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Banana Entomological Research in Cameroon: How Far and What Next?

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ABSTRACT

The African Research Centre on Bananas and Plantains (CARBAP) is an autonomous centre based in Cameroon and has carried out much research on insect pests on bananas/plantains. Major and potential insect pests recorded include borer weevils, white grubs, and long tail mealy bugs. Of these three, the banana borer weevils are the most important as they are found in all major production zones and on pre-flowered/bunched plants, as well as on harvested pseudostems. Larvae of these borer weevils cause damage by creating feeding tunnels within corms that usually result to weak growth, poor anchorage and toppling. Percentage of plants attacked varies between 3-81%. The number of adult borers caught per trap varies with type of traps and agroecological zones with highest catches recorded during the rainy season. As far as management of the pest is concerned, classical insecticides, biocontrol and genetical control techniques have been widely evaluated. Most effective insecticides are fipronil, thiomethoxam, and imidaclopride. Also, both exotic commercial and indigenous *Beauveria bassiana* have shown great potential in managing these borer weevils. Since no single technique has been reported to successfully manage the borer weevils, evaluating the effects of an IPM package (clean planting materials, use of botanicals, entomopathogens, proper field sanitation, incorporating info chemicals, wise use of synthetic chemicals as well as use of resistant or tolerant varieties) is necessary.

Keywords: bio-ecology, *Cosmopolites sordidus*, pest management

Abbreviations: CARBAP, Centre Africaine de Recherches sur Bananiers et Plantains; **IPM**, Integrated Pest Management; **CDC**, Cameroon Development Corporation; **CIRAD**, Centre de Cooperation Internationale en Recherche Agronomique pour le Developpement; **CI**, Coefficient of Infestation; **CIG**, Common Initiative Group; **CORAF**, Conseil Ouest et Centre Africain Pour la Recherches et le Developpement Agricoles; **CRBP**, Centre de Recherches Regionales Bananiers et Plantains; **FAO**, Food and Agriculture Organization; **IITA**, International Institute of Tropical Agriculture; **INIBAP**, International Network for the Improvement of Banana and Plantain (Now Bioversity); **KuLeuven**, Katholieke Universiteint Louven; **MINADER**, Ministere de l'Agriculture et du Developpement Rural (Ministry of Agriculture and Rural Development); **NGO**, Non-Governmental Organization; **PHP**, Plantations Haut de Penja-Njombe; **PIF**, Plant issus de fragments de tiges; **PPTE**, Programmes de Relance de la Filiere Plantain; **SPM**, Societe Plantations de Mbanga; **WECARD**, West and Central African Council for Agricultural Research and Development

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GENERAL INTRODUCTION

Introduction

The African Research Centre on Bananas and Plantains (CARBAP) was created in February 2001 by an intergovernmental agreement, taking over CRBP that was established in October 1989 (CRBP 1994a; InfoMusa 2001a). CRBP was created following a convention signed by the government of Cameroon and the Centre de Cooperation Internationale en Recherche Agronomique pour le Developpement (CIRAD) (CRBP 1994b). The CARBAP research station is situated in Njombe, Littoral Region (a small town about 70 km from Douala, the economic capital). Other antennas are

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found in Ekona (Southwest Region), Mbouroukou (Littoral Region), Dschang (West Region), Mbalmayo (South Region) and Ebolowa (South Region) as well as a liaison office in Douala.

After agreeing on the regional status of CRBP, the governments of Cameroon, Central African Republic, Democratic Republic of Congo, Gabon and Equatorial Guinea decided to transform CRBP to CARBAP. Based on this agreement, the aim of CARBAP was to improve the production of bananas and plantains in the Central and West African region. The ultimate goal therefore was to meet the needs of a growing population through the development of sustainable and environmental friendly agriculture.

Another important aim of CARBAP is to address various problems or constraints limiting the production of plantains and bananas in the countries within the sub-regions. In order to meet these aims, CARBAP carries out Research, Development, and Training. So far, CARBAP has the following achievements in its records: (i) It has played an important role in boosting plantain production in Central African countries especially Cameroon through the development of a rapid multiplication technique that is now commonly used by some farmers, (ii) more than 50% of farmers are now aware of the major pests and diseases on bananas/plantains and their management practices, (iii) most of the management techniques used in plantations are based on research results from CARBAP, (iv) several stakeholders have been trained on key aspects of banana/plantain production e.g. pest and disease management, fertilization and irrigation, agronomic practices, (v) CARBAP has helped to introduce and encourage the planting of some exotic varieties with desirable characteristics, (vi) through the genetic improvement programme, the institution has succeeded in maintaining a collection of *Musa* species; rated as one of the largest in the world, (vii) CARBAP has also succeeded in establishing strong partnerships locally, regionally and internationally especially with agro-industrial plantations, agrochemical companies, universities, NGOs, and CIGs. For this reason, it has been referred as a centre of excellence and base centre for CORAF/WECARD as well as being awarded several grants especially from the European Union, Bioversity International and the government of Cameroon.

Brief on *Musa* species (morphology and distribution)

Generally, *Musa* spp. (including bananas and plantains) are herbaceous perennial plants (Speijer and De Waale 1997; Anon 2005). Their herbaceous nature is as a result of the plants not having woody parts – after ripening of the fruits, the aerial parts die down to the ground, and their perennial nature because new plants grow up from the base of the mature plant to replace the aerial parts that subsequently die. A mature plant consists of (i) a corm with roots and suckers (ii) a pseudo stem with leaves, (iii) a bunch with fruits. The corm is the underground part of the plant (the true stem) consisting of a central cylinder surrounded by a cortex. The mother or parent plant together with its suckers and other followers (smaller plants) form what is known as a mat or stool. All *Musa* species range between 2-9 metres in height.

Fig. 1 Map of Cameroon showing the regions and the countries sharing boundary with it. Figure by Justin Okolle.

The major production areas of bananas/plantains in Cameroon are found in 7 Regions; Centre, East, Littoral, South West, North West, West, and South (Fogain *et al.* 1998; Anon 2005; **Fig. 1**). These zones are usually with rainfall between 2000-3000 mm per year. In all these zones, higher productions are usually obtained from Littoral, South West and South usually with humid and/or volcanic soils. Although very large banana plantations are found in South West and Littoral Regions, monocultures of plantains are generally rare in Central or West African countries (Mbida *et al*. 2000; Adiko and Badou N'Guessan 2001; Temple and Bikoi 2001; Nkendah and Akyeampong 2003). Total surface area cultivated for export banana is about 5000 ha and these plantations are located in Fako and Moungo Divisions, respectively of South West and Littoral Region of Cameroon. Generally, plantains are grown by smallholders, who usually apply traditional farming practices and mix-cropping with either perennial crops or other food crops such as cocoa (*Theobroma cacao*), oil palm (*Elaeis guineensis*), cocoyams (*Xanthosoama* sp), coffee (*Coffea Arabica* or *C. robusta*), cassava (*Manihot esculenta*), and maize (*Zea mays*) (Temple *et al.* 1996; PlantaInfo 1999; Adiko and Badou N'Guessan 2001; InfoMusa 2001b; Nkendah and Akyeampong 2003; Jacobsen *et al*. 2004). However, PlantaInfo (1999, 2000) reported that association of plantains with

Table 1 Effects of associating plantains with some food and cash crops in some farmers' farms in Southwest Region of Cameroon.

Farmer No.	Major objective	Association with	Plantain Density (plants/Ha)	Percentage harvested	Average bunch weight (kg)	Yield (Tons/ha)
1	Self consumption	Old coffee plants	500	64	9.3	3
2	Self consumption	Old cocoa plants	550	33	9.8	1.8
3	Self consumption	Young cocoa and cassava	1000	60	8.7	5.2
4	Commercial purpose	Cocoyams and other food crops	1175	55	11.1	6.1
5	Commercial purpose	Young cocoa and cocoyams	1150	58	13.3	8.9
6	Commercial purpose	Young cocoa and cocoyams	1400	67	10.7	10

Methodological description: Farmers were chosen randomly from the major production zones in the Region. Researchers/technicians from the department of agro-economics followed the farmers to their farms to record the characteristics of the farms. The farmers were also followed up to get percentage of plants harvested, average bunch weight harvested and yield. Source: PlantaInfo (1999) yam (*Dioscorea* sp.), cassava and sweet potatoes (*Ipomoea batatas*) greatly affects yield of bananas and plantains and therefore not recommended. Although there were no data to support this, PlantaInfo (1999) showed that associating plantains with crops such as cocoa, coffee, cocoyams and cassava might have some effects on yield and average weight of bunches (**Table 1**). In mixed crop systems, plantains are usually the main crops in the field until after the third cycle where they start disappearing and eventually become residual crops. According to Nkendah and Akyeampong (2003), a major characteristic of these cropping systems is that very few chemicals are used, resulting to low yields and production costs and consequence of such traditional practices is usually low yield varying between 5 and 10 tons/ha (Adiko and Badou N'Guessan 2001). Furthermore, with the exception of plantations, bananas and plantains are usually produced in small fields under shifting cultivation and bush fallow.

Importance of bananas and plantains

According to FAO (1999, 2007), bananas and plantains together serve as a staple food for at least 400 million people in the world. These food crops have therefore been rated as the 4th most valuable food after rice, wheat, and milk (Ploetz 2001). These crops serve as major non-grain starch staple in tropical and sub-tropical regions, particularly in West and Central Africa, which accounts for about 44% of global production (Chataigner 1988; Frison and Sharrock 1988; Lescot 1997; Moulioum-Pefoura *et al*. 2001; Youdeowei 2002; Fogain and Gowen 2005). In Central and West Africa, bananas/plantains play an important role in food security (consumed as an energy-yielding food), employment, revenue diversification in rural/urban zones, and poverty reduction (Melin and Djomo 1972; Purseglove 1972; InfoMusa 1994; Temple *et al*. 1997; Ngamo and Fogain 1999; Nkendah 2001; PlantaInfo 2002; Nkendah and Akyeampong 2003; Jacobsen *et al.* 2004; Desdoigts *et al.* 2005; Ngoh Newilar 2005; Noupadja *et al.* 2005). Also, few banana cultivars in Cameroon such as 'Batard', 'French Clair', and 'Big Ebanga' are exported to Europe (Tchango Tchango *et al*. 1999). Bananas and plantains provide about 25% of food-energy requirements for around 70 million people in Sub-Saharan Africa. Since the fruits are produced all year round, these crops play an important role in food security and income generation to resource-poor farmers especially during low-peak periods of cash crops like cocoa, coffee and oil palms. The banana plantations also employ thousands of peoples and therefore help many to have jobs and be able to support their families. Also, Temple *et al.* (2001) reported that in 2000, plantain contributed about 73 billion FCFA to the income of smallholders in Cameroon.

With about 55.5 million tonnes per year, dessert bananas occupy 2nd place in world production of fruits (Risede and Tezenas 1997; Lassoudiere 2007) while annual production of plantains is about 18 million tons (Lassoudiere 2007) up from 15 million tonnes 10 years back (INIBAP 1994). In Africa, total production of these food crops combined is about 9.6 million tons while in West Africa, plantain production is estimated at about 10 million tons (Temple *et al.* 1996; Ngoh Newilar 2005). In Central and West Africa, in 1993 bananas/plantains production was about 4 million tons with estimated mean *per capita* consumption of 80 kg/year (CRBP 1993b). Although Cameroon is ranked second after Gabon for consumption rate in the Central African sub-region, it is the highest producer (**Table 2**) and exporter of plantains to countries such as Gabon, Congo, and Equatorial Guinea (Nkendah and Akyeampong 2003; Honfo *et al.* 2007) and consumption is usually greater in the urban than rural areas. Average plantain consumption in Cameroon ranges from 105-128 kg/person/year while that of Gabon is between 161-236 kg/person/year. In Cameroon, total production of bananas/plantains is about 2.23 million tons (FAOSTAT 2007) with about 35% for bananas and 65% for plantains (Temple *et al*. 1996; Fogain *et al.* 1998; Anon 2005; Ngoh Newilah 2005). In terms of tons of bananas exported to European Union, Cameroon comes first with about 300,000 tons annually followed by Cote d'Ivoire with about 202,000 tons (Lassoudiere 2007).

Table 2 Banana and plantain production in Central African countries (FAOSTAT 2007: www.fao.org)

Countries	Production (tons)	
	Plantains	**Bananas**
Cameroon	1,400,000	860,000
Central African Republic	80,000	110,000
Chad	NA	NA
Congo-Brazzaville	650,000	87,000
Democratic Republic of Congo	1,204,860	314,920
Equatorial Guinea	310,000	20,000
Gabon	275,000	130,000

NA = not available

About 500,000 farmers are involved in the production of plantains in Cameroon (Anon 2003). According to PlantaInfo (2003), there are more women (about 53%) involved in the commercialisation of plantains than men. Douala (the economic capital) consumes 45,000 tons of plantains annually; 80% of which comes from the South West Region (Gauer 1994). This region produces 350,000 tons, representing more than 1/3 of national output and it consists of three major production areas (**Fig. 2**); Mile 20 for the Tombel Area (about 110 km from Douala), Bole for the Kumba Area and Owe for the Muyuka Area about 100 km from Douala) (Gauer 1994; PlantaInfo 1994). Consumption of these food crops is gradually increasing in the urban areas with about 40 kg/year/person consumed in Douala and Yaounde (the two largest cities in Cameroon) (Temple *et al.* 1996; Sandrine and Desdoights 2003; Lusty *et al.* 2006).

Bananas and plantains are usually prepared in different forms; they can be fried, roasted, boiled, pounded, used to form porridges and most often these are eaten with various sources, vegetables, and other food complements (Lemaire *et al.* 1997; Happi Emaga 2000; Ngoh Newilar 2005; Honfo *et al*. 2007). Although there are several plantain/banana dishes in Cameroon, the most commonly preferred are boiled plantains/bananas (25%), 'kondre' plantain (20.4%), fried plantains and chips (18.5%), 'ntuba' or pounded plantain (21.3%), banana paste lined with beans (18.6%) and 'malaxe' of banana (44.3%). 'Kondre' plantain; also known as porridge plantain is prepared by first removing the peel of unripe fruits, cut into pieces or left uncut and then put in a pot with water. Salt, hot pepper, vegetable ('bitter leaf'), magi, dry fish/meat, garlic/onion, 'njansang' and palm oil are then added. The entire mixture allowed to boil for about 35-40 minutes. To prepare 'malaxe of banana', entire unripe pulps are mixed with either groundnut, soybean or egusi paste and boiled for about 40-60 minutes in water. Spices such as onion, hot pepper, garlic, ginger and palm oil added to the mixture. Pounded plantain also known as 'piler' or 'ntuba' is prepared by cooking ripe and/or unripe pulps for about 30-45 minutes. The pulps are then pounded and mixed with salt, onion, and palm oil until the paste becomes homogenous. In some cases, no ingredients are added to the pounded pulp, which is then eaten with sauces or vegetables. Concerning banana paste lined with kidney beans, unripe pulps of cooking bananas or some dessert bananas are boiled, pounded and then mixed with kidney beans. Ingredients such as onion, salt, palm oil and hot pepper are then added. The entire mixture in water is then cooked or about 30-45 min. In the South West Region, 'Mpuh' is a common dish. Plantain flour is put into a bowl containing water and mixed with ground ingredients such as garlic, onion, groundnut oil, 'njansang'. Fish, pork or any other meat is added to the mixture, which is then put in a pot and cooked. It is eaten with boiled ripe plantains, cocoyams, yams or sweet potatoes.

Generally, plantains are commonly prepared and consumed during occasions such as wedding, funerals or 'born-

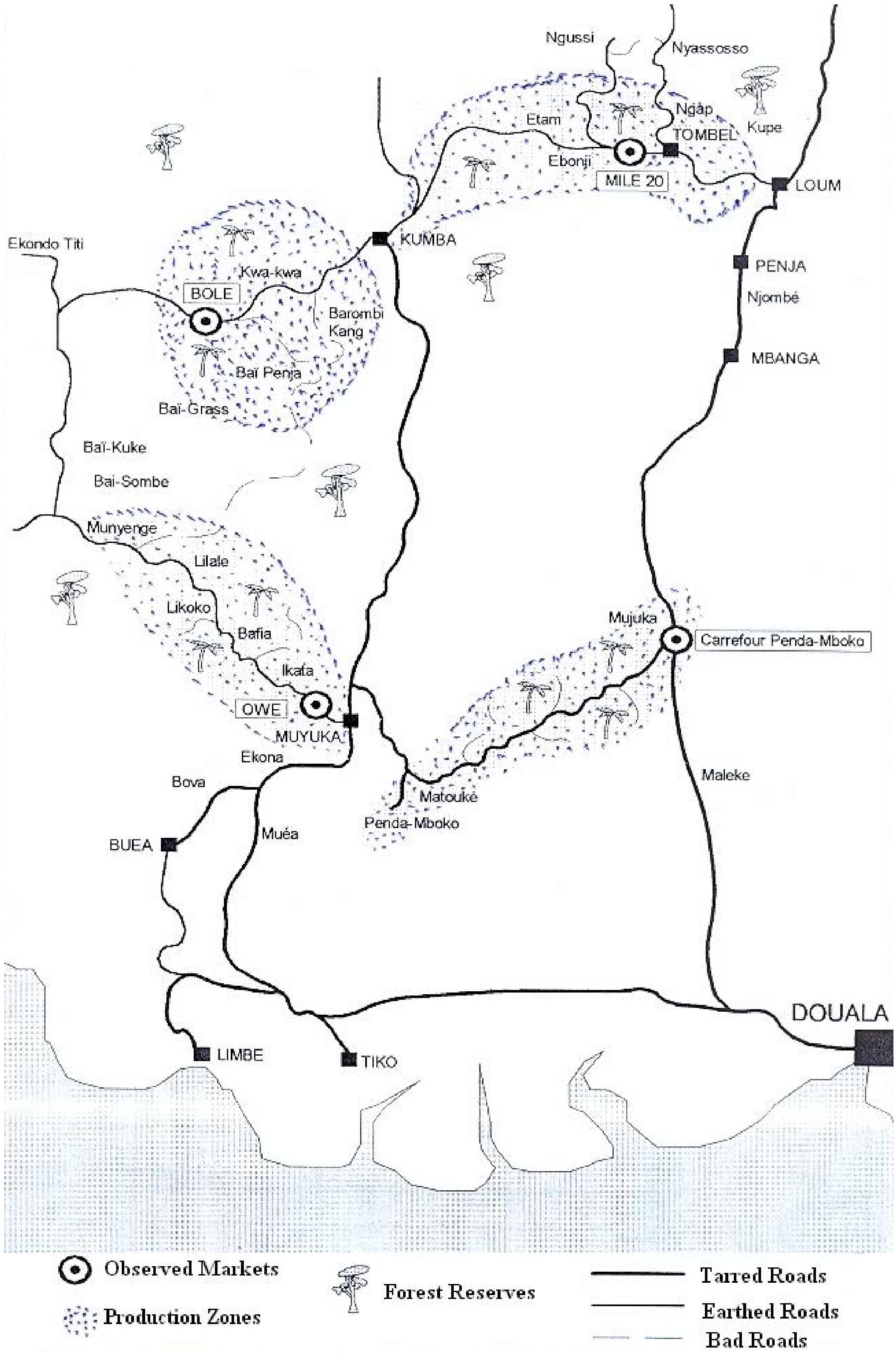

Fig. 2 Map showing the three main production zones of the Southwest Region of Cameroon. (PlantaInfo, CARBAP Info Plantain Special Issue, September 1996, p 2).

houses' i.e. celebrating birth of a new borne child. Most commonly consumed bananas are 'Gros Michel' (AAA), 'Grande Naine' (AAA), 'Cochon' (AAA-EA) while most commonly consummed plantains are 'Elat', 'French Clair', 'Big Ebanga', 'Essong', 'Ebang', 'Kelong', and recently the 'Batard' (Ngoh Newilar 2005; Okolle, pers. obs.). Most of these varieties are relatively rich in provitamin A carotenoids, fibres and other essential minerals like iron, zinc, and potassium (Ngoh Newilar 2005; Lusty *et al.* 2006; Rojas-Gonzalez *et al.* 2006). Lusty *et al.* (2006) reported that 'Cavendish' bananas and the 'Batard' plantain were found to contain higher provitamin A carotenoids and suggested that such varieties could help solve vitamin A deficiency problems. In addition, fried plantains were also reported to retain more carotenoids while Honfo *et al.* (2007) found out that food preparations such as boiled ripe plantains and ripe bananas provide better availability of iron compared to other preparations. In addition, these same authors mentioned that boiled, porridge and roasted forms of plantains provided more minerals than other preparations both in urban and rural areas.

Furthermore, apart of their nutritional values, plantains and bananas also have lots of medicinal importance especially to the people of southern parts or forest zones of Cameroon (Ndemba and Efanden 2003; Okolle 2006b) and virtually every part of these herbs seem to be useful. These crops are used for the following; reduce toothache and backache, traditional artists use a decoction to make their voices clearer and some ripe varieties are used to treat diarrhoea and other related stomach/intestine problems. In the South Region of Cameroon, the 'Bulus' and the 'Ntoumous' recommend a decoction of ripe fingers of the variety 'Ebang' to help facilitate delivery of a baby. The 'Bakokos' too recommend the 'Essouke' variety used to improve on sexual power of men and fecundity of females.

Research themes

Research in CARBAP cuts across five main aspects or programmes; (i) pest and disease management, (ii) Agronomy, (iii), Agro economy, (iv) Post-harvest and food technology (v) genetic improvement (CRBP 1993a, 1993b, 1994a, 1994b, 1995a, 1996, 1999a, 1999b). Entomological research is carried out in the laboratory of Nematology/Entomology, which is part of the pest and disease management programme. This programme has focused mostly on pests and diseases such as the borer weevils, sigatoka, phytophagous nematodes, and trachysphaera. So far, for the past years since its creation, entomological research has been focused on bio-ecological aspects (about 30%), management aspects (about 60%) and technology/knowledge transfer (about 10%). The main entomology research themes are (i) interactions of borer weevils with their host plants (bananas and plantains), (ii) population dynamics of corm borer weevils, (iii) components of integrated management strategies for corm borer weevils, (iv) incidence of other arthropod/vertebrate pests on bananas and plantains, (v) knowledge/technology transfer to relevant stakeholders e.g. farmers, pest managers, extensionists, and students.

MUSA–PEST INTERACTIONS

Borer weevils

1. Morphology and life cycle

Surveys carried out have shown that borer weevils are found in all the banana/plantain producing zone or regions of the country (Fogain 1994a; Fogain *et al.* 1998; Okolle 2006a). According to Fogain *et al.* (1998); CRBP (1993c); Courrier du CRBP (2000a) and Mboueda (2007), there are three species of borer weevils; *Cosmopolites sordidus* Germar, *Metamasius sericeus*, and *Pollytus mellerborgi* Boheman. However, Ysenbrandt *et al*. (2000) and Courrier du CRBP (1993) mentioned four species; *C. sordidus*, *M. hemipterus sericeus*, *M. sericeus* and *P. mellerborgi*. Although *C. sordidus* and *M. sericeus* are almost similar in body length and width, both are much larger and longer than *P. mellerborgi*.

Young adults of *C. sordidus* are reddish-brown in colour while the older ones are dark or black. These adults are very slow in walking, nocturnal, negatively phototropic, and always pretend to be dead whenever they are touched. In the laboratory, adults have been observed mating at any time of the day and even inside the soil found in Petri-dishes (Okolle *et al.* 2007). Generally, there are four main stages of this weevil; eggs, larvae, pupae and imagos (adults) (**Fig. 3**). Although egg-laying has not been observed in the field, oviposition behaviour is spectacular in the laboratory. When placed into Petri dishes or buckets containing banana corms, females use their rostrum to create tiny holes and then lay a single egg in each hole. However, some eggs are laid directly on the corm surfaces. These eggs are white, oval in shape and about 1.8-2 mm in length. After oviposition, an egg may hatch within 5-8 days.

Once hatching has occurred, small larvae are formed, passing through 5-6 instars lasting 30-50 days depending on temperature. A mature larva is about 10-12 mm long, apodous, creamy white, has dark brown and well developed mandibles, as well as a curved body. After intense feeding, the larva undergoes a dramatic change to form a more or less inactive form; the pupa. This stage develops within the plant tissues and its duration may last 5-9 days before emergence of adults. Adult longevity has been reported to be up to about 15 months in the laboratory (Courrier du CRBP 1999b). Adult females are usually larger than the males and the sex differentiation is usually based on the nature of the last abdominal sternite (males with a more inwardly curved sternite) and small punctuations on the rostrum (Longoria 1968; Nankinga 1999).

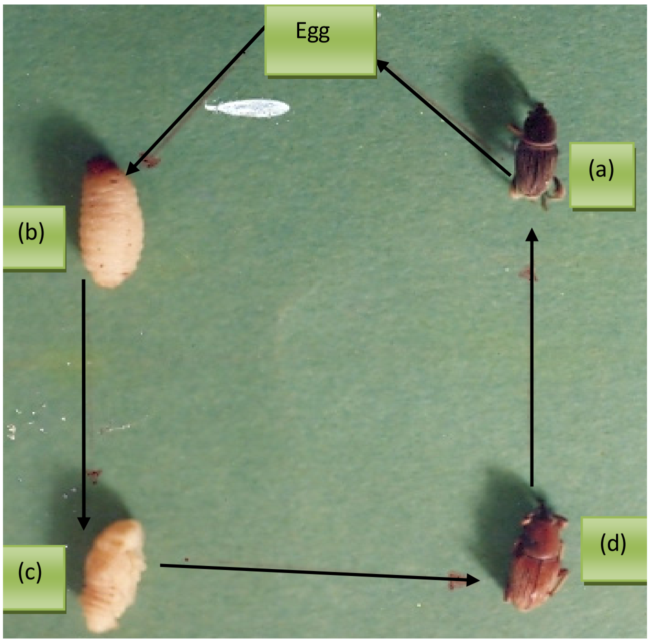

Fig. 3 Life stages of *Cosmopolites sordidus*. Photo by Roger Fogain.

Concerning *M. sericeus* and *P. mellerborgi*, very little research has been carried out. *M. sericeus* adults measure between 9-14 mm in body length with the dorsal body surface consisting of orange and dark spots. The adults are also fast-moving. However, this weevil was found to be 1.0-1.1 cm long (excluding rostrum) with shoulder width of 4 mm (Lavabre 1950; Fogain 1994a). *P. mellerborgi* looks like a miniature *C. sordidus* and therefore commonly known as small banana weevil (Padmanaban *et al.* 2001). First recorded in China (Zhou and Wu 1988), *P. mellerborgi* is a small black weevil between 4-5mm long including the rostrum and farmers usually confuse it with weevil storage pests (Fogain 1994). This small weevil was first reported in Cameroon in 1993 (CRBP 1993c).

2. Distribution and dispersal

The weevils are found in the fields throughout the year and the adults are free-living. Among the 28 borer pests associated with bananas and plantains world-wide (Seshu Reddy *et al.* 1994), banana corm borer weevils and the banana stem borer weevils (*Odioporus longicollis*) are widely distributed (Gold 1994; Fogain 1994a; Padmanaban and Sundararaju 1999; Gold *et al.* 2001; Ploetz 2004). In all the areas that bananas and plantains are grown, there is the presence of either the corm borer weevils or the stem borer weevils. These banana production areas include much of South America, Africa, Asia and Australia with few patches in Europe, North America and Middle East. In Cameroon, Fogain *et al.* (1998) and Fogain (1994a) reported that borer weevils are found in all banana/plantain production zones, although the population varies according to climate, cultivars, agronomic practices and altitude. According to CRBP (1995d) and Ysenbrandt *et al.* (2000), *C. sordidus* was found more in the field followed by *Metamacius* spp. Contrary to this, studies carried out by Mboueda (2007) showed that *P. mellerborgi* was more in the field followed by *C. sordidus*. Clement (1944) reported that *M. sericeus* can be found along the coast of West Africa where it was considered to be an insect of secondary importance.

Generally, adults are active in the night and are not commonly seen in the fields unless caught in traps. The adults are usually found in the soil around mats, within leaf sheaths of living pseudo stems and harvested stumps/corms (Simon 1993; Gowen 1995; Mboueda 2007). Although all the weevil species have been found on all growth and pre-/post harvest residues, infestation was higher in pre-flowered and bunched plants as well as on cut or harvested pseudo stems found horizontally on the ground (Mboueda 2007).

Messiaen (2002) found out that migration of adults by walking between sub-plots that were bordered by 5 m weed-free alleys was not more than 1% per week. This author therefore suggested that movement from and to adjacent fields by walking is limited. In addition, although *C. sordidus* seldom flies (Gordon and Ordish 1986; Pinese and Piper 1992; Valmayor 1994), young weevils with uplifted elytra and unfolded wings have been caught in window traps (CARBAP 1999; Messiaen 2002). According to CARBAP (1999), migration of weevils between test plots is in the months of July and August with peak population observed in October.

3. Damage and damage signs/symptoms

Though Lescot (1988) reported that adult weevils are not pests but feed on decomposed corms, in the fields, borer weevil damage is usually caused by the larvae (first to last instar). Although four weevil species have been reported in Cameroon, only *C. sordidus* is said to be of economic importance on bananas and plantains (Lavabre 1950; Vilardebo 1960; Jenny 1993; Sarah and Jones 1993; Simon 1993; Fogain 1994a; Mestre 1997; Courrier du CRBP 1998a; Lescot 1988; Tomekpe *et al.* 1999; Mouliourn-Perfoura *et al.* 2002; InfoMusa 2003; Anon 2005). However, the economic importance of this insect varies with agro-ecological region, cultivars, and production system. In the major plantain producing zones, about 41% of farmers cite weevils and nematodes as the most important phytosanitory problem (Ludovic *et al.* 2002). However, in South West Region, although many farmers were aware of weevil damage, few knew the pest causing it (Okolle pers. obs.; Okolle 2006a). Fogain *et al.* (1998) reported that 82.5% of farmers are aware of the weevil problem and are capable of recognizing damage caused by the insect. Meanwhile, Ngamo (1998) stated that 93% of farmers recognize banana weevil damage and 85% identified weevils as most important pest.

Corm damage and percentage of plants attacked in the fields is usually assessed or estimated using coefficient of infestation (CI) of Vilardebo (1973) as follows:

0 = No damage or traces of weevil galleries
5 = Traces of weevil galleries
10 = Intermediate between 5 and 20
20 = Galleries present on approximately ¼ of the sampled zone
30 = Intermediate between 20 and 40
40 = Galleries on approximately ½ of the sampled zone
60 = Galleries on approximately ¾ of the sampled zone
100 = Galleries present on the totality of the sampled zone

Damage is usually assessed by observing the periphery of the corm (external damage) and/or observing the cross section of the corm i.e. cortex and central cylinder (internal damage). Weevil damage has been reported in all farms that have been visited and in most cases, nearly all toppled plants contained severe larval damage. In addition, corm damage is common in farms with poor soil and with poor agronomic practices or poor phytosanitary measures applied. Severe damage has been reported on small-scale plantain farms compared to commercial plantations (Fogain *et al.* 1998; Fogain 2000). INIBAP (2000) also reported that resource-poor farmers are frequently vulnerable to serious yield losses via weevil attack. Furthermore, generally, plantains (*Musa* AAB) are attacked more severely by borer weevils than *Musa* AAA (bananas) (Ysenbrandt *et al*. 2000; Messiaen 2002).

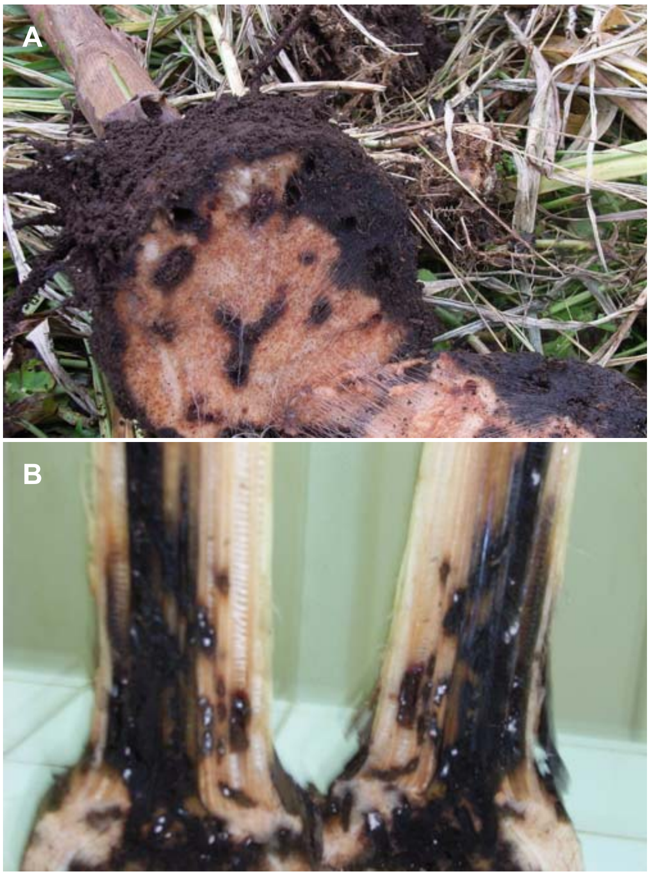

Fig. 4 *Cosmopolites sordidus* damage on plantain corm (**A**) and on plantain pseudostem (**B**). Photos by Justin Okolle.

Larvae of borer weevils are the most destructive stage, using their strong mandibles to escavate and create tunnels or galleries in the rhizome (corm) (**Fig. 4A**) and sometimes extending to the pseudo stem (**Fig. 4B**). This larval feeding usually result to weak growth, poor anchorage and toppling especially during windy periods (March and April) (Planta-Info 1998). In a field experimental plot, Messiaen (2002) observed that plot means of CI for peripheral damage varied between 0.3 and 21.1 while means for cross section damage ranged from 0 to 2.4 in the cortex and 0 to 0.7 in the central cylinder. In addition, percentage of plants attacked varied between 3 and 81% and was higher than 30% in 8 sites out of 17. There was also a very strong correlation between cross-section and peripheral damage or percentage of plants attacked (R^2 values ranged from 0.87 to 0.99). This shows that extent of internal corm damage increases with external or peripheral damage. However, peripheral damage was higher in the above ground part than in the below ground corm part for all plots. Messiaen (2002) also reported that cross-section damage was six times higher in the cortex compared to the central cylinder in the above ground corm part and approximately four times higher in the below ground corm part. This research also found that there was very low or no correlation between number of weevils per trap and the weevil damage. He therefore suggested that the low correlation between trap catches and weevil damage parameters indicates that trapping of weevils is not a reliable parameter for monitoring weevil infestation. This author also concluded that peripheral damage sampling is a good alternative to the destructive cross-section damage sampling.

Lescot (1988) and Courrier du CARBAP (2000) found

Fig. 5 Typical symptoms of a young plantain plant infested with *Cosmopolites sordidus* larvae. Photo by Justin Okolle.

that infestation is usually low in the first cycle but increases significantly during the older cycles. In the West province of Cameroon (45 sites: 800-2000 masl), Lescot (1988) reported strong correlation between intensity of infestation of corms and altitude (r = -0.75). Damage was also found to be highest below 1000 masl and practically non-existent above 1500 masl. Of about 31 toppled plants, CI varied between 30-100% in Ekona, South West Region (CRBP 1995b). Generally, it has been observed in the field that young plants less than 6 months old are severely affected by the borer larvae. Main infestation signs or effects on the plants include pre-mature death, stunted growth, young plants with little or no roots and with pale yellow leaves (**Fig. 5**) (Fogain 1994a; Anon 2005; Mboueda 2007). In an on-station trial in South West Region, a percentage attack of 90 on the plantain 'French Sombre' and 85% on banana Grand 'Naine' was recorded 6 months after planting (Messiaen 2002). However, mortality of young plants was 77% on plantain and 25% on 'Grand Naine' (Ysenbrandt *et al.* 2000)

Although damage caused by *P. mellerborgi* and *M. sericeus* is yet to be assessed, immature of *M. sericeus* were found in cocoons made of decomposed pseudostem fibres from crop residues unlike in boring tunnels in corms for *C. sordidus* (Messiaen 2002). In addition, Messiaen (2002) and CRBP (1998) stated that considering its small size and population, damage by *P. mellerborgi* was limited. *C. sordidus* causes premature death of suckers and percentage loss can be about 75% for new plantings found in highly infested plots (Ysenbrandt *et al.* 2000). Correlation found between external weevil damage and bunch weight of higher cycles (R^2 = -0.37) (Courrier du CARBAP 2000). Furthermore, Messiaen (2002) found that weevil damage in harvested plants was lower than in toppled plants, and highest in dead and stunted plants while Okolle and Fogain (2003) found that of 99 toppled plants dissected, there was a positive linear correlation (r = +0.68) between toppled plants and coefficient of infestation. Also, the more severe the cross-section damage in the central cylinder, the lower the number of harvested plants (R^2 = -0.99, P = 0.007). Again, except for number of leaves and fingers, all growth and yield parameters of 'French Sombre' plantain were significantly correlated to weevil damages (Messian 2002). Okolle and Fogain (2003) also found out that weevil population might have some effect on height of the plants (**Table 3**). From the table, the control (no insecticides) and imidaclopride (pulverized application on corms) treatments with highest mean number of weevils had lowest heights, girth and number of functional leaves.

4. Population dynamics

Generally, population dynamics involves changes in numbers of an organism as well as the biological and environmental processes influencing such changes (Gillman and Hails 1997; Speight *et al.* 1999; Cotgreve and Forseth 2002). Concerning the borer weevils, the main method used to monitor or estimate the population is trapping. The most commonly used traps in Cameroon are the pseudostem traps (mostly used by researchers) and the disc-on-stump traps used in some plantations. The former involves cutting about 30 cm of freshly harvested pseudostems, splitting them into two equal halves and placing them (with cut surfaces on the ground) beside the mats (**Fig. 6A**). Disc-on-stumps traps locally called "Encoche" are made by cutting small disc-like pieces from harvested stumps (**Fig. 6B**). The discs are left in the same areas where they were cut but with small allowance to permit entry of adult weevils. Plantations also use pheromone traps to a lesser extent in fallows. In addition, Messiaen (2002) measured weevil population using mark-recapture technique where the weevils were marked by removal of the tarsal claw (**Fig. 7**)

Population dynamic studies have been focused only on two agroecological zones (Ekona in the South West Region and Njombe in the Littoral Region) and only on *C. sordidus*. Ekona is situated at the foot of Mount Cameroon with an altitude of about 350 masl and consists of rich volcanic soil. Njombe is about 82 masl and also with rich volcanic soil. Both sites have rainy season from April to November.

For the year 1999 and 2000, Messiaen (2002) recorded weevil trap catches ranging from less than 1 to 6 adults/trap, with highest trap catches during the rainy season. Although trapping efficiencies tend to decline due to several factors, Price (1993) observed efficiencies in natural weevil populations of 1% in mulched plots and 16% in unmulched plots. In newly planted field, weevil population is usually very

Table 3 Average number of adult weevils (*Cosmopolites sordidus*) and height, girth and healthy leaves of bananas in a test plot, six months after application of treatments in Ekona, South West Region.

Treatments	Height*	Girth*	Healthy leaves	Adult weevils
Control – No insecticides	111	42.8	5.8	116.3
Reference insecticide (Fipronil)	120.5	45.8	5.9	29.0
Imidaclopride (spot gun)	123.3	46.8	5.8	115.5
Imidaclopride (spot gun after sheath removal)	124.2	46.1	5.8	85.3
Imidaclopride (pulverized application on corms)	106.8	41.0	5.5	197.3

*Height and girth measured in cm.
Methodological description: After application of the respective treatments, numbers of weevils were recorded each month from 100 pseudo stem traps. In addition, height, girth (circumference) and number of healthy leaves of all the experimental plantains were recorded each month. Average values for the six months are represented in the table.
Source: Okolle and Fogain (2003)

Fig. 6 (**A**) Classical split pseudostem trap; (**B**) Modified disc-on-stump trap; (**C**) Pitfall-based pheromone trap. Photos by Justin Okolle.

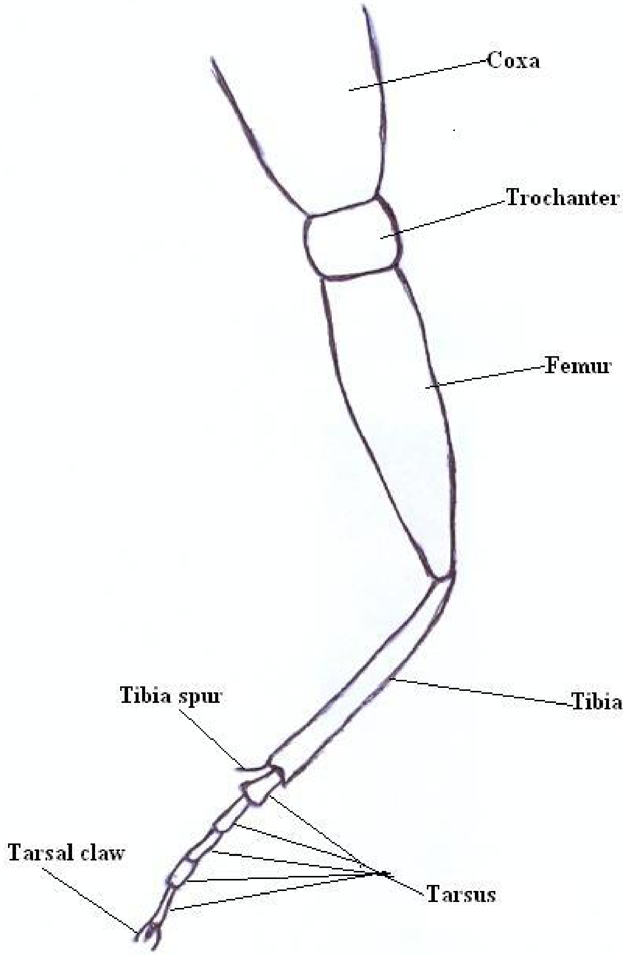

Fig. 7 Leg of an adult weevil showing the tarsal claw. Figure by Justin Okolle.

low in the first two months after planting but rapidly build up after that. Based on this, Messiaen (2002) suggested that weevil population can build up in plantain fields to damaging levels within the plant crop. Contrary to this, dynamic studies carried out in 2006 and 2007 (Okolle 2008) showed that in Ekona, the population intensity ranged from 6.5 (in February) to 17.9 (in September) weevils/trap. Highest intensities were recorded in September and October (rainy season). However, the population in Njombe, varied from 0.2 (February) to 3.4 (May) weevils/trap with lowest in October (<1 weevil/trap). Still in Ekona, Messiaen (2002) recorded peak weevil density at 14 months after planting at approximately five weevils/mat or 5,625 weevils/ha (0.6 weevils/m^2).

Although Messiaen (2002) reported that weevil population and activities always peak in the rainy season, results from Okolle (2008) showed that seasonal fluctuations and weevil density varies with agroecological zones. Price (1994) also recorded marked increase in adult weevils caught in traps following an overnight rain in the dry season and that such increase can occur within 12 hours. Moulioum Perfoura *et al.* (2005) reported that population dynamic studies in the two important production zones (Littoral and South West Regions) indicated that higher populations are observed between August and September (rainy season). According to CARBAP (1999), preliminary results in Ekona showed that population build up started in July with a peak in October (9.5 weevils/mat)

Generally, weather factors and natural biotic agents (predators, parasites, and pathogens) are the two main factors influencing the population dynamics of an insect. Based on field studies in Cameroon, Fansi and Okolle (2008) reported that so far there has been no significant correlation between weather factors and weevil population. In the case of these borer weevils, rainfall has been widely predicted as an important factor. However, Messiaen (2002) also caught more weevils in areas with high soil humidity and slightly higher elevations. As for biotic agents, very little surveys have been carried out to identify natural enemies of the weevils in the field. However, CRBP (1993c) reported the isolation of 3 strains of entomopathogenous fungi (one being *Beauveria bassiana*) from a dead *M. sericeus* in nature. Based on a personal discussion with Dr. Roger Fogain (a prominent banana nematologist), there are indigenous entomopathogenic nematodes that attack the borer weevils in Cameroon. Although Kanga (2008) reported that indigenous entomopathogens have been isolated in Cameroon, there is no evidence that such pathogens were isolated from banana borer weevils. However, Courrier du CRBP (1999b) simply mentioned that local entomopathogenous nematodes for the weevils have been isolated although names of the species and source of isolation were not mentioned.

As for predators, the two that have been observed (lizards and ants) have some controversial reports especially for the ants. Fansi and Okolle (2008) reported that unidentified ants were found eating up eggs of weevils placed inside Petri dishes in the field. Following discussions with some farmers, most of them mentioned that ants are destructive because (i) they eat roots of the plants (ii) they build their nests on the plants and this in turn softens the soil, causing toppling of the plants. Few however, insisted that the ants go to where there are weevil larvae and eat them. In support of this claim, whenever infested plants were uprooted, the corms cut into halves and kept on the ground, within 2-3 min, three different unidentified species of ants were found on the corms; searching and eating larvae and pupae (Okolle pers. obs.). The unidentified red ants ('Mokenge') and soldier ants ('Menyoli') are the two common ants usually found around banana/plantain corms. In addition, in an industrial plantation in Moungo Division – Littoral Region: SPM), little or no larvae or their galleries were found in corms having considerable numbers of these soldier ants (Jacques Simo, pers. comm.).

Long tail mealy bugs and white grubs

In Cameroon, these are relatively newer pests and have not been reported in many production zones. First official report on white grubs attacking bananas and plantains was in 2007 (Okolle 2007 – scientific evaluation). As for mealy bugs, although the problem is claimed to arise some 3 years ago (Jacques Simo, pers. comm.), it is only in the early 2008 that pest managers of banana plantations started discussing the problem with researchers of CARBAP. Based on this therefore, very little research has been carried out on these potential pests.

1. Mealy bugs

Body description, distribution and spread: These bugs are small insects having sizes similar to lice and usually do not have wings. Adults are pink in colour and they secrete a white waxy powder that covers the entire body. Mature forms have 3 tail-like structures or filaments at the end of the last abdominal segment (**Fig. 8**). So far, the presence and damage of mealy bugs have been reported only in plantations. These insects are usually found on plants with bunches and most often their groups are highly concentrated on leaf stalks and on the fruits. Dispersal or spread of the insects is usually by walking and through pruned leaves and harvested bunches.

Fig. 8 Adult long tail mealy bug. Photo by Osborne L.

Damage and damage signs/symptoms: The mealy bugs cause direct and/or indirect damage to the plants. Direct damage is by feeding on buds, leaves or fruits, and this is usually by sucking out sap from the plants. Indirect damage is by (i) secretion of honeydew, whose fermentation results to formation of sooty (black) mold fungus. As population of the bugs increases, concentration of honey dew and sooty fungi also increases. This changes the colour of the fruits from green to black and thus affecting their aesthetic value (not attractive to consumers) (**Fig. 9**). Because of this, most fruits are usually rejected, leading to considerable loss of marketable fruits. (ii) Since they feed by sucking out sap, it might be possible for them to transmit diseases from one plant to another. NB: Serious research collaboration with plant pathologists on this is needed. It is also interesting to note that the mealy bug population reaches its peak in the late dry season and are sometimes found on some flowering plants and cassava nearer the plantations.

Fig. 9 Mealy bug damage (black sooty mold) on banana fruits. Photo by Justin Okolle.

2. White grubs

Body description, distribution and spread: The grubs are larvae of a ground dwelling scarabeid beetle yet to be identified. These grubs are white or yellow in colour and have fleshy wrinkled C-shape bodies (**Fig. 10**). The end of the abdomen is darker, round and larger than the head region. The head is brown and consists of hard and sharp mandibles. These larvae also have 6 brown true thoracic legs and at maturity, the entire body can be 2-4 cm long. As far as bananas/plantains are concerned, these potential pests have been found only in Mbouroukou (a small village in Moungo Division, Littoral Region). In the farms, the insects are usually found inside the soil around the plants.

Fig. 10 White grub larvae. Photo by Justin Okolle.

Damage and damage signs/symptoms: These larvae use their strong mandibles to cut and feed on roots of bananas/plantains. They can eat entire roots of a young plant (< 5 months old). NB: About 30 grubs have been found around a single corm. Young plants that are heavily infested have corms with few or no roots (**Fig. 11**). Such plants are usually very weak and easily uprooted. In addition, the plants have smaller or thin pseudostems.

Fig. 11 Damage of white grub larvae on roots of young plantain plant. Photo by Justin Okolle.

INSECT PEST MANAGEMENT TECHNIQUES

Borer weevils

Several researches have been carried out to come out with different techniques that can be used to manage borer weevils. These techniques include use of chemicals, biocontrol agents, cultural and genetic control (Walangululu *et al.* 1993; Fogain *et al.* 1998; Speijer *et al.* 1999).

1. Use of chemicals

The chemicals here will include classical insecticides, botanicals and infochemicals.

Classical insecticides: In Cameroon, efficacies of several chemical formulations of classical insecticides have been evaluated for the management of borer weevils (**Table 4**) (Cohan *et al.* 2003, 2004). Generally, these chemical trials are carried out in collaboration with Agrochemical companies, Industrial Plantations, and Ministry of Agriculture before they can be homologated (IRAF 1971, 1977, 1979; Hugo 1981; Fogain 1994bc; Foure and Fogain 1994; CRBP 1995b; Fogain 2001a, 2001b). Testing the efficacies of these insecticides usually pass through three stages: (i) laboratory experiments in which adult borer weevils are placed in direct contact with prescribed doses (ii) classical field experiments that are carried out in the research station and are subjected to rigorous control, and (iii) pre-vulgarization field experiments carried out in larger plantations. In this case, with the exception of the chemical treatments, all other agronomic practices are those carried out by the plantation farm managers. In the field trials (research stations and plantations), the following parameters are usually recorded (i) number of adult weevils caught in traps (ii) coefficient of infestation (larval damage) at peripheral level (iii) percentage of plants attacked (iv) few, do record vegetative (growth) and yield parameters. In these trials, new formulations are usually tested or compared to a reference chemical that has already been homologated and often with the same active ingredient. Also, in all such experiments, the cultivars commonly used are Cavendish bananas (‘Grande Naine’) and the plantain ‘French Sombre’ and the ratio of traps to plants/mats varies from 1:2 to 1:25 (Messiaen 2002; Okolle and Fogain 2003; Lombi and Foure 2004a, 2004b, 2004c, 2004d; Lombi and Okolle 2007, 2008).

In addition, the chemical formulations of the insecticides used are usually in the form of granules, wettable powders, suspension concentrate, dustable powder and aqueous solution. According to Cohan *et al.* (2003; 2004), most of the chemicals that have been evaluated have contact and systemic effects and are usually neurotoxic. Some such as Rugby 10G® (cadusaphos), Sesame 10G® (carbofuran), Oftanol®, Curlone®, Primicide®, Mocap 10G® (ethoprophos), Vydate 240 EC®, Cosmopol 10G®, Control 15 EC®,

Table 4 Various classical insecticides whose efficacies to manage borer weevils (*Cosmopolites sordidus*) have been evaluated in Cameroon.

Chemical group	Trade name	Active ingredient	Dose per plant	Frequency of application	Conclusions
Phenyl Pyrazole	Regent 5G	Fipronil[c]	20-30 g (c.p)	2-3/year	Excellent results
Phenyl Pyrazole	Regent 2G	Fipronil[c]	0.1 g (a.i)	2/year	Excellent results
Phenyl Pyrazole	Regent 50 EC	Fipronil[c]	0.2 g (a.i)	2-3/year	Very good results
Neonicotinoid	Attakan 350 SC	Imidaclopride[s/c]	20 ml (c.p)	2/year	Very good results
Neonicotinoid	Confidor 200 SL	Imidaclopride[s/c]	1.25 ml (c.p)	2/year	Excellent results
Neonicotinoid	Confidor 350 SC	Imidaclopride[s/c]	25-50 ml(c.p)	2/year	Excellent results
Neonicotinoid	Plantima 700 WG	Imidaclopride[s/c]	50 ml (c.p)	2/year	Excellent results
Neonicotinoid	Insector 35 SC	Imidaclopride[s/c]	1.4 L/Ha (c.p)	2/year	Excellent results
Neonicotinoid	Caltak	Athiametoxam[s/c]	30-50 g (c.p)	2-3/year	Very good results
Neonicotinoid	Actara 25 WG	Thiametoxam[s/c]	8-50 g (c.p)	2-3/year	Very good results
Nereistoxin Analogue	Kart 500 SP	Cartap[c]	5-10 g (c.p)	2-3/year	Very good results
Pyrethroid	Decis 25 EC	Deltamethrine[s/c]	7.5-0.30 ml (c.p)	3/year	Weak to moderate
Pyrethroid	Talstar	Bifenthrine	100 g (c.p)	2-3/year	Moderate results
Pyrethroid	Fury Dust	Zetacypermethrine[s]	30 g (c.p)	2-3/year	Excellent results
Organophosphate	Rugby 10G	Cadusofos[c]	20-30 g (c.p)	1-2/year	Moderate results
Organophosphate	Counter 10G	Terbuphos[s]	3-30 g (c.p)	2-3/year	Moderate results
Organophosphate	Mocap	Ethoprophos[s/c]	45 g (c.p)	3/year	Excellent results
Organophosphate	Oftanol	Isophenphos	2 g (a.i)	3/year	Excellent results
Organophosphate	Pyrimicid	Pyrimiphos	20 g (c.p)	2-3/year	Excellent results
Organophosphate	Dursban 10G	Chlorpyriphos	0.25-2 g (a.i)	2-3/year	Very good results
Organophosphate	Control 15 FC	Terbuphos[s]	4.5-30 g	2-3/year	Weak to moderate
Organophosphate	Arriba 2GR	Tebupirimphos[c]	1-2 g (a.i)	2-3/year	Moderate results
Organochlorine	Kepone 5%	Chlordecone[c]	20-30 g (c.p)	Not available	Not available
Organochlorine	Curlone	Chlordecone[c]	2 g (a.i)	3/year	Excellent results
Organochlorine	Debendol	Lindane[c]	2 g (a.i)	3/year	Not available
Carbamate	Bastion 10G	Carbofuran[s]	3-30 g (c.p)	Not available	Not available
Carbamate	Temik 10G	Aldicarbe[c]	2-3 g	3/year	Very good
Carbamate	Vydate 240 EC	Oxamyl[s]	7.5 ml (c.p)	3/year	Weak results

[c] = mode of action is contact. [s] = mode of action is systemic. [s/c] = mode of action is systemic/contact. c.p = commercial product. a.i. = active ingredient

Methodological description: We formed this table based on several reports evaluating the efficacies of insecticides to manage banana borer weevils in experimental stations and in the plantations.

Source: IRAF 1971, 1977, 1979; Hugo 1981; Lassoudiere and Viladerbo 1984; Lassoudiere 1985; Fogain and Lassoudiere 1990; Fogain 1994bc; Foure and Fogain 1994; CRBP 1995b; Fogain 2001a, 2001b; Messiaen 2002; Okolle and Fogain 2003; Cohan *et al.* 2003, 2004; Lombi and Foure 2004abcd; Lombi and Okolle 2007, 2008.

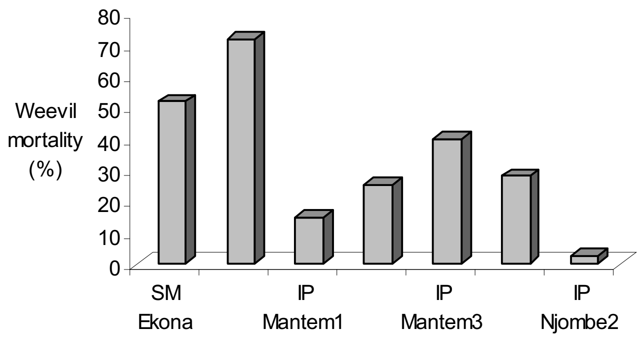

Fig. 12 Evidence of *Cosmopolites sordidus* resistance to insecticides. SM = smallholder's farm. IP = industrial plantation. Figure by Justin Okolle.

Counter 10G®, were found to also have nematicidal effects on banana nematodes (Lassoudiere and Viladerbo 1984; Lassoudiere 1985; Fogain and Lassoudiere 1990; Cohan *et al.* 2004; Lombi and Foure 2004a). Of all these classical insecticides evaluated, those with excellent efficacies so far are fipronil, imidaclopride, isophenfos, chlordecone, zeta-cypermethrine, thiametoxam, ethoprophos and aldicarbe.

Although fipronil, marketed as Regent® has been used as a reference formulation as well as the only authorized efficient and most widely used in banana plantations between 1990s-2000 (Fogain *et al.* 2000), its continuous application resulted to some environmental problems and ecological backlashes. These included (i) severe mortality on non-target arthropods/molluscs such as millipedes, centipedes, slugs and snails, and other ground dwelling beetles (ii) adult weevil resistance (INIBAP 2000; Okolle and Sama Lang 2006; Anon 2007; Okolle pers. obs.). **Fig. 12** shows evidence of resistance development of adult weevils to fipronil (Regent 5G®). Higher mortality of weevils found in smallholders' farms (no chemical applications) compared to lower mortality of weevils from industrial plantations (treated with fipronil; 2-3 times/year). Also, in terms of coefficient of infestation, a field trial showed that Confidor 350 SC® had the lowest (0.8) while Regent 5G® had the highest (>1.2 but <1.5) (Lombi and Foure 2004a, 2004b).

In the fields, from **Table 4**, although doses applied per plant varied for the different chemicals, frequency of application were somehow similar, most between 2-3 times/year. In his chemical trials, Messiaen (2002) however, reported application frequencies of between 4-6 times/production cycle. As for the application methods, the insecticides were commonly applied on (i) soil around corms (ii) area of pseudo stems nearer corms without removal of old leaf sheaths (iii) area of pseudostems nearer corms after removal of old leaf sheaths (IRAF 1978; Anon 1980; Fogain 1994b, 1994c; CRBP 1994b, 1994c; Messiaen 2002; Lombi and Foure 2004a, 2004b, 2004c, 2004d; Lombi and Okolle 2008). With respect to vegetative parameters, Lassoudiere and Vilardebo (1984) found out that plant growth and vigour were significantly higher in Oftanol®, Curlone®, and Primicide® treatments. In support of this, Okolle and Fogain (2003) also found out that those insecticide treatments with higher average numbers of adult weevils all had higher average heights and girths (**Table 3**) while Vilardebo (1988) reported that plants treated with Temik (Aldicarbe) showed best growth compared to the control. However, contrary to these findings, Messiaen (2002) did not find any significant difference in plant growth parameters (height and girth) between control and the different insecticidal treatments. As for yield parameters, Messiaen (2002) reported that mean number of hands and fingers and the percentage of toppled mats did not differ significantly between treatments. Furthermore, percentage of plants attacked and coefficients of infestations have been reported to be higher in higher production cycles (especially 3rd cycle upwards) (Lassoudiere and Vilardebo 1984; Messiaen 2002; Itue Hansel; pers. comm). According to Lassoudiere and Vilardebo (1984), the percentage of plants attacked varied from 0 to 54 while CI varied from 0 to 16.3. However, yield/ha was not significantly different between the chemical treatments (Oftanol®, Curlone®, Kepone® and Primicide®).

Botanicals or biocides: These are natural substances with insecticidal effects. Common botanicals that have been evaluated in the laboratory and fields in Cameroon are neem tree extracts (*Azadirachta indica*), hot pepper (*Capsicum* sp.), coffee husk and wood ash (Fogain and Kakanokou 1994; Ysenbrandt 1996; CRBP 1998; Fogain and Ysenbrandt 1998; Messiaen *et al.* 1998; Courrier du CRBP 1999a, 1999b; Messiaen 2002).

In the laboratory, derivatives of neem have been shown to be the best biocides with the following effects (i) they are repulsive (ii) slows down or inhibit oviposition (iii) affects hatchability of eggs and female fecundity (iv) average mortality/toxicity (Fogain *et al.* 1994; Messiaen *et al.* 1998; Courrier du CARBAP 1999b; Messiaen 2002). Although up to 50% mortality has been reported, mortality build up is usually very slow and always related to neem concentrations or doses used (Fogain and Ysenbrandt 1998; Messiaen *et al.* 1998; Messiaen 2002). Results from Messiaen *et al.* (1998) suggested that neem concentrations of up to 60g/mat are likely to interfere with oviposition and/or larval development rather than affecting adults. CRBP (1993c) reportted that *in vitro* neem evaluation tests on the different borer species showed that the impact was more on *M. sericeus* with a mortality of 100% observed 9, 16 and 23 days after application of neem powder.

Although few neem field experiments have been carried out, promising results have been recorded. Fogain *et al.* (1994) reported that fewer weevils were found on neem treatments applied at 40 g/powder/plant at 2, 3, and 4 times/year. As for damage, CI was 17% for non-treated compared to 3.75% for neem treatments at 3 applications/year. Messiaen *et al.* (1998) found out that in a natural heavily infested site (Ekona–South West Region), suckers dipped in a solution of neem (i.e. neem seed powder dipping + neem seed powder 60 g/mat, 2 applications/year) suffered significantly less damage and less subsequent mortality than untreated suckers. However, the effects of neem on damage and mortality were significantly less than the reference classical insecticide (cocktail of Regent® and Rugby® at 20 g/mat). Furthermore, these authors also found that number of adults trapped in the dipping treatment did not differ significantly from the control. Similarly, the commercial neem product (Azatin®EC; azadirachtin 3%) also had no effect on weevils or their damage. Okolle (2008) also found out that another commercial neem product (Suneem®EC; azadirachtin 1%) had very little or no effects on weevil mortality and damage in a laboratory test although the adult weevil mortality was substantial when the Suneem® was mixed with a commercial entomopathogenic fungus (Botanigard®; *Beauveria bassiana* Strain GHA). However, Fogain and Ysenbrandt (1998) reported that Azatin® caused 100% mortality 4 weeks after 0.2 ml was applied on cut bulbs or corms.

Fogain and Ysenbrandt (1998) reported that of all the neem treatments, neem dipping of suckers before planting showed the best results (26.5% plant mortality compared to 53.3% for control and 60 CI as against 100 CI for the control). However, these authors failed to mention the dose or amount of neem applied per plant. Still at the naturally highly infested zone, Messiaen (2002) reported that neem seed powder at 100 g/mat applied as a contact insecticide (crown application or liquid solution), appeared to have little effect on weevil adult population, damage and levels of plant loss. In spite of this, the author concluded that dipping planting material in a 20% (2 kg/10 L) neem seed powder extract protected young plants from heavy weevil attack during the first 3 months after planting.

As for wood ash, Courrier du CARBAP (1999) reports that more than 30% of farmers used it to control *C. sordidus*. The ash showed some repulsive effects but did not seem to affect all the insect stages. At high concentration, coffee husk is absorbed by banana corm to kill larvae but do not affect adults. A solution of 10% crushed hot pepper tends to inhibit hatching eggs and is also repulsive.

Infochemicals or semiochemicals: According to Dicke and Sabelis (1998), an infochemical is a chemical that conveys information in an interaction between two individuals, evoking in the receiver a behavioural or physiological response. Gullan and Cranston (1994) stressed that insects use these chemicals to communicate within and between species. Typical examples of infochemicals that have been used or still used for the management of banana weevils are kairomones and pheromones (INIBAP 2000; Messiaen 2002; Tinzaara 2005). A pheromone known as sordidine produced from male weevils and that attract both sexes, was first reported by Budenberg *et al.* (1993). This pheromone tends to attract adult weevils of the same species.

In Cameroon, a sordidine-based trap (trade name Cosmotrak®) (**Fig. 6c**) has been evaluated (INIBAP 2000; Fogain 2003). On average, these pheromone traps caught only 0.4-0.5% of the population at any one time, effectiveness only marginally better than classical unbaited traps. CARBAP (1999) mentioned that the number of weevils per pheromone trap ranged from 3-10/week compared to 2-5/ week for pseudo stem traps. Such poor results were reported to be probably due to improper storage (Fogain Roger, pers comm.). However, in the plantations, relatively larger population of weevils were found in these pheromone traps although these were more effective in fallows and also caught many other invertebrates such as spiders, ants, crickets and slugs. In PHP plantations Njombe, average number of weevils per week per trap varied from 8.5 to 11.9.

2. Biological control (biocontrol)

Such a technique usually involves the manipulation and/or use of natural agents and mechanisms to keep pest populations below economic damaging levels or in tolerable balance (Kumar 1984; IITA 1990; Pedigo 1999; Norris *et al.* 2003, Okolle *et al.* 2006a, 2006b, 2008). For the management of weevils, such natural agents usually include predatory arthropods (e.g. histerid beetles and ants), parasitoids, entomopathogenes (*Beauveria bassiana*, *Metarrhizium anisopliae*) and fungal endophytes or mycorrhizae (Neuenschwander 1987; Treverrow *et al.* 1991; Koppennenhofer *et al.* 1992; Fogain 1994a; Gold and Speijer 1997; Haysim and Gold 1998; Nakinga 1999). Although Fansi and Okolle (2008) reported that unidentified species of ants and the rainbow lizards occasionally eat some life stages of the weevil, feasibility for mass rearing and using these animals in the field is still to be studied. According to Waterhouse and Norris (1987), even though the histerid beetle (*Plaeus javanus*) has been successfully introduced in Pacific region and Trinidad, its establishment in Australia, Cameroon, Jamaica, Japan, Samoa, Tanzania and Uganda failed.

Some researches have also been carried out both in the laboratory and field with respect to entomopathogenic fungi. In 1993, three strains (E1, E3 and *B. bassiana*) of entomopathogenic fungi were isolated from a dead *M. sericeus* in a farmer's field (CRBP 1994b; Fogain 1994a; Courrier du CARBAP 2002b; Fogain 2002). Laboratory studies have shown that this indigenous strain of *B. bassiana* has remarkable pathogenicity on borer weevils found on plantains and bananas. After applying different doses (10^5 spores/ml, 10^4 spores, 10^3spores/ml) of this indigenous strain of *B. bassiana*, Fogain and Ysenbrandt (1998) found that highest mortality rate of adult weevils was 25% 10 days after application. Courrier du CARBAP (2001) and Moulioum-Perfoura *et al.* (2005) reported that the local strain caused 92-95% adult mortality 9-14 days after treatment while Okolle *et al.* (2008) found out that an exotic commercial strain (trade name as Botanigard®) caused highest mortality of 60% when applied directly on the bodies; 15 days after application (See **Fig. 13** for adult mortality caused by the

Fig. 13 Mortality and mycosis of *Cosmopolites sordidus* caused by *Beauveria bassiana* in the laboratory. Photo by Justin Okolle.

fungus). Whereas Fogain and Ysenbrandt (1998) recorded first dead weevil from *B. bassiana* infection 10 days after application, Okolle *et al*. (2008) recorded first mortality 5 days after treatment and first appearance of mycelia on dead weevils recorded 7 days after. In all these experiments, viability of the local *B. bassiana* was found to diminish when cultivated on artificial medium, potato dextrose agar or PDA (CARBAP 1999; Courrier du CRBP 2000b). However, on addition of 5% mineral oil, 10^8 spores of the local *B. Bassiana* resulted to 100% mortality 7 days after application (Courrier du CRBP 1999b). Supporting this fact that *B. bassiana* may need boosters, Okolle (2008) found that weevil mortality increased when *B. bassiana* (Botanigard®) was mixed with a commercial neem product (Suneem®).

In the field, the only available study that has evaluated the potential of *B. Bassiana* to manage the weevils in Cameroon is that by Okolle *et al.* (2008). In a naturally highly infested zone (CARBAP Experimental Station in Ekona, South West Region), the following treatments were applied in a randomised block design: T1 = control (no chemical application), T2 = 200 ml of *Beauveria* solution (BS) on soil around plants, T3 = 200 ml of BS applied on pseudostem traps, T4 = 100 ml of BS + 25 ml of imidaclopride (Confidor 350 SC®) applied on corms, T5 = 50 ml of Confidor 350 SC® applied on corms. NB: BS was made by putting 100 g of commercial exotic *Beauveria* (Botanigard®) in 10 L of water. In all the BS treatments, highest number of dead weevils and highest number of dead weevils with fungal mycelia (70.8%) were recorded from T3. Furthermore, one month after first and second application of treatments, adult weevil population dropped although there was rapid population build-up. The authors therefore concluded that when used as a classical insecticide, the commercial exotic fungus has great potentials for managing the weevils especially when applied on pseudo stem or disc-on-stump traps. In addition, significantly lower corm damages were recorded from T4 (CI of 10.5) compared to the control T1 (CI of 43.8). However, to prevent rapid population build-up soon after treatments, there is a need to increase frequency and dose of application.

As far as entomopathogenic nematodes are concerned, although there are reports that some local strains have been isolated (Courrier du CRBP 1999b; Kanga2008), names of the species are not mentioned and there are no researches that have evaluated the potential of these nematodes in managing the weevils. Concerning fungal endophytes, several authors (Fogain and Ngamo 1998; Ngamo and Fogain 1999; Courrier du CRBP 2000a, 2000d; Lombi 2006) reported that a local strain *Glomus* spp. tends to improve growth of bananas/plantains as well as tolerance to nematode attack. In spite of this, there are no studies that test the pathogenicity of these endophytes to the borer weevils.

Fig. 14 Clean plantain planting materials from the 'PIF' technique. Photo by Gerald Ngoh Newilah.

3. Cultural and mechanical techniques

Using pest and disease-free planting material (clean planting material) has been widely reported to reduce spread of plant parasitic nematodes and banana weevils (Prasad and Seshu-Reddy 1994; CRBP 1996; Speijer *et al*. 1999; Masanza 2003; Jacobsen *et al*. 2004). Hot water is used to treat pared suckers at 50-55°C for 15-25 min is found be effective in the elimination of pests such as nematodes and borer weevils. According to Hauser (2000), hot-water treatment of corms reduced nematode infestation to about 30% and increased rhizome survival by 11%. According to Info-Musa (2003), a combination of several cultural techniques is the best available approach to resource-poor farmers as it is likely to reduce weevil and nematode pressure. In Cameroon, both large-scale commercial plantations and small to medium sized farms use different kinds of techniques. The most common cultural technique is the use of clean-planting materials. Such materials include plantlets produced from rapid multiplication techniques (the PIF technique – production of small plantlets from stem bits) (**Fig. 14**, PIF plantlets), tissue-cultured plants and pared suckers (Noupadja 1995; Courrier du CRBP 1996b; CRBP 1997; Fogain *et al.* 1998; Kwa 1998; Kifumfutu and Mpanda 2000; Kwa 2001; Gaidashova *et al.* 2001; Messiaen 2002).

Previously, clean planting materials (especially tissue cultured plants) were mainly used by industrial growers (Fogain *et al*. 1998). However, presently, with the government's emphasis on the importance of bananas/plantains for food security and poverty alleviation, most small scale farmers are now using these pest/disease-free materials. In addition, Fogain *et al.* (1998) reported that removal of plant debris and destruction of old pseudo stems help to reduce toppling resulting from weevil damage. In spite of this widespread use of these cultural techniques, there are no scientific data showing their importance with respect to weevil management in Cameroon. Apart of these plantlets from rapid multiplication techniques, some small-scale farmers use pared suckers that are sun-dried or hot-water treated (52-55°C for 15-27 min) before planting. Paring is removal of the outer surface of the corm of a sucker using a sharp knife or machete. Messiean (2002) mentioned that this method helps to expose larval galleries and therefore allowing the farmer to reject heavily damaged suckers. In addition to paring, hot water treatment and sun-drying helps to kill nematodes and a good proportion of borer weevil larvae. Although in some countries of the Central African Region adoption of this technique might be limited, in Cameroon, Chantelot (1993) found out that nearly all of the 75 small-holders sampled in the South West Region were familiar with the practice of paring suckers before planting. Some farmers even treat the pared suckers with insecticides before planting. Contrary to this, Jacobsen *et al*. (2004) reported that in the North West and West Regions of Cameroon, only 6% of farmers pared their suckers before planting and only 5% used some form of heat treatment, with lukewarm, warm or boiling water.

Messiean (2002) also reported that fallowing or crop rotation is another important cultural technique. In plantations, after about 3-5 years of cultivation, plots are fallowed for about 1-2 years. In some cases, other non-*Musa* crops such as sweet potatoes and pineapples, are cultivated in the fallow areas before replanting of bananas. Price (1993) recommended at least 1 year of fallowing or growing a non-*Musa* crop before replanting of bananas. Although several studies have shown that fallowing reduces nematode populations in banana plantations (Fogain *et al.* 1998; Achard and Fogain 1999; Messiaen 2002; Jacobsen *et al*. 2004), only study by Price (1994) that showed the effects of these practices on weevils. In Ekona, Southwest Region of Cameroon, Price (1994) found out that weevil damage was lowest (CI = 0.5) in the weed-fallow microplots while highest damage (CI = 2.25) was seen in microplots previously planted with plantains. Based on these results, the author concluded that *C. sordidus* can cause serious damage to young plants planted directly into infested land. Another important technique is the use of traps to catch and either destroy or poison adult weevils. In research stations, the most commonly used traps are the classical split pseudostems (Price 1993, 1995; Fogain *et al.* 1998; Messiaen 2002) (NB: see section on population dynamics for description of these traps). Although till present it is difficult for most farmers (small scale) to adopt this technique, most plantations (large scale) adopted it but soon abandoned it because it is labour-intensive or demanding and time-wasting. Currently, most plantations in Moungo Division-Littoral Region are using a trapping technique known as "Encoche" (**Fig. 6b**). This is a sort of disc-on-stump trap made by cutting out a small piece of corm from a harvested stump, removing it and placing it again on the cut spot such that an allowance is left for weevil entry. According to Jacques Simo and Pelagie Chokocheu (pest managers respectively of SPM and PHP plantations), "Encoche" has the following advantages: (i) it is easy to set or put in place, (ii) it is simple and less labour-intensive, (iii) it catches more weevils. However, they emphasized that like classical pseudostem traps, the number of weevils caught reduces with time. In addition, except the "Encoches" are sprayed with chemical immediately after removal of caught weevils, there is higher probability that the adults must have laid eggs. These might eventually result to larvae that might move and attack nearby suckers.

Even though traps based on infochemicals have shown to have high efficiencies at farm level (Budenberg and Ndiege 1993; Alpizar *et al.* 1998; Tinzaara 2005), large-scale plantations in Cameroon are still sceptical in adopting the technique. This is because it has been found that number of adult weevils caught in pheromone traps (Cosmotrak®) is just marginally different from the pseudo stem trap or "Encoche". However, in PHP plantations in Njombe, pheromone traps are still been used in fallows.

4. Genetic techniques

In Cameroon, research on genetic techniques has been focused mainly on screening for resistant/tolerant varieties. Host resistance is generally considered as the most appropriate component of IPM against pest and diseases (INIBAP 1998; Noupadja and Tomekpe 1999) while screening is a first step in the development of a breeding program (Pavis and Lemaire 1996). Used in an IPM strategy, resistant genotypes provide a mechanism that reduces rate of population build up (Messiaen 2002). Limited research has been carried out in the laboratory to find out possible resistant mechanisms for a few varieties.

As far as screening tests are concerned, most are carried out in the field based on cross-section damage (coefficient of infestations or presence/absence of galleries). Screening of 52 cultivars (Fogain 1992; Fogain and Price 1994) by assessing CI 19 months after planting showed that AAB varieties generally suffer the most attack and that AAA are most resistant (except 'Figue Pomme Adju'). Fogain and Price (1994) found out that the CI of the screened varieties ranged from 0-32.3; with highest values from the varieties

Fig. 15 Banana bunches. Varieties: (**A**) 'Yangambi Km5', (**B**) 'French sombre', (Photos by Justin Okolle) (**C**) 'CRBP 039' (Photo by Leopold Sadom).

'Corne #5' (32.2 – *Musa* AAB) and 'Obel' (28.4 – *Musa* AAB) all plantains. Varieties with zero attack (CI = 0) included *M. balbissiana*, *M. accuminata*-Type II, *M. textilis*, 'Gros Michel' (AAA), 'Yangambi Km17' (AAA), 'Figue Sucree' (AA), 'Grande Naine' (AAA) while AAB varieties with zero attack were 'Rajapuri India', 'Foconah', 'Christine' (Bluggoe) and 'Figue Pomme d'Ekona'. Furthermore, Courrier du CARBAP (1999) reported that 'Yangambi Km5' (**Fig. 15a**), *M. balbissiana*, and 'CRBP 60' had zero weevil damage after screening in the field.

Fogain and Price (1991) showed that 'Corne #5' (AAB), 'Popoulou' (AAB), and 'French Sombre' (AAB) (**Fig. 15b**) (all of the plantain sub-group) were highly susceptible to weevils with mean CI of 3.2, 26.1 and 25.6, respectively. 'Yangambi Km17' (Ibota-AAA) and 'Gros Michel' (AAA) were not attacked by borer weevils (CI = 0) while 'Grande Naine' and 'Americani' (Cavendish – AAA) were less susceptible with mean CI of 1.9. In his PhD research work in Cameroon, Messiaen (2002) found out that in the different trials (in different agroecological zones, only 'Yangambi Km5' and 'Pisang Mas' were consistently found to be resistant with zero CI. Mohaman (1998) and Foure *et al*. (1984) in turn reported that the triploid 'Yangambi Km5' and the diploids 'Calcutta 4', *M. balbissiana* and 'Truncata' have good level of resistance to *C. sordidus* and black sigatoka disease. Using most of the varieties with higher levels of resistance, preliminary results on mechanism of resistance suggest that antibiosis is the prevalent mechanism especially for 'Yangambi Km5' (CRBP 1999; Messiaen 2002).

Since CARBAP has a department in charge of genetic improvement, several attempts have been carried out to come out with new varieties that are resistant to pests and diseases (Tomekpe *et al*. 1995; CARBAP 1999; Courrier du CRBP 2000; Noupadja 2000; Cohan *et al*. 2003; Coulibaly and Djedji 2004; Tomekpe *et al*. 2004). These hybrid varieties include 'CRBP 15', 'CRBP 100', 'CRBP 160', 'CRBP14', 'CRBP 50', 'CRBP 47', 'CRBP 205', 'CRBP 222', 'CRBP 85', 'CRBP 39'. Of all these, 'CRBP 14', 'CRBP 39', 'CRBP 85' and 'CRBP 100' have been shown to be resistant to black sigatoka (Courrier du CRBP 1998; Noupadja 2000; Courrier du CARBAP 2002a) while only 'CRBP 39' (**Fig. 15c**) and 'CRBP 60' have been reported to be resistant to borer weevils (Courrier du CRBP 1999a, 1999b; PlantaInfo 2004a). However, there are no scientific data based on damage assessments to support this claim.

Management of long tail mealy bugs

In the plantations, washing and use of chemicals are the two methods used to manage this pest. In some plantations especially in areas or blocks having high populations, Dursban 10G® (chlorpyriphos) is applied at a dose of 0.7 L/ha using a motorized knapsack sprayer (application done twice/ month). In other plantations, various soap solutions (washing detergents) are mixed and sprayed on the plants. Since most of these insects are concentrated on the fingers, as soon as the bunches reach the washing stations, high spray tap water is used to wash out most of the adults. In the washing tanks, washing detergents or soaps are then used to remove soot found on the finger surfaces. However, on serious infestation cases, not all the soot is removed and therefore most fruits are discarded (not packed for commercial purposes).

KNOWLEDGE/TECHNOLOGY TRANSFER

Staver (2005) and Dr. Barbara Adolph (A Social Development Consultant of TripleLine Consulting) have insisted that there is a need for a regular interaction between researchers, extensionists, farmers and other relevant stakeholders. This will usually lead to a participatory approach that will help to transfer research technologies or knowledge. According to CRBP (1993ab), a major mission of CARBAP is to put in place strategies of knowledge or technology transfer within the region. In addition, CRBP (1993a) mentioned that such an extension is usually attained through training, spread of information, animations and expertise.

As far as the laboratory of Entomology/Nematology is concerned, technology/knowledge transfer has been carried out through (i) publications e.g. journals, newspapers, fact sheets and technical guides, (ii) consultancy services to agrochemical companies, large commercial plantations, CIGs and NGOs, (iii) workshops, (iv) supervising students' research. As for publications, research results have been disseminated through publications such as Courrier du CARBAP, PlantaInfo, Annual Reports and Scientific reports. Interested persons usually subscribe to or consult these documents. Sometimes, research results are published in local newspapers such as The Farmers' Voice. Other articles have been published in regional journals or bulletins such as MusAfrica, Coraf Action as well as international peer-reviewed journals such as Fruits and InfoMusa (a former publication of Bioversity International). The laboratory had signed several research contracts with industrial plantations (e.g. SPM, DELMONTE, PHP), agrochemical industries (e.g. Agrochem, Ader, Fimex, Jako) as well as co-operations with research institutes or universities such as CIRAD, IITA, KuLeuven, University of Dschang (CRBP 1993; PlantaInfo 2004b) and the department of plant and animal sciences of the University of Buea. In addition, the laboratory has also carried out professional services in some of the plantations including analysing monitoring methods and wise management, experiments to evaluate bioefficacies of insecticides, evaluation of resistance to insecticides and population dynamic studies (Courrier du CARBAP 2000).

Furthermore, the laboratory has carried out several workshops on IPM and crop protection practices on bananas/plantains (Courrier du CRBP 1993b, 1994, 1998; Temple and Kwa 2001). In these workshops, technology or knowledge transfer was carried out through Farmer Field Schools (FFS) and Training/Visit (T&V). With FFS, researchers meet group of farmers, both farmers and researchers discuss all possible pest related problems as well as approaches to solve them. Finally, a visit is carried out to one of the farmer's field where the researchers demonstrate; showing the farmers some pests, where they are found, how they can be trapped and where to apply chemicals if necessary. With T&V, researchers meet group of farmers, explain to them recent results and pest management innovations, and then visit the farmers after sometime to see whether they are really applying what they learnt. Almost all of these activities were carried out in the South, Centre and Littoral Regions and included; basic knowledge on cultural practices, identification of pest/diseases, impact of pests/diseases on yield, spread of pests/diseases, diagnoses of weevil damage and control strategies. In addition to organising workshops, the laboratory has attended local, regional and international workshops/training/seminars (Courrier du CRBP 1997, 2000b, 2002c; Moulioum *et al*. 2005). In these workshops/seminars, the participants learnt the following: agricultural research management, factors hindering adoption of research technologies by farmers, importance of clean planting materials for managing pests, and integrated pest management of borer weevils.

Lastly, the laboratory has trained some local and foreign students from Universities and Agricultural Colleges. Local students are usually from the Faculty of Agricultural Sciences and Agronomy of the University of Dschang (West Region). Students from the Faculty of Agronomic Sciences (Gembloux-Belgium) have been trained on analysing systems of evaluating weevil damage (Courrier du CRBP 2000e) while a Belgian national (Stijn Messiaen), successfully carried out his PhD research in the laboratory. A Cameroonian national (Ngamo Leonard), after obtaining his PhD from KuLeuven, Belgium, also successfully finished his postdoctoral training in the laboratory.

Evaluation of the above mentioned extension services were usually met with some successes as well as failures and/or weaknesses. As for successes, with respect to workshops/seminars/training, most farmers learnt new knowledge and techniques. For instance, most of them can now identify the major insect pests on bananas/plantains, the damage caused by the pests and how to manage the weevils using simple tools such as trapping, paring and treatment of suckers before planting. Also, most stakeholders (farmers, pest managers, extensionists and students) have increased their knowledge on pest of bananas/plantains and their management through CARBAP publications. Weaknesses recorded include (i) Extension services have not been carried out in all major banana/plantain production zones in Cameroon. For example, even though the Southwest Region supplies about 1/3 of the national production of plantains, very little or no workshops or training have been organized in the region. This is most often due to lack or inadequate funds to extend such services to all the regions. (ii) In most of the trainings/workshops/seminars organized, technology/knowledge transfer most often takes the top-down or paternalistic approach where researchers teach and tell farmers or stakeholders what to do. The disadvantage here is that farmers are not given the opportunity to share their own knowledge, to experiment with the researchers and then take decisions on which technologies to adopt or not. (iii) Ignorance and resistance to change sometimes results to difficulties in adopting new technologies that are even simple, more practical and cost-effective. For example, it has been very difficult for some farmers to use clean-planting materials (pared suckers); most claiming that removing the roots will kill the plants at planting and that such practices are against the norms of nature.

CONCLUSIONS AND THE WAY FORWARD

Bananas and plantains are very important staples for the Central African population in general and the Cameroonian population in particular. This therefore means that more attention should be focused on research and development that would enhance, improve and sustain production of these food crops. Also, the black banana borer weevil as the most damaging pest on these crops imply much has to be done to enhance entomological research in the Central African Region.

Although about 90% of banana entomological research in Cameroon is been carried out only in CARBAP, there is still much to be done. During most periods of its existence, CARBAP did not have an entomologist. Most local students who are admitted in the laboratory for training usually opt to carry out research in nematology. There is therefore a need to encourage and train more local students in the field of agricultural entomology in general and banana entomology to be specific.

Spatial and temporal distribution/dynamics studies of borer weevils are limited only to two agro-ecological zones in Cameroon (Littoral and South West Regions). Such studies should be extended to more zones and for longer periods (at least 2 years) for they will result to deeper insights on these bioecological aspects of the pest as well reducing insecticidal sprays. As for population dynamics, there is absolute need to search for local natural enemies of insect pests on bananas especially *C. sordidus*. Focus should be on parasitoids and predators such as ants that are usually found associated with banana/plantain corms.

Researchers commonly use pseudo stem traps although the results may vary due to factors such as size, variety, age of harvested pseudo stems and length. There is need to attempt standardizing trapping methods. Use of the disc-on-stump trap ("Encoche") may be a better option for plantations and large farms.

Since pest status of borer weevils is not well understood, vigorous field experiments to study effects of weevil population/damage on growth/yield parameters of plantains are a must. To rapidly assess damage of the weevils in the field (plantations and small scale farms), peripheral damage assessment is preferable, as it has been shown to correlate with cross section damage that usually involves destructive sampling.

More surveys are needed in major banana/plantain producing zones or regions so as to identify more major/potential arthropod or vertebrate pests. For now, especially in the plantations, focus should be given to the long tail mealy bugs (their distribution within fields and plants, their seasonal fluctuations, their natural enemies, and other host plants) as well as the banana aphid.

No single technique has been reported to successfully manage the borer weevils. Evaluating the impact of an IPM package is necessary and this package should include clean planting materials, use of botanicals such as neem, entomopathogens such as *B. bassiana*, proper field sanitation, possibilities of incorporating info chemicals, wise use of synthetic chemicals as well as use of resistant or tolerant varieties. In their review, Abate *et al*. (2000) emphasized that IPM should be given highest priority as a pest management strategy for Africa. With the increasing interest on botanical pesticides and entomopathogens, there is urgent need to search for more local plants with insecticidal properties (e.g. "masepo", black pepper or "bush pepper", and "fever grass") and indigenous entomopathogenic fungi. Recently, in the University of Buea (Cameroon), an entomopathogenic fungus has been reported killing large populations of the sweet potato weevil (Ntonifor, pers. comm.). There are therefore plans to isolate, mass-produce and evaluate the efficacy of such pathogens on banana borer weevils.

Generally, plantains (AAB) are more susceptible to weevil damage than bananas (AAA). Of all common locally consumed plantains recorded in Cameroon, 'French Sombre' is the most susceptible (with highest coefficient of infestation) while 'Batard' is the least susceptible. Studies are therefore needed to find out why these local plantains are more susceptible than bananas. This might include testing the chemical constituents, measuring hardness of corms, studying mechanisms of resistance (antibiosis or antixenosis) or finding out the effects of overall crop management practices on weevil population/damage. Most local farmers plant plantains in mixed cropping systems or do not apply regular sanitary practices in their fields. In addition, more screening of local varieties to find out their levels of susceptibility or resistance is needed.

Although most farmers are aware of borer weevil damage, most do not have basic knowledge on the biology and ecology as well as management of the pest. In collaboration with relevant NGOs, Cooperatives, CIGs and the Regional Delegations of Agriculture, workshops should be organised periodically in different areas so as to teach farmers on these aspects. Such training should also insist on the wise use of chemicals as well as the effects on human health and on the environment.

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