A Review :

Insect pests of banana with special reference to weevil borers

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Banana is fourth most important commodity in the world after rice, wheat and corn. It is cultivated over 130 countries in the tropical and subtropical world (Anonymous, 2000). The fruit is preferred for high nutritive value, year round availability and low price (Robinson, 1996). Banana contains large quantities of energy but without any cholesterol. It contains high carbohydrate, low sodium and high potassium (Chandler, 1995). India is the largest producer of banana and plantain in the world. Banana is attacked by more than 200 species of insect and non-insect pests (Simmonds, 1966 and Singh, 1970).In India, more than 15 insect pests attack banana which include insects, mites, mollusks and birds. Insect attack noticed from planting to harvest at different stages of crop growth. Among the major insect pests, weevil borers are very important and most destructive because they not only destroy the crop but also affect the yield and quality of the product. Rhizome weevil, *Cosmopolites sordidus* and pseudostem weevil, *Odoiporus longicollis* are the two most important weevil borers. In this article an attempt has been made to review the damage, biology and management of these destructive pests of banana.

Banana rhizome weevil, *Cosmopolites sordidus* (Coleoptera: Curculionidae):

Distribution:

The banana rhizome weevil evolved in Southeast Asia has spread to all banana and plantain production regions in the tropics and subtropics. Weevil problems appear to be most severe in plantains, highland cooking bananas and ensete. Pest status may vary across sites and farms: in one study, 100-fold differences in weevil densities were found among farms in a single watershed. Weevil pest status in other groups of bananas is variable. In commercial Cavendish plantations, the banana weevil has been reported to be relatively unimportant. Banana rhizome weevil, *Cosmopolites sordidus* has been recorded from various parts of India *viz.*, Kerala, Karnataka, Tamilnadu, Assam, Maharashtra, Gujarat and Delhi (Viswanath, 1976, Charles *et al.*, 1996). This pest has also been recorded from the non-traditional banana growing areas of some state (Padmanaban and Sundararaju, 1999).

Damage and yield loss:

The grubs burrow into the rhizome at different locations creating a net work of galleries. The attacked rhizome gets riddled with holes and weakness the plant. In the initial stages of infestation, one can find yellow lines on the green leaf and reduction in leaf size, whereas in the advanced stage, rhizome shows extensive patches of tunneling, weak appearance of plant, apical stem tapering and reduction in the yield. If the grub damage occurs during bearing stage of the crop, the yield loss up to 85 per cent was reported (Rukazambuga, 1996). Most of the commercial cultivars like Malbhog, Robusta, Kanthali, Adukkan, Thellackarakeli, Nendran are susceptible to this pest. Banana weevil attack has been reported to interfere with root initiation, kill existing roots, limit nutrient uptake, reduce plant vigour, delay flowering and increase susceptibility to other pests and diseases. Yield reductions are caused by both plant loss (plant death, rhizome snapping, toppling) and lower bunch weights. Toppling, more commonly attributed to nematodes, has been observed under conditions of high weevil attack in the absence of nematodes.

Biology:

The adult rhizome weevil is black and measures 10-15 mm. It is free living, though most commonly found between leaf sheaths, in the soil at the base of the mat or associated with crop residues. The weevil is nocturnally active and very susceptible to desiccation. Adults may remain at the same mat for extended periods of time, while only a small proportion will move > 25 m within 6 months.

The weevils rarely fly. Dissemination is primarily through infested planting material.

The banana weevil is a "k" selected insect with long life span and low fecundity. Many adults live 1 year, while some survive up to 4 years. On moist substrates, the weevil can survive without feeding for several months. The sex ratio is 1:1. Oviposition rates of more than 1 egg/ day have been recorded, but, most commonly, oviposition has been estimated at 1 egg/week. The female places its white, oval eggs singly into holes made by the rostrum. Most oviposition is in the leaf sheaths and rhizome surface. Eggs are laid superficially on the surface and crevices of the rhizome (Koppenhoefer, 1993). Flowered plants and crop residues are favoured stages for oviposition.

The emerging larvae preferentially feed in the rhizome, but will also attack the true stem and, occasionally, the pseudostem. The larvae pass through 5-8 instars. Larval stage lasts for two to six weeks. Pupation is in naked cells near the surface of the host plant. Pupation is completed in a week. Developmental rates are temperature dependent. Under tropical conditions, the egg to adult period is 5-7 weeks. Egg development does not occur below 12°C.

Control measures:

Cultural control:

Wherever possible, new production areas should be established in uninfested fields using clean planting material. Tissue cultured plantlets are widely used in commercial banana plantations for pest and disease control. Where tissue culture is not available, farmers should pare suckers to remove weevil larvae and eggs. Paring of the leaf sheaths and other surface of the rhizome remove most weevil eggs and first instar larvae (Gold *et al.*, 1999). Badly damaged suckers should not be used for planting. Hot-water treatment has also been widely promoted for weevil and nematode control. Recommendations suggest immersing pared suckers in hot-water baths of 52-55^{0}C for 15-27 minutes. These baths are very effective in eliminating nematodes, but kill only a third of the weevil larvae (Gold *et al.*, 1999). Thus, clean planting material is likely to provide protection against weevil for several crop cycles only.

Systematic trapping with pseudostem or rhizome pieces may be effective in reducing populations of adult banana weevils. In Uganda, after one year of pseudostem trapping, weevil population declined by 61 per cent in researcher managed field (1 trap/mat/month), 43 per cent in farmer managed field (0.3-0.6 traps/mat/month) and 23 per cent in control (Gold and Okech, unpublished data). However, trapping is labour demanding and often limited by available materials. Crop sanitation (*i.e.* destruction of residues) is also believed to eliminate weevil refuges from breeding sites and to reduce weevil numbers. Currently, no data are available on the relationships between different methods of crop sanitation and weevil status.

Biological control:

There is no record of biological control agents of rhizome weevil either natural occurrence or control studies. This may be due to the following reasons- neglect of crop, lack of quantification of yield loss and cryptic nature of the pest. The following coleopteran natural enemies of *C. sordidus viz*., *Plaesius javanus* Richson, *Hyposolenus laevigatus* (Mar.), *Hololeptas quandridentata* (F.) (Histeridae), *Belolnuchius ferrugatus* Erichsoon, *Leptochirus unicolor* Lepeletier (Staphylinidae), *Cathartus* sp. (Silvanidae), *Dactlylosterbum hydrophilordes* sp., *D. abdominale* F. (Hydrophilidae) and dipteran, *Chrysopilus ferruginosus* Wied. were studied in south East Asia (Cuille, 1950).

Microbial agents tested against the rhizome weevil include entomopathogenic fungi e.g. *Beauveria bassiana* and *Metarhizium anisopliae*, entomopathogenic nematodes e.g. *Steinernema* spp. and *Heterorhabditis* spp. and endophytes eg. non-pathogenic *Fusarium* spp. entomopathogenic fungi and nematodes are mostly used to kill adult weevils, while endophyles effectively control the immature stages of the pest. A number of *B. bassiana* strains have been shown promise in the laboratory (*i.e.*, effecting mortality rates of > 95 per cent) and in preliminary field studies (Nankinga, 1999). Entomopathogenic nematodes have received wide attention as biocontrol agents because of their wide host range, ability to kill host rapidly with no adverse effects on environment. A wide variety of endophylic fungi have been isolated from nearly all examined plants (ranging from grasses to trees) and plant tissues. Griesbach (2000) obtained 200 isolates of endophytes from 64 recently harvested banana plants. Spore suspensions of 12 isolates (8 *Fusarium*, 3 *Acremonium*, 1 *Geotrichium*) caused 80-100 per cent mortality in weevil eggs, while 74 additional isolates caused 60-70 per cent mortality. Two *Fusarium* strains also produced 30-48 per cent mortality of weevil larvae.

Host plant resistance:

Screening trials, surveys and clonal comparisons suggest that plantains are the most susceptible group to banana rhizome weevil attack. East African Highland cooking banana and ensete also appear to be highly susceptible. Primary sources of resistance seem to be found in Yangambi Km5, FHIA-03 (or its parents) and some IITA diploid hybrids (TMB2x8075-7, TMB2-7197-2 and TMB2x6142-1). Prasad and Seshu Reddy (2001) from East Africa reported that besides AAB and ABB groups, cooking, roasting and wine type of bananas of AAA genome were also susceptible to *C. sordidus* infestation in comparison to dessert type. The banana weevil is readily attracted to and will freely oviposit on resistant clones. Host plant resistance appears to be primarily due to antibiosis mechanisms causing high mortality rates in the larval stage.

Chemical control:

Control in commercial banana plantations is mainly chemical, using nematicides with insecticidal activity and specific insecticides applied close to the base of the mat. Insecticides are fast acting and efficient. Cyclodiene insecticides were once widely used but eventually abandoned with the development of resistant weevil populations and because of environmental concerns. Less persistent organophosphates are available but these are more expensive and more toxic to the handler and therefore less suitable for smallholder production systems. The banana weevil has now shown the ability to develop resistance to most classes of chemicals.

Botanical compounds may serve as substitutes for pesticides. Dipping suckers in a 20 per cent *neem (Azadirachta indica)* seed solution at planting protects the young suckers from weevil attack by reducing oviposition through its repellent effect on adult weevils. Egg eclosion rates may also be lowered in neem-treated plants.

IPM of banana weevil:

– Maintaining banana crop weed free to avoid the spread of weevil.

– Removing roots and outer skin of banana corm and dip the suckers in monocrotophos or trizophos solution (14 ml in 1 liter) for about 20 minutes to kill the eggs and grubs of corm weevil and plant parasitic nematodes.

– Removing pseudostes after harvesting and treating it with carbaryl (2g/liter) or chloripyrifos (2.5 ml/ litre).

– Monitoring weevil activity in a garden by keeping longitudinal split banana pseudostem traps @ 10-15/ acre. Once weevil is attracted to the laid traps, keep the longitudinal split banana traps@ 100/ha with 20 g biocontrol agents like *Beauveria bassiana* or entomopathogenic nematode, *Heterorhabditis indica*. These biocontrol agents can be swabbed on the stem traps and keep the cut surface facing the ground.

– Keeping pheromone traps @ 4 traps/ha. Collect the trapped weevils and destroy.

Banana Pseudostem weevil, *Odoiporus longicollis* Oliver (Coleoptera: Curculionidae):

Distribution:

The banana pseudostem weevil is believed to have originated in South and South East Asia, which is also the centre of origin of the present day bananas and plantains. This insect is found in India, China, Malaysia, Indonesia and Thailand and is a key pest of bananas and plantains, posing a great threat to banana production systems in these countries (Valmayor *et al*., 1994). Pest density may vary from field to field. The weevil prefers plantains and highland bananas, particularly 'Pome' types. Total crop failure will result in farms where the weevils are not managed efficiently. Such crop failures are not uncommon in banana production systems in India. This pest has been reported from all the banana growing states of India *viz*., Assam, West Bengal, Delhi, Bihar, Uttar Pradesh, Karnataka, Kerala, North East Hill States (Isahaque, 1978, Dutta and Maiti, 1972, Batra, 1952, Shukla and Kumar, 1970, Jayanthi and Varghese, 1999, Visalakshi *et al.*, 1989, Prasad and Singh, 1987).

Damage and yield losses:

The early stage symptoms include yellowing of leaves, exudation of sap from pseudostem, whereas the advanced stage of infestation shows extensive patches of tunneling, weak appearance of pseudostem, apical stem tapering, reduction in leaf size and bunch size. Dead plants remain succulent for a long time, thus affording shelter for completion of life cycle. Infestation occurs from fifth month onwards, pseudostems of 25-50 cm circumference are preferred by the weevil for oviposition. Infestation can be classified into three types *viz*., (i) apparently healthy without any external symptoms (ii) moderately infested healthy pseudostem showing only few stem feeding patches (iii) heavily infested plants showing extensive patches of tunneling by the grubs in the pseudostem with secondary rotting at the feeding sites. Stem weevil infestation interferes with the translocation of nutrients and water, retards growth and development and increases susceptibility to wind lodging, which is more commonly associated with nematode infestation. Weakening of the stem by larval tunneling may result in breakage by wind or inability to bear the weight of the maturing bunch. It is estimated that the stem weevil causes 10-90 per cent yield loss depending on the growth stage of the crop and management efficiency (Padmanaban and Sathiamoorthy, 2001). The severity of the loss is greater when infestation occurs at the early vegetative stage (5 months old). Padmanaban *et al.* (2001) reported that total crop failure results in farms where the weevils are not managed efficiently.

Biology:

The banana pseudostem weevil, *O. longicollis* is one of the most important pests of bananas and plantains. The adult weevils are black-coloured and measure 23-39 mm. Red-coloured morphs of the banana pseudostem weevil are also encountered in certain banana growing areas of India. Based on mating studies, it has been concluded that the colour difference is not due to sexual dimorphism but is a phenomenon of non-sex limited variation and of sympatry (Dutt and Maiti, 1972). The weevils are predominantly nocturnal in habit, although during cloudy days and cooler months, they may fly during the daytime. They often confine themselves within the pseudostem and in the decomposing tissues of harvested pseudostems. All life stages of the weevil are present throughout the year in the infested plant. Adults are strong fliers and in this way, move from plant to plant.

The banana pseudostem weevil has a long life span and many adults live for a year. The sex ratio of adults encountered in banana gardens is 1:1.17 (male:female) (Dutt and Maiti, 1972). The sensory structures present on the rostrum of the weevils provide a key for sex differentiation (Nahif *et al*., 2000). The pre-oviposition period is 15-30 days and the adult weevils mate throughout the day and night. The mean number of eggs laid by a female following a single mating is nine eggs at the rate of one egg per day. Gravid females lay yellowish white, elliptical eggs by inserting the ovipositors through ovipositional slits cut by the rostrum on the outer epidermal layer of the leaf sheath of the pseudostem down to the air chambers. Oviposition takes place only in the leaf sheaths. The number of eggs deposited is considerably reduced as the number of weevils increases, indicating the existence of a spacing pheromone, epideictic compounds which act as a deterrent to conspecific females (Ranjith and Lalitha, 2001).

Eggs are cream in colour and cylindrical in shape with rounded ends. Typically, eggs are 3.14 mm in length and 1.1 mm in diameter. The incubation period ranges from 3 to 8 days. The emerging larvae are fleshy, yellowish white and apodous. The larvae feed on tissues of the succulent sheath by tunneling extensively and may reach as far as the true stem. If larvae emerge during the advanced pre-flowering stage of the plant, the ascending flower bud and the peduncle inside the pseudostem can be eaten and damaged, resulting in non-emergence of the flower bud which decays inside the pseudostem (Padmanaban *et al.,* 2001). In severely infested plantations, more than 20 per cent plants do not flower due to this reason. The depth of the tunnels made by the larvae range between 8 to 10 cm. The tunnels are widespread and may go as high as the fruit peduncle or to the lowermost collar region near the rhizome. The larvae pass through five instars. The fifth instar larvae enter a non-feeding pre-pupal stage and construct a cocoon by winding short pieces of fibrous materials of the sheath around its body. The pupa is exarate and present inside the cocoon. The developmental rates are highly dependent on climatic factors with the duration of the life stages longer in the winter season than in the summer. Under laboratory conditions, the duration from egg to adult stage is 44 days.

Control measures:

Cultural control:

Field sanitation is imperative in the control of this pest. Dried old leaves must be removed to allow the detection of early symptoms of weevil infestation and to increase the efficacy of chemical application. Suckers should be pruned periodically and infested pseudostem must be removed from the field and destroyed. Banana stumps kept in the field after harvest must be removed and destroyed as they serve as weevil refuges and breeding sites. Investigations made at the National Research Centre for Banana (NRCB) in India have indicated that traps could be efficiently used to monitor and reduce the adult weevil population. Among the disc-on-stump and longitudinal split pseudostem traps, the disc-on-stump traps with higher exudations of plant fluids have been found to be more effective. However, in general, banana corm weevil outnumbered the BSW in the traps. Use of pheromones to trap and destroy weevil populations is under investigation. Good husbandry practices, such as weeding, manuring and mulching produce vigorous banana plants that have improved weevil tolerance (Feakin, 1971, Gowen, 2000).

Biological control:

Two species of earwigs feeding located on the antennal tip and mouthparts of larvae and pupae are reported from China. There is a report of an acarid mite parasitizing larvae and adults. Release of an ectoparasitic mite, *Uropodia* sp. on adult banana pseudostem weevil had been tried for its control with limited success. *Metarhizium anisopliae*, an entomopathogenic fungus, affected more than 90 per cent mortality under laboratory conditions. Fungal pathogens such as *Fusarium solani*, *Mucor heimalis f.* sp. *heimalis*, *Aspergillus niger* and *Scopulariopsis brevicaulis* have also been isolated from field populations of the banana pseudostem weevil (Anitha *et al*., 1999 a and b). Although these entomopathogenic fungi caused more than 90 per cent mortality in the laboratory, there is a long way to go before they can be used in the field, as the safety of these fungi to non-target organisms is still to be tested and efficient mass production systems and application methods need to be devised.

Host plant resistance:

Host plant resistance may offer a long-term solution to the problem. Screening trials and surveys to determine the resistance to banana pseudostem weevil need further work although it appears that the pest, with the aid of a host of sensory structures located on the antennal tip and mouthparts, exhibit a high degree of host plant preference. Resistance to banana pseudostem weevil seems to depend on the morphological and anatomical characteristics of the banana leaf sheath along with the interaction of the chemicals present in plant sap, thus suggesting a combination of antixenosis and antibiosis mechanisms. Through field screening of 212 banana accessions of various genomes, Charles *et al.* (1996) identified 27 accessions that exhibited tolerance to the pest. Laboratory screening were conducted at NRC on Banana, Trichy, of 119 accessions led to the identification of a high degree of resistance in *Musa balbisiana* clones, such as Bhimkol, Athiakol, Elavazhai and Sawai. In general, plantains are the most preferred host.

Chemical control:

Control of banana pseudostem weevil is an elusive and complex problem as the life cycle of the pest may be completed within the pseudostem. Application of organochlorine insecticides is no longer carried out due to the possible development of insecticide resistant weevil strains and environmental concerns. Currently stem injection of a systemic organophosphorus compound (e.g. monocrotophos) is extensively used in controlling the pest (Sathiamoorthy *et al.,* 1998). As well as stem injection, other insecticide application methods may be used, such as swabbing along with surfactants, swabbing with mud slurry containing the insecticide (Mathew *et al.*, 1997), spraying and fumigation of the spaces between the leaf sheaths in the pseudostem. Fumigation of banana plants using Celphos (aluminium phosphide tablets), especially during the vegetative phase is phytotoxic and should be discouraged.

IPM Strategies:

– Removing old and dried leaves.

– Treating cut end of leaf petiole with Chlorpyrifos (2.5 ml/liter) + 1 ml sticking agent.

– Monitoring banana weevil activity in a garden by banana stem traps *i.e.*, longitudinal trap (30 cm) and disc-on-stump trap of 100 traps/ ha.

– Collecting weevils daily.

– Swabing banana stem with Chlorpyrifos (2.5 ml/ liter + 1 ml wetting agent) or azadirachtin (2.5 ml/litre) after 5 months.

– Swabing cut surface of longitudinal split traps with 20 g of formulation of pathogenic (insect killer) fungus, *Beauveria bassiana* or entomopathogenic nematode, *Heterorhabditis indica* and keep split traps near banana plant facing cut surface to the ground. The trapped weevils need not to be collected for killing.

– Injecting monocrotophos or trizophos solution (150 ml in 350 ml water) using stem injector at 2 and 4 feet above the ground level at 30 degree angle on either side of the angle. Injection should not be given after flowering. Injection needle should reach only to 2 or 3 leaf sheath and without touching the centre core.

– Avoiding matocking (leaving 1 m of the plant after harvesting for recycling of nutrients) in weevil endemic areas.

– After harvesting of bunches, spent pseudostem has to be cut into 80 cm length pieces and use it as a trap for weevil collection, instead of keeping as heap.

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