has devastated conifer plantations in Uganda since the 1960s. The pest is a serious defoliator of conifers in East Africa and was first described from Mt. Elgon Kenya, where its larvae were defoliating indigenous conifer; *Podocarpus* spp. The pest has since adapted to feeding on exotic conifers. There have been several serious resurgences of this pest in Uganda, the latest being 2011 and 2012. Studies carried out during the peak of these outbreaks in Muko, Kiriima and Mafuga Central Forest reserves in South Western Uganda established *G.podocarpi* infestations in Kiriima and Mafuga but none in Muko. The studies also identified a tachnid fly, *Palexorista gilvoides* as a potential biological control agent for *G. podocarpi*. Field and laboratory studies further established that *P. gilvoides* is a larval parasitoid of *G.podocarpi,* with parasitism levels of 43.0 and 62.0% in the field and laboratory respectively. These levels of parasitism are considered high enough to control the pest. However, causes of this pest resurgence need further investigations.

Key words: **Defoliator, parasitoid, parasitism, pest outbreak, resurgence**

Introduction

Forest plantations are important to Ugandans as the natural forests can no longer meet the demands for the different wood products and services. At present, Uganda has about 25,000 ha of dedicated forest plantations SPGS (2009) planted majorly with exotic tree species such as pines and cypress. A typical scenario in the use of exotics in forest plantation programmes is that they enjoy a pest free "honeymoon" for a period of time. During this period, management practices often evolve that make the plantations especially susceptible to pests and diseases. This is

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coupled by the fact that most exotic tree species are planted as monocultures resulting in an unlimited supply of host material for potentially damaging organisms. This makes them appear more like agro-ecosystems, increasing their susceptibility to pests and diseases such as *Gonometa podocarpi.*

The genus *Gonometa* is widespread in Africa, but G. *podocarpi* seems to be confined to East Africa (Austara, 1970). It was first described by Aurivillius (1925) from Mt .Elgon Kenya where the larvae were defoliating the indigenous conifer *Podocarpus* spp. This indigenous insect pest has since adapted to feeding on exotic conifers, the first report being from *Cupressus* sp in Uganda and Kenya in 1950 (Austara, 1970). There have been several serious resurgences of this pest in Uganda. The first outbreak occurred in 1965 in Muko conifer plantation in Kabale district where 40 acres of nine year *Pinus patula* were completely defoliated (Brown, 1965). The second outbreak occurred in 1969 and 16 acres were completely defoliated by the pest while another 16 acres suffered 50-70 % defoliation (Austara, 1970). In 2011, the outbreaks of *G. podocarpi* completely defoliated 16 ha of Pines in Kiirima Central Forest reserve (CFR) in Kabale district, South Western Uganda while the 2012 outbreak defoliated 8ha (Kiwuso and Tumuhimbise, 2012)

Survey results of earlier outbreaks revealed some diseases that caused mortality to *G. podocarpi*. Harrap et al. (1966) isolated a small ribonucleic acid virus from diseased *G. podocarpi* collected in *Pinus patula* in Kabale district and Longworth *et al*. (1973) determined its properties. Norman Moore *et al*. (1981) isolated a nuclear polyhedrosis virus (NPC; Baculoviridae) and a small ribonucleic acid virus from Kenyan G. *podocarpi.* Okelo (1972) reported that some parasites belonging to order Hymenoptera and Diptera attack different stages of G. *podocarpi* and that these in addition to some viral diseases offer some hope for biological control of the pest.

Following the 2011 and 2012 *G. podocarpi* outbreaks in Kiirima and the severe damage caused to Pine plantations (Fig. 1), studies were conducted on the pest from October 2011 to June 2012. The objective was to establish incidence of *G. podocarpi* in conifer plantations of South Western Uganda and also determine efficacy of *Palexorista gilvoides* against *G. podocarpi.*

Palexorista gilvoides belongs to a large family of parasitoid flies in the insect family tachnidae, order Diptera. It resembles an ordinary housefly (Fig. 2), but like other parasitoids part of the life cycle of *P.gilvoides* is spent inside the body of its hosts eating up the vital organs inside and killing the hosts in the process. The parasitoid eventually emerges out of its dead host to continue the cycle.

Materials and methods

Study site. The study was conducted in Kiriima, Mafuga and Muko central forest reserves (CFRs). These reserves are located in South Western Uganda in Kabale and Rukungiri districts. They are under the management of the National Forestry Authority (NFA). They are located between 1200 and 2800 masl. Kiriima forest reserve has a total gazetted area of 1,028 ha while Mafuga has a total gazetted area of 3699 ha. Muko has an area of 166.8 ha. The forests experience a bimodal rainfall with a mean annual value ranging between 800 -1264 mm. Average

Figure 1. ***Gonometa podocarpi*** **damage in Kiriima**

Figure 2. ***Palexorista gilvoidesi*** **in a cage.**

daily temperatures vary between 10.7^0 C and 23.9^0 C. They are planted mainly with pines but have a few cypress tree species.

Establishing incidence of *G. podocarpi* in Conifer plantations of S.W. Uganda

Baseline information, viz period of pest outbreak, compartments attacked by the pest, damage levels and natural enemies that were attacking the pest were collected from the National Forestry Authority (NFA) staff at Kiriima, Mafuga and Muko forest stations. This was followed by general walk through the three affected CFRs to verify the information given by staff and also to score the damage levels. Damage levels were scored by observing the crown damage, which was scored using a four point scale (Innes *et al.*, 1990) as below:

Category 1	0-10% crown defoliation
Category 2	11-25% crown defoliation
Category 3	26-60% crown defoliation
Category 4	61-100 % crown defoliation

Incidence was scored by presence (+) or absence (-) of the *G. podocarpi*. Tree crown was chosen because it is the main forest component usually observed for estimating health condition by assessing two particularly important variables, foliage discoloration and defoliation. These are related to stress factors and are considered reliable parameters to assess forest damage (Innes, 1993).

Estimating damage levels involved moving in the compartments at random, making observations on the crown and scoring it using a four point scale above. Binoculars were also used to observe the general crown for damage in each of the three CFRs, looking out for discoloration or blotched appearances of the crown.

Determination of cause of death of *G.podocarpi*

Following the baseline information collected by making walkthroughs in Mafuga and Kiriima Pine plantations, and information from the NFA staff, studies were focused in pine sites most infested by *G.podocarpi* and later laboratory experiments were conducted. Eggs, larvae, pupae and adult moths were examined in the infested sites for attack by observing them for exit holes and also dissecting and observing the internal parts for presence of any parasite. Eggs being small were taken to the laboratory where they were examined under a microscope for parasitism. The different *G.podocarpi* life stages were also collected and placed in separate insect collection boxes that had lids made out of nylon gauze and observed for any emerging parasites. Observations were made every morning and evening. Fresh *P. patula* branches were added to the collection box in which larvae had been placed to provide sources of food to the larvae. The branches were replaced every two days to provide fresh food. Altogether, 100 adult moths and 248 for each of the *G.podocarpi* life stages of larvae, pupae and eggs were examined in the field. Number of parasitoids and growth stage attacked were recorded. The parasitoids that emerged from the caged *G.podocarpi* were identified using insect keys.

Vulnerability of *Gonometa podocarpi* to parasitism by *Palexorista gilvoides*

Larvae of *G. podocarpi* were collected in the field and placed on young *Pinus patula* in cages in the laboratory and reared through to adult stages. Eggs, larvae, pupae and adults, emerging from this first generation were used in the susquent studies of parasitism by *P. gilvoides*. Using first generation stages from the laboratory ensured starting the experiment with healthy eggs, larvae, pupae or adults. To establish vulnerability of the different stages to parasitism by *P.gilvoides,* 8 adult moths (4 males and 4 females), 24 eggs, 24 larvae and 24 pupae were placed in separate cages measuring 43 cm wide X 43 cm deep X 60 cm high (Fig. 3). The cage frames were made from 8 mm wire, welded at the corners and covered with muslin netting with a base of thick khaki cloth. The netting was designed to open in front to allow access and monitoring of the study materials. For the cage housing larvae, two *P. patula* seedlings were placed into each of the cages as sources of food for the larvae and rest places when moths emerged. 3 male and 3 female *P. gilvoides* were introduced into each of the cages (Fig. 4). The different *G.podocarpi* growth stages (eggs, larvae, pupae and adults) were monitored for parasitism by examining them for mortality and symptoms of attack from from *P.gilvoides*. Dead larvae, pupae and adults were also dissected to observe parasites attacking them. Eggs that did not hatch were broken carefully

Figure 3. Rearing *G.podocarpi* in Kifu lab.

and contents observed under a microscope for any parasitoids. Experiment for eggs was replicated 8 times, that of adult *G.podocarpi* 20 times while for larvae and pupae 10 times. Replication varied because it depended on the availability of the life stage. Dates and numbers of parasites per each lifecycle stage were recorded.

Data analysis

Data collected was entered into excel, cleaned and descriptive statistics generated. To establish vulnerability of the different growth stages of *G. podocarpi* to *P. gilvoides* percentages of individuals parasitised were calculated and transformed into bar graphs (Fig. 5) to facilitate concise characterisation of life cycle stage attacked in the field and laboratory. All data were analysed using Statistical Package for social scientists version for windows (SPSS, 2002).

Results

Gonometa podocarpi was present in Mafuga and kirrima CFRs. No *G.podocarpi* was observed in Muko CFR. Nine out of the 51 compartments in Kiriima and Mafuga pine plantations had incidence of *G. podocarpi* (Table 1). The highest damage was in Kiriima with all the 5 affected compartments having damage levels ranging from 60-100% of the crop (Fig. 1 and Table 1). The cause of death in *G. podocarpii* was a parisitoid, *P. gilvoides*. Its parasitism levels varied in the field and laboratory, (62 % in the laboratory and 43% in the field) and life cycle stages attacked (Fig. 5). No parasitism was observed in the egg and adult stages. Highest parasitism was larval parasitism (43% in the field and 62%) in the laboratory compared to pupa stage parasitism level of 6% in the field and 8% in the laboratory. Many parasitised larvae had up to eight puparia in their bodies.

Figure 4. Palexorista gilvoidesi introduced against adult *G.podocarpi* in a cage

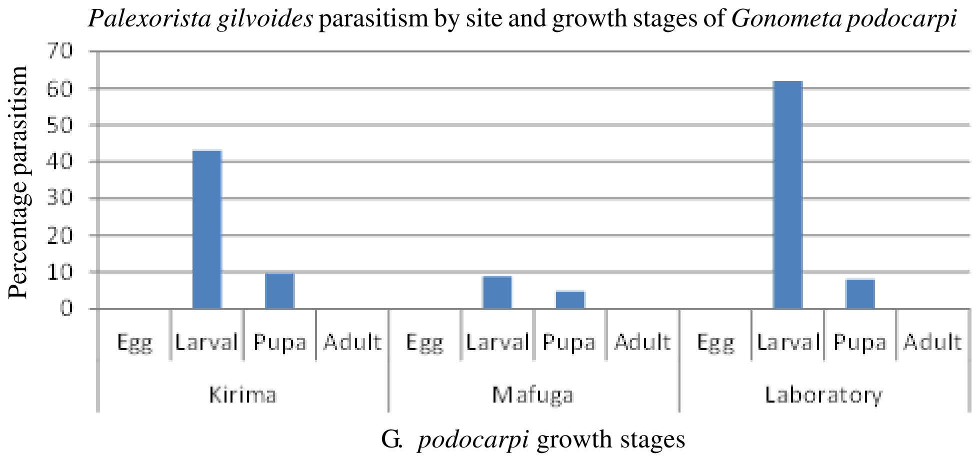

Figure 5. Vulnerability of different *Gonometa podocarpi* stage to parasitism by *Palexorista gilvoides*.

Discussion

Although only 17.6% of the compartments in both Kiriima and Mafuga pine plantations had been attacked and damaged by *P. gilvoides,* the level of damage is extremely high particularly in Kiriima where all the five compartments found infested were scored under damage category 4 (60-100% tree crown damage), This is severe damage and could be a source of infestation to pine plantations in the country. This level of damage therefore calls for immediate control.

Palexorista gilvoides was observed to parasitise only larval and pupae stages of *G. podocarpi* (Fig. 4). It does not parasitise eggs and adults. This is in line with Okello (1972) observation, that the only known egg parasite of G. *podocarpi* belongs to genus *Anastus* and that there is no known parasite of adult *G. podocarpi*.

Although *P. gilvoides* was observed parasitising both larvae and pupae stages of G. *podocarpi* the life cycle stage preferred by *P. gilvoides* seems to be the larval stage as observed in higher larval parasitism percentages in both the field and laboratory. Thus, *P. gilvoides* could be a larval parasitoid and the parasitism observed in pupae could be larvae that are parasitised in the last larval stages and survive dying, progressing into pupae stage with the parasite in them. As was noted the parasitised pupae do not progress to adult stage.

Parasitism levels of *G. podocarpi* by *P. gilvoides* are higher in the laboratory (62%) than in the field (43%). This disparity could be due to factors such as differences in temperature, and time spent searching for the host (*G. podocarpi*). The situation in the laboratory is different from the field. In the laboratory the host (*G. podocarpi*) is enclosed together with the natural enemy and restricted into a small space and little vegetation for it to hide. The pest is thus more easily located by the parasitoid than would be in the wild where the parasitoid would take some time searching for the host and sometime even fail to locate the host. Temperatures also affect performance of natural enemies as the latter have an optimum temperature in which they perform best. Temperatures

Table 1. Incidence of *G.podocarpi*

Site(Forest)	Pine species	Compartment No.	Damage category	Remarks
Kirima CFR	*P. patula*	2	4	*G.podocarpi* observed dying from unknown cause
	P. patula	4	4	*G.podocarpi* observed dying from unknown cause
	P. patula	6	4	*G.podocarpi* observed dying from unknown cause
	P. patula	7	4	*G.podocarpi* observed dying from unknown cause
	P. patula	8	4	*G.podocarpi* observed dying from unknown cause
Mafuga	*P. patula*	11	1	Very few *Gonometa* observed
Mafuga	*P. patula*	12	1	Very few *Gonometa* observed
Mafuga	*P. patula*	13	1	Very few *Gonometa* observed
Mafuga	*P. patula*	14	1	Very few Gonometa observed

in the laboratory and Kifu in general are higher than in Kabale (average 21.7 °C and 18 °C, respectively) during day and falling to 10C at night in Kabale. The higher temperatures in the Labaratory at Kifu could be the optimum at which *P. gilvoides* perform*s* and thus responsible for the higher parasitism levels observed in the laboratory.

The cause of the *G. podocarpi* resurgences despite the existence of *P. gilvoides* is yet unknown. There are a number of possible causes. One of the causes may be inherent factors within the forest ecosystem that lead to fluctuations in the pest population. Forest insect pest populations can fluctuate tremendously over time, sometimes in cyclical patterns related to density-dependent processes, but also due to stochastic events (Berryman, 1986; Speight *et al.*, 1999). Populations are often cited to be controlled by top-down factors (natural enemies) and/or, bottom-up factors (food supply, or host plant quality which is related to soil nutrients and water availability) (Berryman 1988; Perry, 1994; Speight *et al*., 1999). Herbivore outbreaks are often considered to occur as a result of some kind of stress on host plants, because stressed plants become more suitable as food for insect herbivores, due to increased levels of available nitrogen (White, 1974). Another factor for resurgences of *G.podocarpi* despite the presence of *P. gilvoides* could be hyper parasitism occurring on *P. gilvoides*. Hyper parasitism is a condition in which a secondary parasite or parasitoid develops inside a primary parasite or parasitoid. Thus *P. gilvoides* could be a host to some unknown parasitoid which is parasitising it, thus reducing its effectiveness against *G. podocarpi* during certain favourable periods to the hyper parasitoid thus leading to increased populations of *G. podocarpi* hence pest resurgences.

The fact that there were more than one puparia in the dissected larvae indicates multiple parasitism of already parasitised larvae. An efficient parasitioid should be able to identify an already parasitised host and go for afresh one, thus maximising the number of hosts attacked. The causes of *G. podocarpi* resurgence require further studies to establish permanent control of the pest.

Conclusions and recommendations

Gonometa podocarpi is a serious pest of pines in Uganda and therefore there is need to control it. *Palexorista gilvoides is* an important parasitoid of G. *podocarpi,* with high parasitism levels on the pest. However, it has not kept down the populations of the pest leading to cyclic resurgences in the pine plantations. There is need to carry out further studies on factors affecting effectiveness of the parasitoid, particularly possible existence of hyperparasitoids and need for augmentation of the parasitoid for effective management of the pest including augmentation of the parasitoid. There is increasing importance of nuclear-polyhedrosis virus to control *G. podocarpi.* This control option could be further evaluated and possibly integrated with biological control using *Palexorista gilvoides.*

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References

Aurivillius, C. 1925. O. F. Byrks samlinger, Ost Afrika Entomol. *Tidskr* 46:206-212.

Austarå, O. 1970. *Gonometa podocarpi* Aur. (*Lepidoptera: Lasiocampidae*), a defoliator of exotic Softwoods in East Africa. The biology of life cycle at Muko, Kigezi District in Uganda. *East African Agricultural and Forestry Journal* 36: 275-289.

Berryman, A.A. 1986. Forest insects. Plenum Press, New York and London. 279 pp.

Berryman, A. A. 1988. Dynamics of forest insect populations: Patterns, causes and Implications. Plenum Press, New York and London. 603 pp.

KW. 1965. Notes on the recent outbreaks of looper caterpillars in coniferous plantations in Uganda. Uganda For Dept Tech Note 99: 1-7.

George, D. and Malley, P. 2003. SPSS for windows step by step: A simple guide and Reference.11.0 update (4th edition.) Boston: Allyn and Bacon.

Harrap, A.K, Long worth, J.F. Tinsley, T.W. and Brown, K.W. 1966. Anon-inclusion virus of *Gonometa podocarpi* (Lepidoptera Lasiocampidae). *Journal of Invertebrate Pathology* 8:270-272.

Innes, J.L. 1990. Assessment of tree condition. Forestry Commission Field Book. 12 HMSO, London.

Innes, J.L. 1993. Forest health: its assessment and status. CAB International, Wallingford.

Innes, J. 1993. Forest health: its assessment and status. Cab International, Cambridge. 667 pp.

Jacovelli P, Milligan B, Amumpa A, Nalwada C, Kakungulu Z, Odeke C, Atuyamba A, and Businge T. 2009. Tree planting Guidelines for Uganda. Sawlog,Production Scheme. p. 16.

Kiwuso, P. and Tumuhimbise, R. 2012. Report to National Forestry Authority on *Gonometa podocarpi* outbreak in Kiriima.

Longworth, J.F.C. Payne and R. Macleod. 1973. Studies on a virus isolated from *Gonometa podocarpi* Aur. (*Lepidoptera: Lasiocampidae* Journal of General Virology 18:119-125.

National Forestry Authority, National Biomass Study Report, 2009.

Norman, F., Moore, Terry Armstrong, Bernedette Green, David Brown, Jill Hibin, David C Kelly, Thomas W. Tinsley and Thelesa C. Aloo 1981. Characterisation of a nuclear *Polyhedrosis* virus isolated from diseased *Gonometapodocarpi* (*Lepidoptera Lasiocampidae*) *Journal of Applied and Environment Microbiology* pp. 308-316.

Okelo, O. 1972. Life history studies of *Gonometa podocarpi* Aurivillius (Lepidoptera: Lasiocampidae) in East Africa. *Ohio Journal of Science* 72: 301-303.

Perry, D. A. 1994. Forest ecosystems. The John Hopkins University Press, Baltimore or London. pp. 649.

Speight, M. R., Hunter, M. D. and Watt, A. D. 1999. Ecology of insects concepts and applications. Blackwell Science Ltd., Oxford. 350 pp.

SPSS, 2002. Scientific Package for Social Scientists, Miller, R.L. and White, T. C. R. 1974. A hypothesis to explain outbreaks of looper caterpillars, with special reference to populations of *Selidosema suavis* in a plantation of *Pinus radiata* in New Zealand, Oecologica (Berlin) 22, 119-134.

Zar, J.H. 1996 Bio statistical analysis. Third edition. Prentice Hall, New York. 662 pp.