RESEARCH PAPER

Distribution of coconut stick insect, *Graeffea crouanii* and its parasitoids in selected islands of Fiji

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ABSTRACT

The Coconut stick insect, *Graeffea crouanii* (Le Guillou) (Orthoptera: Phasmidae), known as "mimimata" in Fiji, is a widespread economic pest of coconut palms in Fiji and in many Pacific Island countries. The nymphs and adults stages of pest are polyphagous, but prefer coconut palms.This paper reveals findings from the surveys conducted between 2009 and 2012 during the field work in selected islands of Fiji, and discusses needed research to enhance natural-mortality control mechanisms. Preliminary studies of *G. crouanii* in selected islands of Fiji (Viti Levu, Vanua Levu and Taveuni) showed that the pest was localised and abundant in areas with low temperature, which was also statistically proven.The pest was found to be feeding on leaves with damage starting from tip and ends up leaving only the midribs. The older fronds had more damage than new frond due to longest pest exposure. The two elasmid egg parasitoids in Fiji, *Paranastatus verticalis* and *Paranastatus nigriscutellatus* of order Hymenoptera have potential as a biological control agent. This study on the *G. crouanii* in Fiji provides significant recommendations for further management of *G. crouanii* in coconut farms.

Keywords: coconut stick insect, *Graeffea crouanii*, egg parasitoids, biological control, coconut pest distribution, Fiji.

1.0 INTRODUCTION

The Coconut stick insect (*Graeffea crouanii*) order Phasmatodea, was first described by Le Guillou in 1841, based on the specimen from Samoa (Paine 1968). The *G. crouanii* is native to South West Pacific, has long slender bodies with long, thin legs. They are broad green or pinkish-brown species, with bold pink, shortened wings thus allowing them to blend in with trees, leaves and twigs. This is their primary defence and camouflage against predators. Their eggs survive seawater, in which they float (Swaine 1969), and so have high capacity for natural dispersal. Canoes on beaches where eggs could fall into them from the palms could have transported this pest to many islands and coconut leaves infested with coconut stick insects may well have been transported from place to place. In many islands of the South Pacific, *G. crouanii* has for long been known to defoliate coconut palms *Cocos nucifera* (L.), a member of the family Arecaceae (palm family) (Taffin 1998). A significant decrease in *G. crouanii* infestation levels in coconut palms is thus mandatory for the survival and boost of the coconut industry.

Coconut palms are one of the most important crops often referred to as "Tree of Life", reflecting its dietary value and the uses for other products from the tree and nut (Watson 1997). The coconut industry remains the most important agricultural commodity for many smaller islands within Fiji and throughout the Pacific Islands where it is extensively grown and plays important roles in the livelihoods of people in terms of food and nutrition security, social, cultural and the economic aspects. Pest and disease tend to affect the quality and quantity of produce and if not controlled effectively, they can cause huge damage to crops thus affect the economic status of the country as a whole. In order to improve Fiji's economy, the Fijian government is investing heavily in agriculture by assisting farmers and stakeholders to produce better quality produce for export market.The insect eats pieces out of the edges of the oldest fronds, as these have been longest exposed to attack, and the worst damage is usually seen on old trees at least 25 m high (Swaine 1969). At times if the damage is very severe, it could defoliate the whole plant which could lead to death of the plant. For example, in 1958-1959, a severe outbreak in the island of Taveuni, Fiji affected over 200 ha whereby at least 50% of the palms were defoliated and nearly 400 killed (Paine 1968). By the end of 1961 the outbreak had extended over 500 acres in which the older fronds were at least 50 per cent defoliated and nearly 400 palms had been killed (Paine 1968). While coconut is the main host of *G. crouanii,* other plants of commercial importance attacked were sago, *Metroxylon sagu* Rottb. and panadanus, *Pandanus tectorius* Parkinson (Bedford 1978).

Earlier attempts to control this pest had been unsuccessful, because there were no practical means of applying insecticides to foliage of very tall palms. Adhesive bands round the trunks of the palms caught large numbers of nymphs, but a proportion of the eggs dropped by the stick insect lodged in the crowns of palms. Nymphs which hatch from these avoid the sticky bands. Chemical control is practicable on young palms, in which the crown is accessible (Swaine 1971), but the treatment if the crowns of tall palms with contact or stomach poison from ground is out of the question. Mist blowers are able to reach heights of about 12m, whereas many of the crowns are 25m above the ground (Anon. 1966). Aerial spraying was shown to be effective (O'Connor 1959), but is considered too costly for general use (Swaine 1969). Trunk injection with monocrotophos (Stelzer 1970) was reported to be highly effective, and left no significant residues in the milk or meat of the nut. The technique appears to have been routinely used in Fiji (Anon. 1970). This systemic chemical had no phytotoxic effect, but the adverse effects on arthropods' parasitoids introduced for the control of coconut pests is poorly known. However, the disadvantage of injecting chemicals is that fungal pathogens may invade the holes bored in the trunk and kill the palm (Dharmaraju 1977). The misuse and abuse of pesticides by farmers also led to negative impacts on environment.

Consequently, there have been several attempts at establishing other different aspects of biological control for this pest. Various management options for the pest have been documented in the Annual Research Reports of Department of Agriculture in Fiji (Singh *et al*. 1974-75; 1977; Kamath *et al*. 1979, 1981). One of them was to use the two egg parasitoids native to Fiji. Eady (1956) described two wasp parasitoids reared by O'Connor *et al*. (1954) from the eggs of *G. crouanii* in Fiji.These

two elasmid egg parasitoids, *Paranastatus verticalis* Eady and *Paranastatus nigriscutellatus* Eady of Order Hymenoptera had potential as biological control agent. These wasps can be mass reared in laboratory. However, recent research data is not available to assess the effectiveness of these parasitoids for the control of the pest.

Therefore, in order to address the continuous damage caused by this pest to coconut farms, Fiji's Ministry of Agriculture, the Koronivia Research Station (KRS), initiated preliminary studies on distribution of pest and its parasitoids in some selected islands of Fiji. This paper reveals the findings from the field work conducted between 2009 and 2012 in selected islands of Fiji, and discusses research needed to enhance natural-mortality control mechanisms.

2.0 MATERIALS AND METHODS

2.1 *Survey sites*

For this study only three bigger islands namely, Viti Levu, Vanua Levu and Taveuni were chosen (Fig. 1). The *G. crouanii* surveys were conducted on main coconut growing areas with reference to three climatic conditions (temperature, rainfall and humidity).

Figure 1. The survey sites for *Graeffea crouanii* in Fiji.

2.2 *Mapping-out pest distribution and damage in coconut growing areas*

Fields were selected at random depending on the pest distribution, road accessibility and area to be sampled. Between 2009 and 2012, a total of 40 farms (15 in Vanua Levu, 15 in Viti Levu and 10 in Taveuni, respectively), were visited and surveyed. At each farm during the survey, a visual assessment of *G. crouanii* occurrence was made on plants foliage of all ages using the damage scale index (Fig. 2). The distribution of the *G. crouanii* was determined by sampling coconut plantations of different growth stages in farmers' fields in each of these three islands. Some of the sites marked as "hot spots" were repeatedly visited between these four years field work.

< 30 % **30-50%** **50-80%** **≥ 80%**

Figure 2. The damage scale index used for survey of *Graeffea crouanii* in Fiji.

2.3 Study of *egg parasitoids* of *G.crouanii*

In this study, the effectiveness of the biological control agents in controlling *G.crouanii* was studied. The wasps, *P.verticalis* and *P. nigriscutellatus,* used for biological control of *G.crouanii* was retrieved from the fields by placing white sheets around the base of pest infested palms to obtain eggs of *G.crouanii.* The eggs were collected after three days from the sheets expecting parasitism by the parasitoids. These eggs were kept under observation in laboratory and checked for emergence of egg parasitoids.The parasitoids reared from these collected eggs were used for rearing of more parasitoids by exposing the fresh *G.crouanii* for field release in infested sites.

2.4 *Statistical analysis*

The MINITAB statistical software was used to analyse data of this study using a logistic regression since it is useful to study the effect of different climatic conditions (i.e. temperature, rainfall and humidity) on the level of pest infestation. The logistic regression model for the expected number of infestation in a particular location is given by:

$$E(y) = \frac{n}{1+e^{-[\beta_0+\beta_1 x_1+\beta_2 x_2+\beta_3 x_3]}},$$

where, n = number of farms trialled in the location, y = number of infested farm, x_1 = temperature, x_2 = rainfall, x_3= relative humidity and $\beta_i; (i = 1,2,3)$ are the regression coefficients.

3.0 RESULTS AND DISCUSSION

There are ca 300 islands in Fiji and the entire islands have coconut palms which is widely used for the livelihood of the people. Presence of pest has hugely affected the development of the coconut palms and the presence of coconut stick insect in Fiji has been reported by researchers since early 1950. Results from this study further confirm that the pest distribution is not only all over Fiji, but at different levels as well.

3.1 *Pest distribution*

The highly infested coconut plantations were mostly in the leeward sides of the three larger islands surveyed (Fig. 3 and Table 1). Because of low temperature and wet nature of these environments, the survival and development of coconut stick insect is ensured in the overgrown weeds beneath the palms. The eggs laid by adults from the crown of palms normally undergo development at the base of palms. The moisture present protects the eggs and assists in early development stage of the pest nymphal stages. Moisture was vital for early development and since its absence in dry climatic zones induced death and controlled the pest population.

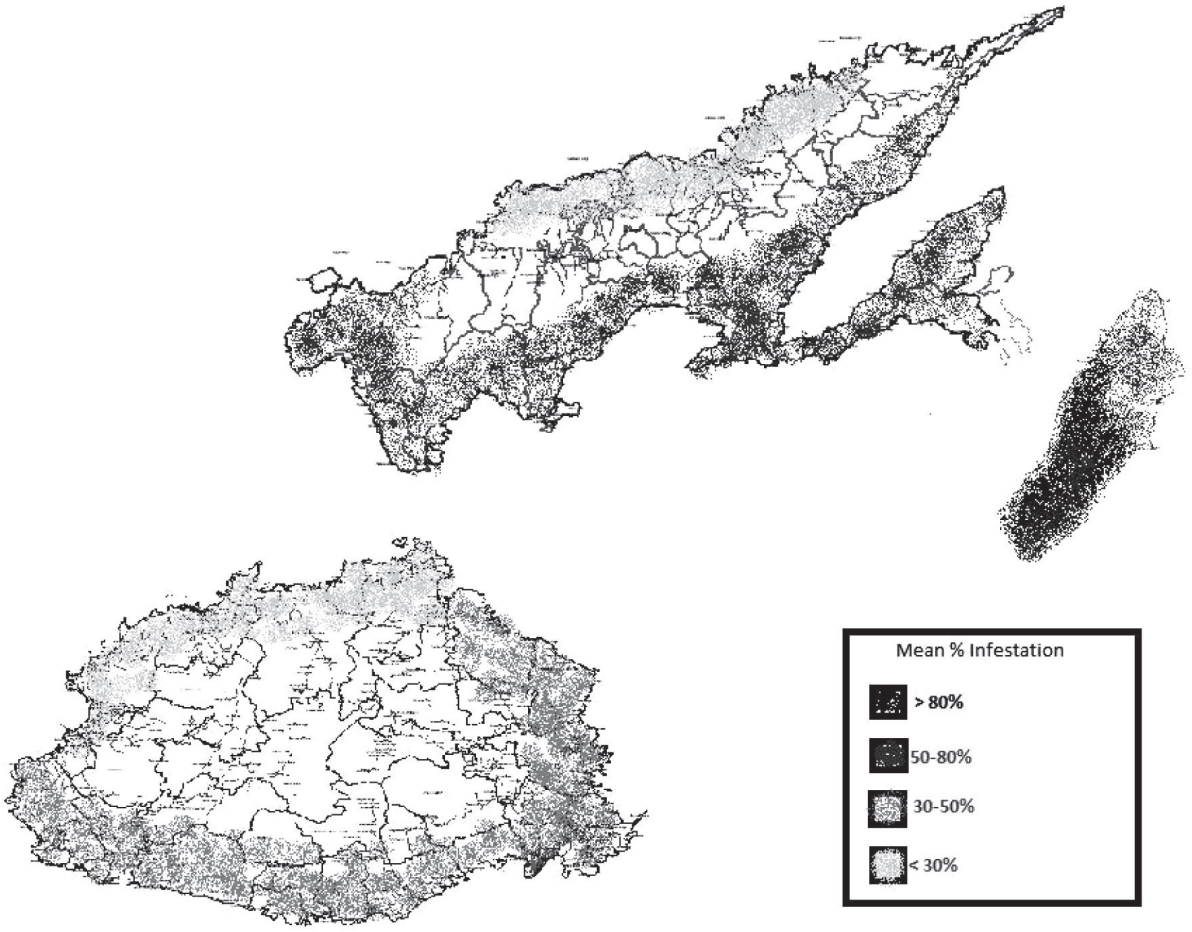

Figure 3. Distribution and infestation of *Graeffea crouanii* in three selected islands of Fiji between 2009 and 2012.

Table 1. Relative damage by *Graeffea crouanii* and parasitism in three selected islands of Fiji between 2009 and 2012.

Location (Island)	Coconut fields visited			Climatic conditions 2009-2012 (Average)*		
	Total No.	No. of farms infested with pest	% infestation	Temperature (°C)	Rainfall (mm)	Relative Humidity (%)
Central Viti Levu	5	2	40	29.22	261.83	80.81
Western Viti Levu	5	1	20	29.95	218.00	76.35
Eastern Viti Levu	5	2	40	29.22	261.83	80.81
Northern Vanua Levu	5	1	20	31.07	213.80	76.08
Western Vanua Levu	5	4	80	28.97	261.91	78.82
Southern Vanua Levu	5	4	80	29.16	191.15	78.98
Northern Taveuni	5	4	80	29.12	225.16	79.23
Southern Taveuni	5	5	100	29.12	225.16	79.23
* Source: Fiji Meteorological Services.						

3.1.1 *General trends*

The statistical analysis of results show that the only coefficient = -2.24326 is significant (*P*-value = 0.042), indicating that the temperature has a significant effect on the level of infestation in farm surveyed. However, the effect of rainfall and the humidity on the infestation is not statistically significant. The odds ratio for temperature is 0.11, which explains that every one degree increase in temperature reduces the odds of infestation by 0.11. Where as, from the odd ratios of rainfall and humidity, every one centimetre increase of rainfall and one percent increase of humidity reduce the infestation by 0.94 and 0.42, respectively. However it is statistically not significant.

3.1.2 *Viti Levu*

A total of fifteen coconut plantations were visited of which five of the plantations were located in Central part, five in Western part and five in Eastern part of the island. In Central and Eastern parts most of the coconut is cultivated along the coastal areas, while for Western part the coconut is cultivated along coastal and inland. *G. crouanii* infestation was high (30-50%) in Central and Eastern areas where temperature was less compared to the Western part which had higher temperature and lower pest infestation (< 30%). This correlation of temperature and pest infestation was statistically proven and implies that rise in temperature will lead to reduction in pest infestation.

3.1.3 *Vanua Levu*

Fifteen coconut plantations were visited of which five plantations were located in northern part, five in western part and five in southern part of the island. In northern part the temperature was more and level of pest infestation was lower (<30%) compared to western and southern parts which had lower temperature and high level of pest infestation (50-80%).

3.1.4 *Taveuni*

A total of ten coconut plantations were visited, of which five plantations were located in northern part while another five in southern part of the island. Coconut is grown throughout this island and the level of pest infestation was found to be very high due to favourable weather conditions in Southern part of the island which was also observed by previous researchers. It should be noted that the average temperature provided by Fiji Meteorological Services was only taken at one site in Taveuni which represents whole of Taveuni, however the climatic conditions differs for southern and northern parts of the island. In southern part of the island the pest infestation was more ($\geq$80%) compared to northern parts which had slightly lower pest infestation (50-80%).

3.2 *Biological control: Egg parasitoids of G.crouanii*

In Fiji, the biological control agents, the wasp (egg parasitoids) *P.verticalis* and *P. nigriscutellatus,* were present and used as control measure in conjunction with field sanitisation against *G. crouanii.* Successful rearing of the two species of biocontrol agents, *Paranastatus* was done in the laboratory and it was observed that it parasitized up to 65% of exposed fresh egg of *G. crouanii*. Previous field studies have found parasitism from less than 10% up to as high as 52% of the eggs (Paine 1968). In the outbreak area on Taveuni in 1963, Paine (1968) obtained less than 10% parasitism by *Paranastatus* spp. Singh *et al.* (1974-75; 1977) observed highly variable levels of parasitism by *P. verticalis* and *P. nigriscutellatus*, whereby they found that thick weed cover led to lower parasitism by both species. A range of 2.7-35.9% and 24.5-52.4% parasitism was observed in two studies by Kamath *et al.* (1979, 1981). In all these studies, *P. verticalis* was found to be the most active of the two egg parasitoids. In addition, about 6-17 adult egg parasitoids emerged after approximately 18-111 days of incubation period upon parasitism.

4.0 CONCLUSION

Graeffea crouanii is widely spread on the three island surveyed and found to cause significant damage to coconut palms. The best prospects available for biological control are the establishment which should be combined with clearing around the bases of affected trees and if facilities are available, the occasional mass rearing and release of egg parasitoids in hotspots. Clearing around palm bases to expose eggs to sun and predators, and also interplanting with non-host would help to reduce pest status. Cultural practices should help to reduce the damage to coconuts by reducing weed cover and exposing eggs, nymphs, and adults to natural mortality. In addition, the continuing nation-wide farmers' education and awareness training programmes in the outbreak areas will assist them to learn about the life cycle of *G. crouanii,* how to recognize its damage, and

understand why cultural and biological control methods are preferred to the 'shot-gun approach' to pesticides which is not ecologically sustainable. Detailed ecological studies evaluating the critical mortality factors and mechanisms affecting the eggs of *G. crouanii* need to be carried out to improve the biological control for *G. crouanii*.

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