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The Distribution and Biological Control of *Lantana camara* in Micronesia

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Abstract—*Lantana camara* L. was introduced into Micronesia as an ornamental plant at the turn of the century and quickly established as a significant weed pest throughout the region. Over the past forty years various natural enemies of lantana have been introduced into Micronesia in an attempt to curb the spread of the lantana. However, little information has come out of the area with respect to the establishment and effectiveness of these species. For this reason, surveys were undertaken to assess the status and natural insect enemies of lantana on major islands within the Caroline and Mariana island groups. Lantana was found to be widespread throughout the region although its abundance and pest status varied between islands. At least four different color varieties were noted, the most common of which resembled the Hawaiian Pink, *L. camara* var. *aculeata*. Seven of the thirteen exotic insect species introduced into the area were found to have established, although not all were found on all islands where lantana was present. Similarly, certain insects were more effective bio-control agents than others although once again inter-island variability was evident. The five most important insect species, in terms of their distribution and effectiveness, were the tingid bug, *Teleonemia scrupulosa* Stal; the hispine beetle, *Uroplata girardi* Pic; the pterophorid moth, *Lantanophaga pusillidactyla* (Walker); the tortricid moth, *Epinotia lantana* (Busck), and the pod-fly *Ophiomyia lantanae* (Froggat).

Introduction

The perennial shrub, *Lantana camara* L., is a member of the Verbenaceae family and a native of the tropical and sub-tropical Americas. Several highly colored and attractive varieties were first introduced as ornamental plants to other parts of the world during the late seventeen hundreds. Certain vigorous growing varieties eventually escaped their garden confines and, in the absence of their natural enemies, flourished in their new environments. Unfortunately their

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tendency to form impenetrable thorny thickets, invade pasture land, and compete with agricultural crops for water, nutrients and light, quickly established them as a serious weed pest in many areas. Indeed, lantana has been reported in 47 countries (Holm et al. 1977) and is considered to be among the ten worst weeds in the world (Holm & Herberger, 1969).

Lantana is widely distributed throughout the Pacific (Thaman 1974) although relatively few publications have emerged regarding its current distribution, pest status and control within Micronesia. For this reason, surveys were conducted, between September 1988 and October 1989, on Pohnpei, Chuuk and Kosrae in the Eastern Caroline Islands; Belau and Yap in the Western Caroline Islands; and Guam, Rota, Aguijan, Tinian and Saipan in the archipelago of the Marianas (Fig. 1). The findings of the study are outlined below.

Distribution Within Micronesia

Lantana camara was probably introduced into Micronesia by European settlers during the late eighteen and early nineteen hundreds although records are incomplete. Most likely, Guam, the Marshall Islands, Pohnpei and Belau were important entry points for the weed into the region. By the mid 1940's it was considered to be problem weed on several Micronesian islands (Schreiner 1989).

During the current study, lantana was found on all islands visited except Rota and Kosrae. For how long these islands can remain free of lantana is uncertain. Given the close proximity of neighboring islands, where lantana is found, it would seem only a matter of time before the weed is introduced unless the appropriate regulatory authorities act to ensure otherwise.

Pest Status

Where present, lantana was found to be more abundant on some islands than others (Table 1). For example, it was extremely common and widespread on the uninhabited island of Aguijan. Likewise, on the neighboring islands of Tinian and Saipan, large expanses of lantana were found in the southern portion of each island and were of concern to local graziers. On all other islands visited, lantana was not considered to be a major weed pest. On the contrary, the general feeling among the local peoples was that the pest status of lantana had declined in recent years following the introduction of some of its natural enemies into the area.

Such inter-island differences in the pest status of lantana are due, at least in part, to differences in agricultural and land use practices in addition to variations in soil type, climate, and the abundance and effectiveness of the various natural enemies introduced into the area. Equally important are the many varied and different interactions between lantana and other plant and animal species sharing the same environment. On Aguijan, for example, the spread of lantana had been greatly facilitated by the grazing influence of the island's large, endemic goat population. At the same time, however, its growth and vigor was to some extent

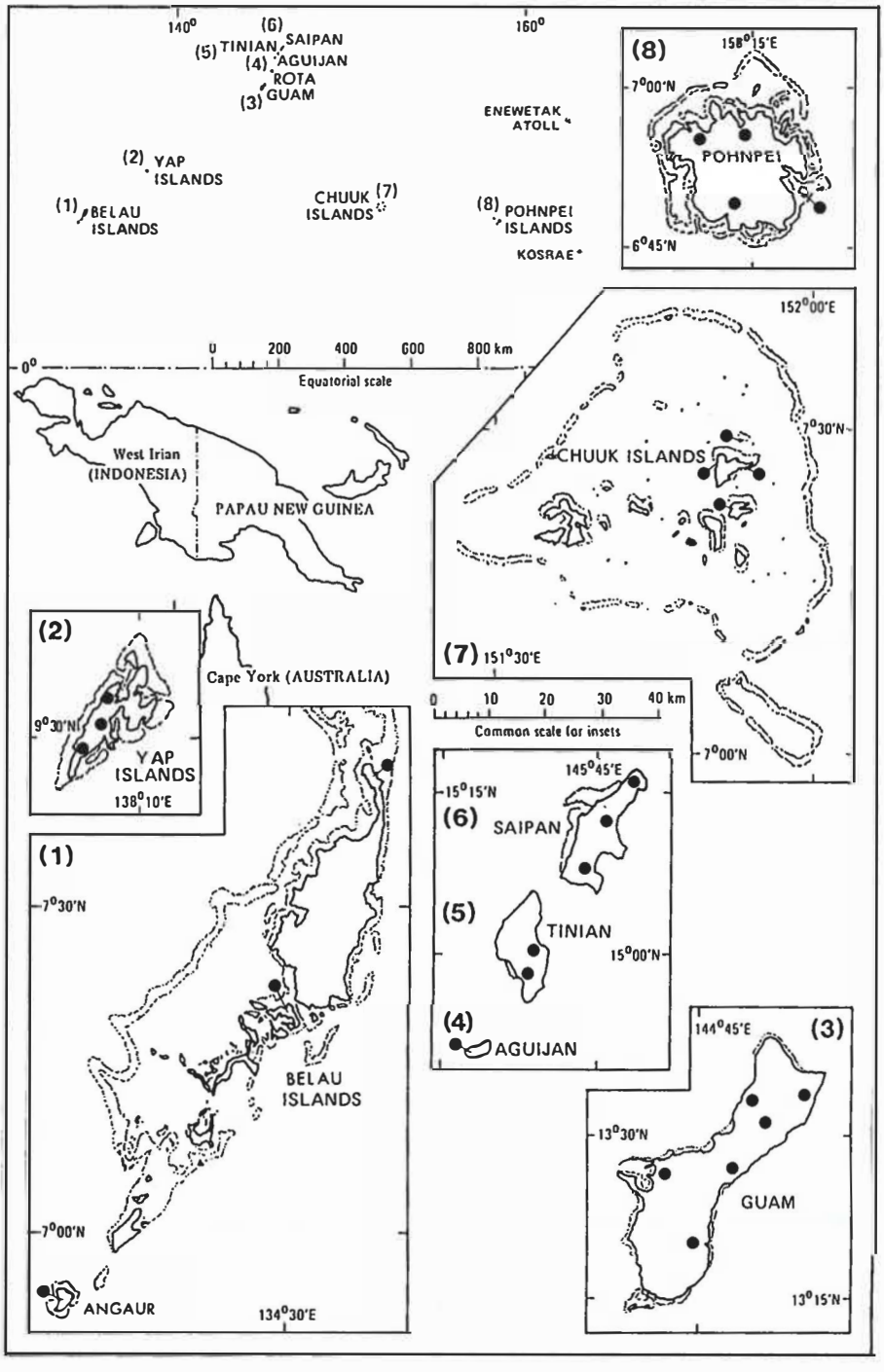

Figure 1. Micronesian Islands surveyed for *Lantana camara* and associated natural enemies (sampling locations are indicated by closed circles).

Table 1. The status of *Lantana camara* in Micronesia.

Island	Status
Western Caroline Islands	
Belau	++
Yap	+
Eastern Caroline Islands	
Pohnpei	+
Truk	+
Kosrae	A
Archipelago of the Marianas	
Guam	+
Rota	A
Aguijan	++
Tinian	++
Saipan	+

++ =Abundant and widespread and/or of local importance.
+ =Relatively common but restricted distribution. Generally not of local importance.
A=Absent.

hampered, here, by some fierce competition for space between itself and another recent invader, the Siam weed (locally referred to as "masiksik"), *Chromolaea odorata* (L.) R. M. King and H. Robinson (Asteraceae). The latter weed species was found to varying degrees on all islands visited except Chuuk where it was entirely absent.

Both the above examples illustrate direct interactions with other living organisms. Indirect interactions are, of course, less obvious although a noteworthy example tentatively links the relatively recent decline of lantana, on Guam (Fig. 2), to the brown tree snake, *Boiga irregularis* which was accidentally introduced onto the island sometime shortly after the last world war (Savidge 1987, Muniappan 1988). This species has dramatically reduced the forest avifauna of Guam among which are several species suspected of playing a key role with respect to lantana seed dispersal on the island (Muniappan 1988, Denton et al. in press). Interestingly, this is the first time that evidence (albeit circumstantial) has been presented to illustrate the negative impact of the brown tree snake on Guam flora.

Taxonomic Variations

Our surveys revealed at least four distinct color-morphs of lantana, although not all were found together on the same island. The most commonly encountered color-morph was the pink and yellow flowering variety believed to be the Hawaiian Pink taxon, *L. camara aculeata.* It was found on all lantana-infested islands except Yap. An attractive Orange-red and yellow variety, probably the

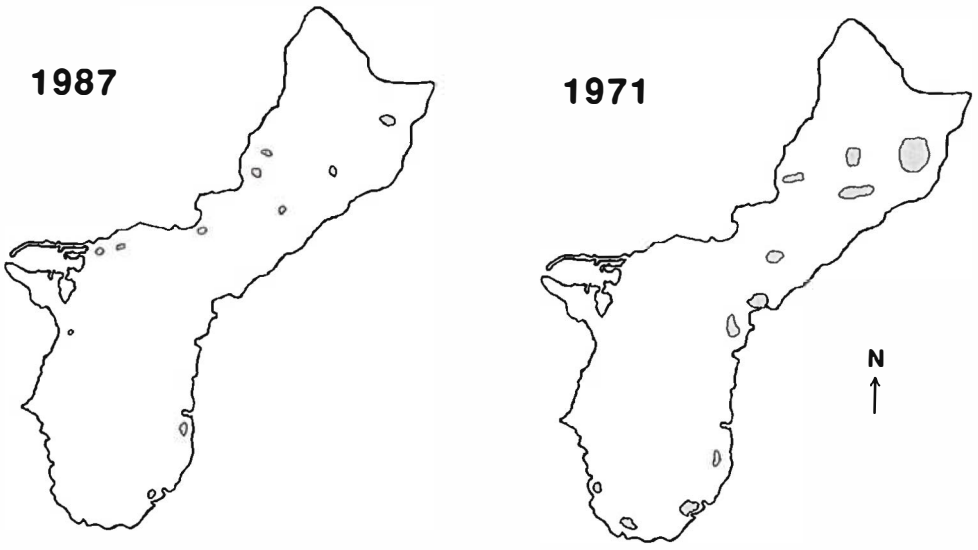

Figure 2. Decline of *Lantana camara* on Guam between 1971 and 1987.

Hawaiian orange-red taxon, *L. camara mista*, was found in Palau (Koror), Yap (largest most southerly island only), and Saipan (a single, small bush amidst 2 hectares of established *L. camara aculeata* located at Koblerville in the south of the island). On Angaur, a tiny island in the south of the Palau island group, two additional color-morphs were found. One was very similar to *L. camara aculeata* although the corolla of each floret was bordered with orange. The other was a relatively uncommon, light orange and yellow flowering variety similar to *L. camara mista* although somewhat paler in appearance.

Introduced Natural Enemies

Attempts to control lantana biologically were first pioneered in Hawaii at the turn of the century (Perkins & Swezey 1924) although it was not until the late forties that candidate species of insects were first introduced into Micronesia for this purpose.

Of the 35 insects that have been used for the biological control of lantana, thirteen species are known to have been introduced into Micronesia (Table 2). However, relatively little information has subsequently emerged from this area, regarding the fate, distribution and effectiveness of these biological control agents. Our surveys indicated that only seven of the thirteen species established (Table 2). However, not all were represented on all islands where lantana was present and, typically, some species were more effective than others. In addition, the effectiveness of certain species varied between islands and between different colored varieties of lantana. Further details of these findings are outlined below.

Table 2. Natural enemies of *Lantana camara* introduced into Micronesia.

Natural Enemy	Date First Introduced	Established
HEMIPTERA		
Tingidae		
Leptobyrsa decora	1971	No
Teleonemia scrupulosa	1948	Yes
COLEOPTERA		
Chrysomelidae		
Octotoma scabripennis	1971	No
Uroplata girardi	1963	Yes
Cerambycidae		
Plagiohammus spinipennis	1973	No
DIPTERA		
Agromyzidae		
Ophiomyia lantanae	1948	Yes
LEPIDOPTERA		
Noctuidae		
Diastema tigris	1955	No
Hypena strigata	1958	Yes
Noegalea esula	1955	No
Tortricidae		
Epinotia lantana	1948	Yes
Pterophoridae		
Lantanophaga pusillidactyla	1948	Yes
Pyralidae		
Pseudopyrausta acutangulalis	1955	No
Salbia haemorrhoidalis	1955	Yes

Teleonemia scrupulosa STAL (TINGIDAE)

Both adults and developing nymphs of this bug feed on vascular fluids drawn from the flower buds, growing tips and young leaves of lantana. Damaged florets blacken and eventually wither whilst damaged leaves display chlorosis, progressive necrosis and mild to severe distortion. These symptoms may manifest themselves for some distance from the actual point of attack due to the systemic action of the salivary toxins.

Originally from Central and South America, *T. scrupulosa* was one of four insects shipped to Pohnpei from Hawaii in 1948. It was reported to have established on Pohnpei in 1951 (Pemberton 1954) and in 1956 seemed to be exerting some control (Gardner 1958). It was considered to be only partially effective by 1967 (Schreiner 1989) and during the present survey it was not found anywhere on the island. However, on a visit in 1989 one of us (RM) found a small population of *T. scrupulosa* feeding on lantana near Ponape Agriculture and Trade School. The reason for the decline in effectiveness of *T. scrupulosa* on Pohnpei is not clear although we suspect the high annual rainfall (200″ spread fairly evenly

throughout the year) is a major factor since the bug does not do well in unusually wet or cold conditions (Harley 1971).

T. scrupulosa was introduced to Belau from Pohnpei in 1960 but has only established on the pink and yellow lantana found growing there. Both pale and dark orange/yellow flowering varieties (in Angaur and Koror respectively) were completely free of tingid attack indicating host incompatibility—a phenomenon previously reported by Harley & Kassulke (1971) for certain color-morphs of lantana from Australia. Host incompatibility also seems to be the most likely reason why a shipment of tingids sent to Yap from Belau in 1962 failed to survive on the orange/yellow variety of lantana found growing there.

In 1963 the tingid was introduced to Saipan from Belau and quickly established. From Saipan it was introduced into Guam in 1969 and again in 1971. On both islands it has proved to be a very effective bio-control agent, particularly in open, sunny areas during the dryer months. The bug was also found to be exerting a good degree of control on lantana on Chuuk, Aguijan and Tinian although no records exist of it ever being introduced to these islands.

Uroplata girardi PIC (CHRYSOMELIDAE)

This beetle feeds exclusively on lantana leaves reducing the plants effective photosynthetic area and upsetting its water balance. Both adults and larvae attack the leaves; the former scarifying the leaf surface and the latter mining the mesophyll layer protected between the upper and lower epidermis.

Specimens of *U. giarardi* were first introduced from Hawaii into Micronesia, via Pohnpei and Saipan, in 1963. Shipments were subsequently transported to Belau from Pohnpei in 1974 and to Guam from Saipan in 1967. The beetle was found on all of these islands at the time of our survey and was found to be exerting light to moderate leaf damage to plants. It was most effective in shaded areas at relatively high humidity. We also found *U. girardi* on Chuuk where it had, presumably, been introduced from Pohnpei. However, we were unable to locate records documenting the introduction of any natural enemy of lantana to this island. On Belau, the beetle was observed to be equally effective on both the orange/yellow and pink/yellow flowering varieties, unlike the tingid. For this reason, it could prove a useful addition to the suit of natural enemies found on Yap should the need ever arise. The absence of *U. girardi* from Tinian coupled with the need for additional bio-control measures here prompted us to introduce approximately 700 specimens of the beetle to the island in August 1989. Surveys, made 10 months later, revealed that although the beetle had established, the population was small and ineffective and had spread little from its point of release. Further releases, at more favorable sites on Tinian and on the neighboring island of Aguijan, are scheduled for the near future.

Ophiomyia lantanae (FROGGAT) (AGROMYZIDAE)

Commonly known as the pod-fly, the larvae of this species excavate tunnels in the developing fruits causing them to shrivel and drop prematurely. *O. lantanae* is a native of Central America and was one of the four insects initially introduced

into Pohnpei from Hawaii in 1948. It was reported to have established in 1949 (Bryan 1949) although our survey failed to find it anywhere on the island.

The deliberate introduction of the fly to Guam from Hawaii, in 1971, was the only other record found of its entry into Micronesia. Despite this, it was also located on Tinian, Saipan and the Belauan island of Angaur during the present survey. On all these islands it was observed to be well established and widely distributed. The numbers of fly infested pods frequently exceeded 50% of total pods produced per flowering head. According to Waterhouse & Norris (1987), the impact of *O. lantanae* in reducing the abundance and distribution of lantana remains in question since the larvae only feed on the endosperm and do not affect the seed embryo. However, we have experimental evidence to indicate that fly infested fruits are rendered less attractive to birds (Table 3) which, in turn, must reflect upon lantana seed dispersal and distribution by avifauna. Interestingly, this was originally suggested by Beeson & Chatterjee (1939) over half a century ago.

Lantanophaga pusillidactyla (WALKER) (PTEROPHORIDAE)

L. pusillidactyla is one of four surviving lepidopteran species introduced into Micronesia to control lantana. The larvae of this species feed predominantly on the florets of lantana and have, on occasions, been observed to attack the fruits. Thus, they are instrumental in reducing seed production. *L. pusillidactyla* was among the first insects to be introduced into Pohnpei in 1948 and from there was sent to Belau in 1960. Despite there being no other records of its intentional distribution throughout Micronesia, it was found to be widespread during the present study and was recorded on all islands where lantana was present except Aguijan.

Epinotia lantana (BUSCK) (TORTRICIDAE)

The larvae of this Central American moth aggressively attacks the florets receptacles and developing pods of lantana significantly influencing seed production. It was among the first shipment of insects sent Pohnpei in 1948 and from there would appear to have spread throughout Micronesia in a fortuitous

Table 3. The acceptability of *Ophiomyia lantanae* infested lantana fruits to the Philippine turtle dove, *Streptopelia bitorquata* (Temmink).

	% Lantana Fruits Eaten Over 6 Hour Period*			
	Succulent Fruit		Dry Fruits	
Feeding Trial	Non-infested	Infested	Non-infested	Infested
1	100	72	34	8
2	100	42	10	4
3	100	53	35	0
Average	100	56	26	4

*Between 50–100 berries/category used in each trial.

manner. Its distribution paralleled that of *L. pusillidactyla*, with which it ranked among the most effective bio-control agents of lantana in this region. Together, these species have been reported to account for up to 80% decline in berry production in Yap (Muniappan 1989) and Guam (Denton et al. in press).

Hypena strigata (FAB.) (NOCTUIDAE)

The larvae of this species are foliar feeders, and have proved to be very effective bio-control agents of lantana in Hawaii (Davis 1959). From here the species was introduced to Pohnpei and Yap in 1959, and to Guam in 1967. However, the promise shown by the species in Hawaii did not manifest itself on these islands. On Pohnpei for example, the species does not appear to have established and on Yap and Guam its impact is insignificant. We also found it at low levels on Aguijan, Tinian and Saipan where it appears to have been accidentally introduced in some way. It is noteworthy that this species has met with little success in Australia because of high mortalities associated with predation and parasitization (Waterhouse & Norris 1987). Quite possibly, the ineffectiveness of this species in Micronesia is for the same reasons.

Salbia haemorrhoidalis GUENEE (PYRALIDAE)

Also known as the lantana leaf roller, this species was introduced into Pohnpei along with *H. strigata* in 1958. Like the latter species it also feeds on lantana leaves and, as its name suggests, lives under the protective covering of the leaf margin which it folds and fastens down with silk. The species was very common on Pohnpei although its impact on lantana was minimal. It was also found on the neighboring island Chuuk but once again had little impact on the lantana growing there. We did not find it on any of the other islands visited.

Attempts were made to introduce *S. haemorrhoidalis* to Yap and Guam in 1958 but it failed to establish. Likewise, its introduction to Belau in 1960, and again to Yap in 1962, met with similar results.

Indigenous Natural Enemies

A number of adult, polyphagous insects, indigenous to the islands of Micronesia, have been observed to feed on lantana but we have, so far, only discovered two lepidopteran species that utilize the plant for egg laying and larval development. These noteworthy adaptions are discussed for each species below.

Zizula hylax F. (LYCAENIDAE)

Normally a consumer of small, leguminous, ground covering plants, the rather attractive larvae of this species were found grazing the florets of the orange/yellow lantana on Yap and Angaur. On the former island, larvae were isolated from 25–30% of all damaged lantana flowers examined. It is pertinent to note here, that other species of lycaenid butterfly are known to feed on lantana and two of these, *Strymon* (=*Thecla*) *ecion* and *S. bazochii* were among the eight candidate species first established in Hawaii for such purposes (Perkins & Swezey

1924). However, this is the first work that shows *Z. hylax* attacks this plant. Also of interest is the fact that *Z. hylax* is very common on Guam although the larvae are not found on the pink/yellow variety of lantana found growing there. The fact that the larvae can be successfully reared out on this variety in the laboratory suggests the adults prefer nectar from certain color-morphs over others.

Adoxopheyes melia CLARKE (TORTRICIDAE)

Isolated from lantana flowers on Guam and Saipan, larvae of this polyphagous species have, in the past, only been recorded to feed on the leaves of *Citrus* sp. and *Maytenus thompsoni* (Celastacae) locally known as "luluhut". Like *L. pusillidactyla*, it only consumes the lantana florets, webbing their remains together to form a protective covering over itself. It was first recorded on Guam in 1971 and at the present time is considered to play a relatively minor role in controlling the spread of lantana on the island.

Concluding Remarks

Clearly, lantana is widespread throughout Micronesia although the introduction of several of the weed's natural enemies has, on the majority of islands visited, resulted in an acceptable level of control. In the event that more effective, long-term control of this weed be required, the introduction of additional insect enemies, may be a worthwhile consideration. One candidate species, in particular, that merits consideration is the leaf mining fly *Calycomyza lantanae* Frick (Agromyzidae). This species is wide spread throughout the southeast Asian region and has been reported to cause severe defoliation of lantana in Malaysia (Ooi 1987).

Several other candidate species are available and these are discussed at length in previous communications (Muniappan & Viraktamath 1986, Muniappan 1988).

It should be mentioned here, however, that *L. camara* is a particularly hardy and resilient plant species, that demonstrates a remarkable capacity to recover from the severest of insect attacks. It, therefore, seems unlikely that the weed will ever be reduced to a level where it is difficult to find unless chemical and/or mechanical means are additionally used to implement its control.

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