White Grub, *Leucopholis irrorata* (Coleoptera: Scarabaeidae): Pest Status, Population Dynamics, and Chemical Control in a Rice-Maize Cropping Pattern in the Philippines

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ABSTRACT *Leucopholis irrorata* Chevrolat is a perennial white grub pest of the dryland rice-maize cropping pattern in localized fields of Batangas, Philippines. Adults emerge from underground pupal cells and fly to nearby host trees before oviposition in response to the onset of monsoonal rains after a 3-month dry season coterminous with establishment of the rice crop. Damage via loss of stand occurs on the following young maize crop when the white grub population is composed of 3rd-instar larvae. Maize fields with perennial damage are located near adult flight trees in areas where sugarcane is the predominant crop. Furrow-applied lindane granules at 0.25 kg of Al/ha during sowing of rice provide year-long control of this univoltine species at a cost small-scale farmers can afford.

The white grub, *Leucopholis irrorata* Chevrolat, caused intensive but highly localized damage to dryland rice and the following maize crop in 1974 in NE Batangas province, Southern Luzon, Philippines (IRRI 1976a). Damaged rice plants occurred in patches within a field, and plants near maturity could be pulled up by hand with little effort. Third-instar larvae (L3) were found at the base of wilted plants.

Maize sown in those same fields suffered up to 27% stand reduction (IRRI 1976b), because the entire root system of a 2-week-old maize plant could be severed by an L3. Farmers recognized white grub damage (Litsinger et al. 1980), and discussions with them revealed that white grub is a perennial problem only in certain fields located near groves of adult host trees (Otanes 1924) in predominantly sugarcane-growing areas (IRRI 1976b).

The distribution of *L. irrorata* in the Philippines is associated with sugarcane. *L. irrorata* first gained notoriety in 1910 as a sugarcane pest in Negros Occidental (Uichanco 1930) and reached outbreak proportions in Batangas and Negros Occidental from 1923 (Otanes 1924) to 1930 (Lopez 1930, 1931) during an era of rapid expansion of sugarcane in the Philippines (Quirino 1974). *L. irrorata* also severely damaged rice and maize in Batangas during this outbreak period (Otanes 1924). Damage to annual crops in North America (Fuchs et al. 1980), and discussions with them revealed that *L. irrorata* is a perennial white grub pest of the dryland rice-maize cropping pattern in localized fields of Batangas, Philippines. Adults emerge from underground pupal cells and fly to nearby host trees before oviposition in response to the onset of monsoonal rains after a 3-month dry season coterminous with establishment of the rice crop. Damage via loss of stand occurs on the following young maize crop when the white grub population is composed of 3rd-instar larvae. Maize fields with perennial damage are located near adult flight trees in areas where sugarcane is the predominant crop. Furrow-applied lindane granules at 0.25 kg of Al/ha during sowing of rice provide year-long control of this univoltine species at a cost small-scale farmers can afford.

The univoltine *L. irrorata* initiates oviposition after adult emergence from the soil at the beginning of monsoonal rains after a 3-month dry season (Otanes 1931). The rice crop ('Dagge,' a 125-day traditional variety) is cropped because the plants are near maturity by the time the L3 appears.

Trials in 1975 in infested maize fields showed that furrow application of soil insecticides, even at 4 kg of Al/ha, gave less than 80% control of L3, whereas lindane G at 1 kg of Al/ha, applied to rice in furrows made during interrow weed cultivation 20 days after sowing, provided 100% control (IRRI 1976b).

A strategy to control *L. irrorata* on the rice-maize cropping pattern was developed by using low doses of lindane (the least expensive insecticide available) during the rice-growing season. Granules were applied to the soil during three periods: (1) land preparation, (2) sowing, and (3) weed cultivation.

The population dynamics of *L. irrorata* were studied in the rice-maize pattern to understand the occurrence of the various life stages in relation to timing of insecticide placement. Similarities in the life history of *L. irrorata* to other univoltine tropical white grub species are noted to indicate that this strategy may have wider application.

**Materials and Methods**

**Population Dynamics**

The seasonal abundance of *L. irrorata* was determined for the 1975–1976 crop year in Malvar, Batangas. Adult beetles were collected daily 1 April through 30 June from flight trees around homesites in Luta del Sur and Natatas villages. Beetles were dislodged from trees where they rest during the day (Otanes 1931) by shaking branches. Subsamples of 100 beetles per village were preserved in alcohol and dissected to determine sex and stage of egg development of females.

Larvae were sampled every 2 weeks from three perennially infested fields remote from the adult collection sites, using a stratified grid (Guppy and Harcourt 1973), nine equal quadrats per field, two random soil samples per quadrat. Each sample (12 by 50 cm) (Burrage and Gyrisco 1954) was positioned to include half of the root systems of rice and maize. Soil dug to 20 cm was sieved through wire screen (1 by 1 cm). Larval instars were identified by head capsule width (Lopez 1931). Pits 1 m deep were dug monthly during the dry season from January through April 1976 for recording pupal and adult development. Too few specimens were recovered to estimate field populations. Rainfall gauges were placed in each village.
Insecticide Trial

Low doses of lindane (6% G) were tested against white grubs during three rice tillage periods in one field: (1) at final harrowing before seed furrows were made (broadcast 18 May at 0.25 and 0.5 kg of AI/ha); (2) sowing in seed furrows (29 May at 0.125, 0.25, and 0.5 kg of AI/ha); and (3) interrow weed cultivation (Fig. 1) in furrows (15 June at 0.25 and 0.5 kg of AI/ha). Treatments in plots (15 by 15 m) were replicated three times in a randomized complete block design. White grubs (L3) were sampled after rice harvest on 29 October by plowing three random rows (13 m long by 18 cm wide) per replication. Clods were broken by hand to recover larvae.

Results

Population Dynamics

Adult flight to host trees was first detected in both villages on 7 May after two rainfall periods that occurred in the first (53 mm) and fourth (64 mm) weeks of April (Fig. 2). No rain fell during the first flight period. During this 1 day flight before rice was sown, 58% were females, of which 41% contained fully developed eggs. The second and largest flight occurred during a rainy period, 17 May through 7 June, coinciding with the sowing of rice. Insignificant adult numbers were collected after 7 June.

First-instar larvae (L1) peaked on the 10 June sampling date coincident with the farmers’ interrow weed cultivation and were detected until 14 August (Fig. 2). A partial second generation of L1 occurred at the end of the rainy season from January through February 1976. Rice was at maximum tillering on 23 June, marking the first appearance and population peak of 2nd-instar larvae (L2). No L2 were found after 29 August.

L3 appeared on 18 July at mid-growth of the rice crop and peaked on 21 November at mid-growth of the following maize crop. Only one L3 was found on the last sampling date at the end of February. At this time the soil was dry to 20 cm deep, and systematic sampling was stopped.

Soil pits dug in mid-February contained pupae at 30 to 80 cm. Adults were first found in late March in pupal cells, and those found in April were still sexually immature.
Insecticide Trial

Furrow application of lindane G during rice sowing provided significant white grub control (87%) with a minimal dose of 0.25 kg of Al/ha (Table 1). Furrow application at 0.5 kg of Al/ha during interrow weed cultivation, 20 days later, failed to significantly control \textit{L. irrorata}. Broadcast application during plowing 10 days before sowing rice likewise did not control larvae.

Discussion

Synchronization of Life Stages

The temporal synchronization of individuals within each life stage is an essential precondition for \textit{L. irrorata} to achieve pest status and is a key to its chemical control, using only one application annually in the rice-maize pattern. Crop damage is associated with the occurrence of the last larval instar. The L3 appears only when rice is near maturity, and consequently that crop escapes significant damage. Maize, however, is planted when virtually the entire white grub population is in the L3 and significant stand reduction occurs.

It is significant that the L3 are not present when rice is sown and chemical control with low dosages can be achieved against small grubs. The proper timing of lindane applications against L1 on the preceding rice crop can protect maize at a cost small-scale farmers can afford.

Synchronization is assured because of the long life cycle of the white grub, the intervention of the 3-month dry season, and the fact that adults remain in the soil awaiting rainfall to trigger emergence and oviposition.

Life stages would lose synchrony between individuals if a complete second generation occurred annually. A second generation was begun in the late rainy season (Fig. 2) by adults which most likely developed from eggs laid during the first flight period. In Negros Occidental, Philippines, Lopez (1930) also reported second-generation adult flights in November and December 1929. We found no evidence that a second generation in Batangas or Negros developed beyond L1. The L1 in other white grub species (Maelzer 1961, Milne 1964, Davidson et al. 1972) are particularly sensitive to moisture stress. No L2 or L3 was collected in Batangas during the early-1975 rainy season, indicating that the 1975 population began with newly laid eggs and not older larvae that survived the dry season in the soil.

Prolonged dry seasons in areas where \textit{L. irrorata} occurs in the Philippines act to further synchronize the population. Evidence from the known life cycle of \textit{L. irrorata} and similar univoltine species (Reinhard 1941, Pollard 1956, Veeresh 1977, Nigam and Awasthi 1978) strongly suggests that \textit{L. irrorata} pass the dry season as inactive adults within pupal cells that offer protection against desiccation (Fidler 1936).

Lopez (1931) made excavations in dry soil in mid-April 1931 and found adults tunneling upward in the soil profile. Females near the surface contained mature eggs, whereas those collected deeper in the soil were still sexually immature. When heavy rains fell on 29 April, the initial adult flight occurred the next day. Lopez concluded that adult development continued throughout the dry season, with adults leaving their pupal cells but not emerging from the ground until triggered by rains. Rao (1969) made a similar conclusion for seven species of white grubs attacking rubber plantations in Malaysia.

In Batangas, adult flight did not initiate with the first heavy rains during the first week of April 1975, but 1 month later. Rainfall records for La Carlota and Ma’ao in Negros Occidental in 1931 (Maso 1932), where Lopez made his excavations, showed that 30 mm of rain fell from 10 to 12 March, thus supporting our contention that \textit{L. irrorata} remains dormant as sexually immature adults within moist pupal cells until rainfall reactivates them.

This correlation of events suggests a reproductive diapause or aestivation induced by a drying soil (Masaki 1980). An aestival diapause, in which adult metabolism slowed down, would mean conservation of energy and subsequent enhancement of survival during the unfavorable dry season. Once aestivation is terminated by rainfall, existing evidence supports a preovipositional period of ca. 1 month, during which time adults tunnel up to the soil surface. Two rainy periods during the first and fourth weeks of April generated two flight periods i.e., the first and third weeks of May. The smaller first flight probably was composed of adults which had reached the soil surface sooner.

It would be biologically advantageous for \textit{L. irrorata} to pass the dry season in environmentally favorable pupal cells rather than near the soil surface and to delay oviposition until new roots developed on larval hosts stimulated by rainfall.

Clustered Distribution

\textit{L. irrorata} occurs throughout the Philippines in dryland environments from Northern Luzon to Mindanao in the south (Otanes 1924), but it is highly localized as a pest in the equally widespread dryland rice-maize cropping pattern (Garrity et al. 1979). Clustered distribution is a common feature of white grub species, and infestations tend to reoccur in the same fields annually (Mungomery 1949, Schneider 1962, Sweeney 1967, Veeresh 1977).

Factors contributing to patchy white grub distribution have been enumerated for other species. They are: (1) narrow range of soil texture and soil moisture tolerated by larvae, (2) selection by adults of oviposition sites by differences in plant cover, (3) prevalence of favorable larval plant hosts, and (4) proximity to adult "flight" trees.

Soil Texture.—With few exceptions, white grub species are reported to be confined to light-textured soils which offer a moisture gradient in the soil horizon (Maelzer 1961, Milne 1964, Wilson 1969, Davidson et al. 1972, Gaylor and Frankie 1979). Species found in heavier soils exist in low-rainfall areas (Sweeney 1967). Lopez (1930) noted that \textit{L. irrorata} occurred in low numbers in areas of heavy soils in Negros Occidental.
Table 1. Effects of application time and dosage of lindane 6 G during the rice crop on white grub control

<table>
<thead>
<tr>
<th>Application method</th>
<th>Application time</th>
<th>Dosage (kg of Al/ha)</th>
<th>No. of larvae/13-m row*</th>
<th>% Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broadcast</td>
<td>Land preparation</td>
<td>0.25</td>
<td>11ab</td>
<td>27</td>
</tr>
<tr>
<td>Furrow</td>
<td>Sowing</td>
<td>0.25</td>
<td>5ab</td>
<td>67</td>
</tr>
<tr>
<td>Furrow</td>
<td></td>
<td>0.25</td>
<td>2a</td>
<td>87</td>
</tr>
<tr>
<td>Furrow</td>
<td>Weed cultivation</td>
<td>0.25</td>
<td>6ab</td>
<td>60</td>
</tr>
<tr>
<td>Check</td>
<td></td>
<td>0.5</td>
<td>7ab</td>
<td>53</td>
</tr>
</tbody>
</table>

*Means in a column followed by a common letter are not significantly different (P = 0.05), by Duncan's multiple range test. Larvae sampled from three 13-m rows per replication with a plow on 15 October after rice harvest.

In the Philippines, typhoons are a common occurrence north of Mindanao. In heavier soils, concentrated rainfall from typhoons over a period of several days probably causes high larval mortality (Mungomery 1927, Maelzer 1961, Davidson et al. 1972). In Los Banos, Laguna, where IRRI is located, and which has a heavy clay soil, *L. irrorata* has not become a pest in the sugarcane areas. We attempted to rear *L. irrorata* larvae outdoors in pots, using heavy clay from sugarcane areas near IRRI experimental farm, but the larvae died after periods of high rainfall. We could rear larvae outdoors only in the lighter Batangas soils.

Plant Cover.—The higher white grub densities in some fields are influenced by the preference of females to oviposit in areas of low plant cover (young plants) rather than in bare soil or in areas of tall (old) plants (Smyth 1917, Sweeney 1967, Kelsey 1968, Rao 1969, Wilson 1969, King 1980). Lopez (1930) cited evidence showing that *L. irrorata* preferred to oviposit in weedy, fallow fields rather than in those containing full-grown sugarcane. It is reasonable to assume that ovipositing females select fields with host plants that are producing new root growth. Oviposition occurs within 1 month after the first heavy rainfall, which assures that plants will have begun a flush of root growth and can tolerate some root removal.

Rice, in neighboring Tanauan, is normally sown 1 month later than in Malvar, and the white grub problem in the rice-maize pattern there is less than that in the Malvar site. Tanauan fields would lack plant cover during most of the adult flight period and would be less attractive as oviposition sites.

Sugarcane is on an annual cropping cycle in the Philippines and is harvested and replanted in the dry season. Sugarcane 1 to 4 months old would also be attractive to ovipositing females because of its low growth.

Larval Host Plants.—*L. irrorata*, as well as other tropical species, require a sustained larval feeding period of at least 6 months. White grub larvae are relatively immobile in their soil habitat and if, by feeding, host plants were readily killed, they would succumb from lack of food.

White grub species of agricultural importance worldwide tend to be associated with perennial crops that have fibrous root systems, such as pasture grasses and sugarcane. Annual crops, particularly those with tap root systems, are more severely damaged than perennial grasses by a given white grub density, and even fully grown plants die once the taproot is severed (Chamberlin and Fluke 1947, Tarr 1954, Rai et al. 1969).

White grub species have prolonged larval development periods initiated by a saprophagous L1. This behavior apparently is a delaying strategy, thus allowing host plants to produce vigorous root systems before the larval feeding period.

The root systems of rice and maize are smaller than those of sugarcane, and therefore can sustain smaller white grub populations. The timing of tillage operations and their greater frequency in the rice-maize pattern compared with that of sugarcane result in greater larval mortality from mechanical damage and predation by chickens on exposed larvae (Otanes 1924). In North America, before soil insecticides were widely used, white grubs were more numerous in maize planted after pasture than in a maize monoculture (Metcalf and Flint 1962), indicating that maize alone cannot sustain high white grub numbers. Sugarcane, a 2- to 3-year crop like grassland pastures, provides an ideal environment for undisturbed and sustained white grub population development. In the Philippines, soil disturbance in sugarcane is minimal because the crop is normally ratooned one to two times, and land preparation is done during the dry season when *L. irrorata* are in pupal cells below the plow zone. Sugarcane is at least 4 months old by the time the phytophagous L2 develop and can sustain higher white grub densities before plants mortality occurs.

The rice-maize pattern cannot sustain high densities of *L. irrorata*. Extensive planting of sugarcane or other perennial grasses appears to be a necessary requirement for white grub population development in a region. The rice-maize pattern occurs extensively in light-textured soils in Bukidnon province in Mindanao, but sugarcane or other perennial grasses are less common, and subsequently *L. irrorata* has a lower pest status. Similarly, the Tanauan area of Batangas is more extensively planted to rice and other annual crops than neighboring Malvar, which is planted mainly to sugarcane and consequently has a lower carrying capacity for white grubs. We believe that *L. irrorata* is not a perennial pest in Tanauan because of the smaller crop area planted to sugarcane.
Adult Flight Trees.—Local variation in white grub abundance among fields has been attributed to their proximity to adult flight trees. Flight trees perform several biological functions for species which possess the hypostatic behavior to fly in search of tall objects set against the skyline (Schneider 1962, Farrell and Wrightman 1972). The flush of new tree growth in response to rainfall ensures a nutritious food source for females in need of energy for oviposition and oviposition. The fact that the host plants of adults differ from those of larvae eliminates intraspecific competition for food sources.

*L. irrorata* adults apparently do not feed as extensively as some Indian species (Veeresh 1977), because significant defoliation on flight trees has not been reported in the Philippines even during the 1920s outbreak. The L3 apparently build sufficient fat body reserves (Milne 1957) to meet most of the adult energy needs.

Besides being a food source, flight trees serve as mating sites for *L. irrorata*. Mating in Scarabaeidae is a precondition to laying eggs (Ritcher 1958). *L. irrorata* mates in trees rather than near the emergence hole as reported in other melolonthine species (Milne 1959, Farrell and Wrightman 1972). *L. irrorata* adults remain in the trees during the day and take short flights to lay eggs in nearby fields at night. Therefore females, as do similar white grub species (Shorey et al. 1960, Rai et al. 1969, Fiori 1976, Veeresh 1977, King 1981), lay proportionally more eggs near flight trees. Because trees are not evenly distributed in Batangas, white grub damage will recur each year near the same groves.

### Chemical Control

Furrow application of lindane at planting was effective at low dosages because it was directed at the L1. Furrow application 20 days later, during interrow weed cultivation, was inferior at corresponding insecticide dosages, because a significant portion of the population had matured to the L2. Higher dosages are required to kill L2 white grubs (Hove and Campbell 1953). In addition, application at planting is superior to that at a later date; in years of prolonged rainfall, farmers cannot incorporate granules at the time for weed cultivation, because the soil remains saturated and cannot be tilled.

At equivalent doses, furrow application, by concentrating insecticides, is superior to broadcasting (Munro 1959). Band placement in furrows lowers the soil moisture to its pasture scarab *Seriesithis nigrolineata* Boisd. Effects of soil moisture and temperature in survival of first-instar larvae. J. Appl. Ecol. 9: 427–430.


