SEMIOCHEMICAL-BASED TRAPPING METHODS FOR WEEVIL PESTS IN GUAM

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1. Banana root borer, *Cosmopolites sordidus* (Germar) (Insecta: Coleoptera: Curculionidae)

In previous years, most bananas in local markets were imported from other countries. Today, banana growing has become increasingly popular among farmers in Guam and plantations are found throughout the island. One of the most serious insect pests of bananas is the banana root borer, *Cosmopolites sordidus*. The larvae of the banana root borer tunnel in the corm (Figure 1), weakening the stability of the plant and interfering with nutrient uptake. Relatively little damage is caused by adults feeding on plant tissues. Borer attack can lead to poor crop establishment, plant loss due to snapping and toppling, lower bunch weights, mat disappearance (failure to produce suckers), and shortened plantation life (Rukazambuga et al. 1998, McIntyre et al. 2002, Gold et al. 2004). Yield losses increase with time and can exceed 50%. The banana root borer's host range is restricted to *Musa* and *Ensete* (Musaceae). The complete life cycle of the borer is 30 to 40 days; egg 5 to 7 days; larva 15 to 20 days, pupa 6 to 8 days. Adults are long-lived (up to 4 years), nocturnally active, and have low fecundity (< 2 eggs/week) (Figure 2; Gold et al., 2001). The presence of this weevil in Guam and other islands raises concern among growers, consumers, and scientists.

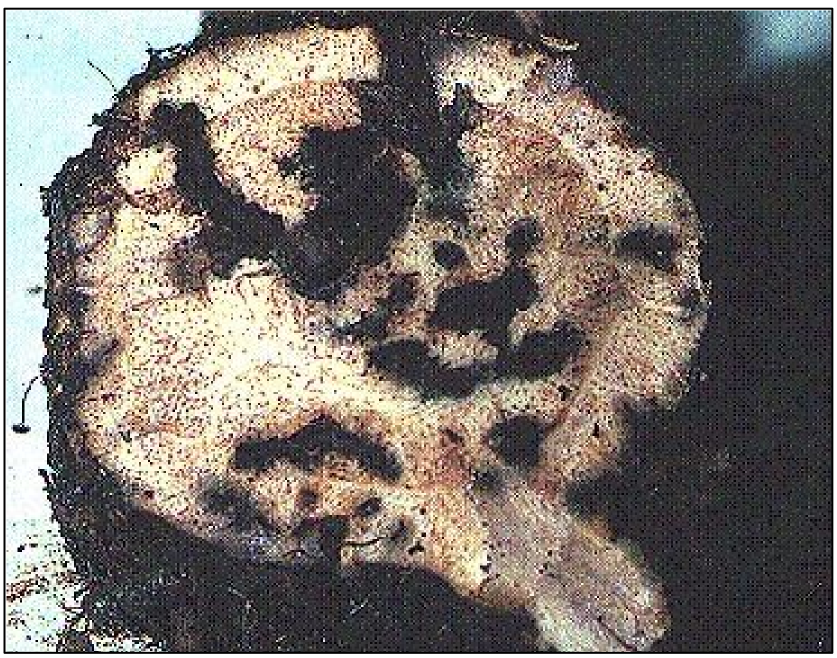

Figure 1: Banana root borer damage to corms

The weevil is native to Malaysia and Indonesia, but has spread to nearly all banana-growing areas of the world, including Australia, Africa, Central and South America, Florida, Mexico, some Pacific islands, South and Southeast Asia, and the West Indies. The weevil was first detected in Hawaii on the island of Oahu in 1981 and has spread to the islands of Hawaii, Kauai, Maui, and Molokai. It has been reported in the Marianas since the early 1940s. Recently, this borer has become a very serious problem for commercial banana farms in Guam and the Northern Mariana Islands.

The weevils prefer moist environments and are most commonly found in banana leaf sheaths, in the soil around the base of the mat, or in undercut residues. Flight is uncommon and dispersal by crawling appears to be slow; therefore, the major movement of this weevil must be assisted by human activities. Effective and economical management of this pest is essential for the success of infested commercial banana farms.

Recommendations for integrated pest management of the banana root borer have emphasized cultural controls, including the use of clean planting material, pseudostem trapping, and crop sanitation (i.e., destruction of crop residues). While a number of banana root borer predators have been reported, attempts at biological control using predators throughout the Pacific, especially *Plaesius* (Coleoptera: Histeridae) and *Dactylosternus hydrophiloides* (Coleoptera: Hydrophilidae), have been largely disappointing (Gold et al. 2001). For many years, persistent insecticides, such as dieldrin and aldrin, which have already been banned, were used in developing countries to control this pest. Banana weevils have developed resistance to these chemicals and in recent years insecticides such as Primicid, Furadan, Nemacur, Dasanit, and Lorsban have been used. Furadan is the most effective of these insecticides and although it is commonly used by commercial banana growers, it is highly toxic to humans and its use is restricted to licensed applicators.

Banana root borer traps are useful for the detection of new infestations, monitoring population increases to economic levels, and/or trapping out populations for control or eradication. Adult weevils are attracted to banana pseudostems, but the number of pseudostem traps allowed for use in the field is restricted by the number of recently harvested banana plants and the amount of available crop residues. Pheromone-based trapping can be very effective. Data from our previous pheromone trapping studies (lure packs, each containing 90 mg of sordidin) in Guam indicate a higher population level (>10/week) in the northern region and a lower (<5 weevils/week) to medium level (5-10 weevils/week) population in the southern parts of the island (Reddy et al. 2008). This weevil can cause a yield loss of up to 100% if left uncontrolled. Trapping with synthetic pheromones (based on the male aggregation pheromone sordidin) has also been promoted (Reddy and Guerrero 2010). Below is a description of a ground trap and its optimal method of use.

Figure 2: Adult banana root borer, *Cosmopolites sordidus*

Trapping Technique Developed by the Chemical Ecology and Entomology Laboratory at the Western Pacific Tropical Research Center, University of Guam.

Trap Type: The ground trap (Figure-3) was constructed and developed by the Chemical Ecology and Entomology Laboratory at the Western Pacific Tropical Research Center, University of Guam, from a 120 × 60 × 0.5-cm piece of white corrugated plastic board, with a 50 × 8-cm slitted baffle fitted at the top to prevent the borers from escaping (Reddy et al. 2005).

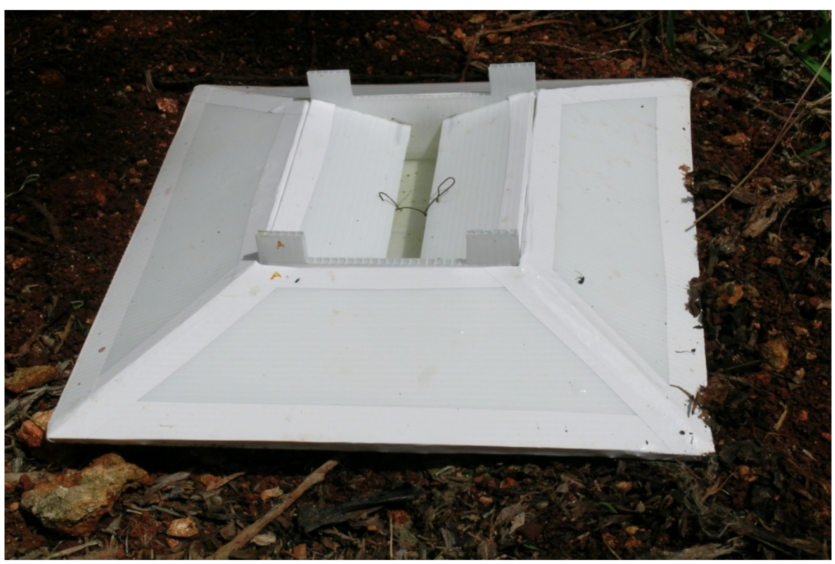

Figure 3: An effective ground trap used for monitoring and controlling the banana root borer

Trap Type and Size: Our previous studies indicated that ground traps 40 × 25 cm in size most efficiently catch banana root borer adults in the field and have the greatest potential for use in mass trapping and programs for the control and eradication of this pest (Reddy et al. 2009).

Color of Trap: Mahogany brown-colored ground traps are more effective than other colored traps.

Pheromone Lures: Pheromone lures (Cosmolure), sealed in a polymer membrane release device and optimized for *C. sordidus*, can be obtained from ChemTica Internacional S.A. (San José, Costa Rica). The lure packs, each containing 90 mg of pheromone and having a release rate of 3 mg/day, must be stored at 4°C until use. Lures are hung on 2-cm wires suspended across the tops of the ground traps. The lures must be changed when the transparent container with the pheromone is empty, usually once or twice a month, although occasionally more frequent changes are necessary.

Inter-Trap Distance: Manufacturer recommendations are to use four pheromone-baited traps per hectare in a single line, spaced 20 m apart.

Trap Placement: The traps are placed on the ground. Moreover, pheromone-baited ground traps positioned in the shade of the canopy catch significantly more adults than those placed in sunlight (Reddy et al. 2009).

Baiting Traps: Traps are sealed at all four corners and along the edges with marine adhesive sealant, and water mixed with a dishwashing liquid detergent (1%–3%) is placed in the bottom of the container to retain adults. The lower outer edges of the ground traps are covered with earth to prevent weevils from crawling under the traps. The lure should be replaced every 1 to 2 months and the trap line should be moved 20 m such that the entire field is systematically covered every 4 months. This recommendation is based on the assumption (1) that the traps will capture most of the weevils within a 15-m radius of the trap, and (2) that there will be limited reinvasion of the cleaned areas after removal of the trap. Thus, the benefits of trapping and other management methods may be offset by the immigration of adult weevils from neighboring stands or untreated parts of the field (Gold et al. 2001, 2002). The best management practices currently recommended for this pest include a combination of pheromone-based traps and improved field hygiene.

2. New Guinea sugarcane weevil, *Rhabdoscelus obscurus* (Boisduval) (Insecta: Coleoptera: Curculionidae)

The New Guinea sugarcane weevil *Rhabdoscelus obscurus* (Boisduval) (Coleoptera: Curculionidae) is a very serious pest of ornamental palms and coconut plantations in the Mariana Islands and other Pacific islands (Muniappan et al. 2004). In Guam, *R. obscurus* is a major pest of ornamental and other palms such as coconut palm (*Cocos nucifera* L.), betel nut (*Areca catechu* L.), champagne palm (*Hyophorbe lagenicaulis* [Bailey]), pritchardia palm (*Pritchardia pacifica* Seem. & H. Wendl), pygmy date palm (*Phoenix roebelenii* O'Brien), Alexander palm (*Archontophoenix alexandrae* [F. Muell.] H. Wendl & Drude), royal palm (*Roystonea regia* [Kunth] O.F. Cook), and date palm (*Phoenix canariensis* hort. ex Chabaud) as well as sugarcane (*Saccharum officinarum* L.) (Reddy et al. 2005b). The incidence is extremely high during the hot and dry season (Timberlake 1927). Even small populations of this weevil can cause severe damage, and these pests are a year-round problem in warm climates (Sallam et al. 2004).

Adult female borers chew a 3-mm deep cavity into the sugarcane stalk, usually in existing adult feeding scars or cracks and occasionally at internodes or near the base of leaf sheaths (Napompeth et al. 1972). On palms, weevils lay their eggs in the petiole and on the stem (Figure 1). Larvae bore into the living tissue, producing frass-filled tunnels that weaken the affected parts of the host plant and permit invasion of fungal and bacterial pathogens. Mature larvae pupate in cocoons made of plant fibers close to the exit holes (Halfpapp and Storey 1991). Currently this weevil poses a serious threat to ornamental palms in the nursery industry and to betel nut production in Guam (Figure 2). Withdrawal of the ban by the Food and Drug Administration on the entry of betel nuts into the US mainland from Guam has encouraged commercial cultivation of the betel nut in Guam.

Figure 1: *Rhabdoscelus obscurus* damage on Sago palm

Because the weather in Micronesia is mostly dry and hot throughout the year, *R. obscurus* infestation is very severe (Bianchi and Owen 1965). Guam and other Micronesian islands are therefore in the midst of a decline in nursery and ornamental plant production. According to feedback from local farmers and homeowners in the region, and the extension faculty of the University of Guam, thousands of ornamental nursery and betel nut plants are dying as a result of *R. obscurus* infestation.

R. obscurus has recently begun attacking coconut palms in Guam. Although some control methods exist, chemical application is both undesirable and expensive (Robertson and Webster 1995). In the absence of appropriate effective control, these *R. obscurus* populations are likely to cause widespread or even complete loss of nursery and betel nut production in Micronesia and other regions. Although a parasitoid, *Lixophaga sphenophori* (Villeneuve) (Diptera: Tachinidae), from Maui (Hawaii) was introduced in Guam in 2005 to control *R. obscurus*, it is not yet established. Farmers, homeowners, and commercial firms in this region apply insecticides (dimethoate, acephate, carbaryl, malathion, naled, and lambda-cyhalothrin) up to 20 to 30 times per cropping period, particularly in ornamental nurseries, but these costly measures are associated with ecological and toxicological hazards. Therefore, ecologically sound and cost-effective semiochemical (pheromone)-based trapping methods developed by the Chemical Ecology and Entomology at the Western Pacific Tropical Research Center provide effective adjuvants or alternative control methods that can mitigate the negative effects of current pesticide usage.

In our previous study, traps baited with lures (ChemTica Internacional) optimized for the Australian geographical population caught significantly more weevils than traps baited with lures optimized for the Hawaiian *R. obscurus* population, suggesting that the Guam population reacts similarly to the Australian population (Muniappan et al. 2004). Moreover, this population is predominantly present in the north where the majority of commercial nurseries are located. We also observed that the addition of ethyl acetate to the pheromone lures as a synergist significantly increases trap catches of *R. obscurus.*

Figure 2: Adult New Guinea sugarcane weevil, *Rhabdoscelus obscurus*

Trapping Technique Developed by the Chemical Ecology and Entomology Laboratory at the Western Pacific Tropical Research Center, University of Guam.

Trap Types: The ground trap (Figure-3A) was constructed and developed at the Chemical Ecology and Entomology Laboratory at the Western Pacific Tropical Research Center, University of Guam from a 120 × 60 × 0.5-cm piece of white corrugated plastic board, with a 50 × 8-cm slitted baffle fitted at the top to prevent the borers from escaping (Reddy et al. 2005a). The lower outer edges of the ground traps are covered with earth to prevent the weevils from crawling under the traps.

The ramp traps (Figure-3B) are commercially available from ChemTica Internacional S.A. They are made of durable yellow Perspex and comprise two box-shaped components, each 14 cm wide by 4 cm high (inside dimensions), one component is open side-up and forms the floor of the trap and the other is open side-down, supported on short pillars at the corners, and forms the roof (Reddy 2007). Wide Perspex ramps on all four sides lead up to the rim of the lower box, which can be rested on the ground in the field.

Our previous studies indicated that ramp and ground traps captured similar numbers of weevils, and both captured significantly more adults than bucket and pitfall traps in the field (Reddy et al. 2011). For economy and ease of handling, the russet brown ground trap (40 × 25 cm and above) is recommended for capturing adults in the field, whereas otherwise-identical black-colored traps must be used indoors.

Trap Sizes: The ground trap of 120 × 60 × 0.5 cm and ramp traps 14 cm wide by 4 cm high are recommended.

Lures: The pheromone and ethyl acetate lures can be stored in a refrigerator until use. The pheromone lures [(*E*2)-6-methyl-2-hepten-4-ol and 2-methyl-4-octanol] are sealed in polymer membrane release devices optimized for the Australian population of *R. obscurus*. Pheromone and ethyl acetate lures must be changed every 4 months and the freshly cut sugarcane sections must be replaced once a week (Reddy et al. 2005b).

Color of Trap: Studies conducted by the Western Pacific Tropical Research Center indicate that russet brown-colored traps are the most effective in the field, and that *R. obscurus* prefer black-colored traps to those of other colors in indoor conditions.

Trap Placement: The traps should be strapped to the trees and at ground level to maximize the number of weevils caught.

Inter-Trap Distance: It is recommended to use 10 semiochemical-baited traps per hectare in a single line spaced 60 m apart.

Baiting Traps: In the ground traps, the pheromone and ethyl acetate (*Rhynchophorus palmarum* lure) lures must be suspended inside the traps on wires hung from the top. Two pieces of freshly cut sugarcane, 12 cm long, are placed directly in the ground trap and replaced with fresh canes weekly. The inside bottom of the trap is treated with a 5-ml spray of permethrin (0.75 ml/liter) to kill the attracted *R. obscurus*. Lures should be changed every 4 months (Reddy et al. 2005b).

In the ramp trap, the pheromone lure and ethyl acetate should be attached to the ceiling of the trap with a piece of vinyl-clad steel wire (the same wire used in all trap types), and two cut pieces of sugarcane placed inside the trap. The floor of the trap should be treated with a 5-ml spray of permethrin (0.75 ml/l).

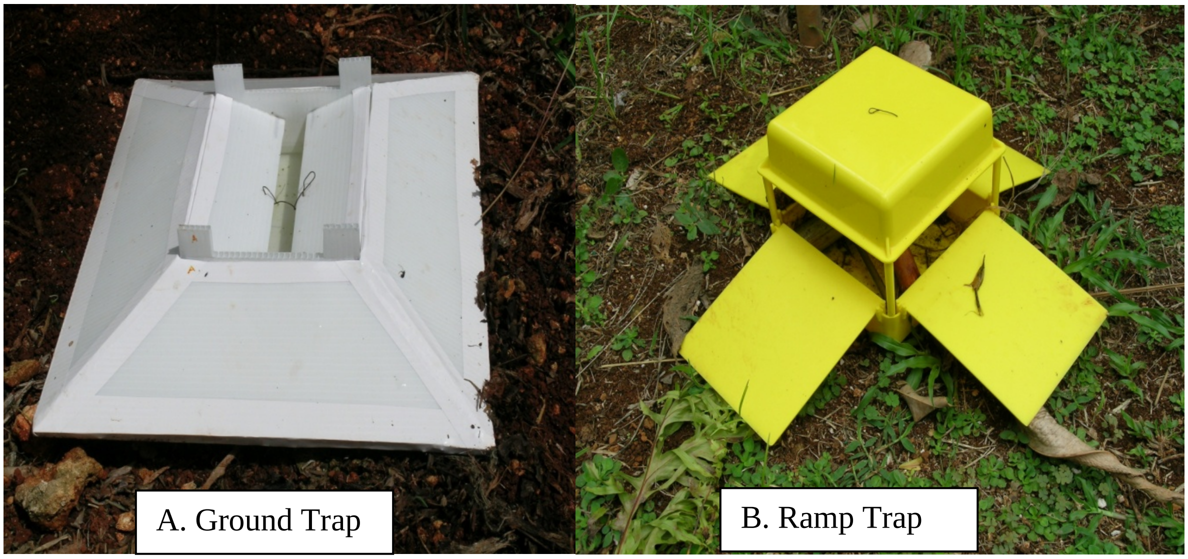

Figure 3: Effective trap designs used for monitoring and controlling the New Guinea sugarcane weevil, *Rhabdoscelus obscurus*

3. Sweet potato weevil, *Cylas formicarius* (F.) (Insecta: Coleoptera: Curculionidae)

Sweet potato (*Ipomoea batatas* L., family Convolvulaceae) is an important food crop in the Mariana Islands. This crop grows continuously throughout the year. The total harvested area and productivity in this region, however, indicate that crop development is declining due to a high infestation of the sweet potato weevil *Cylas formicarius* (F.) (Coleoptera: Curculionidae). The West Indian sweet potato weevil *Euscepes postfasciates* rarely occurs in Rota, but is not a problem in Guam. *C. formicarius* is the most serious sweet potato pest, both in the field and in storage (Chalfant 1990, Sutherland 1986). Adults prefer to live in the canopy of vines and leaves, feeding on all parts of the sweet potato plant. Females oviposit within cavities excavated either in the stems or the tubers where the larvae develop. Damage results from adult feeding, cavities excavated for oviposition, and tunneling of larvae through the tubers (Figure 1). The tunnels are filled with excrement, which resembles sawdust and gives the characteristic terpene odor and bitter flavor of infested sweet potato that renders them unsuitable for human or livestock consumption (Jansson and Raman 1991). A sign of infestation by the sweet potato weevil is yellowing of the vines, but a heavy infestation is usually necessary before this is apparent. Thus, incipient problems are easily overlooked, and damage may not be apparent until the tubers are harvested. The principal form of damage to the sweet potato is larval mining of the tubers.

Figure-1: Sweet potato damage by *Cylas formicarius*

A complete life cycle lasts 1 to 2 months, with 35 to 40 days being common during the summer months (Cockerham et al. 1954). Eggs are deposited in small cavities in the sweet potato root or stem created by the female with her mouthparts. Females apparently produce 2 to 4 eggs per day or 75 to 90 eggs during their life span of about 30 days. When the egg hatches, the larva usually burrows directly into the tuber or stem of the plant. Duration of each successive instar is 8 to 16, 12 to 21, and 35 to 56 days, respectively. The mature larva creates a small pupal chamber in the tuber or stem. The pupa is similar to the adult in appearance. Duration of the pupal stage averages 7 to 10 days. The adult usually emerges from the pupation site by chewing a hole through the exterior of the plant tissue, but sometimes it remains inside for a considerable period of time and feeds within the tuber (Figure 2). Under laboratory conditions, adults (Figure 3) can live over 200 days if provided with food and about 30 days if starved (Sherman and Tamashiro 1954).

Many farmers and homeowners spray toxic pesticides such as dimethoate, acephate, malathion, carbaryl, dibrom, and warrior to control this weevil. Because the grubs bore inside the tubers, the chemicals do not affect the weevil at immature stages. Further, it is unsafe to use chemicals on tuber crops. The underground feeding habits of the larvae and nocturnal activity of the adults make it necessary for farmers to apply insecticide 15 to 20 times during the 5 or 6 months of the growing season, which is not only costly but is also associated with ecological and toxicological hazards. The rate of tuber damage caused by *C. formicarius* is typically 45%, and sometimes reaches 88% in severely infested fields in Guam. Infestation of sweet potato farms by *C. formicarius* can reach 100% in the Commonwealth of the Northern Mariana Islands. Pheromone-traps have been developed for monitoring and controlling populations of this weevil in the field.

Figure-2: Sweet potato weevil entry hole.

Figure 3: Adult sweet potato weevil *Cylas formicarius*

Trapping Technique Developed by the Chemical Ecology and Entomology Laboratory at the Western Pacific Tropical Research Center, University of Guam.

Trap Type: The field studies at the Western Pacific Tropical Research Center indicated that the Unitrap (Figure 4) was significantly more effective than other traps for capturing *C. formicarius*. The Unitraps are commercially available from Trécé Inc (Adair, OK). Unitraps consist of a funnel-shaped plastic receptacle with a lid and holder for attaching lures mounted over a bucket to retain the captured insects. Bucket traps used in the Western Pacific Tropical Research Center studies have white receptacles and yellow lids.

Trap Size: Based on the field studies conducted at the Western Pacific Tropical Research Center, a Unitrap 20.5 cm high × 13 cm in diameter is recommended for capturing *C. formicarius* in the field.

Trap Color: Grey Unitraps catch a significantly higher number of insects than the other colored traps.

Pheromone Lures: The lures are commercially available from ChemTica Internacional S.A. This product consists of the pheromone of *C. formicarius* Z3-dodecenyl-E2 butenoate formulated in rubber septa for slow release over 4 to 6 weeks. The devices are further packed in an impermeable bag for shipping and storage. The product is intended for use in crops as an attractant for *C. formicarius*. The rate of release of the pheromone is greatest just after the lure is placed in the field and decreases thereafter.

Baiting Traps: To place lures in Unitraps, the lure is placed in the pheromone cup, and the cup is placed into the hole in the top of the trap. The traps need to be inspected and cleaned weekly for reuse by dumping the insects and wiping the inside of the trap (Jansson et al. 1990).

Trap Placement: For best results, traps should be placed approximately 1 m above the ground. Traps should be placed in the field to be monitored on a grid basis at 1 per hectare. The lures should be replaced every 6 weeks. Exhausted lures can be disposed of in household garbage.

Figure 4: Effective trap design for monitoring and controlling the sweet potato weevil *C. formicarius*

References

Bianchi, F.A., and R.P. Owen. 1965. Observations on *Rhabdoscelus obscurus* (Boisduval) and *Rhabdoscelus asperipennis* (Fairmaire) in Micronesia (Coleoptera: Curculionidae). Proc. Hawaiian Entomol. Soc. 19: 77–82.

Chalfant, R.B. 1990. Ecology and management of sweetpotato insects. Ann. Rev. Entomol. 35: 157–180.

Cockerham, K.L., O.T. Deen, M.B. Christian, L.D. Newsom. 1954. The biology of the sweet potato weevil. Louisiana Agricultural Experiment Station Technical Bulletin 483: 30 pp.

Gold, C.S., G.H. Kagezi, G. Night, and P.E. Ragama. 2004. The effects of banana weevil, *Cosmopolites sordidus* (Germar), damage on highland banana growth, yield and stand duration in Uganda. Ann. Appl. Biol. 145: 263–269.

Gold, C.S., J.E. *Peña* and E.B. Karamura. 2001. Biology and integrated pest management for the banana weevil, *Cosmopolites sordidus* (Germar) (Coleoptera:Curculionidae). Integ. Pest Manage. Rev. 6: 79–155.

Gold, C.S., S.H. Okech, and S. Nokoe. 2002. Evaluation of pseudostem trapping as a control of banana weevil, *Cosmopolites sordidus* (Germar), populations and damage in Ntungamo district, Uganda. Bull. Entomol. Res. 92: 35–44.

Halfpapp, K.H., and R.I. Storey. 1991. Cane weevil borer, *Rhabdoscelus obscurus* (Coleoptera: Curculionidae), a pest of palms in Northern Queensland, Australia. Principes 35: 199–207.

Jansson, R.K., F.I. Proshold, L.J. Mason, R.R. Heath, and S.H. Lecrone. 1990. Monitoring sweetpotato weevil (Coleoptera: Curculionidae) with sex pheromone: effects of dosage and age of septa. Trop. Pest Manag. 36: 263-269.

Jansson, R.K., and K.V. Raman. (ed.). 1991. Sweetpotato Pest Management: A Global Perspective. Westview Press Inc., Boulder, Colorado, USA. 439 pp.

McIntyre, B.D., Gold, C.S., Kashaija, I.N., Ssali, H., Night, G. and Bwamiki, D.P. 2002. Effects of legume intercrops on soil-borne pests, biomass, nutrients and soil water in banana. Biol. Fert. Soils 39:74-79.

Muniappan, R, J. Bamba, J. Cruz, and G.V.P. Reddy. 2004. Field response of Guam populations of the New Guinea sugarcane weevil, *Rhabdoscelus obscurus* (Boisduval) (Coleoptera: Curculionidae), to aggregation pheromones and food volatiles. Micronesica 37: 57–68.

Napompeth, B., T. Nishida, and W.C. Mitchell. 1972. Biology and rearing methods of the New Guinea sugarcane weevil, *Rhabdoscelus obscurus*. Hawaii Agricultural Experiment Station, Honolulu, Hawaii, Technical Bulletin, No. 85: 51 pp.

Reddy, G.V.P. 2007. Improved semiochemical-based trapping method for old-house borer, *Hylotrupes bajulus* (Coleoptera: Cerambycidae). Environ. Entomol. 36: 281–286.

Reddy, G.V.P., R. Fettköther, U. Noldt, and K. Dettner. 2005a. Capture of female *Hylotrupes bajulus* as influenced by trap type and pheromone blend. J. Chem. Ecol. 31: 2169–2177.

Reddy, G.V.P., R. Fettköther, U. Noldt, and K. Dettner. 2005. Capture of female *Hylotrupes bajulus* as influenced by trap type and pheromone blend. J. Chem. Ecol. 31: 2169–2177.

Reddy, G.V.P., S. Balakrishnan, J. E. Remolona, R. Kikuchi, and J.P. Bamba. 2011. Influence of trap type, size, color, and trapping location on the capture of the New Guinea sugarcane weevil, *Rhabdoscelus obscurus* (Coleoptera: Curculionidae). Ann. Entomol. Soc. Am.

Reddy, G.V.P., and A. Guerrero. 2010. New pheromones and insect control strategies. Vitam. Horm. 83: 493–519.

Reddy, G.V.P., Z.T. Cruz, and A. Guerrero. 2009. Development of an efficient pheromone-based trapping method for the banana root borer *Cosmopolites sordidus*. J. Chem. Ecol. 35: 111–117.

Reddy, G.V.P., Z.T. Cruz, J. Bamba, and R. Muniappan. 2005b. Development of a semiochemical-based trapping method for the New Guinea sugarcane weevil, *Rhabdoscelus obscurus*. J. Appl. Entomol. 129: 65–69.

Reddy, G.V.P., Z.T. Cruz, F. Naz, and R. Muniappan. 2008. A pheromone-based trapping system for monitoring the population of *Cosmopolites sordidus* (Germar) (Coleoptera: Curculionidae). J. Plant Prot. Res. 48: 515–527.

Robertson, L.N., and D.E. Webster. 1995. Strategies for managing cane weevil borer. Proc. Aus. Soc. Sugarcane Tech. 17: 90–96.

Rukazambuga, N.D.T.M., C.S. Gold and S.R. Gowen. 1998. Yield loss in East African highland banana (*Musa* spp., AAA-EA group) caused by the banana weevil, *Cosmopolites sordidus* Germar. Crop Prot. 17: 581-589.

Sallam, M.N., C.A. McAvoy, G.D. Puglisi, and A.M. Hopkins. 2004. Can economic injury levels be derived for sugarcane weevil borer, *Rhabdoscelus obscurus* (Boisduval) (Coleoptera: Curculionidae), in far-northern Queensland? Aus. J. Entomol. 43: 66–71.

Sherman, M., and M. Tamashiro. 1954. The sweetpotato weevils in Hawaii, their biology and control. University of Hawaii Technical Bulletin 23. pp. 3-34.

Sutherland, J.A. 1986. A review of the biology and control of the sweetpotato weevil, *Cylas formicarius*. *Trop. Pest Manage* 32: 304–315.

Timberlake, P.H. 1927. Biological control of insect pests in the Hawaiian Islands. Proc. Hawaiian Entomol. Soc. 6: 529–556.