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Biology and integrated pest management of banana weevil, ***Cosmopolites sordidus*** *(Germar)*

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The banana weevil, *Cosmopolites sordidus* (Germar), is an important pest of banana, plantain and ensete. Weevil attack can prevent crop establishment (Price 1994), cause significant yield reductions in ratoon crops (Rukazambuga *et al.* 1998) and contribute to shortened plantation life (Gold *et al.* 1999a). The weevil has been implicated as a primary factor in the decline and disappearance of highland cooking banana (*Musa* spp., genome group AAA-EA) from its traditional growing areas in central Uganda (Gold *et al.* 1999a) and western Tanzania (Mbwana and Rukazambuga 1999).

Adult banana weevils are free living (not confined to the banana plant), but most often found at the base of banana mats or associated with crop residues. In a survey of 50 farms in Ntungamo district, Uganda, adult densities ranged from 1600-149 000/ha (median population of 9300/ha or 15/mat) (Gold *et al.* 1997). The sex ratio was 1:1. Adults generally have one-year life span but may live up to four years. Although adults move freely within banana stands, few disperse more than 50 m in three months (Gold *et al.* 1999b). They rarely fly. Widespread infestation is caused primarily by movement of planting materials containing the pest in its immature stage and, occasionally, adult stages.

The weevils place their eggs in the rhizome or leaf sheaths at the base of the banana plant. Females may lay > 10 eggs/week; but most studies suggest oviposition rates at one egg/week under field conditions. After hatching, the larvae tunnel into the rhizome where they feed. In flowered plants, the larvae may attack the true stem and, occasionally, the pseudostem. Pupation is within the host plant. Development time is temperature dependent. Under tropical conditions, the egg stage lasts for 1 week, the larval stage, 4-6 weeks and the pupal stage, 1 week.

Tunneling by banana weevil larvae weakens the plant and may even cause death of suckers, as well as snapping, toppling, deterioration of the root system, reduced nutrient uptake, smaller bunches, diminished vigour of followers and mat die-out. Many plants may fail to establish if planting is done in a previously infested field. In a trial on highland banana in Uganda, Rukazambuga *et al.* (1998) findings showed that damage increased with crop cycle resulting in associated yield loss rising from 5% in the plant crop to 44% in the third ratoon. Gold *et al.* (unpubl. data) found >33% mat loss in weevil-infested plots six years after planting, compared to 5% in controlled conditions. Sengooba (1986) observed 100% loss during weevil outbreaks on farms in Masaka and Rakai districts, Uganda.

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The banana weevil evolved in southeast Asia, coincident with the area of origin of bananas. From there it has spread throughout the world, presumably through the movement of infested planting materials. The weevil is not considered much of a pest in Asia, although it may be locally viewed as a serious threat (Waterhouse 1993). This suggests that co-evolved natural enemies of weevil may maintain it at sub-economic levels.

This paper provides an overview of research results obtained in Uganda by IITA and the Ugandan National Banana Research Programme (NARO).

Sampling methods

Trapping has been used to monitor weevil numbers. Although trap catches have been used as action thresholds for pesticide applications, capture levels may be influenced by trap quality and weather, rendering interpretation difficult (Vilardebo 1973). Therefore, damage indices on recently harvested plants are most often used to determine weevil pest status. Scoring methods to assess damage on the rhizome surface were proposed by Vilardebo (1973) and Mitchell (1978) and are widely used. However, larval feeding in the rhizome interior may be more destructive to the plant than damage on the rhizome surface (Rukazambuga *et al.* 1998). Moreover, surface damage may be poor indicator of internal damage (Ogenga-Latigo and Bakyalire 1993). Therefore, IITA and NARO have developed a sampling scheme by which damage to the central cylinder and cortex is estimated in cross section cuts (see Gold *et al.* 1994a for details).

Integrated pest management

At present, no single management strategy appears likely to provide complete control of banana weevil. Therefore, a broad integrated pest management strategy might provide the best chance for success in controlling this pest. The components of such a programme would include host plant resistance, cultural control and biological control (including microbial control).

Host plant resistance

All plantains and highland banana clones appear highly susceptible to banana weevil (Gold *et al.* 1994b, Ortiz *et al.* 1995, Kiggundu *et al.* 1999, Kiggundu 2000). Surveys and screening trials suggest that at least some clones in other genome groups are resistant or partially resistant to banana weevil (Pavis *et al.* 1997, Kiggundu *et al.* 1999, Kiggundu 2000). Some of these might serve as parents in breeding programmes for weevil resistance. It is likely that many of the *Musa* cultivars grown in Asia are resistant or partially resistant to banana weevil. Conventional breeding for pest resistance in banana is a long-term strategy; resistant clones may not satisfy consumer tastes. Therefore, there is increasing interest in breeding for banana weevil resistance by using biotechnology techniques. This would allow incorporation of resistant genes without changing other desirable properties in highland bananas and plantains.

Cultural control

The use of clean planting material can reduce initial banana weevil infestation and retard pest build-up for several crop cycles. The benefits of clean planting material are reduced when bananas are planted in proximity to infested fields that provide a source of weevils. Tissue culture is widely used in commercial banana plantations in Latin America, Asia and Africa for pest and disease control, but this method is beyond the reach of most small-scale farmers in much of Africa. Paring of the leaf sheaths and outer surface of the rhizome removes most weevil eggs and first instar larvae (Gold *et al.* 1998). Hot-water treatment, widely promoted for nematode control, has only limited benefit as compared to paring for banana weevil (Gold *et al.* 1998).

Trapping has also been recommended for control of banana weevil. In Uganda, after one year of pseudostem trapping, weevil populations declined by 61% in researcher-managed fields (1 trap/mat/month), 43% in farmer-managed fields (0.3-0.6 traps/mat/month) and 23% in controls (Gold and Okech unpubl. data). Results within treatments were highly variable and there were no significant treatment effects. Participating farmers concluded that intensive trapping could work, but labour and material requirements exceeded their resources.

Crop sanitation has also been widely recommended as a means of controlling weevils. It has been proposed that crop residues serve as a refuge and breeding ground for adult weevils, resulting in higher populations and increased damage. It is also possible that the residues serve as trap crops, attracting gravid females away from standing plants. IITA and NARO are currently studying the effects of different types of crop sanitation on weevil populations and damage.

Biological control with arthropod natural enemies

Banana weevil is an exotic pest in Africa and Latin America, suggesting that classical biological control may be possible. Early searches for natural enemies in the insect's area of origin in southeast Asia uncovered several opportunistic predators. Of these the most important appeared to be the histerid beetle *Plaesius javanus* Erichson whose larvae and adults both attack banana weevil immatures. Between 1913 and 1959, 45 attempts were made to introduce eight natural enemies from Asia to other banana growing regions. In most cases, these natural enemies failed either to establish or to provide adequate control (Waterhouse and Norris 1987). More recent searches in Indonesia provided evidence that suggests the existence of banana weevil egg and larval parasitoids (Abera, Hasyim and Gold unpubl. data). Parasitoids tend to be host-specific and have excellent searching capacity for locating their hosts, making them more effective biological control agents than predators. Therefore, further exploration for parasitoids is warranted in Indonesia, southern India (the area of origin of plantains) and elsewhere in Asia. These natural enemies can then be introduced into Africa and Latin America, as well as disseminated into weevil hot spots within Asia.

In Kenya, endemic natural enemies of banana weevil (histerids, hydrophilids, staphylinids and earwigs) appear to offer limited promise (Koppenhofer *et al.* 1992). By contrast, myrmicine ants has been used in Cuba to control banana weevil with positive results (Castineiras and Ponce 1991). Myrmicine ants are widespread in East Africa banana systems. Their control potential in highland banana systems is currently under study by IITA and NARO.

Microbial control

Microbial agents tested against the weevil include entomopathogenic fungi (e.g. *Beauveria bassiana* and *Metarhizium anisopliae*), entomopathogenic nematodes (e.g.

Steinernema spp. and *Heterorhabditis* spp.) and endophytes (e.g. non-pathogenic *Fusarium* spp.). Entomopathogenic fungi and nematodes are mostly used to kill adult weevils, while endophytes effectively control the immature stages of the pest.

A number of *B. bassiana* strains have shown promise in the laboratory (i.e. effecting mortality rates of >95%) and in preliminary field studies (Nankinga 1999). However, efficient and economically viable delivery systems still need to be developed. Entomopathogens have been reported to establish following applications in banana fields in a few cases. Without adequate establishment, entomopathogens will require repeated applications as a biopesticide. This will entail continued production, distribution and storage costs that will be passed on to the farmer.

Entomopathogenic nematodes have received wide attention as biological control agents because of their wide host range, ability to kill host rapidly with no adverse effects on environment. Treverrow and Bedding (1993) developed a delivery system that involved releasing nematodes into conical shaped cuts made in residual rhizomes. The nematodes were released at a density of 250 000 per hole in a formulation including a polyacrylic gel (to reduce water build-up and incidence of nematode drowning) with an adjuvant of 1% parafin oil (to encourage the weevils to raise their elytra, exposing the first spiracle for nematode entry). Although the nematodes were able to reduce weevil numbers, they were not economically competitive with pesticides (Treverrow 1994). Development of such resource delivery systems for poor farmers in Africa seems a long-shot.

A wide variety of endophytic fungi have been isolated from nearly all examined plants (ranging from grasses to trees) and plant tissues. Many of these have developed mutualistic relationships with plants and some act as antagonists to pests and diseases. At IITA and NARO, the current approach has been to isolate endophytes from banana rhizomes, screen them for activity against banana weevils, reinoculate candidate strains of endophytes into tissue plants and then assess entomopathogenic activity under laboratory and field conditions. Endophytes can extend the benefits of clean planting material and serve as a component of ‘host plant resistance’.

Griesbach (2000) obtained 200 isolates of endophytes from 64 recently harvested banana plants in Ntungamo district, Uganda. Spore suspensions of 12 isolates (8 *Fusarium*, 3 *Acremonium*, 1 *Geotrichium*) caused 80-100% mortality in weevil eggs, while 74 additional isolates caused 60-79% mortality. Two *Fusarium* strains also produced 30-48% mortality of weevil larvae. Currently, IITA and NARO are evaluating additional isolates in the laboratory and assessing endophyte performance in tissue culture plants.

Discussion

Few data are available to elucidate banana weevil pest status in the insect’s area of origin in southeast Asia. Waterhouse (1993) suggests that the weevil is unimportant in much of the region. Weevil pest status on the highly susceptible plantain group in their area of origin in southern India is unclear. It would be useful for the different national programmes to document weevil pest status by mapping damage on different *Musa* clones.

Low weevil populations in Asia might be attributable to a predominance of resistant cultivars. For example, Pisang Awak is known to be resistant to the weevil in East

Africa, while in Indonesia, the weevil appears to prefer crop residues to standing plants (Gold and Hasyim pers. observ.).

Alternatively, it is possible that co-evolved natural enemies, adapted to banana systems and the banana weevil's biology, might maintain pest levels below damage thresholds. In Indonesia, recent evidence suggesting the existence of egg and larval parasitoids is an exciting discovery.

Further searches for natural enemies (especially parasitoids) in south and southeast Asia should be strongly encouraged. Such natural enemies might be used against banana weevil in pest hot spots in Asia, as well as form the basis for classical biological control programmes in Africa and Latin America.

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