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Bananas, Laos and economic development: Farming practice and farmers' perceptions

Thesis submitted by

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ABSTRACT

Banana is a crop that has long been important in traditional Lao culture and customs. In more recent times, banana has been identified as an agricultural product with export potential. Accordingly, there has been increasing land use for banana cultivation by local farmers and international investors. This reflects a strategic policy of the agriculture and forestry sectors in contributing to the reduction of rural poverty by generating more income for farmers. Any country seeking to trade agricultural products internationally is obliged to establish pest lists for those commodities. In Laos, however, the study of insect pests of banana and of traditional banana cultivation practices is very limited. This thesis provides the first detailed study on the status of banana growing in Laos as an initial step in developing the banana export market and helping farmers in management and planning.

Data was collated from reports of banana production areas in Laos, including both "grey literature" and published studies of banana pests in Laos and globally, as well as the surveys and field experiments outline in the thesis. Opinions and feedback on the status of banana growing in Laos was also obtained from a variety of forestry departments, research stations and agricultural staff in Laos. Although many studies on banana pests were found, only one, dating from 1978, had been based in Laos. This study listed insects found on economic crops of Laos, but lacked details such as insect biology, impact on crops, sampling methods and illustrations.

Based on an analysis of this data and input from government officials, suitable sampling locations to examine banana farm practices were identified, totalling 22 farms in two provinces Bolikhamxay (central Laos) and Saravan (southern Laos). Details of each farm (size, farm age etc.), and the approaches to banana cultivation practiced (banana species grown, pest status and pest practices etc.) were documented. Two classes of sampling methods were tried: (1) sampling on specific banana plants and (2) opportunistic sampling of non-selected banana plants and surrounding vegetation. The four types of sampling techniques used to collect insects from banana plants were: pyrethroid spray, sticky traps, visual scanning and pitfall traps. The three types of opportunistic sampling used were: scanning (direct observation), examination of cut stems and sweep netting. The field sampling was conducted during the dry season of 2012.

Parallel to field sampling, a questionnaire was designed to assess farmers' understanding and perceptions of banana pests on their farms. The questionnaires were administered in the Lao language to farmers in three provinces; Vientiane Capital, Bolikhamxay and Saravan. Farmers from the sites used for the insect surveys were among those chosen.

Insect specimens collected were transported to James Cook University (Queensland, Australia) for identification. Identifications were based on *The Insects of Australia*, other available sources and the advice of specialist entomologists (outlined in more detail in the relevant Chapters).

Insects were initially sorted into orders and families. The family-level identity of each taxon was taken as an initial indication of whether it might be a pest. Efforts were made to identify these, focusing on the recognized banana pests already reported from Laos and Southeast Asia. Some specimens were very small (less than two millimetres) and could not be identified. They were named a, b or c, according to their morphological characters.

Characteristics of banana farms in the two major banana-growing regions of Laos are reported. This is an important component of any strategic development of the banana industry. The two largest farms were large-scale commercial enterprises in Bolikhamxay, with a relatively sophisticated management system in place and growing only the Cavendish variety. On the other hand, the majority of farms in both Bolikhamxay and Saravan were small back-yard cultivations, surrounded by other kinds of vegetation and largely un-managed after planting.

A guide to the nine key pest taxa of banana in Laos is presented. These nine taxa were selected based on my field surveys (2 952 samples of insects were studied in detail), feedback from farmers and a study of the literature, both local and global. This guide represents a useful tool to improve the understanding of readers (farmers, agriculture staff and non-specialist users) in Laos. The nine pests were *Cosmopolites sordidus* (root borer), *Odoiporus longicollis* (stem borer), *Basilepta subcostata* (scarring beetle), Chrysomelidae, Acrididae, *Erionota thrax* (banana skipper), Tephritidae, *Bactrocera dorsalis* (fruit fly), and *Stephanitis typica* (lace wing bug). The guide includes useful illustrations, common and Lao names, information on lifecycle, distribution, damage caused, host range, monitoring and control options, as well as references and Lao government sources for further information.

An important element of this thesis was the development of a set of field sampling protocols for detecting the insect pest species determined to be the nine key banana pests of banana in Laos. Observation of cut stems was more likely to detect *O. longicollis* and *C. sordidus* than other types of pests. Scan methods showed a bias towards detecting Acrididae, Chrysomelidae and *B. subcostata*. Sampling using pyrethroid spray was more likely to yield *Stephanitis typica* on the banana plant and Tephrititidae were most easily caught on sticky traps. However, there was no sampling method that more likely to detect *Erionota thrax* (banana skipper) and *B. dorsalis*.

The survey questionnaire results revealed that a typical Lao banana farmer was aged between 41-61 years and that more than half had attended primary school. Banana farms were typically small-scale, around 0.25 hectares or less. Farms were generally on land owned by the farmers themselves. The most common banana variety grown in their farms was Kuay Nam (KN). Farmers perceived that the main pest on their farms was *Erionota thrax* (approximately 44.8% of total respondents), while other significant pests causing economic losses included scarring beetle, thrips, fruit fly, grasshopper and termites (group 1) (56.3% of total respondents). There was a relationship between the farm size and the type of pest management used by farmers in different locations. If the farm was larger than 0.75 ha, control methods were generally applied (especially against scarring beetle). Although farmers considered that harmful economic pests were present, more than half of the respondents (55.3%) did not try to control the pests. Only a small number of respondents (18.4%) used chemical controls, while the majority employed a variety of manual approaches. Farmers correctly recognized some banana pest taxa, but these were only a subset of the probable pest taxa found during the farm sampling.

The results of this thesis provides the first overview of the status of banana production in Laos, identification of the key insect pest species that impact banana production and the identification tools designed to allow farmers to detect and understand these nine pest species. Together, this information represents the first steps in the advancement of the farmer support network required to develop a long-term and sustainable banana production industry within Laos. Ongoing studies into the taxonomic status of some of the currently unidentified pest species, seasonal and annual changes in pest abundance and the further refinement of pest sampling techniques would all serve to enhance the banana growing industry.

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CHAPTER 1: General introduction

1.1 Bananas on a global scale

Banana, *Musa* species (Order Zingiberales and Family Musaceae (CABI, 2005; Nelson, Ploetz, & kelper, 2006; Ortiz, 1997) is an important food crop on a global scale. It is the fourth major staple food crop after rice, wheat and maize, and is grown in about 130 countries. Approximately 70 species of *Musa* are recognized (GRIN, 2006), together with about 1 000 seedless domesticated varieties produced as interspecific hybrids and as polyploids (KEW, 2015; Valmayor, 2000). Bananas are especially important in developing countries including many in Africa, south Asia, and northern Latin America. Of the main growing areas, 98% are in developing countries. Banana ranks second after citrus in the international food trade. In 2007, the five leading banana producers were India, China, the Philippines, Brazil and Ecuador. In 2006, the four major banana exporters were Ecuador, Costa Rica, the Philippines and Colombia (United Nations Conference on Trade and Development, 2011). Bananas are grown under many different environmental conditions, generally in tropical and subtropical regions that have an annual rainfall of approximately 200 cm or 80 inches (Ostmark, 1974) and mean annual temperatures ranging from 26 to 30 degrees Celsius (ºC) (Nelson et al., 2006).

Banana is native to the Asian, Indo-Malaysian and Australian tropics. The domesticated *Musa* species are thought to have originated in Southeast Asia (Ortiz, 1997). More than 1 000 clonally reproduced cultivars are known, with sweet or dessert bananas making up 43% and cooking bananas 57% of world production (Tenhaj, 2008). Reflecting their importance, the species and varieties have numerous common names such as banana, plantain, dessert banana, cooking banana (English), pisang, getang (Indonesia), saging (the Philippines) (CABI, 2005; Nelson et al., 2006; Ortiz, 1997) and kuay, kuay par, kuay lep meu narng, kuay aew, kuay darp, kuay heem daeng, kuay heen, kuay hoy vee, kuay kaen, kuay kai mae, kuay khai, kuay khao, kuay nam var, kuay ngao, kuay peeng, kuay xan, kuay som, kuay teen tao, kuay teep and kwai (Laos) (Callaghan, 2004).

Banana is a perennial crop and cultivation usually contains different ages of plant, with heights between 2 and 9 m. Some species, such as *Musa ingens*, can grow as high as 15 m (Tenhaj, 2008). Banana is the only staple food crop that can be harvested at any time of the year (Ortiz, 1997). Harvesting can start about 16 to 18 months after planting and the second harvesting round is about 6 to 12 months after the first harvesting. In all species, the flowers form a cluster called the heart or bell, which extends out from the central leaves. The inflorescence is a set of flowers; female, male and hermaphroditic. There are 12-20 flowers in the first large female flower whose ovary germinates to become fruits, covered by bracts. The pseudostem is comprised of 6-20 leaves while the true stem is in the central part of the pseudostem and produces flowers and fruits (Rukazambuga, Gold, & Gowen, 1998). The banana fruits have a wide range of sizes, shapes and colours. The root of a banana tree is fibrous, about 1.5m in depth and able to extend to 4.9 m laterally. A mother banana plant suckers an underground rhizome called a mat or stool. About 40 000 kg of fruit is produced per hectare each year. The fresh fruits of an edible banana are generally seedless. Banana propagation is mainly by vegetative separation, while seeds are mostly used for breeding programs, ornamental types and wild species. In large scale commercial production, tissue culture techniques have been applied to mass-produce banana seedlings (Nelson et al., 2006; Tenhaj, 2008).

In addition to carbohydrates (starch) the banana fruit is a source of essential dietary requirements and minerals such as vitamin A, potassium, calcium, magnesium, zinc, iron, and pigments such as carotenoids. In addition to its use as a human food, banana plants are also used for other purposes, such as animal feed, fibre production, religious ceremonies, ornamental uses, cooking, brewing, medical uses such as wound bandages poultices, and a variety of industrial products (Rukazambuga et al., 1998; Tenhaj, 2008). An interesting recent issue has caused controversy concerning banana genetic modification. Researchers in Queensland have created a banana with enhanced beta-carotene content to help combat vitamin A deficiency in African children. The banana is expected to be released for Ugandan farmers by 2020 (Rebgetz, 2014).

1.2 Insect pests of Bananas

Insect pests are a key problem in banana production worldwide. The problem is exacerbated by the clonal nature of domesticated banana cultivars. Pests are responsible for economic losses due to decreased yields and/or increased costs of control (Ostmark, 1974; Rukazambuga et al., 1998; Rukazambuga, Gold, Gowen, & Ragama, 2002). There have been surprisingly few global reviews of banana pests. Ostmark (1974) stated that there are 470 species of significant arthropod (insects and mites) pests worldwide. In 2005, the Centre of Agricultural Bioscience International (CABI) produced a database of 14 217 insect pest species found on *Musa* species and other crops. There are many studies on a regional or country-specific basis. These include studies focused on Thailand (Wongsiri, 1991), Malaysia (Wahad, 2000), the Philippines, Southeast Asia (DF. Waterhouse, 1993), Australia (Pinese, 1994; Tenhaj, 2008), Pacific Islands (Nelson et al., 2006) and America (Gilman & Watson, 1994; Peno, 2006). The most common pests reported are Coleoptera: *Cosmopolites sordidus* (root borer weevil), *Odoiporus longicollis* (banana stem borer); Lepidoptera: *Erionota thrax* (banana skipper); and Orthoptera: *Nomadacris succinata* (locust).

1.3 Dynamics of banana pest

The dynamics and impact of pest species on bananas depend on numerous factors. Among the ecological factors considered in various studies are patch size, spacing and density, and plant variety.

Ecologists are increasingly recognizing that the size of a plant patch is an important factor influencing the number of herbivores. The scale of patches may differ, depending on the system studied (Wu & Loucks, 1995). For example, Root (1973) writing on arthropod pests of *Brassica oleracea* (cabbage), regarded a single row of plants as forming a small patch and a plot with 12 rows as a large patch. Cromartie (1975) however considered a small plot to contain one plant, a medium plot ten plants and a large plot 100 plants. Hamback *et al*. (2010) regard plots of 6 x 0.5 m as small, 6 x 3 m as intermediate, and plots of 6 x12 m as large. Patch sizes in agricultural areas can now be quantified precisely using remote sensing tools such as Landsat images (M. P. Grilli, 2010; M. P. Grilli & Bruno, 2007; Sahlin & Schroeder, 2010). Patch size studies differ as to which factors influence herbivore density. Root (1973), in "the resource concentration hypothesis", predicted that a large pure stand of a crop has a higher insect density because insects are more likely to find and remain on the host species. Many authors also pointed out that increased food plant densities in large patches and monocultures will often be afflicted by the highest density of specific herbivores (Adati et al., 2011; Cromartie, 1975; Mariano P. Grilli, 2008; M. P. Grilli & Bruno, 2007; Risch, 1981; Sahlin & Schroeder, 2010). However, counter examples exist. In the case of *Phyllotreta cruciferae* (flea beetles) density is controlled by predators and is not consistent with patch size (Fahrig & Jonsen, 1998; Kareiva, 1985; Ratnadass et al., 2008). In the case of cabbage white butterflies (*Pieris rapae*), females in Canada laid more eggs on isolated plants and those in small patches than on plants in large patches. In Australia, the same butterfly species laid small numbers of eggs regardless of patch size (Jones, 1977).

The spacing of plants is also an important aspect in food resource distribution. Spacing can be measured as plant density but also as patch-to-patch distance (Biedermann, 2004; Cromartie, 1975; Dosdall, Dolinski, Cowle, & Conway, 1999; Mariano P. Grilli, 2008; Tscharntke & Brandl, 2004). Ecologists predict that isolated patches will be occupied by fewer specific species and this has been demonstrated in a number of studies. For instance, delphacid plant hoppers were shown to be less abundant when a greater distance separated patches (Grilli 2008). Interestingly, Biedermann (2004) showed contrasting effects of patch spacing on two specialist hemipterans; *Adarrus multinotatus* (Cicadellidae) and *Neophilaenus albipennis* (Cercopidae). The latter was present in smaller numbers in more widely separated patches while the former was not affected by patch isolation. The difference between the two species was probably caused by individual insect species' ability to disperse and colonize (Tscharntke & Brandl, 2004). Dosdall *et al.* (1999) stated that increased plant density and wider row spacing decreased the chance of damage to seedlings of *Brassica* species caused by flea beetles (*Phyllotreta cruciferae*, *P. striolata* (Coleoptera: Chrysomelidae)). Yamamura and Yano (1999) also found that the survival rates of eggs and larvae are lower in an isolated plot.

In banana, pest abundance and impact is sensitive to plant variety. Research has been done on the susceptibility of banana cultivars to pests. Most of these projects were on cultivars susceptible to weevils, *Cosmopolites sordidus*, in Africa (Fogain, 2001; Gold, Ragama, Coe, & Rukazambuga, 2005; Kiggundu, Gold, Labuschagne, Vuylsteke, & Louw, 2003; Night, Gold, & Power, 2010). Some cultivars showed no difference in susceptibility to the pest (Fogain, 2001), while Kiggundu *et al*. (2003) found different levels of resistance to the pest in different varieties.

Understanding and managing insect pests of bananas is an important component of banana production. High weevil densities can cause yield losses of 40-100% (Rukazambuga *et al*. 1998), while the loss of bananas due to banana skipper infestation in Papua New Guinea between 1988 and 2020 was estimated at AUS$ 301.8 million (Australian Centre for International Agricultural Research (ACIAR), 1988). A key element before attempting to manage any pest is to assess existing information, perceptions and practices within the farming community. This information is crucial for determining appropriate control options (Van Mele *et al.* 2001; Tefera 2004). Most studies on farmers' perceptions of banana cultivation involve variety preference, pesticide use and ways to improve production. Examples are surveys, including those addressing farmers' knowledge of wild *Musa* species in India (Ashton, 2009), pesticide risk in Costa Rica (Barraza, Jansen, Van Wendel de Joode, & Wesseling, 2011; Dahlquist, 2008), variety preference in Uganda (Gold, Pinese, & Peña, 2002) and plantain production problems in Ghana (Schill *et al.* 2000).

1.4 Bananas in Laos

Laos in Southeast Asia is suitable for growing banana and plantain as it is located in a tropical and mountainous area (FAO, 2008). Of its 236 800 sq.km, 70% is located more than 500 m above sea level (Kenichiro, Masayuki, Yasuyuki, & Eiji, 2004). Laos has a monsoon climate with two seasons; the dry season that starts in November and ends in May, and the rainy season that starts in June and ends in October. Rainfall varies in different parts of Laos; the northern part has less rainfall than the central and the southern parts. Across the country, yearly rainfall ranges from 247 mm to 3 231 mm (FAO, 2007). The country's economy is based on agricultural production. More than 80% of the cultivated land is used for growing glutinous rice (sticky rice), which is a staple food in Laos. The agriculture sectors employ 85% of the total labour workforce and contribute half of the gross domestic product (GDP).

The Lao banana crop has been important in traditional Lao culture and customs. Banana species recorded are *Musa acuminata*, *Musa paradisiaca*, *Musa sapientium, Musa nana* (Callaghan, 2004; Inthakoun & Delang, 2008). Specifically, in northern Laos, *Musa acuminata* var. *chinensis* and var. *burmannica* and wild banana (*Musa ensete*, *Ensete ventricosum*) have been recorded (Schöffl, Varatorn, Blinnikov, & Vidamaly, 2004; Slesak et al., 2011). However, there is no specific report on banana cultivars that are grown in Laos.

Increasing land use for banana cultivation has been recorded since 1961. Food and Agriculture Organization (FAO) statistic shows that the harvest area in 1961 was 755 hectares (ha) and 13 590 ha in 2005 (CABI 2005; DOA 2009). Banana is an agricultural product that has potential to be exported to international markets to complement supply of coffee, maize, wood and wood products (Douangphrachanh 2007). Cultivation of bananas as a cash crop has been recently introduced in Bolikhamxay province (the central part of Laos), which has the largest banana plantation established by the Laos Banana Company. The company currently farms an area of about 250 ha, although that will expand from the central part of the country to new sites in the southern part. It will export mainly to Japan, China and Russia. Banana exports for 2011 were expected to be 4 000 tones (KPL, 2011; Ministry of Agriculture and Forestry, 2010a). The expansion of bananas as an agriculture commodity for export is part of an agriculture development strategy enacted by the Laos Ministry of Agriculture and Forestry (Ministry of

Agriculture and Forestry, 2010b) with the goal of reducing poverty in Laos and allowing the country to improve on its current 'Least Developing Country' status (Kawamura, 2014).

In Laos, there have been few studies on banana pests. The first publication was by Dean (1978) who reported that the major pest in Laos was *Erionata thrax thrax* while others (*Parasaissestia nigra*, *Hieroglyphus banian*, *Patanga succincta* and *Gangara thyrsis thysis*, Curculionidae and Halticidae) are often found in Thailand, bordering on Laos. However, this study was based on only one province of Laos and also covered neighbouring countries. Waterhouse (1993) stated that according to records, there are five major pest species of banana in Laos: *Erionata thrax*, *Spodoptera litura*, *Nomadacris succinate* (= *Patanga succincta), Bactrocera dorsalis* and *Pentalonia nigronervosa*. In addition, the CABI (2005) database showed 29 species of banana pests in Laos. This database had gathered information from different sources.

Understanding the perceptions of banana farmers is a key component of developing sustainable banana production within Laos (Ministry of Agriculture and Forestry 2010b), but to date there have been no studies on farmers' perceptions concerning banana cultivation and management (including pest management) in this country. The only study on farmers' perceptions in Laos concerned staple foods such as rice (Saito, Linquist, Keobualapha, Shiraiwa, & Horie, 2006; Tanaka, 1993).

The goal of the research described in this thesis is to provide the information and strategies required to sustain banana production in Laos. This was achieved by developing an understanding of the insect pests that impact bananas, deriving appropriate methods for surveying these pests in this and future studies, and gaining an understanding of the attributes and perceptions of banana growers within Laos. Farmer surveys were implemented as an initial step in determining how farmers currently manage pests in their banana crops and deriving effective ways to introduce long term Integrated Pest Management (IPM) for banana. Banana crop management in Laos is subject to many setbacks. These include insufficient human resources such as specialists in biology, entomology, plant pathology, weed science, and nematology as well as limited availability of funding for operational activities, and inadequate equipment, laboratories, and tools (Douangphrachanh 2007). Laos banana growing has recently been moving towards establishment of large-scale farms, which might reasonably be expected to impact pest dynamics and have implications for management.

1.5 Research aims, objectives and thesis structure

The primary aim of this thesis was to provide the first detailed study on the status of banana growing in Laos as a first step in developing bananas as a potential export market.

The thesis is framed around three broad research questions:

Question1: Which arthropod species are the most important pests impacting banana cultivation in Laos?

Question 2: Which methods are most effective in detecting each pest taxon?

Question 3: To what extent do farmers perceive arthropods as harmful to their banana crop and what approaches do they use to control them?

This thesis is structured as follows:

Chapter 1: An introduction to banana growing in Laos, a discussion of the rationale the research conducted in this thesis and outline of the thesis structure

Chapter 2: An overview of the materials and methods utilised in this thesis

Chapter 3: A summary of the types of farms and farmers that grow bananas in the two major regions

Chapter 4: A guide to the nine key pests of banana in Laos, representing a major step in the management and development of the banana industry

Chapter 5: A set of field sampling protocols available to farmers, governments and industry partners that provide a framework for detecting the nine key banana pests

Chapter 6: An overview of the status of banana pests in Laos based on field surveys, along with a study of the perceptions of banana farmers concerning priority insects

Chapter 7: A final discussion of the research outcomes of this thesis

References: A list of all citations is provided in the final thesis chapter

CHAPTER 2: General materials and methods

2.1 Abstract

This chapter provides a description of the three districts of two provinces in Laos where sampling and farm surveys were conducted, along with an overview of the different sampling methods used. The sampling was conducted in Pakxane and Pakkading districts of Bolikhamxay province and Laongam district of Saravan province. Four sampling methods were evaluated: pitfall traps, direct observation (scanning), sticky traps and knock-down pyrethroid sprays. Farmers at these locations also completed a questionnaire designed to determine their perception and knowledge of banana pests and the influence of their knowledge on how they managed pests on their farms. The statistical methods used to analyse the insect survey and farmer perception questionnaires is also presented.

2.2 Field location and selection

The field component of this study was conducted in Laos, between 23 January and 19 March 2012. Suitable sites in two provinces (Bolikhamxay in central Laos and Saravan in southern Laos) (Figure 2.1) were chosen. No site in northern Laos could be surveyed, due to limited accessibility (poor road conditions), and time constraints. Sites were selected in two districts in Bolikhamxay Province; Pakxane and Pakkading (Figure 2.2), while only one district; Lao- ngam was surveyed in Saravan (Figure 2.3). Site survey and selection were conducted before the actual sampling of the two provinces commenced, in January 2012. The survey began with a meeting between the District Head of the Agricultural Section and our team, to obtain banana farm information. Our team was then accompanied by a nominated agricultural staff member who acted as a guide while we travelled to farms and met with local people.

The sites were selected based on accessibility and the presence of banana cultivation. It became apparent that types of banana cultivation differ between the two provinces. In Bolikhamxay province, two large-scale farms and eight small farms were selected. Those farms are located in Pakxane and Pakkading districts, which are around 50 km apart. In Saravan province, most banana cultivation is in one district named Lao-ngam where farms are small scale, each less than one hectare in area, and occurring close together.

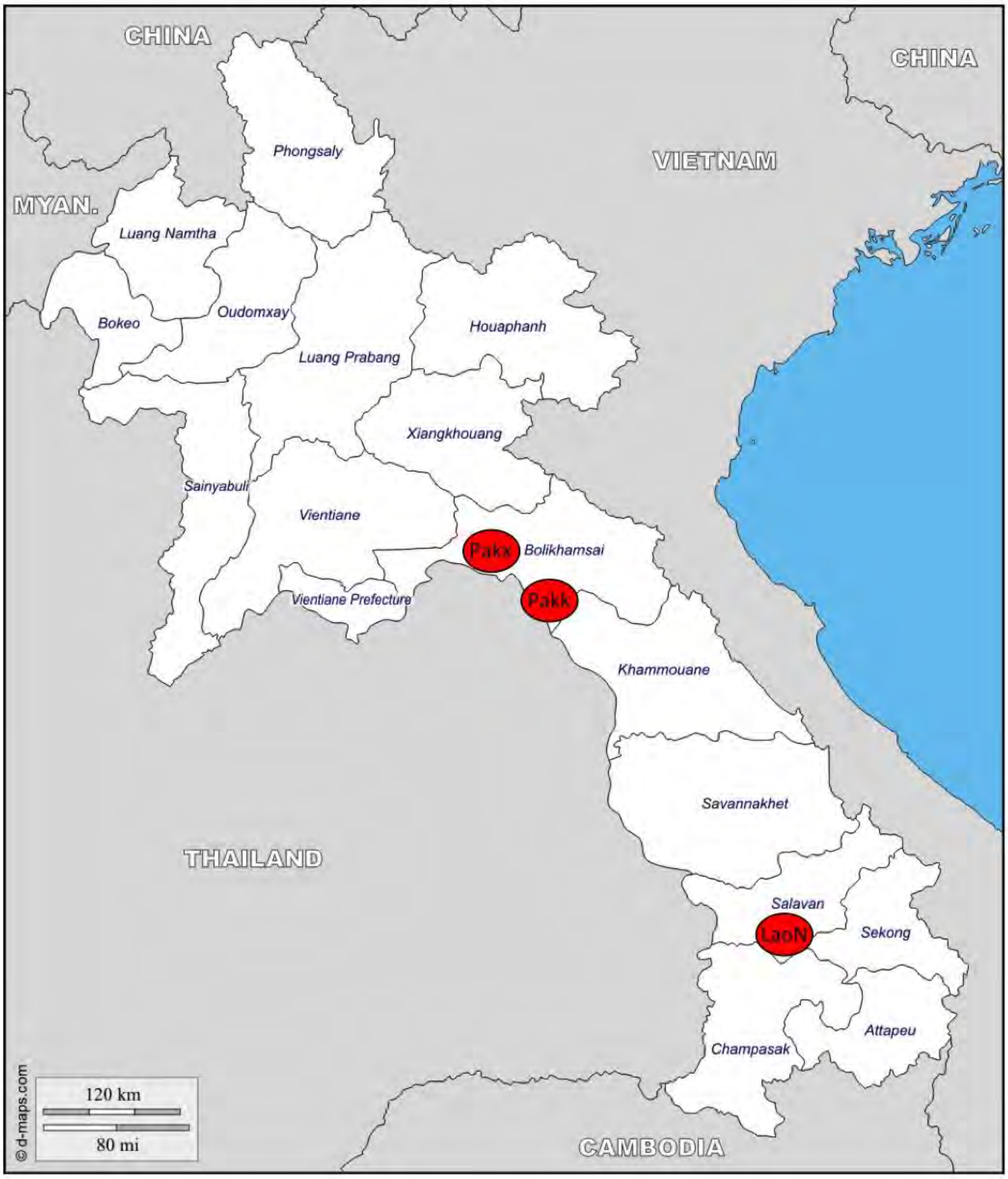

Figure 2.1: Locations of the two farm sites in the Bolikhamxay Province (Pakxan (Pakx) and Pakkading (Pakk) and the single farm site in the Saravan Province (LaoN) of Laos.

2.3 Sampling materials and methods

Sampling materials and equipment included: handheld GPS unit, camera, plastic vials (5 ml and 25 ml), ethanol 90%, tape measure, insect tool kit, markers, stem label rolls, insect pins, insect boxes, scissors, face masks, gloves, rain coats, tape recorder, empty water bottles (1litre) cut in half, water, detergent, grub hoes, mattock, sickles, knives, plastic board cut in squares, trays, cotton filter sheet, sweep nets, sticky roll (yellow), cutter, pyrethroid spray (Baygon), plastic sheets, ladder, wooden sticks, plastic bags, rubber bands and foam boxes (Figure 2.2).

Four different techniques of sampling insects were used on or around selected banana plants: pitfall traps, direct observation, sticky band traps and knock-down pyrethroid sprays (Table 2.1, Figure 2.3). Banana plants were selected that looked weak and therefore may have had numbers of insect pests on them. Ten plants were selected and labelled in each small farm and 30 in each large-scale farm. The sampling took five days to complete in each area with a total of 900 sampled plants overall. Farmers whose plants had been sampled were interviewed using a set questionnaire in relation to their perception of insect pests and their management.

The following sampling scheduled was implemented at each farm.

Day 1: Set up pitfall traps
Label the selected plants with area code, plant number 1 to 10
Set up sticky traps
Collect site description of each farm

Day 2: Direct observation or cutting of harvested stems while walking to scan for insects on individual plants and on the ground. A sweep net was used to catch observed insects and decayed stems were dissected

Day 3: Collect insects from pitfall and sticky traps

Day 4: Spray pyrethroid and collect killed insects

Day 5: Continue spraying

Pitfall traps: Ten traps were used per farm and were placed in areas most likely to yield the target pests. The traps were set up on the first day of sampling by digging a hole near the base of the pseudostem, and the container was placed in the hole so that its top was level with the soil surface. Water containing detergent was then added to fill approximately half of the container. A square of cardboard was used to prevent rain water entering. The total number of traps laid across both provinces was 120 (10 traps x 12 farms of two provinces). Insect specimens were collected after two days by removing the traps from the ground and pouring the contents through a fine filter sheet (Figure 2.3 A and B).

Visual observation of individual banana trees was used for finding insects that live on leaves, branches and around the tree. Old leaves were pulled off and any dead pseudostems were dissected and searched for insects in the inner parts of the petioles. Any signs of damage to the plant were noted. Photos were taken of any insect damage. In addition, a sweep net was used to collect insects on leaves and on the ground. Across both provinces, the total numbers of observations were 260 (10 plants x 20 farms and 30 plants x 2 farms) (Figure 2.3 F).

Sticky band traps were wrapped around the pseudostems of the selected plants about 1 m above the ground. Again, 260 selected plants were sampled in this way across both provinces (10 plants x 20 farms and 30 plants x 2 farms) (Figure 2.3 C).

Knock-down pyrethroid sprays are used to make insects fall from the trees. There are many pyrethroid brands available in Laos that are used for killing mosquitos. Four brands were chosen to test in a banana garden, and were compared based on how quickly, and how many, insects fell down onto the plastic sheet. The most effective brand was Baygon, a mosquito and flying insect killer, which contains prallethrin 0.1% w/w and permethrin 0.1% w/w. Baygon was used throughout the entire project. In each sampling area, two plastic sheets (1 x 5 m) were spread out on the ground around the tree, the pyrethoid was sprayed around the banana leaves and the pseudostem was shaken and killed insects collected on the plastic sheets. Overall, 260 plants were sampled in this way (10 plants x 20 farms and 30 plants x 2 farms) (Figure 2.3 D and E).

All specimens were stored in ethanol vials (90%), except some lepidopterans (butterflies and moths) and orthopterans (grasshoppers and crickets), which were dry-pinned. All the specimens were brought back to the Plant Protection Centre, Vientiane, for initial sorting and curation.

Figure 2.2: Preparation of material used to sample banana pests.

Figure 2.3: Sampling techniques used to detect banana pests (A & B: Pitfall traps, C: Sticky trap, D & E: Knock-down pyrethroid spray, F: Observation and sweep net).

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Table 2.1: Outline of sampling methods indicating numbers of samples from each location and using each method.

	Bolikhamxay Province										Saravan Province												
	Pakxan District					Pakkading district					Lao-ngam D. Area1						Lao-ngam D. Area2						
	Farm #					Farm #					Farm #						Farm #						
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**Total**
Sampling on selected banana plants																							
Pitfall	10			10	10	10		10		10	10	10				10	10		10			10	120
Spray	30	10	10	10	10	30	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	260
Sticky	30	10	10	10	10	30	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	260
Scan	30	10	10	10	10	30	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	260
No. banana plants sampled	30	10	10	10	10	30	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	260

Questionnaire design

Farmers' knowledge/perception of banana pests and the influences of their knowledge on management of insect pests on their farms were evaluated.

A questionnaire was developed for administration to farmers or growers and was translated into the Lao language. The farmers were chosen in three provinces of Laos; Vientiane Capital, Bolikhamxay and Saravan. Farmers from the sites used for the insect survey were among those chosen. The questionnaire detail is in chapter 6, section 6.3.2.

The questions numbered 3, 4, 5, 6, 7, 8 and 9 are intended to indicate what insect pests the farmers think are important. Questions 1, 10, 11, 12, 13, 14, 15, 16, 17 and 18 address their attitudes towards pest management and any techniques actually used for this. Banana patch size, which can affect insect abundance and management, is addressed by question number 2 and. Spacing and density are tackled in question number 24. Questions 19, 20, 21, 22 and 23 provide information on the susceptibility of different varieties to pests.

2.4 Taxonomic identification

Specimens were transported from Laos to Australia for identification and kept at the College of Marine and Environmental Sciences, James Cook University. All specimens were collected in the dry season of year 2012. There were approximately 900 vials containing specimens in 90% ethanol, in addition to dry specimens. Morphological identification of specimens mainly used the descriptions provided in '*The Insects of Australia'* (CSIRO, 1970), the expertise of my supervisory panel and other sources of information that were available online and in the scientific literature. These resources allowed for classification of all the specimens to family level. Additional identification to genus and species was made where possible.

The insect specimens were sorted into different orders and identified to family level with the aid of a stereomicroscope Zeiss STEMI SR (Germany). The family-level identity of each taxon was taken as an indication of whether they might be pests. Attempts were then made to identify to species level taxa that were likely to represent pest species. This was guided in part by published reports of recognized banana pests in Laos and Southeast Asia. Identities and numbers of insects were recorded in an Excel spread sheet. Numbers of each species were categorized in three levels; fewer than 10 (<10), between 10-50 and more than 50 (>50). Some specimens were very small (less than two mm) and could not be identified. They were named a, b or c, according to their morphological characters.

2.5 Statistical Analyses

Presence-absence sampling for common pests: individual known species (pest prevalence), was analysed using a General Linear Model with binomial error distribution. The relationship between the known-pest presence and absence based on trap type sampling methods was analysed using logistic regression in S-Plus statistical software (TIBCO software Inc. 1997).

Farmers' perception analysis: each question was summarized in terms of a percentage, diagrams and tables. The factors influencing pest management were analysed using S-Plus statistical software to assess the association between questions. In particular, Fisher's exact test and logistic regressions were used for comparing two or more categorical variables. Simple linear regressions were conducted to determine the significant relationship among farmers, farm characteristics and pest management.

CHAPTER 3: Site descriptions of banana farms

3.1 Abstract

An important component of the strategic development of the banana industry in Laos requires an understanding of the characteristics of the farms on which bananas are grown. A description of the huge variety of banana farms found in Laos, based on a study of twenty-two banana farms from three districts across two provinces (Bolikhamxay and Saravan) during February and March 2012, is provided. In Bolikhamxay, two large-scale commercial farms were the largest of the selected farms (100 ha). These had a relatively sophisticated management system in place and grew only the Cavendish variety. Most other farms in the province were less than 4 ha in size, essentially back-yard farms surrounded by different vegetation types and largely un-managed after planting. In Saravan, individual banana plants attained larger circumferences, grew taller with many pseudostems, and produced more bunches and fruits than did those in Bolikhamxay province. All farms surveyed in Saravan were less than 1 ha in size, located near each other and separated from the farmer's home. This area in Saravan was situated in Bolaven Plateau and has highly fertile soil. The extensive small-scale cultivation of bananas in Saravan supplies domestic needs and local markets.

3.2 Bolikhamxay Province

Bolikhamxay province is located in the central part of Laos, about 150 kilometres south of Vientiane City (The Department of Tourism Marketing, 2012b). The average rainfall ranges from 1 500 to 3 500 mm in the central and southern parts of Laos (UNFCCC, 2009). Its population is 272 794 distributed among 323 villages and 43 915 households (Lao Statistics Bureau, 2011). The province covers an area of approximately 14 863 square kilometres with an average population density of 18 people per square kilometre. There are seven districts: Pakxane, Thaphabath, Pakkading, Bolikhanh, Viengthong, Khamkeuth and Xaychamphone. Bolikhamxay is an important conservation area in the country, especially the tropical rainforest and wetland, which is inhabited by many terrestrial species, including some endangered species (The Department of Tourism Marketing, 2012a).The main agricultural production is rice, and minor crops such as maize, beans, vegetables, coffee and banana. Recently, production of banana has expanded because it is seen as a potential crop for exporting to the international market (Douangphrachanh, 2007). This study selected farms in two districts; Pakxane and Pakkading. Two commercial large-scale farms and eight small-scale farms in total were selected in these districts.

A summary of the characteristics of the farms examined in Bolikhamxay Province is provided in Table 3.1 and as follows.

Table 3.1 Overview of farms examined in the Bolikhamxay Province.

Province	District	Village	Farm #	Farm size
Bolikhamxay	Pakxane	Na-oi-noo	1	Large-scale (100 ha)
Bolikhamxay	Pakxane	Somsavad	2	Small-scale (<5 ha)
Bolikhamxay	Pakxane	Songkorn	3	Small-scale (<5 ha)
Bolikhamxay	Pakxane	Padsum	4	Small-scale (<5 ha)
Bolikhamxay	Pakxane	Padsum	5	Small-scale (<5 ha)
Bolikhamxay	Pakkading	Tha-hin	6	Large-scale (100 ha)
Bolikhamxay	Pakkading	Tha-hin	7	Small-scale (<5 ha)
Bolikhamxay	Pakkading	Na-hin	8	Small-scale (<5 ha)
Bolikhamxay	Pakkading	Na-keuay-nai	9	Small-scale (<5 ha)
Bolikhamxay	Pakkading	Na-keuy-nork	10	Small-scale (<5 ha)

3.2.1 Bolikhamxay Province, Pakxane district, Na-oi-noo village, Farm # 1, large-scale

Banana farm #1 is located in Na-oi-noo village (18°26'04.0"N, 103° 51' 03.4"E, 167 metres above sea level (m.a.s.l)) and is owned by Lao Banana Company (Figure 3.1). The weather during the survey was dry and hot during the day. This site was surrounded by bushland and mountains. The cultivation area was approximately 100 ha and the spacing between plants was 2 x 2 m with a total of 2 500 plants / ha. The main banana variety grown was Cavendish Grannian. The shorter pseudostems of this variety confer wind resistance. The Cavendish William variety was grown in relatively small numbers. During the sampling, approximately 90% of plants were in the vegetative growth stage and 10% were flowering and fruiting. The soil was fertile, sandy loam and well-drained, light grey in colour and of fine texture. The farming system was well managed by an agricultural expert who employed sufficient labourers. A sprinkler watering system was set up at each individual plant and utilized ground water as a main water source. However, the farm was located very far from main electrical power and consequently there was not sufficient electricity to pump ground water for the sprinkler. The farm had machinery for propagation and harvesting and facilities for post harvesting as well as a monthly program for fertilizer and pesticide application.

Figure 3.1: Bolikhamxay Province, Pakxane district, Na-oi-noo village, Farm #1, large-scale farm.

3.2.2 Bolikhamxay Province, Pakxane district, Somsavad village, Farm # 2, small-scale

Banana farm #2 (18°27'28.5" N, 103° 47' 22.3"E, 165 m.a.s.l) was a small area at the back of the owner's house and contained around 50 banana plants (Figure 3.2). The cultivation area was approximately 20 x 20 m and the spacing between plants was estimated to be 2 x 2 m. This banana farm was surrounded by a few other types of trees, such as mangoes, other bush trees and cassavas. The banana variety here is Kuay Nam, which was generally in vegetative growth, while flowering and fruiting stages were fewer. The soil was sandy loam, well-drained with a light grey colour and fine texture. The farm was not well managed because there was no watering system or fertilizer application. Family members were the only labourers, and routine management was negligible until the harvesting period. Many corms had originated from one corm only, which was quite different from the large-scale farms where workers pruned the old pseudostem and only kept one or two pseudostems.

Figure 3.2: Bolikhamxay Province, Pakxane district, Somsavad village, Farm # 2, small-scale farm.

3.2.3 Bolikhamxay Province, Pakxane district, Songkorn village, Farm # 3, small-scale.

Banana farm #3 was also a small-scale farm located in Songkorn village (18 °28'03.8"N, 103° 41' 56.9"E, 159 m.a.s.l). The cultivation area was about one hectare and the spacing between plants was estimated about 2 x 2 m. The farm was in a floodplain area, next to a river bank and surrounded by mango trees, sugarcane, galangal, forest and bush. The area was some distance from main roads and houses. Kuay Nam (KN) and seeded banana (Thany) were grown on this farm. KN was the dominant variety. On the farm, the vegetative growing stage was more prevalent than the flowering stage. The soil type was sandy loam, well-drained with light grey colour and fine texture (Figure 3.3). The farmer did not employ practices such as watering and fertilizer application, and the farm was left unattended until the harvesting period. There were many pseudostems, without any pruning or cutting of old pseudostems.

Figure 3.3: Bolikhamxay Province, Pakxane district, Songkorn village, Farm # 3, small-scale farm.

3.2.4 Bolikhamxay Province, Pakxane district, Padsum village, Farm # 4, small-scale.

Banana farm #4 was located in Padsum village (13°25'43.4"N, 103° 42'45.5"E, 155 m.a.s.l) (Figure 3.4). The total area of the farm was approximately 56 m^2 and the spacing varied from 1 x1 m to 1 x 2 m (22 individual plants). The farm was in a backyard garden with many kinds of herbs and vegetables, such as sugarcane, pineapple, galangal, lemongrass and bamboo. This garden was also surrounded by neighbouring houses and situated in a lowland area, away from the main unpaved road. KN was the only variety grown. Most bananas were in the vegetative stage of growth, but had been adversely affected by heavy flooding the previous year. The soil was loam and dark brown. The farmer did not provide additional water or fertiliser or any other type of management.

Figure 3.4: Bolikhamxay Province, Pakxane district, Padsum village, Farm # 4, small-scale farm.

3.2.5 Bolikhamxay Province, Pakxane district, Padsum village, Farm # 5, small-scale.

The last farm of this district (Banana Farm #5) was located in Padsum village (48 °25'59.5"N, 103° 41' 40.1"E, 147 m.a.s.l) and belonged to the provincial agricultural promotion section (Figure 3.5). The cultivation area was about four hectares and the spacing between plants was 3 x 3 m. The farm was in a floodplain next to a river, and was surrounded by maize, mango trees and a research station. KN was grown and produced for subsistence. This banana plantation was very old, at more than ten years, and was generally in the vegetative stage with few plants at the fruiting stage. Soil was sandy loam and light grey. According to the staff, the farm was initially managed very well in terms of fertilizing, harvesting and weeding by agricultural staff, but now it has been abandoned. It is occasionally harvested for local consumption.

Figure 3.5: Bolikhamxay Province, Pakxane district, Padsum village, Farm # 5, small-scale farm.

3.2.6 Bolikhamxay Province, Pakxane district, Tha-hin village, Farm # 6, small-scale

Banana farm #6 was located in Tha-hin village (16°18'34.4"N, 104 °11' 56.5"E, 179 m.a.s.l) and belonged to the same company who owned Farm #1 in Pakxane district (Figure 3.6). The area was approximately 100 ha and the spacing between plants was 2 x 2 m with an estimated number of 250 000 plants in total. The banana cultivation area was a long way from the main road, and was close to a mountain, bushland and forest. Natural rivers surrounded and flowed through the farm. Banana plants were generally in vegetative stages (approximately 70-75%), with around 25-30% in flowering and fruiting stages. Soil characteristics were sandy loam, well-drained with light grey and orange colour. The farm was maintained using the same methods as the one in Pakxane, especially in terms of the watering system, fertilizer and pesticide application.

Figure 3.6: Bolikhamxay Province, Pakkading district, Tha-hin village, Farm # 6, large-scale-farm.

3.2.7 Bolikhamxay Province, Pakxane district, Tha-hin village, Farm # 7, small-scale.

Banana farm #7 was situated in Tha-hin village (18° 15' 08.9"N, 104° 13' 07.8"E, 164 m.a.s.l) (Figure 3.7). The cultivation area was approximately 10 x 15 m and the spacing between plants varied between 2 and 3 m. The farm was located far from the village and was intercropped with sugarcane and other trees. Creeks and tobacco fields were situated close to the farm. Three varieties of banana were cultivated; KN, seeded and wild, though KN was the dominant variety grown. Few plants were flowering and fruiting at the time of the survey. Soil was sandy loam, well-drained with a light grey colour. No management practices were implemented after planting, until the fruits were ready to harvest.

Figure 3.7: Bolikhamxay Province, Pakkading district, Tha-hin village, Farm # 7, small-scale farm.

3.2.8 Bolikhamxay Province, Pakxane district, Na-hin village, Farm # 8, small-scale.

Banana farm #8 was located in Na-hin village (18 °14' 30.2 "N, 104° 12' 42.3"E, 168 m.a.s.l) (Figure 3.8). The farm covered an area of approximately 48 m^2, and contained twelve individual plants. The spacing between plants was from 1 to 2 m. The farm was grown in a back yard, which also included a mixture of coconut, mango, tamarind, lychee trees and vegetables. Behind the farm were neighbouring houses and tobacco fields. Banana varieties grown were: KN, E-tam and Lep-meur-nang, with KN being the dominant variety. Growing stages were mostly vegetative, with a few at the fruiting stage. Soil was sandy loam and light grey in colour. There was no practical management on this farm after planting; the purpose of planting was for domestic consumption.

Figure 3.8: Bolikhamxay Province, Pakkading district, Na-hin village, Farm # 8, small-scale farm.

3.2.9 Bolikhamxay Province, Pakkading district, Padsum village, Farm # 9, small-scale.

Banana farm #9 was located in Na-keuay-nai village (18° 13' 38.2"N, 104° 12' 11.9"E, 165 m.a.s.l) (Figure 3.9). The farm covered an area of 800 m^2 and contained different kinds of trees and herbs, such as bamboo (Nor-yair), galangal, mango, tamarind, kedsana tree, neem and pineapple. The banana farm was surrounded by an open area, which was used as a rice field during the rainy season. KN was mainly grown in the farm, along with a few of a seeded banana variety (Thany). All the plants were in the vegetative stage. The soil was clay and of light grey to orange colour. The farmer did not employ any type of management after planting.

Figure 3.9: Bolikhamxay Province, Pakkading district, Na-keuay-nai.village, Farm # 9, small-scale farm.

3.2.10 Bolikhamxay Province, Pakkading district, Na-keuy-nork village, Farm # 10, small-scale

Banana farm #10 was located in Na-keuy-nork village (18° 13' 28.0"N, 104° 11' 58.2"E, 163 m.a.s.l) (Figure 3.10). The area covered was about 20 x 20 m and the spacing varied from 1 to 2 m. The banana garden was in a backyard, bounded by a small creek, houses and trees such as eucalyptus, mango, coconut, pineapple, noni tree and rattan palm (Nor-ngair). Two banana varieties were grown, KN and a seeded variety (Kuay-kean) which were all in a vegetative stage, apart from two fruiting plants. The soil type was loam with grey colour. The banana farm was left alone after planting, without extensive care.

Figure 3.10: Bolikhamxay Province, Pakkading district, Na-keuay-nork village, Farm # 10, small-scale farm.

3.3 Saravan Province

Saravan province is located in the south of Laos and about 897 km from Vientiane capital city, and covers an area of 10 692 km^2. The average rainfall ranges between 1 500 to 3 500 mm (UNFCCC 2009). The population is 375 571 inhabitants with an average population density of 35 people per km^2 (Lao Statistics Bureau 2011). Bolaven Plateau is a highly fertile land for extensive agricultural production. The main crops are coffee, cabbage, banana and vegetables. Saravan is an important area for biodiversity, with the dense forests being the home of many minority groups and animal species (The Department of Tourism Marketing, 2012c).

The province comprises of eight districts namely Saravan, Ta-oi, Toomlarn, Nakhonepheng, Vapy, Khongxedone, Lao-ngam and Samuoi; 605 villages and 61 211 households (Lao Statistics Bureau 2011). Lao-ngam district was selected for sampling based on information from the head of the agriculture district. It is an extensive area of banana production, which supplies the capital city and neighbouring countries, specifically Thailand and Vietnam. Other districts in the province have limited road access and small numbers of farms that are far apart. There is currently no established banana-growing company in this area. Despite the absence of large-scale commercial farms, bananas are very extensively cultivated, often in interconnected plots. Farmers rarely grew banana plants at the back of their houses and there was no exact measurement of planting space. Two areas were selected in this district and were about one kilometre apart.

Area 1 of Lao-ngam district

Six farms were selected, connected and located near to each other. The area of each farm was estimated roughly in hectares, as there was no actual map. The weather was changeable, sometimes cloudy and rainy and sometimes very hot and sunny. Individual banana plants attained larger circumferences, grew taller with many pseudostems, and produced more bunches and fruit than did those in Bolikhamxay province. Kuay Nam was the dominant variety grown in this area. Their growing stage was mostly vegetative, while a few plants were flowering and fruiting. The main purpose was to supply to local markets and also to neighbouring countries.

A summary of the characteristics of the farms examined in Bolikhamxay Province is provided in Table 3.1and as follows:

Table 3.2: Overview of farms examined in the Saravan Province.

Province	District	Village	Farm #	Farm size
Saravan	Lao-ngam	Lane	11	Small-scale (<5 ha)
Saravan	Lao-ngam	Lane	12	Small-scale (<5 ha)
Saravan	Lao-ngam	Lane	13	Small-scale (<5 ha)
Saravan	Lao-ngam	Dong-bang	14	Small-scale (<5 ha)
Saravan	Lao-ngam	Dong-bang	16	Small-scale (<5 ha)
Saravan	Lao-ngam	Te-me-poom	17	Small-scale (<5 ha)
Saravan	Lao-ngam	Te-me-poom	18	Small-scale (<5 ha)
Saravan	Lao-ngam	Te-me-poom	19	Small-scale (<5 ha)
Saravan	Lao-ngam	Te-me-poom	20	Small-scale (<5 ha)
Saravan	Lao-ngam	Te-me-poom	21	Small-scale (<5 ha)
Saravan	Lao-ngam	Te-me-poom	22	Small-scale (<5 ha)

3.2.11 Saravan Province, Lao-ngam district, Lane village, Farm # 11, small-scale

Banana farm #11 was located at 15° 29' 34.4"N, 106° 09' 26 4", 498 m.a.s.l (Figure 3.11). The total area of banana farm was about 0.12 hectare and the spacing between plants was 6 x 6 m. The soil type was highly fertile, with dark orange reddish colour. The soil became sticky and slippery after rain. The farmer did not practice any management on the banana farm but the crop was growing very well. The farmer sometimes visited the farm for general care. The harvest was carried out by a 'middle man' who purchases banana products from farmers and then distributes them to markets or other stakeholders.

Figure 3.11: Saravan Province, Lao-ngam district, Lane village, Farm # 11, small-scale farm.

3.2.12 Saravan Province, Lao-ngam district, Lane village, Farm # 12, small-scale

Banana farm #12 was located adjacent to farm #11(15° 29' 32.8"N, 106° 09' 21,6"E, 504 m.a.s.l) (Figure 3.12). The total area of farm #12 was about 0.32 ha and the spacing between plants was 6 x 6 m. Sweet potatoes were grown at the back of the farm, and next to that was an open area, which was set aside for growing maize in the wet season. The soil type was the same as that on the previous farm. Similarly, the farmer did not manage the farm, or apply any treatments to the bananas. The owner only harvested when bananas ripened and were ready for sale.

Figure 3.12: Saravan Province, Lao-ngam district, Lane village, Farm # 12, small-scale farm.

3.2.13 Saravan Province, Lao-ngam district, Lane village, Farm # 13, small-scale

Banana farm #13 was located next to farm #12 (15° 29' 43.2"N, 106° 09' 26.6"E, 493 m.a.s.l) (Figure 3.13). The total area was 0.08 ha and the spacing between plants was estimated at 7 x 7 m. The farm covered quite a small area with 40 individual plants. KN was the only variety cultivated in this area and it was surrounded by other banana plantations and sweet potato crops. Soil type and banana management were the same as on the previous farm. The farmer visited the farm infrequently and harvesting was performed by a middle man.

Figure 3.13: Saravan Province, Lao-ngam district, Lane village, Farm # 13, small-scale farm.

3.2.14 Saravan Province, Lao-ngam district, Dong-bang village, Farm # 14, small-scale

Banana farm #14 was located in Dong-bang village (15° 30' 00.0"N, 106° 09' 33.4"E, 491 m.a.s.l) (Figure 3.14). The total area of the banana farm was 0.16 ha and the banana spacing was approximately 6 x 6 m. Soil type and farm management were the same as for Farm # 13.

Figure 3.14: Saravan Province, Lao-ngam district, Dong-bang village, Farm # 14, small-scale farm.

3.2.15 Saravan Province, Lao-ngam district, Dong-bang village, Farm # 15, small-scale

Banana farm #15 was located close to farm #14 and was separated by an open area (15° 29' 51.6"N, E 106° 09' 31.7"E, 497 m.a.s.l) (Figure 3.15). The total area of the farm was around 0.16 ha, the spacing between plants was estimated at 7 x 7 m and the same variety was used as on farm #14. Sweet potatoes, bush trees, big trees and other banana farms were close to this site. Soil type and farm management was also the same as the previous banana farm.

Figure 3.15: Saravan Province, Lao-ngam district, Dong-bang village, Farm # 15, small-scale farm.

3.2.16 Saravan Province, Lao-ngam district, Dong-bang village, Farm # 16, small-scale

The last farm in area 1 (Banana farm #16) was located at 15° 29' 54.1"N, 106° 09' 36.5"E, 496 m.a.s.l (Figure 3.16). The total area of banana farm was 0.16 ha and the banana spacing was estimated at 7 x 7 m. KN was the only variety in this farm, and was found mostly in the vegetative stage. There were no management practices in place. Bananas were harvested when requested by a middle man.

Figure 3.16: Saravan Province, Lao-ngam district, Dong-bang village, Farm # 16, small-scale farm.

Area 2 of Lao-ngam district

The area was about one kilometre north of the first area. It also featured extensive plantations of bananas along the village road. There were six sites in the area; four sites were connected to each other, while the other two were located nearby. All farms were located in Te-me-poom village, and had fertile volcanic soil. Areas were estimated visually or using steps, without any actual tape measurements. Kuay Nam was the only variety grown in this area. There were large banana stools with many suckers growing from mother corms. The banana growth was generally vegetative, although there were some fruiting and ripening plants. The connected farms were surrounded by banana farms, teak trees, sugarcane, a forest and creeks.

3.2.17 Saravan Province, Lao-ngam district, Te-me-poom village, Farm # 17, small-scale

The first farm in this area (Banana farm #17) was located in Te-me-poom village (15° 27' 43.9"N, 106° 13' 20.6"E, 631 m.a.s.l) (Figure 3.17). The total area of banana cultivation was approximately 0.12 ha and the spacing between plants was estimated as 7 x 7 m. Farm management was not practised after planting. The bananas were harvested for household consumption and sale to a market and to a middle man.

Figure 3.17: Saravan Province, Lao-ngam district, Te-me-poom village, Farm # 17, small-scale farm.

3.2.18 Saravan Province, Lao-ngam district, Te-me-poom village, Farm # 18, small-scale

Banana farm #18 was located adjacent to farm #17 and separated by a row of trees used as a fence (15° 27' 46.4"N, 106° 13' 19.7"E, 615 m.a.s.l) (Figure 3.18). The total area of banana farm was about 0.08 ha and the banana spacing was estimated at 7 x 7 m. Inter-cropping plants were bamboo, papaya tree, herbs and other trees. Soil type was fertile volcanic and dark orange reddish. The farmer visited the plantation, but there were no management or treatment practices employed during plant development. Bananas were harvested when ready for consumption and markets.

Figure 3.18: Saravan Province, Lao-ngam district, Te-me-poom village, Farm # 18, small-scale farm.

3.2.19 Saravan Province, Lao-ngam district, Te-me-poom village, Farm # 19, small-scale

Banana farm # 19 was connected to farm #18 (15° 27' 44.4"N, 106° 13' 18.1"E, and 618 m.a.s.l) (Figure 3.19). The total area was approximately 0.06 ha and the spacing between plants was estimated at 7 x 7 m. Soil type was fertile volcanic and dark orange reddish. As for previous farms, there was minimal management. The purpose of banana production was for household consumption and

Figure 3.19: Saravan Province, Lao-ngam district, Te-me-poom village, Farm # 19, small-scale farm.

3.2.20 Saravan Province, Lao-ngam district, Te-me-poom village, Farm # 20, small-scale

Banana farm #20 was located at the back of farm #19 (15° 27' 46.4"N, 106° 13' 19.7"E, and 615 m.a.s.l) (Figure 24). The total area of banana farm was about 0.2 ha and the spacing was approximately 7 x 7 m. Intercropped plants of the banana area comprised of a commercial tree called Bong and a cooking tree called Sompoy, while surrounding vegetation was the same as around the other farms in the area. Soil type and farm management were similar to Farm # 19. The purpose of banana production was for household consumption and sale to a market and to a middle man.

Figure 3.20: Saravan Province, Lao-ngam district, Te-me-poom village, Farm # 20, small-scale farm.

3.2.21 Saravan Province, Lao-ngam district, Te-me-poom village, Farm # 21, small-scale

Banana farm #21 was located about 300 m from farm #20 (15° 28' 01.5"N, 106° 13' 04.0"E, and 609 m.a.s.l) (Figure 3.21). Its total area was around 0.1 ha and the spacing between banana plants was approximately 7 x 7 m. Soil was dark and orange in colour. Farm management was the same as other farms, without any routine fertilizers or pesticide application. The bananas were grown for household consumption and sale to a market and to a merchant.

Figure 3.21: Saravan Province, Lao-ngam district, Te-me-poom village, Farm # 21, small-scale farm.

3.2.22 Saravan Province, Lao-ngam district, Te-me-poom village, Farm # 22, small-scale

The final farm within Area 2 (Farm #22) was located around 300 m from farm #21 (15° 28' 03.6"N, 106° 13' 02.9"E, and 608 m.a.s.l) (Figure 3.22). The total area of the banana farm was about 0.04 ha and the banana spacing was estimated at 7 x 7 m. The farm was surrounded by banana farms, bush, sugarcane, teak trees and a forest and intercropped by sweet potatoes. Soil characteristics and the way in which the farm was managed were the same as previous farm. This banana plantation was for food and commercial sale.

Figure 3.22: Saravan Province, Lao-ngam district, Te-me-poom village, Farm # 22, small-scale farm.

This chapter provides an overview of the farms and farming practices examined in this thesis. While more detailed analysis of farm characteristics and farming practices are provided in Chapter 6, a general summary is provided here. Two large-scale farms in Bolikhamxay province (approximately 100 ha) grow mainly Cavendish varieties of banana for commercial production and employ appropriately large-scale management techniques. The remaining farms examined in Bolikhamxay and Saravan province are much smaller (< 5 ha in Bolikhamxay and Saravan), tend to be unmanaged after planning, and produce a variety of banana varieties for domestic needs and local markets and domestic needs.

CHAPTER 4: A guide to nine important insect pests of banana in Laos

4.1 Abstract

This chapter provides a guide to the nine important pests of banana and assists farmers, agriculture staff and non-specialist users in identifying and recognising the represented species. This is a useful tool to improve the understanding of readers in Laos. The nine pests are *Cosmopolites sordidus* (root borer), *Odoiporus longicollis* (stem borer), *Basilepta subcostata* (scarring beetle), *Sphaeroderma* spp. (leaf beetles), *Hieroglyphus banian* (rice grasshopper), *Erionota thrax* (banana skipper), *Bactrocera cucurbitae* (melon fruit fly), *Bactrocera dorsalis* (fruit fly) & *Stephanitis typica* (lace wing bug). The pest facts include useful illustrations, common and Lao names, information on lifecycle, distribution, damage caused, host range, monitoring and control options, as well as references and Lao government sources for further information.

4.2 Overview

Insect pests are a significant issue for banana production worldwide, particularly in those regions where bananas are a major staple food. These pests are responsible for economic losses and decreased yields or increased costs of control (Ostmark 1974; Rukazambuga *et al*. 1998, 2002). There have been few global reviews of banana pests and most primary records are out-dated. Ostmark (1974) published the most recent review of economic arthropod pests (insects and mites) of bananas worldwide. In Laos, insect pest species have rarely been reported and there is no current information. The list of nine important insect pests of Laos given here was derived from a combination of the field survey results (Chapter 5), the study of farmers' perceptions concerning the most significant pests (Chapter 6), and available information sources about banana pests in Southeast Asia and globally. The main literature sources for countries and regions are: Laos (Dean 1978), Thailand (Wongsiri 1991), Malaysia (Wahad 2000), the Philippines (Aguilar *et al.* 2014), Southeast Asia (Waterhouse 1993; CABI 2005), Australia (Pinese 1994; Tenhaj 2008), Pacific Islands (Nelson *et al.* 2006), the USA (Gilman & Watson 1994; Peno 2006), and various countries (Gold et al., 2002).

Thus, the nine important insect pests/ taxa were comprised of seven species and three taxa (families): Coleoptera; *Odoiporus longicollis*, *Cosmopolites sordidus*, Coleoptera; Chrysomelidae, Coleoptera; *Basilepta subcostata*, Orthoptera; Acrididae, Hemiptera; *Stephanitis typica*, Lepidoptera; *Erionota thrax*, Diptera; Tephritidae, and Diptera; *Bactrocera dorsalis*. Some members of the three families, Chrysomelidae and Acrididae and Tephritidae could not be identified to species level. Therefore, *Sphaeroderma* spp. are used here as an

example of Chrysomelidae, *Hieroglyphus banian* represents Acrididae and *B.cucubitae* represents of Tephritidae.
The recognition and identification of insect pest species is a critical step in developing an appropriate program of pest management. Identifying a pest early in a crop will help to prevent or limit economic losses that might arise from a major infestation. Although there are numerous taxonomic keys available for insect identification, these tend to be global or regional in scope and their use is difficult for non-taxonomists (Marshall, 2006; Prabhaker, Sood., & K., 2012).

The purpose of this chapter is to provide a tool for primary identification of the key insect pests of bananas. It is presented in a style that should be accessible to farmers and agricultural staff, and to individuals that may have no specialist knowledge of insect taxonomy. It also includes directions indicating where additional resources and advice can be obtained.

For each of the nine target species found in Laos, this chapter will provide useful illustrations, information on lifecycle, distribution, damage caused, host range, monitoring and control options, as well as references. This guide will help to fill the knowledge gap for Lao farmers and other non-specialist readers. These pests are:

1. *Cosmopolites sordidus* (root borer),
2. *Odoiporus longicollis* (stem borer),
3. *Basilepta subcostata* (scarring beetle),
4. *Sphaeroderma* spp (leaf beetles – representing Chrysomelidae),
5. *Hieroglyphus banian* (rice grasshopper – representing Acrididae),
6. *Erionota thrax* (banana skipper),
7. *Bactrocera cucurbitae* (melon fruit fly– representing Tephitidae),
8. *Bactrocera dorsalis* (fruit fly) and
9. *Stephanitis typica* (lace wing bug).

The following pages have been formatted to allow them to be printed together and provided to farmer as a 'separate' guide. Although the numbering of figures and tables follows that of the thesis as a whole, these could easily be modified if these pages are reproduced as a single separate document.

Together, these guides should provide a valuable resource for farmers and provincial agricultural officers, leading to improved understanding of banana production and ongoing assistance in developing regional banana production strategies.

4.3 Root borer (*Cosmopolites sordidus*, Coleptera:Curculionidae, ດ້ວງເຈາະເຫງົ້າຕົ້ນກ້ວຍ, duang-cho-ngao-ton-kuay)

Two common weevil pests of banana damage the root and stem: root borer, *Cosmopolites sordidus* and stem borer, *Odoiporus longicollis*. The pests are frequently found in the same plant and can be hard to differentiate. Both species descriptions are below (Fig. 4.1, Fig. 4.2, Table 4.1, Fig. 4.3 and Table 4.2).

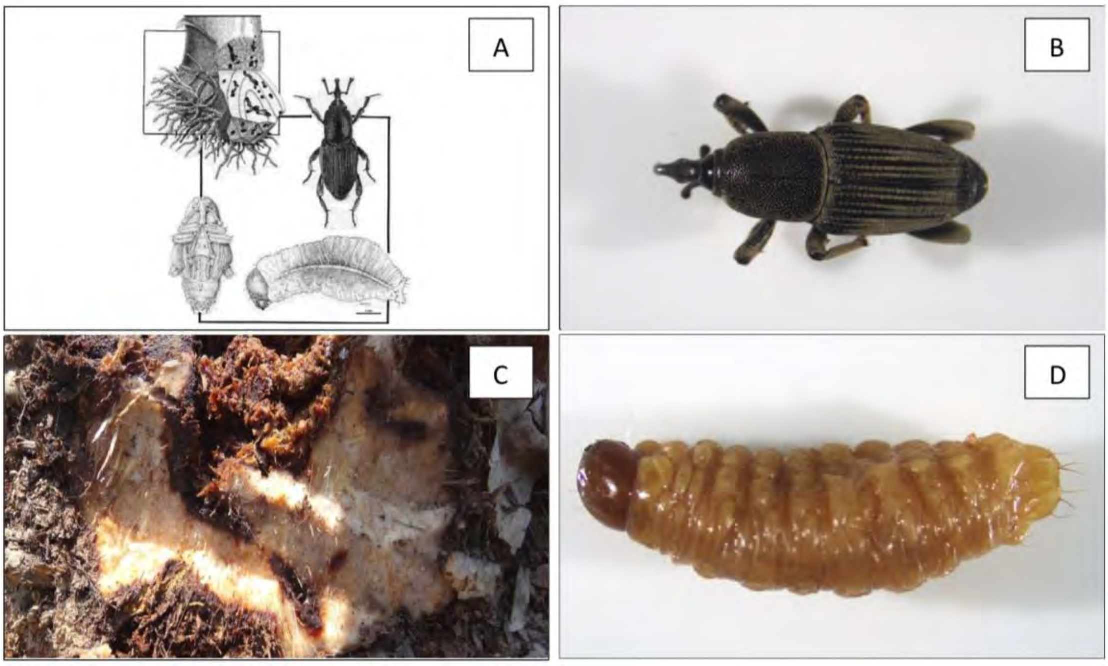


Figure 4.1: Pictorial guide to the root borer (*Cosmopolites sordidus*) A: Lifecycle (Cook Islands Biodiversity Database, 2007), B: Adult , C: Borer tunnels in banana corn showing brown staining, D: Root borer larva (V. Vansilalom source for B, C & D).

It is difficult to distinguish between the root borer and stem borer without the detailed view allowed with a microscope. The illustrations below show distinguishing features of the head and back (elytra) of both species (Fig.4.2).

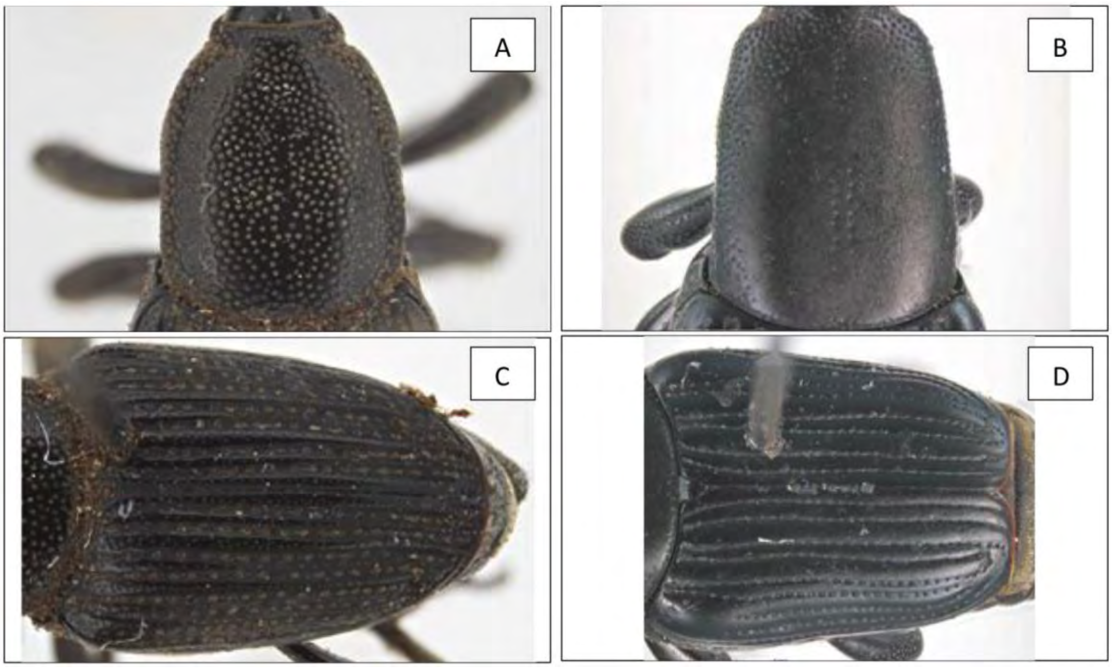


Figure 4.2: Dorsal view of the head of the root borer *Cosmopolites sordidus* (A) and stem borer *Odoiporus longicollis* (B) and the elytra of the root borer *Cosmopolites sordidus* (C) and stem borer *Odoiporus longicollis* (D) (PaDIL, 2010a, b, c).

Table 4.1: Species description of *Cosmopolites sordidus*

Scientific name	*Cosmopolites sordidus*
Common names	**Banana weevil borer, banana root borer, banana corm borer, banana rhizome weevil, ດ້ວງເຈາະເຫງົ້າຕົ້ນກ້ວຍ, duang-cho-ngao-ton-kuay**
Lifecycle	Not studied in Laos. Reports from other countries indicate that eggs are white, oval in shape, and laid singly in the leaf sheaths and corms. Egg laying is primarily around flowering time and after harvesting in the residue from banana parts (Messiane & Gold, 2000). Generation time is 30-40 days from egg to adult. Eggs hatch after 5 to 7 days (Woodruff & Fasulo, 2015). Larvae prefer feeding in the corm. The tunnel made by larvae provides shelter for all stages until adult emergence (Sahayaraj, 2009). Development takes 5 to 8 instars (stages) (15-20 days) depending on the temperature (Messiane & Gold, 2000). Larvae are white, with a dark reddish brown head capsule. Pupation takes 6-8 days (Woodruff & Fasulo, 2015). Adults

Scientific name	*Cosmopolites sordidus*
Common names	**Banana weevil borer, banana root borer, banana corm borer, banana rhizome weevil, ດ້ວງເຈາະເຫງົ້າຕົ້ນກ້ວຍ, duang-cho-ngao-ton-kuay**
	are 10-15 mm, glossy black/dark brown/grey black, mainly nocturnal (Messiane & Gold, 2000; Woodruff & Fasulo, 2015), and tend to remain on the ground near the mat/old stools (seldom move far). Weevils are long-lived (4 years) and can fast for long periods.
Damage	The larvae attack rhizomes and roots by tunnelling. Tunnels reach approximately 8 mm in diameter (Biovision Foundation for Ecological Development, 2015). Weevil activities inhibit nutrient uptake by the plant, resulting in slow growth, delayed flowering and increased susceptibility to other pests, disease and wind damage (Messiane & Gold, 2000).
Host plants	Banana, plantain and ensete, Manila hemp and yam. In Laos, *Musa acuminata* (Cavendish) and *M. sapientum* (Kuay Nam)
Distribution	The species is cosmopolitan in tropical and sub-tropical regions. In Laos, field studies indicate that root borer is more prevalent in banana-producing regions, especially Bolikhamxay and Saravan provinces.
Monitoring for infestation (Where to find them)	To search for the borer, cutting old or harvested banana plant material from corms to pseudostem is a fast way to detect larvae and adults. Adults can be regularly monitored by using banana stems as traps; place cut stems sliced lengthwise close to the base of the plants to attract adults. Many studies have followed the Mitchell method (G. Mitchell & Association, 1980) for monitoring the borer (Jeger, Waller, Johanson, & Gowen, 1996; Ogenga-Latigo, 1993; Pinese, 1994). Pheromone traps have also been used (G. V. P. Reddy, Cruz, & Guerrero, 2009).
Control	Cultural: Remove weeds and old debris of harvested banana stems. Rotation might be an effective means of sanitation (Masanza, Gold, & Van Huis, 2005). In Queensland, Australia, if farmers want to replant, all previous banana residue must be destroyed and the land left

Scientific name	*Cosmopolites sordidus*
Common names	**Banana weevil borer, banana root borer, banana corm borer, banana rhizome weevil, ດ້ວງເຈາະເຫງົ້າຕົ້ນກ້ວຍ, duang-cho-ngao-ton-kuay**
	fallow for at least six months (Department of Agriculture and Fisheries 2010). Biological: Many general predators such as ants, beetles, and cane toads contribute to reduce the borer numbers in Australia. Predators have not yet been identified in Laos. Chemical: In India, neem has been used as insecticide to control the borer (Sahayaraj & Kombiah, 2010). Pheromone traps can lure and remove the pest (G. Reddy, Cruz, Naz, & Muniappan, 2008; Gadi V. P. Reddy & Raman, 2011). In Laos, the economic status of farmers might inhibit use of chemicals and clarification is required concerning pesticide regulation and permitted uses.
Further information and enquiries	Please contact Plant Protection Centre, Department of Agriculture, Ministry of Agriculture and Forestry (MAF), Thadeua Rd, Km 13 Vientiane, Lao PDR, Tel, Fax: (+856) 21 812164

4.4 Stem borer (*Odoiporus longicollis*, Coleptera:Curculionidae, ດ້ວງເຈາະຕົ້ນກ້ວຍ, duang-cho-ton-kuay)

Detailed information is provided in Figure 4.3 and Table 4.2.

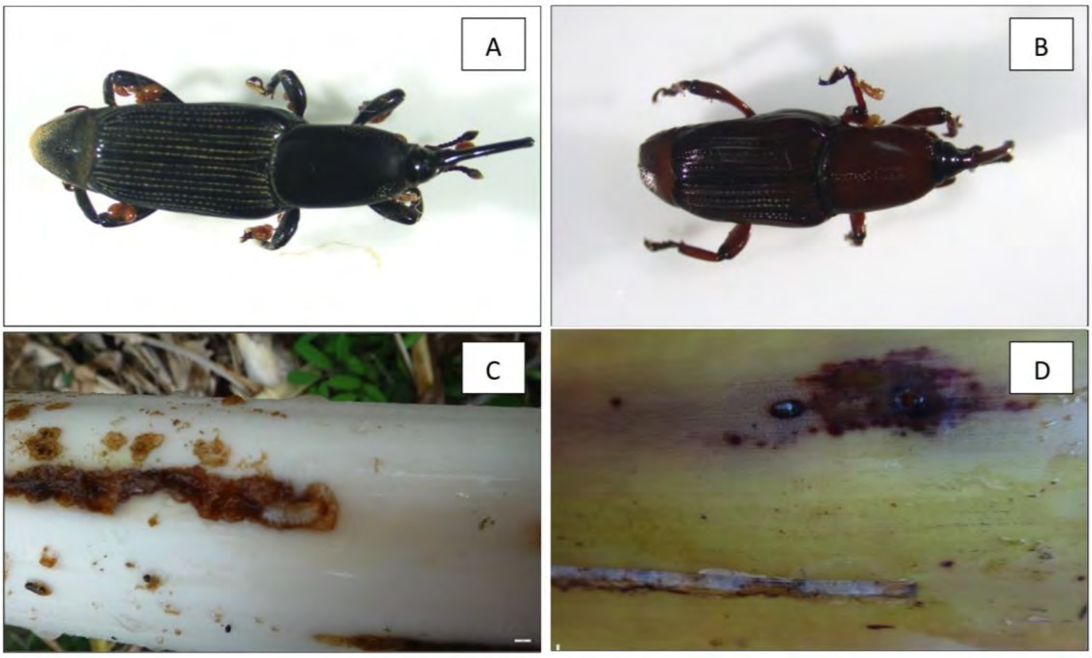


Figure 4.3: Pictorial guide to the stem borer (*Odoiporus longicollis*). A & B: Dorsal view of adults, C: Larvae feeding on stem, D: Small symptomatic pin holes on stem. (V. Vansilalom source).

Table 4.2: Species description of *Odoiporus longicollis.*

Scientific name	***Odoiporus longicollis***
Common names	**Banana stem weevil, weevil, banana stem borer, banana borer, pseudostem borer, ດ້ວງເຈາະຕົ້ນກ້ວຍ, duang-cho-ton-kuay**
Lifecycle	Not studied in Laos. Stem borer takes 42-44 days to complete its life-cycle (Azam, 2010; Padmanaban & Sathiamoorthy, 2001). Eggs are either yellowish white or cream and cylindrical or singly laid on stems (Azam, 2010). In Java, stem borers laid eggs near the ground, in particular close to a cut stem or damaged area (Froggatt, 1928). In Taiwan, egg development took 5-12 days during the cooler

Scientific name	*Odoiporus longicollis*
Common names	**Banana stem weevil, weevil, banana stem borer, banana borer, pseudostem borer, ດ້ວງເຈາະຕົ້ນກ້ວຍ, duang-cho-ton-kuay**
	months and 3-5 days in the warmer season (Kung, 1955). In India, egg development took 3-8 days (Tamil Nadu Agriculture University, 2009). Larvae lack feet, are soft, yellowish white and cylindrical with a dark brown head (Azam, 2010; Padmanaban & Sathiamoorthy, 2001). Freshly hatched larvae feed vigorously on soft tissue in their vertical burrow through the stem and might burrow down as far as the corm. The tunnel made by larvae provides shelter for all stages until adult emergence (Sahayaraj, 2009). The larval stage encompasses five instars (stages), which occur inside the tunnel. The duration of the larval stage is 26 days in summer and 68 days in winter in India (Dutt & Maiti, 1979). In Taiwan, larval duration is 3-6 weeks (February to April) and 25-27 days (September to October) (Kung, 1955). Pupae are pale yellow. The pupal cycle as well as pre-emergence period, in summer takes 20-24 days and 37-44 days in winter (Azam, 2010). In winter, their life span is longer than in summer (Padmanaban & Sathiamoorthy 2001). Adults are robust and nocturnal, black and reddish brown in coloured. The full-growth adult length is 17.5-19 mm in length and 5-6 mm in width. Various adult survival times have been reported: around 90-120 days (Visalakshi, Nair, Beevi, & Amma, 1989), 200 days (Prasuna, Jyothi, Prasad, Yadav, & Padmanaban, 2008) and up to two years (CABI 2005).
Damage	The first symptom of weevil attack is the appearance of small holes on the stem around the bases of leaf petioles and exudation of a gummy liquid from the stem. After heavy damage, the stem start decaying and rotting as pathogens take advantage of the damage. Young plants (~ 5 months old) are the most vulnerable (Padmanaban & Sathiamoorthy, 2001). If there is an extensive infestation, stems

Scientific name	*Odoiporus longicollis*
Common names	**Banana stem weevil, weevil, banana stem borer, banana borer, pseudostem borer, ດ້ວງເຈາະຕົ້ນກ້ວຍ, duang-cho-ton-kuay**
	(pseudostems) become pale and stunted, leaves turn yellow and curl and fruit production is low.
Host plant	Musa (banana), *Musa x paradisiaca* (plantain), *Musa textilis* (Manila hemp). The stem borer is highly specific to banana plants. In Laos, *Musa acuminata* (Cavendish) and *M. sapientum* (Kuay Nam).
Distribution	This species is widespread throughout Southeast Asia and South Asia; including Myanmar, Thai, Cambodia, Vietnam, Malaysia, Indonesia, the Philippines, India, China, Malaysia, Laos, Hong Kong, Sri Lanka, Taiwan, Nepal, Japan, Andaman island, Iran and Pakistan (Azam, 2010; Muhammed, 2011; PaDIL, 2010c; DF. Waterhouse, 1993). In Laos, stem borer is most likely to be found in banana production areas, especially Bolikhamxay and Saravan provinces.
Monitoring for infestation (Where to find them)	To quickly locate the larvae and adults, cut old or harvested banana plant material from corms to pseudostem. Stem borer and root borer are normally found together on banana trees and corms in Laos and the same methods can be used for monitoring them; by observation of cut stems and stem trapping.
Control	Cultural: In India, the whole infested tree is removed and burned. Stems should be removed from the ground after harvesting to prevent pests using them as breeding shelters. Mud mixed with neem oil (5%) can be applied to the stem a month after planting to inhibit egg laying. New shoots should be pruned every month. The plant should be monitored for signs of infestation using pseudostem traps. These are made by either cutting pseudostem (stem) 45 cm in length, which are then laid close to cultivated bananas or cutting the stem into round pieces, then placed on top of old cut corms (Tamil Nadu Agriculture University, 2009).
Control (*continued*)	Biological: Swab the cut surface of the pseudostem traps with 20g of *Beauveria bassiana* fungus or *Heterorhabditis indica* nematode. Weevils

Scientific name	*Odoiporus longicollis*
Common names	**Banana stem weevil, weevil, banana stem borer, banana borer, pseudostem borer, ດ້ວງເຈາະຕົ້ນກ້ວຍ, duang-cho-ton-kuay**
	become infected and die. Soak the suckers in 20% neem seed solution at planting. Predators such as big-headed ants are important predators of the banana weevil (Tamil Nadu Agriculture University, 2009). <u>Chemical:</u> Apply Furadan about 20 gms or Phorate 10g or 12 gms or neem cake 1/2 Kg per hole at planting. Apply 100 ml of Carbaryl (2g per litre) or *Beauveria bassiana* on a cut stem after harvesting of the banana bunch (Tamil Nadu Agriculture University, 2009). Before applying chemical treatment, check the pesticide regulations and permitted uses.
Further information and enquiries	Please contact Plant Protection Centre, Department of Agriculture, MAF. Thadeua Rd, Km 13 Vientiane, Lao PDR Tel, Fax: (+856) 21 812164

Leaf beetles (Chrysomelidae)

Chrysomelidae is one of the largest families of Coleoptera. There are over 50 000 species worldwide, many as yet undescribed (LeSage, 1861). Chrysomelids exhibit extremely varied body forms, but are often brightly coloured. They are phytophagous (plant eating), consuming a broad range of plant parts from root to seed (Lawrence & Britton, 1991), although most chrysomelids feed on leaves as larvae and as adults. Numerous chrysomelids can feed on a wide range of host plants and many have become pests of banana cultivation. In Laos, *Sphaeroderma veripennis* and *Sphaeroderma* spp. were recognised by Dean (1978). *Basilepta subcostata* and *Basilepta viridipenne* were mentioned by Waterhouse (1993). In Thailand, *Nodostoma viridipennis* (*Basilepta viridipenne*) (fruit eating beetle) was recorded as a pest of banana crop (Wongsiri, 1991). In Australia, two chrysomelids have been recorded as minor pests of banana production; *Rhyparida discopunctulata* (black swarm leaf beetle) and *Monolepta australis* (red shoulder leaf beetle) (Pinese, 1994). In India, *Basilepta subcostata* has been reported as a major pest of banana (Mustaffa & Sathiamoorthy, 2002).

Many chrysomelids were collected during this study, some of which could not be identified to species. Hence; two examples of Chrysomelidae are provided here. These are scarring beetle (*Basilepta subcostata*) and leaf beetles (*Sphaeroderma* spp). Both are known (or are likely) to occur in Laos.

4.5 Scarring beetle (*Basilepta subcostata*, Coleoptera: Chrysomelidae, ດ້ວງກິນໝາກ, duang-kin-mak)

Detailed information isprovided in Figure 4.4 and Table 4.3.

Figure 4.4: Pictorial guide to the scarring beetle (*Basilepta subcostata*). A & B: Adults, C & D: Signs of scaring on banana fruit and leaf. (V. Vansilalom source).

Table 4.3: Species description *Basilepta subcostata.*

Scientific name	***Basilepta subcostatum* or *Basilepta subcostata***
Common names	**Banana leaf and fruit scarring beetles, scarring beetle, ດ້ວງກິນໝາກ, duang-kin-mak.**
Lifecycle	Largely unknown. Scarring beetle was reported as a major pest of banana in India where their population increased from May to August when humidity and rainfall was high (Ahmad, Mandal, & Mukherjee, 2010). Adult size ranges from 3 - 3.7 mm. They look either blue or green in colour (Kimoto & Gressitt, 1982).
Damage	Adults feed by cutting into the surfaces of tender leaves and fruit skin. In Laos, the species was detected during field surveys at relatively high abundance on newly emerged leaves of Cavendish bananas In plantations.
Host plant	*Musa* spp. In Laos, *Musa acuminate* (Cavendish) and *M. sapientum* (Kuay Nam).
Distribution	Laos, Cambodia, Myanmar, Thailand, India (Kimoto & Gressitt, 1982; Prasad & Singh, 1987; DF. Waterhouse, 1993; Wongsiri, 1991).
Monitoring for infestation (Where to find them)	Search for scar marks on young, folded leaves and fruit.
Control	Cultural: Remove by hand picking. Biological: In India, biopesticide *Beauveria bassiana* (5g per litre), or neem tree products such as azadirachtin (5ml per litre) were found effective for control of the pest (Choudhary, Mukherjee, & Ahmad, 2013). Chemical: Cabaryl (0.3%) sprayed on leaves (Choudhary et al., 2013). Control measures appropriate for Laos remain to be determined.
Further information and enquiries	Please contact Plant Protection Centre, Department of Agriculture, MAF Thadeua Rd, Km 13 Vientiane, Lao PDR, Tel, Fax: (+856) 21 812164

4.6 Leaf beetles (*Sphaeroderma* spp, Coleoptera: Chrysomelidae, ດ້ວງກິນໃບ, duang-kin-bai)

Detailed information is provided in Figure 4.5 and Table 4.4.

Figure 4.5: Pictorial guide to two species of leaf beetle A: *Sphaeroderma rubidium* Source: (WCG, 2015) and B: *Sphaeroderma testacea* Source: (WCG, 2015).

Table 4.4: Species description of the leaf beetle *Shaeroderma* spp.

Scientific name	***Sphaeroderma* spp**
Common names	**Leaf beetles, ດ້ວງກິນໃບ, duang-kin-bai**
Lifecycle	Unknown
Damage	Adults feed on leaves. In Laos, further identification needed.
Host plant	*Musa* spp
Distribution	Laos, Russia, UK (Dean, 1978; Hill, 1983; Loboda, 2007)
Monitoring for infestation	Search young, folded leaves and fruit for the presence of scar marks.
Control	Unknown
Further information and enquiries	Please contact Plant Protection Centre, Department of Agriculture, MAF. Thadeua Rd, Km 13 Vientiane, Lao PDR Tel, Fax: (+856) 21 81216

Grasshoppers and locusts (Orthoptera: Acrididae, ຕັກແຕນໜວດສັ້ນ, thak-than-nuad-sun)

Acrididae includes short-horned grasshoppers and locusts. All have antennae shorter than their body length. There are many genera and species in the family, which globally attack crops and non-crops. Some are important pests in Southeast Asia Locust nymphs and adults are able to swarm resulting in widespread destruction, especially in Africa (Kumar & Usmani, 2015) and recently in Laos (FAO, 2015), while grasshoppers tend to be geographically restricted (Rentz, 1994). *Valanga nigricornis* (large short-horn grasshopper) was recorded by Waterhouse (1993) as a minor pest of banana. Other acridids attacking bananas include *Patanga succinta* (Bombay locust) (Dean, 1978; DF. Waterhouse, 1993; Wongsiri, 1991), *Cyrtacanthacris tatarica* and *Hieroglyphus banian* (rice grasshopper) (Dean, 1978; Lanjar, Talpur, Khuhro, & Qureshi, 2002; Wongsiri, 1991).

Given that no member of the Acrididae collected during this study could be identified to species level, the rice grasshopper *Hieroglyphus banian*, has been used as an example of this family likely to occur in Laos.

4.7. Rice grasshopper (*Hieroglyphus banian*, Orthopera:Acrididae, ຕັກແຕນ, thak-than)

Detailed information provided in Figure 4.6 and Table 4.5.

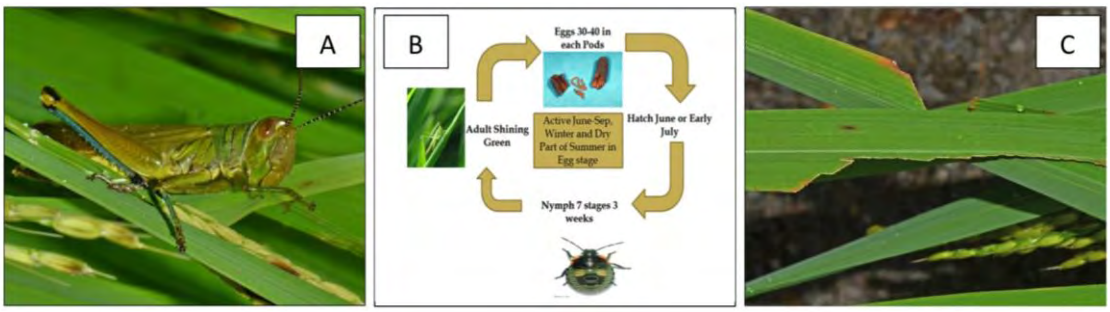


Figure 4.6: Pictorial guide to the rice grasshopper (*Hieroglyphus banian*) (IRRI, 1962).

Table 4.5: Species description of *Hieroglyphus banian.*

Scientific name	***Hieroglyphus banian***
Common names	**Rice grasshopper, ຕັກແຕນ, thak-than**
Lifecycle	In Pakistan, eggs are laid in the soil in a series of pods, each containing many eggs, from September to November. Then the egg remains until March before hatching. At the end of June or early July, which is the monsoon season, they start feeding on rice. Early nymphs are yellow with many red-brown spots. They then turn to green as they get older. Adults reach a size of about 4-5 cm, are shiny green-yellow with three black lines on their back. Adults are able to feed year-round (Muhammad, Faryad, & Muazzama, 2013).
Damage	Nymphs and adults fed on leaves, new shoots, rice panicles and tender parts causing defoliation (Lanjar et al., 2002), which in Pakistan is most severe in August and September (Muhammad et al., 2013).
Host plant	Rice, maize, sorghum, sugarcane, pearl millet, peas, pigeon pea (NBAIR, 2003), lentil, other grasses (Muhammad et al., 2013) and banana (Dean, 1978; Lanjar et al., 2002; Wongsiri, 1991)
Distribution	Laos, Thailand, Vietnam, Cambodia, Myanmar, Nepal, India, Sri Lanka, Bangladesh, Pakistan and China (Muhammad et al., 2013).
Control	Cultural: Since rice grasshopper eggs are laid under the soil, mechanical disturbance by turning the soil can reduce the chance of successful emergence of nymphs. Sweep nets can be used to collect individuals. Adults can be hand-picked from leaves at night time when they are slow-moving. Biological: Bio-agents and predators include scelionid wasps, parasitic flies, nematodes, and fungal pathogens, birds, frogs, and web-spinning spiders, ants, birds, bats, field rats, mice, wild pigs, dogs, millipedes, fish, amphibians, reptiles and monkeys. Chemical: Apply foliar spraying to control the grasshopper in rice fields, which is more effective then granular pestide (IRRI, 1962) For instance, spray fenitrothion + BPMC (fenobucarb) at 400 ml/acre (Saeed, Hussain, & Batool, 2013). In Laos, before employing chemicals, check the pesticide regulations

Scientific name	***Hieroglyphus banian***
Common names	**Rice grasshopper, ຕັກແຕນ, thak-than**
	and permitted uses.
Further information and enquiries	Please contact Plant Protection Centre, Department of Agriculture, MAF. Thadeua Rd, Km 13 Vientiane, Lao PDR Tel, Fax: (+856) 21 812164

4.8. Skipper, leaf roller (*Erionota thrax*, Lepidoptera: Hesperiidae, ແມງກະບ ບ ນໄວ meang-ka-by-bin-wai, ບ ງຮໍາໃບ bong-ham-bai)

Detailed information provided in Figure 4.7 and Table 4.6.

Figure 4.7: Pictorial guide to the skipper (*Erionota thrax*). A: Eggs (CSIRO, 1926), B: Adult, C: Larvae and pupae, D: Leaves rolled by larvae (V. Vansilalom source B, C & D).

Table 4.6: Species description of the skipper *Erionata thrax*.

Scientific name	***Erionota thrax***
Common names	**banana skipper, banana leaf-roller, ແມງກະບີ້ບິນໄວ meang-ka-by-bin-wai, ບົ້ງຮຳໃບ bong-ham-bai**
Lifecycle	Eggs are usually laid singly, occasionally in clusters, under banana leaves. They are yellow to orange in colour and hatch in 5 - 8 days (Ronald & Jayma, 2006b). The larvae roll leaves, using thread they produce, to make a shelter. As they grow, larvae need to build successively larger shelters. Larvae are pale green and their heads turn black when they develop to the second instar stage. The entire body is covered with a white waxy powder to shed rain water. The larval stage lasts around 20-32 days (Doug. Waterhouse, Dillon, & Vincent, 1998). Pupae can be as large as six centimetres in length. This stage lasts about 8-12 days. The pupa remains in the rolled leaf and is covered with wax. The life-cycle takes around 5-6 weeks to complete. Adults are rarely pests and visit flowers at dusk (CABI, 2005; Doug. Waterhouse et al., 1998).
Damage	Larvae of skippers damage banana crops by rolling the leaves. Feeding scars subsequently become necrotic (dead) and extensive defoliation (leaf loss) can occur (Ostmark, 1974; Peña, Sharp, & Wysoki, 2002).
Host plant	Sugar palm, Butea, *Calamus trachycoleus*, coconut, African oil palm, *Licuala grandis*, sago palm, manila hemp, plantain, nipa palm, Saccharum and more. In Laos, *Musa acuminate* (Cavendish) and *M. sapientum* (Kuay Nam).
Distribution	Asia, Africa, North America, Oceana (CABI, 2005) In Laos, skipper is more likely to occur where bananas are produced, especially in Bolikhamxay and Saravan provinces (based on the field observation).
Monitoring infestation (Where to find them)	To search for the skipper, observe leaf rolling by caterpillars, sign of leaf shredding and flying adults.

Scientific name	*Erionota thrax*
Common names	**banana skipper, banana leaf-roller, ແມງກະບ ບ ນໄວ meang-ka-by-bin-wai, ບົ້ງຮຳໃບ bong-ham-bai**
Control	<u>Cultural:</u> The caterpillar is an edible food in Laos. <u>Biological:</u> Parasitoids; *Ooencyrtus erionotae, Cotesia erionotae, Brachymeria albotibialis* were tested to control the skipper (Okolle, 2006a, 2006b). <u>Chemical:</u> In Laos, before employing chemicals, check pesticide regulations and permitted uses.
Further information and enquiries	Please contact Plant Protection Centre, Department of Agriculture, MAF. Thadeua Rd, Km 13 Vientiane, Lao PDR Tel, Fax: (+856) 21 812164

Fruit flies (Diptera:Tephritidae)

Tephritidae is a large and cosmopolitan family. Females deposit numerous eggs and larvae are voracious fruit feeders, consequently having a high impact on the fruit industry (Aluja & Mangan, 2008). Numerous species of Tephritidae have been reported infesting a range of crops around the world, many in places where bananas are produced. Of some 4 000 species in the family, 350 species are regarded as economic pests (Plant Health Australia, 2011). In Laos, *Bactrocera dorsalis* was reported by Waterhouse (1993), and *Dacus dorsalis* is known from Thailand (Wongsiri, 1991). In Australia, two species of Tephritidae, *Bactrocera musae* and *Bactrocera tryoni* are a problem for the banana industry (Pinese, 1994). In Hawaii, four species of Tephritidae infest banana and other cultivated crops: melon fly, oriental fruit fly, solanaceoous fruit fly (*Bactrocera latifrons*) and Mediterranean fruit fly () (Ronald & Jayma, 2006a).

In Laos, according to the Integrated Pest Management (IPM) project undertaken by the Plant Protection Centre in 2008, the common species found were *B. dorsalis a*nd *B. cucurbitae*. These are among the top five pest species in Southeast Asia (Waterhouse 1993). Hence, two examples of tephritids, melon fruit fly (*B. cucurbitae*) and fruit fly (*B. dorsalis*) are provided here.

4.9. Melon fruit fly (*Bactrocera cucurbitae*, Diptera: Tephritidae, ແມງວ ັນທະກ ູແຕງ, meang-wan-tha-gool-teang)

Detailed information provided in Figure 4.8 and Table 4.7.

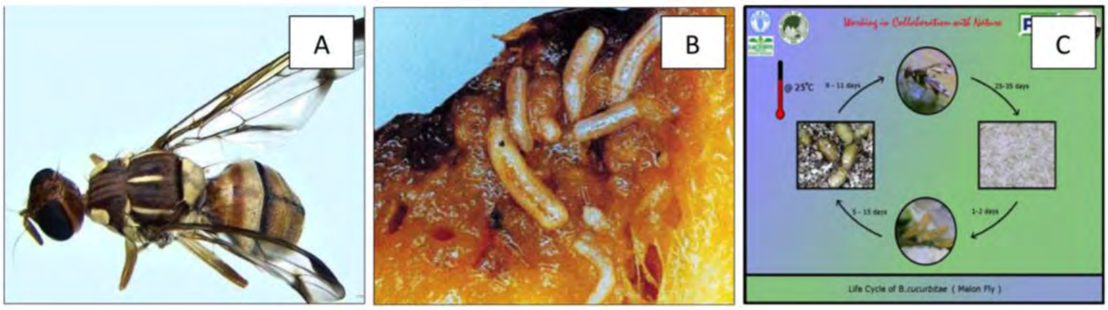


Figure 4.8: Pictorial guide to the melon fruit fly (*Bactrocera cucurbitae*). A: Adult (CABI, 2005) , B: Larvae feeding inside a food source (ACISAI, 2010b), C: Melon fly life-cycle (ACISAI, 2010b).

Table 4.7: Species description of *Bactrocera cucurbitae*.

Scientific name	***Bactrocera cucurbitae***
Common names	**Cucumber fruit fly, fruit fly, melon fly, ແມງວ ັນທະກ ູແຕງ, meang-wan-tha-gool-teang**
Lifecycle	Females live for five months in tropical regions and up to fifteen months in temperate regions. Each has the potential to lay over 1 000 eggs during her lifetime. Eggs are usually laid on young fruits or soft tissue of plant stem. Twenty-four hours after being laid, eggs begin hatching (ACISAI, 2010b). Pupation occurs in the soil, 0.5cm - 15cm below the surface, and takes seven days (Dhillon *et al*. 2005). Adult body length is between 6 and 8 mm (UF/IFAS 2010a) Adults are light brown in colour and have three parallel yellow stripes on the thorax and a distinctive pattern on the wings (Sagar, 1991). Generation time ranges from 12 - 28 days (ACISAI, 2010b). The melon flies tend to increase in abundance when the temperature is below 32°C and the humidity between 60 and70% (Dhillon *et al.* 2005).
Damage	Melon flies prefer to infest young, green, soft-skinned fruits (Dhillon, Singh, Naresh, & Sharma, 2005)

Scientific name	***Bactrocera cucurbitae***
Common names	**Cucumber fruit fly, fruit fly, melon fly, ແມງວັນທະກູນແຕງ, meang-wan-tha-gool-teang**
Host plant	Primary hosts: *Bactrocera cucurbitae* is a severe pest of pumpkin, squash, tomatoes, bean, sweet potato, eggplant, snake gourd, watermelon, bitter gourd and other species. There are approximately 125 species of host plants in Asia and Hawaii (Sim, 2002; UF/IFAS, 2010a). Dhillon *et al*. (2005) pointed out that melon fly damages over 81 plant species based on the same source of information.
Distribution	Melon fly is widespread in tropical Asia, all of Southeast Asia (CABI, 2005; DF. Waterhouse, 1993) as far as Bangladesh and also occurs in some parts of Africa (SPC, 2006). It is considered as a native insect of India (Dhillon et al., 2005; UF/IFAS, 2010a).
Monitoring infestation (Where to find them)	Pheromone traps can be used as a cue-lure.
Control	<u>Cultural:</u> Crop sanitation: destroy infested fruits on the tree or fallen fruit from the ground by soaking in water topped by a layer of kerosene. However, do not simply bury the infested fruits. Bagging fruits can be effective. Choose varieties that are less susceptible to the melon fly. <u>Biological:</u> Parasitoids of larvae and eggs include *Psyttalia fletcheri*. *Fopius arisanus* was used to control Bactrocera *cucurbitae* in Hawaii (Harris et al., 2010). Protein baits provide a non-chemical option for fruit fly management worldwide. <u>Chemical:</u> In Laos, before employing chemicals, check the pesticide regulations.
Further information and enquiries	Please contact Plant Protection Centre, Department of Agriculture, MAF. Thadeua Rd, Km 13 Vientiane, Lao PDR Tel, Fax: (+856) 21 812164

4.10. Fruit fly (*Bactrocera dorsalis*, Diptera: Tephritidae, ແມງວັນທອງ, meang-wan-tong)

Detailed information is provided in Figure 4.9 and Table 4.8.

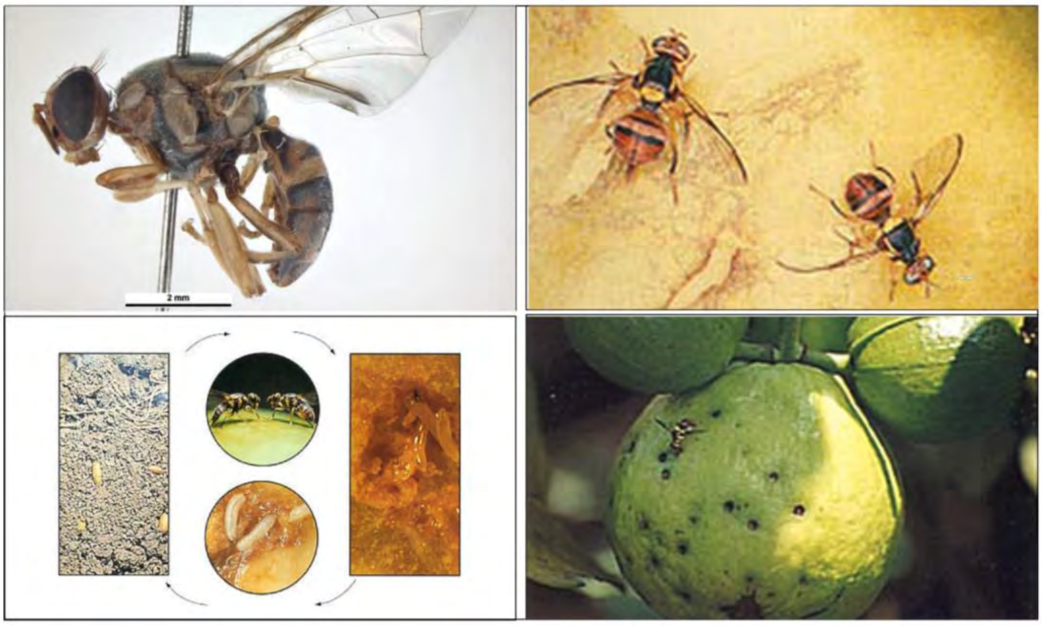


Figure 4.9: Pictorial guide to the fruit fly (*Bactrocera dorsalis*). A & B: Adult fruit fly (ACISAI, 2010b), C: Life cycle (ACISAI, 2010b), D: Marks on fruit from fruit flies (FFTC, 1998).

Table 4.8: Species description of *Bactrocera dorsalis*

Scientific name	*Bactrocera dorsalis*
Common names	**Oriental fruit fly, ແມງວັນທອງ, meang-wan-tong**
Lifecycle	Eggs of *B. dorsalis* are laid below the skin of the host fruit. A female can lay from 1 000 to 3 000 eggs during her lifetime depend on location and conditions (Ronald & Jayma, 2006a; USDA, 2006). Eggs are white, elongate and hatch within a day or two, although hatching can be delayed up to 20 days in cool conditions. There are three larval instars (stages) extending over as much as 35 days, depending on season. Pupation occurs in the soil and typically takes 8-12 days. However, pupation can last up to 90 days in cold weather. Adults exhibit a variety of colours. They can be found year-round and begin mating about 8-12 days after emergence. Adults may live 1-3 months depending on temperature (up to 12 months in cool

Scientific name	*Bactrocera dorsalis*
Common names	**Oriental fruit fly, ແມງວັນທອງ, meang-wan-tong**
	conditions) (Christenson and Foote (1960) cited in CABI (2005)).
Damage	The larvae (maggots) feed preferentially on ripe banana fingers, which consequently soften and become rotten.
Host plant	The fly is a world-wide fruit pest common in banana production areas (Plant Health Australia, 2011). It has a wide range of hosts; including banana, golden apple, cashew nut, bullock's heart, sugar apple, betel nut palm, breadfruit, jackfruit, carambola, bell pepper, papaw, caimito, citrus, lime, pomelo (full lists of hosts are in CABI (2005) and Allwood et al. (1999)). In Laos, fruit flies are considered one of the most serious pests of fruits and vegetables, including mango, guava, jujube, bitter gourd, cantaloupe, water melon and cucumber (ACISAI, 2010a).
Distribution	The species is now widespread in Asia, Africa, North America, South America and Oceania (Drew & Hancock, 1994) with the current exception of Australia (PaDIL, 2010a) and Papua New Guinea (Mararuai, 2010).
Monitoring infestation (Where to find them)	Fruit flies can be directly observed around trees and fruits. Methyl-eugenol can be used as an attractant for monitoring the oriental fruit fly. Protein baits; when flies feed on the baits sprayed on leaves, they die (ACISAI, 2010a; UF/IFAS, 2010b).
Control	<u>Cultural:</u> Same application as melon fruit fly <u>Biological:</u> Methyl eugenol is an excellent bait for trapping male oriental fruit flies as part of integrated pest management (IPM), and can be used in conjunction with the “sterile male method”. <u>Chemical:</u> In Laos, before employing chemicals, check the pesticide regulations and permitted uses.
Further information and enquiries	Please contact Plant Protection Centre, Department of Agriculture, MAF. Thadeua Rd, Km 13 Vientiane, Lao PDR Tel, Fax: (+856) 21 812164

4.11. Lace wing bug (*Stephanitis typica*, Hemiptera: Tingidae, ແມງຕາຄໍາ, meang-tha-kham)

Detailed information provided in Figure 4.10 and Table 4.9.

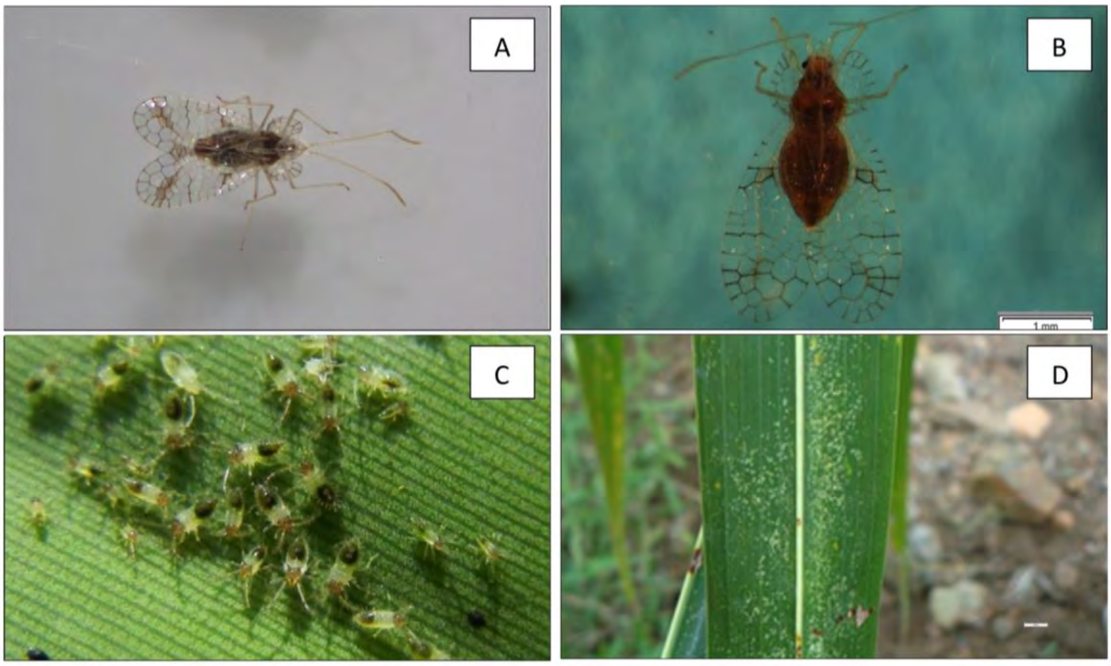


Figure 4.10: Pictorial guide to the lace wing bug (*Stephanitis typica*). A & B: Adults of lace wing bug (Source: V.Vansilalom and S. Cowan), C: Nymph stage (Bioderversity Reaserch Centre, 2007), D: Signs of lace bug damage (Tamil Nadu Agricultural University, 2009).

Table 4.9: Species description of *Stephanitis typica*.

Scientific name	***Stephanitis typica***
Common names	**banana lace wing bug, lace bug, ແມງຕາຄໍາ, meang-tha-kham**
Lifecycle	Eggs are deposited singly or in a cluster into plant tissue near the midrib of a young leaves. Larvae hatch after approximately 10 days. There are five instars (nymph stages) occurring over the span of around 10 days (Tigvattnanont, 1990). A larval duration of 13 days was reported on coconut trees in India (Mathen & Kurain, 1980). Adult lifespan is reported to average around 39 days for males and 26 days for females on a galangal plant (*A. galana*) (Tigvattnanont, 1990). In one laboratory study of these pests on coconut, adult lifespan was 21 days for males and 25 days for females.

Scientific name	*Stephanitis typica*
Common names	**banana lace wing bug, lace bug, ແມງຕາຄຳ, meang-tha-kham**
Damage	Nymphs at all stages feed by sucking plant sap from under leaves. The leaves become whitened and wilt, exhibiting brown spots in the case of heavy damage. The bug is known to be a vector of root wilt disease of coconut, as are many true bugs (Mathen et al., 1990; P. L. Mitchell, 2004).
Host plant	Banana, plantain, Alpinia, soursop, *Artocarpus integer*, camphor laurel, coconut, turmeric, African oil palm, cardamom, ginger. In Laos, *Musa acuminate* (Cavendish banana) and *M. sapientum* (Kuay Nam)
Distribution	Asia (Laos, Thailand, India), Papua New Guinea, Japan and Maldives (PestNet, 2007). In Laos, banana lace wing bugs were first recorded in Sedone and Paksong districts in 2007 (Guilbert. E, 2007). Bolikhamxay and Saravan provinces based on field study.
Monitoring infestation (Where to find them)	Pyrethroid (mosquito spray) can be sprayed on banana leaves where lace wing bug has been detected.
Control	<u>Cultural:</u> Manual cleaning, smoking and crop rotation ((Aguilar, Zapico, Namocatcat, Fortich, & Bojadores, 2014) <u>Biological:</u> Potential predators: spiders, lady bugs, praying mantis and earwigs (Aguilar et al., 2014) <u>Chemical:</u> Unknown In Laos, before employing chemicals, check the pesticide regulations and permitted uses.
Further information and enquiries	Please contact Plant Protection Centre, Department of Agriculture, MAF. Thadeua Rd, Km 13 Vientiane, Lao PDR Tel, Fax: (+856) 21 812164

CHAPTER 5: A comparison of sampling methods for banana pest management

5.1 Abstract

Monitoring insect pests is important for pest management in banana production. In this study, two classes of sampling methods were tried: sampling on specific banana plants and opportunistic sampling of non-selected banana plants and surrounding vegetation. The four types of sampling techniques used to collect insects from banana plants were: pyrethroid spray, sticky traps, visual scan and pitfall traps. The three types of opportunistic sampling used were; scanning (direct observation), observation of cut stems and sweep netting. The sampling was conducted in two provinces, Bolikhaxay and Saravan in the dry season of 2012. All specimens were identified to order and family level and some could be identified to the species level. The 2 952 examined samples included nine taxa recognized as banana pests according to the combination of this survey and previous references (Chapter 6). These were *Odoiporus longicollis*, Acrididae, *Stephanitis typica*, Chrysomelidae, *Basilepta subcostata*, Tephritidae, *Cosmopolites sordidus*, *Erionota thrax* and *Bactrocera dorsalis*. Although detection of known pest taxa varied significantly across different sampling methods, they formed only a small proportion of the total abundance of insects collected. Sampling by observation of cut stems was more likely to detect *O. longicollis* and *C. sordidus* than other types of pests. Scanning methods showed a bias towards detecting Acrididae, Chrysomelidae and *B. subcostata*. Sampling using pyrethroid spray was more likely to yield *Stephanitis typica* on the banana plant and Tephrititidae were more easily caught on sticky traps.

5.2 Introduction

Banana is an important crop in Laos as the country has been moving toward larger banana plantations for export (Douangphrachanh, 2007). Increasing availability of this food source for insects may lead to increased and perhaps unprecedented outbreaks of banana-specific pests (Risch, 1981). Only two previous studies have reported banana pests in Laos. These were written by Dean (1978) and Waterhouse (1993). The most common pests reported by Dean were Coleoptera; *Cosmopolites sordidus* (root borer weevil), *Odoiporus longicollis* (banana stem borer), *Sphaeroderma veripennis*, *Sphaeroderma* spp. Lepidoptera; *Erionota thrax* (banana skipper), *Gangara thyrsis* (giant redeye skipper), Hemiptera; *Parasaissetia nigra* (scale), Orthoptera; *Hieroglyphus banian* (rice grasshopper), *Patanga succincta* (locust). Waterhouse (1993) listed pest records from Southeast Asia. Among 22 species, five were considered as major pests of banana in Laos. These were Lepidoptera; *Erionata thrax*, *Spodoptera litura* (Army worm), Orthoptera; *Nomadacris succincta* (*Patanga succincta*), Diptera; *Bactrocera dorsalis* (fruit fly) and Hemiptera; *Pentalonia nigronervosa* (aphid). Choice of sampling method is important for the surveillance and detection of pests. This is necessary to provide estimates of insect population sizes and is a fundamental aspect of integrated pest management (IPM) (Department of Agriculture and Fisheries, 2010; Mo & Baker, 2004). Several kinds of sampling approaches for arthropods have been mentioned but it remains unclear which should be preferred (Yi, Jinchao, Dayuan, Weiguo, & Axmacher, 2012). Different insect species may be restricted to specific parts of a plant, so it is essential to employ sampling strategies to match (Southwood & Henderson, 2000).

Sampling methods might include direct collection from leaves or soil, canopy fogging, pitfall traps, sticky traps and other traps to attract a wide range of arthropods. Scanning or observation methods involve searching for insects in different parts of plants. Although not a good method for bulk collection, direct observation allows collectors to study insect behaviour and life-cycles while hand-picking or searching around the tree (Upton, 1991). Examples of this approach include root sampling for the occurrence of banana weevil in Cameroon (Fogain, 2001) and of weevils in Kenya (Muasya, Njau, Mwangi, Gathu, & Mbaka, 2011).

Sweep nets or aerial nets are commonly used for collecting insects resting on vegetation or on the ground (Upton, 1991). Sweep net use is most effective at catching insects flying around upper levels of vegetation, provided this is not too dense. This technique is simple and portable, permitting collection of many samples from different locations. However it is not as effective in wet weather. It also requires much time, a high energy expenditure by collectors and good visual acuity (Leather, 2008). Yi *et al*. (2012) mentioned that sweep nets are commonly used for sampling butterflies or flying insects in open areas rather than in dense forest, as well as around low vegetation or small bushes and shrubs. Netting and beating of the stem were evaluated for collection of Curculionoidea in New Delhi (Tara, Sharma, & Kour, 2010), grasshopper biodiversity in Pakistan (Gul-e-Shadab, Nawaz, Nawaz, & Asmathullah, 2010), patch structure for grasshopper abundance (Kemp, Harvey, & O'Neill, 1990) and grasshoppers by sweeping rate in Nebraska (Whipple, Brust, Hoback, & Farnsworth-Hoback, 2010).

Pitfall traps target crawling insects and those that walk on the substrate, as well as wingless moths (Upton, 1991). Pitfall trapping is a well-tried and simple approach. In forest conditions, pitfall traps commonly catch coleopteran groups, hymenopterans, spiders and other predators (Leather, 2008). This method can be used to monitor flightless pests (such as root weevil adults). Pitfall traps are cheap, easy to make and easy to install. Preservative liquids, often containing a small amount of detergent to prevent surface-film effects, are usually added to pitfall containers. Pitfall traps have been used for evaluation of attractants to sugarcane borer in Florida (Giblin-Davis, Peña, & Duncan, 1994), for estimation of abundance and diversity of soil arthropods in Portugal (Santos, Cabanas, & Pereira, 2007), of the abundance of crickets and slugs in Australia (Melbourne, Gullan, & Su, 1997) and of occurrence of Carabidae in Minnesota (Epstein & Kulman, 1990; Lang, 2000).

Sticky traps carry sticky glue on their surfaces to catch insects. They are used to capture blown and flying insects, and those climbing stems. These kinds of traps are economical and useful for measurement of movement and colonization. A disadvantage is that the sticky substance cannot be dissolved. Parts of some fragile insects may be lost or damaged, making identification more difficult (Leather, 2008). In addition, traps must be left in place for several days (Yi et al., 2012). Sticky traps are commonly used for capture of pests. Many papers mention the use of this technique for capture of psyllids, citrus pests in Florida (Hall, Sétamou, & Mizell Iii, 2010), whitefly and thrips monitoring (Broughton & Harrison, 2012), fruit fly in Taiwan (Chuang et al., 2014). Such traps have also been used to effect the capture of *Chaetocnema pulicaria*, Chrysomelidae in Iowa (Esker, Obrycki, & Nutter, 2004) and forest arthropods in Papua New Guinea (Bar‐Ness et al., 2012).

Aerosol spraying and fogging using insecticide is an excellent way to collect insects on vegetation. Insects are collected when they fall onto the ground sheet placed under the target plants (Upton, 1991). The method is very rapid, but can only be used in still, dry weather (Leather, 2008). Southwood *et al.* (1982) studied abundance of arboreal insects using this method. Beetle diversity in cacao plantations in the north-east of Borneo, Indonesia, was evaluated using this method (Bos, Steffan-Dewenter, & Tscharntke, 2007).

Knowledge of banana pests in Laos is limited. Rice is the only major crop species in the country to have received attention in this regard (Heong, Escalada, Sengsoulivong, & Schiller, 2002; Saito et al., 2006). Most of the available information is based on government reports relating to specific areas. Therefore, the object of this study is to examine the different types of sampling methods that are suitable for the detection and study of banana pests in Laos.

5.3 Methods

Sampling locations

Sampling of insect pests of bananas was conducted in three districts of two provinces (Bolikhamxay and Saravan) in Laos in February and March 2012. The three districts are Pakxane (18 °25'43.4"N, 103° 42'47.5"E, 155 m.a.s.l) and Pakkading (18°14'30.2"N,104°12'42.3"E, 168 m.a.s.l) in Bolikhamxay province, and Lao-gnam district (15°29'35.5"N, 106°09'23.8"E, 505 m.a.s.l) in Saravan province (see Chapter 4). These are the main areas of banana production in Laos.

Two classes of methods were used in the sampling: sampling on banana plants and opportunistic sampling of non-selected banana plants and surrounding vegetation. Sampling on banana plants used pitfall traps, scanning (observation), sticky traps and knock-down pyrethroid sprays. These four sampling types on banana plants were used to detect the presence of known insect pests. At each of 22 banana farms across two provinces, ten banana plants were selected that looked weak and therefore may have had numbers of insect pests on them (Table 1). All specimens were stored in labelled ethanol vials after sampling.

Pitfall traps were set up near the base of the plant. This was done for 10 traps x 12 farms x 2 provinces. Insect specimens were collected after two days by removing the traps from the ground and pouring the contents onto a tray with cotton filter sheet for draining water out. The insect specimens were stored in ethanol vials and labelled.

Visual observation or scanning of individual banana trees was used to search for pests on leaves, branches and around the tree. This was done for 10 plants x 20 farms and 30 plants x 2 farms across two provinces. Old leaves were removed and any signs of insect damage to the plant were noted. A sweep net was used to collect insects on leaves from the plant.

Sticky traps were wrapped around the pseudostems of the selected plants about one metre above the ground and left for two days: 10 traps x 20 farms and 30 traps x 2 farms across two provinces.

Knock-down pyrethroid sprays were used on banana leaves. This was done for 10 plants x 20 farms and 30 plants x 2 farms across two provinces. The insecticide used contained prallethrin 0.1% w/w and permethrin 0.1% w/w. Two plastic sheets (1 x 5 m) were spread out on the ground around the base of the tree. The pyrethroid then was sprayed on and under the banana leaves. After about five minutes, the pseudostem was shaken to dislodge dead insects.

Opportunistic sampling involved general scanning surrounding the banana plants and vegetation, and destructive searching for pests by dissecting old, decayed pseudostems and corms close to the plants selected for sampling and elsewhere in the farms. In addition, a sweep net was used to collect insects on leaves and on the ground under banana plants. This method depended on the availability of decayed, fallen, and harvested pseudostems in the farms and occupied less time than on-plant sampling. Numbers of insects detected using this method ranged from 22, 77 and 78 respectively in the two provinces.
Statistical analysis: The relationship between the known-pest presence and absence based on trap type sampling methods was analysed using logistic regression in S-Plus statistical software (TIBO software Inc, 1997).

Table 5.1: Summary of sampling methods indicating numbers of samples collected from each location and using each method

	Bolikhamxay Province										Saravan Province												
	Pakxan District					Pakkading district					Lao-ngam D. Area1						Lao-ngam D. Area2						
	Farm					Farm					Farm						Farm						
	#1	**#2**	**#3**	**#4**	**#5**	**#6**	**#7**	**#8**	**#9**	**#10**	**#11**	**#12**	**#13**	**#14**	**#15**	**#16**	**#17**	**#18**	**#19**	**#20**	**#21**	**#22**	**Total**
Sampling on selected banana plants																							
Pitfall	10			10	10	10		10		10	10	10				10	10		10			10	**120**
Spray	30	10	10	10	10	30	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	**260**
Sticky	30	10	10	10	10	30	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	**260**
Scan	30	10	10	10	10	30	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	**260**
Plants not sampled	30	10	10	10	10	30	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	**260**
Opportunistic sampling of non-selected banana plants and surrounding vegetation																							
Scan	4	3	9		4	13	2		6	1	8	7	5	4	3	4		2	1	1		1	**78**
Sweep netting	2	2		1		1			1		2	4	2	2	3		1	1					**22**
Observation of cut stem	8	1	6	1	1	6	5	2	5	3	2	6	4	2	3	2	3	2	3	6	4	2	**77**
Number of plants sampled																							**177**

5.4 Results

This section provided the analysis of insect taxon collected using different sampling methods at all locations.

A total of 2 952 insect samples were examined. Of these, 1 200 specimens belonged to the order Diptera (40.7%), 906 to the order Coleoptera (30.7%) and 343 to the order Hemiptera (11.6%) (Table 5.2). The summary result of sampling methods is provided in Table 5.1.

Table 5.2: Insect orders ranked by level of representation in the collected samples (all capture methods at all locations).

Rank	Taxon	Number	Cumulative Number	Percentage (%)	Cumulative percentage (%)
1	Diptera	1200	1200	40.65	40.65
2	Coleoptera	906	2106	30.69	71.34
3	Hemiptera	343	2449	11.62	82.96
4	Orthoptera	172	2621	5.83	88.79
5	Hymenoptera	146	2767	4.95	93.73
6	Thysanoptera	124	2891	4.20	97.93
7	Lepidoptera	54	2945	1.83	99.76
8	Dermaptera	5	2950	0.17	99.93
9	Neuroptera	1	2951	0.03	99.97
10	Mantodea	1	2952	0.03	100.00
	Total	2952			

The recognized pest species of banana were not ranked among the most abundant insects recovered during sampling. *Odoiporus longicollis* was the highest-ranked pest (number 15) and comprised 2.07% of the total number of insects caught (Table 5.3, Figure 5.1).

Table 5.3: Insect taxa ranked by abundance (all capture methods at all locations). The "top 20" insects are listed including four recognized pest species (in bold). The remaining recognized pest species detected in this study are listed for information, including their ranking.

Rank	Taxon	#	Cumulative #	Percentage (%)	Cumulative %
1	Diptera a	241	241	8.16	8.16
2	Diptera a.1	179	420	6.06	14.23
3	Diptera x2	151	571	5.12	19.34
4	Hemiptera Miridae	147	718	4.98	24.32
5	Diptera j	147	865	4.98	29.30
6	Hymenoptera Formicidae	145	1010	4.91	34.21
7	Diptera m	140	1150	4.74	38.96
8	Coleoptera Cleridae	130	1280	4.40	43.36
9	Coleoptera h	122	1402	4.13	47.49
10	Thysanoptera Phlaeothripidae	120	1522	4.07	51.56
11	Coleoptera m	104	1626	3.52	55.08
12	Orthoptera Gryllidae	96	1722	3.25	58.33
13	Coleoptera c	79	1801	2.68	61.01
14	Diptera b	67	1868	2.27	63.28
15	**Coleoptera Curculionidae *Odoiporus longicollis***	**61**	**1929**	**2.07**	**65.35**
16	***Orthoptera Acrididae***	**59**	**1988**	**2.00**	**67.34**
17	**Hemiptera Tingidae *Stephanitis typica***	**55**	**2043**	**1.86**	**69.21**
18	Coleoptera g	52	2095	1.76	70.97
19	Diptera_h	46	2141	1.56	72.53
20	Coeloptera_Chrysomelidae	44	2185	1.49	74.02

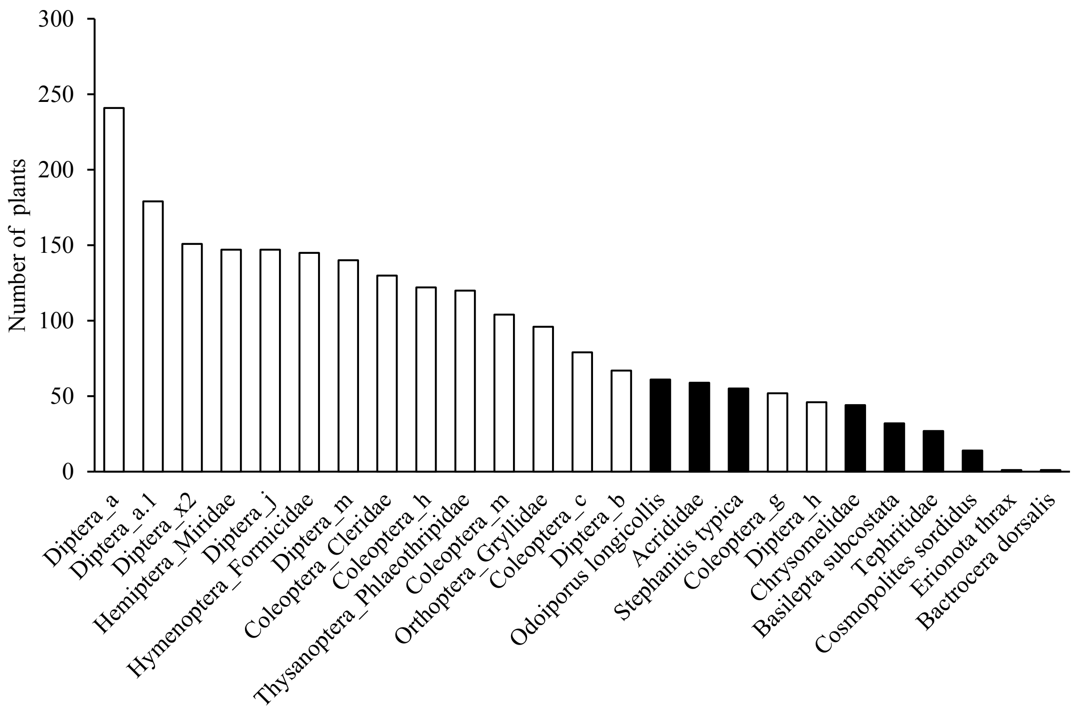


Figure 5.1: Insect taxa ranked by abundance. Data includes all sampling methods. Known pest species are indicated by black columns.

Pest species detectability is significantly influenced by sampling type (Logistic regression: deviance = 207.8572, df = 6, $P < 0.001$, Table 5.4, Figure 5.2).

Table 5.4: Comparison of different sampling methods for catching the nine known pest species (recorded as either present or absent).

All sampling methods								
	Banana sample				**Opportunistic sample**			**Total**
	Spray	**Sticky**	**Scan**	**Pitfall**	**Scan**	**Observation of cut stem**	**Sweep netting**	
Present	57	108	27	12	22	65	3	294
Absent	203	152	233	108	56	12	19	783
Total of plants	260	260	260	120	78	77	22	1077

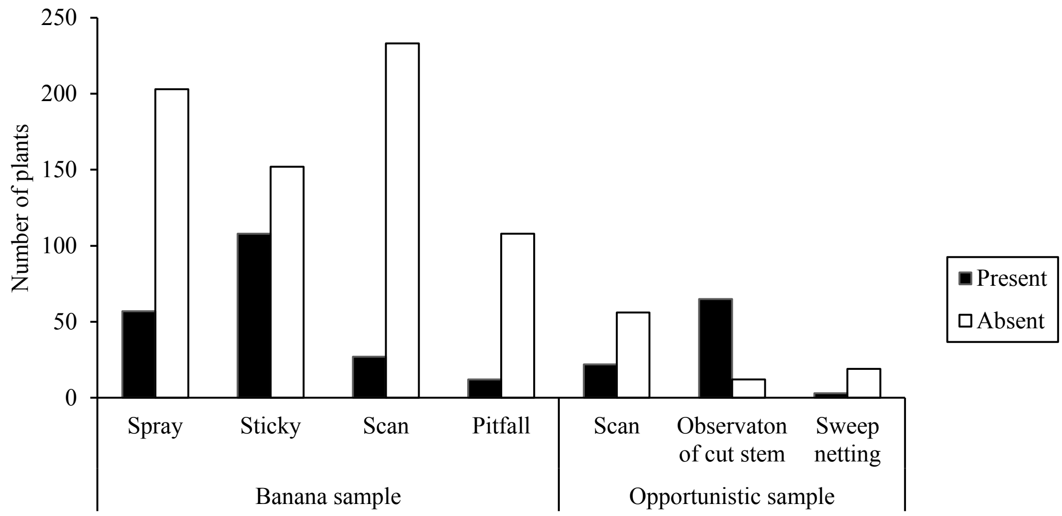


Figure 5.2: A comparison of the ability of different sampling methods to detect the nine known pest species of banana.

Sticky trap sampling was the method most likely to detect any of the nine known pests. Observation of cut stems (an opportunistic method) occupied second place and spraying was in third place.

Most of the known pests were found when sampling on banana plants rather than by opportunistic sampling. These pests were *Stephanistis typica*, Acrididae (short-horn grasshopper), Chrysomelidae (leaf beetle), *Basilepta subcostata*, Tephritidae (fruit fly) with total numbers detected by sampling on banana plants being 55, 45, 38, 29 and 26 respectively. On the other hand, *O. longicollis* and *C. sordidus* were more highly represented in opportunistically collected samples (Figure 5.3, Table 5.5).

Table 5.5: A comparison of the numbers of specimens of known pests of bananas detected on banana plants using opportunistic sampling methods.

Overall rank	Taxon	Banana sampling	Opportunistic sampling
15	*Odoiporus longicollis*	8	53
16	Acrididae	45	14
17	*Stephanitis typica*	55	0
20	Chrysomelidae	38	6
22	*Basilepta subcostata*	29	3
27	Tephritidae	26	1
38	*Cosmopolites sordidus*	2	12
106	*Erionota thrax*	0	1
139	*Bactrocera dorsalis*	1	0
	Total	204	90

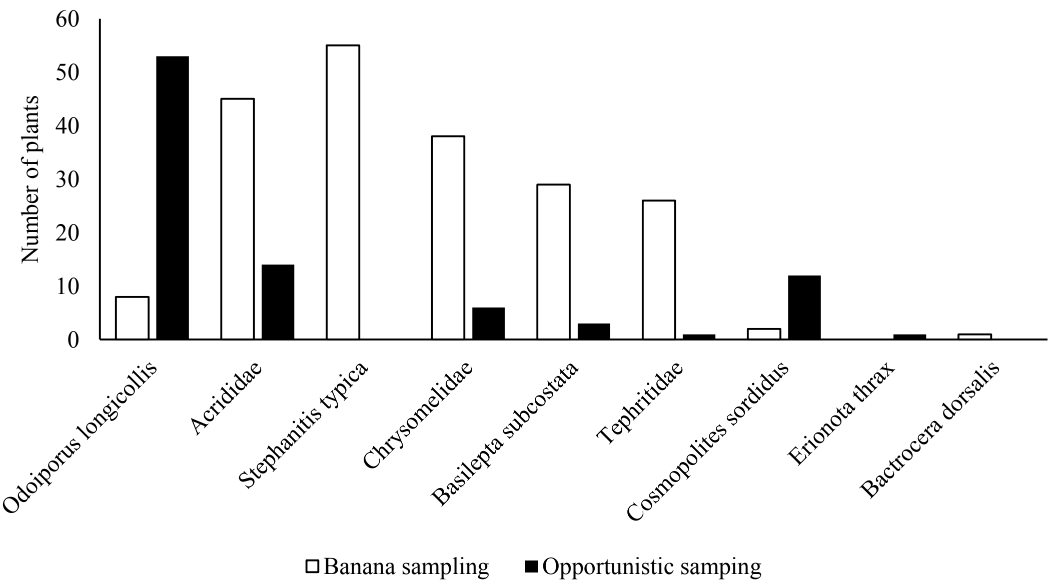


Figure 5.3: A comparison of the numbers of plants in which specimens of known pests of bananas were detected using sampling on banana plants or opportunistic sampling methods.

The following section provides detailed analysis on the detection probabilities of the nine recognized insect pests and the various sampling methods used.

5.4.1 *Odoiporus longicollis*

The influence of sampling type on the detectability of the pest species *Odoiporus longicollis* is shown for sampling on banana plants and for opportunistic sampling in Figures 5.4 and 5.5.

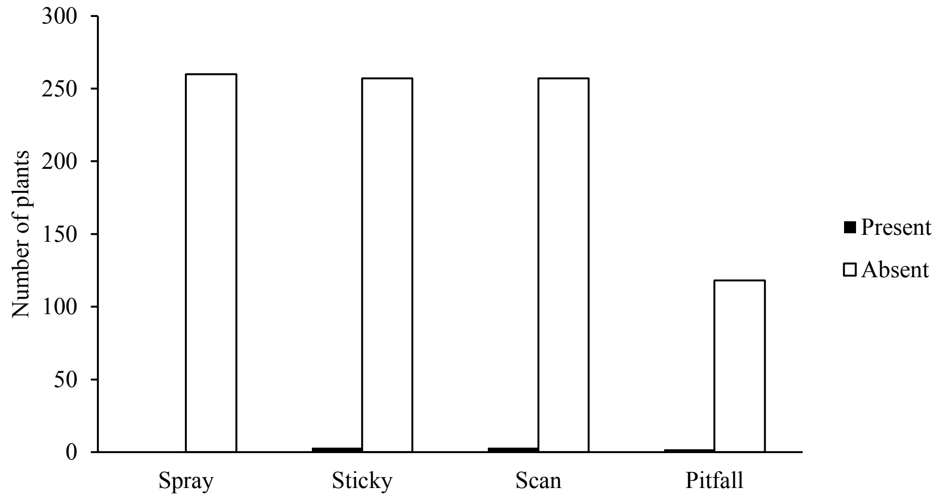


Figure 5.4: The number of targeted banana plants sampled using the spray, sticky trap, scan or pitfall methods that contained *Odoiporus longicollis.*

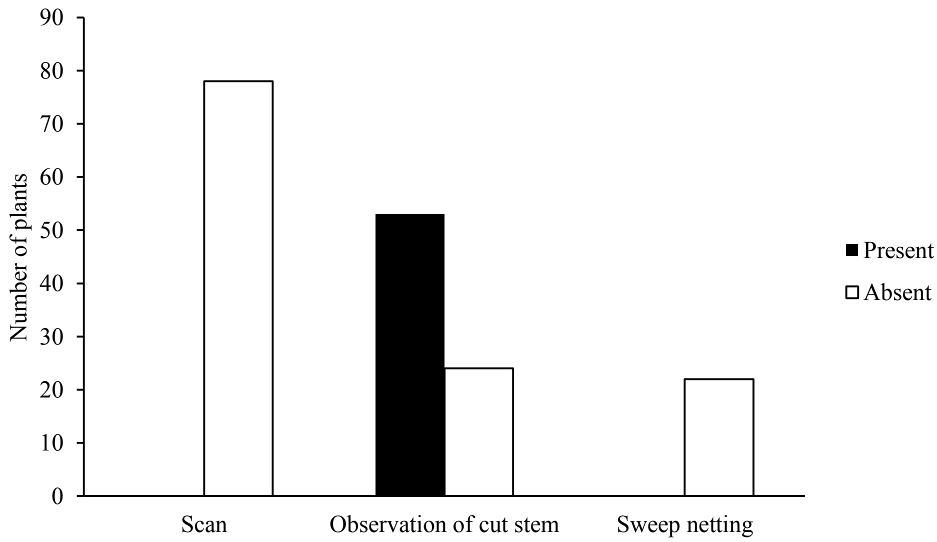


Figure 5.5: The numbers of plants sampled opportunistically, using the scan, observation of cut stem and sweep netting methods, which contained *Odoiporus longicollis.*

Odoiporus longicollis detectability was not significantly influenced by sampling type when sampling on banana plants (logistic regression, deviance = 5.6767, df = 3; P = 0.1284), but was significantly influenced by sampling type in opportunistic sampling (logistic regression, deviance = 120. 5277, df = 2; P <0.001). This result was influenced by the bias of the scanning cut method in opportunistic sampling towards detection of *O. longicollis*; 69% of specimens of this species were obtained in this way.

5.4.2 Acrididae

The influence of sampling type on the detectability of the pest species *Acrididae* is shown for sampling on banana plants and for opportunistic sampling in Figures 5.6 and 5.7.

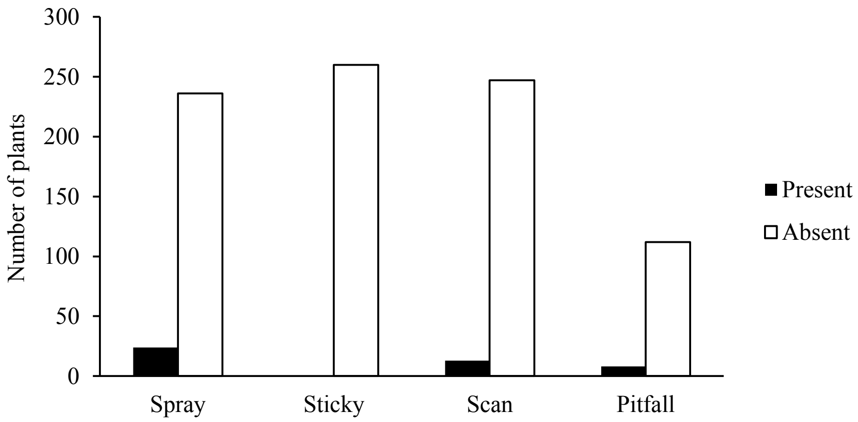


Figure 5.6: The numbers of targeted banana plants sampled using the spray, sticky trap or pitfall method that contained Acrididae.

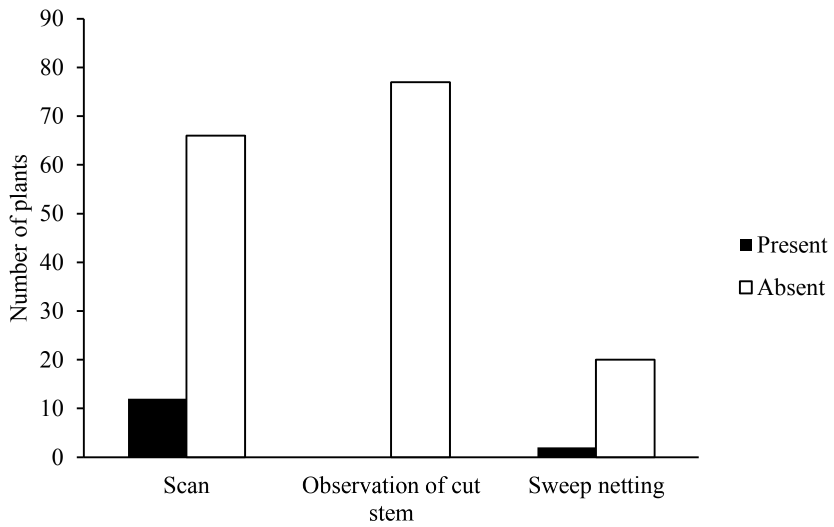


Figure 5.7: The numbers of plants sampled opportunistically using the scan, observation of cut stem and sweep netting methods that contained Acrididae.

In the case of Acrididae, there were highly significant differences among sampling methods in numbers of samples that contained this taxon (logistic regression, deviance = 35.2370, df = 3; P <0.001). Among the opportunistic methods, significant differences also occurred (logistic regression, deviance = 17.4859, df = 2, P < 0.001). Fifteen percent of the scan samples contained Acrididae. Among sweep netting and spray samples, 9% contained this taxon.

5.4.3 *Stephanitis typica*

The influence of sampling type on the detectability of the pest species *Stephanitis typica* is shown for sampling on banana plants and for opportunistic sampling in Figures 5.8 and 5.10.

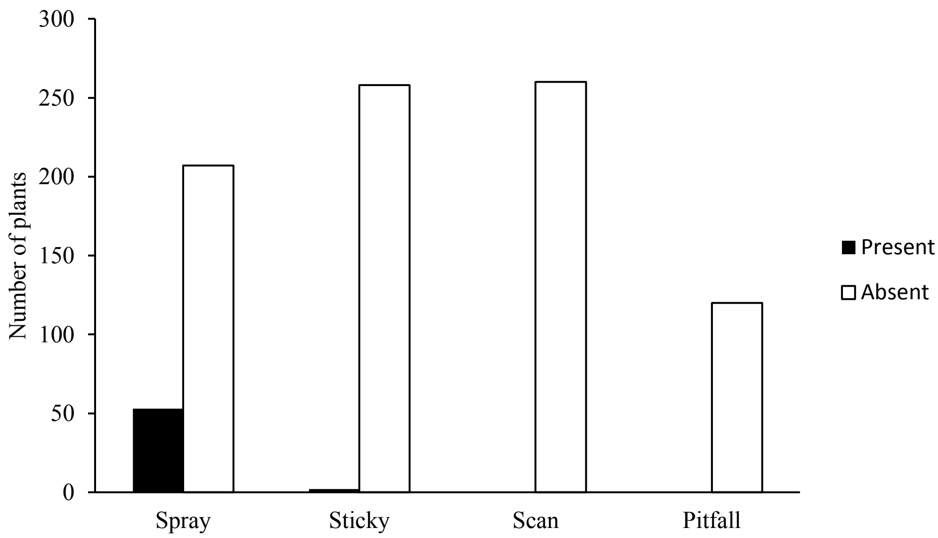


Figure 5.8: The numbers of targeted banana plants sampled using the spray, sticky trap, scan or pitfall method that contained *Stephanitis typica.*

The proportions of samples on banana plants containing *Stephanitis typica* differed according to the sampling method used (logistic regression, deviance = 127.6124, df = 3; P <0.001). Twenty percent of samples obtained using pyrethroid spray contained this species, but representation was very low among samples obtained in other ways.

Stephanitis typica were not detected using opportunistic sampling techniques.

5.4.4 Chrysomelidae

The influence of sampling type on the detectability of the pest species *Chrysomelidae* is shown for sampling on banana plants and for opportunistic sampling in Figures 5.9 and 5.10.

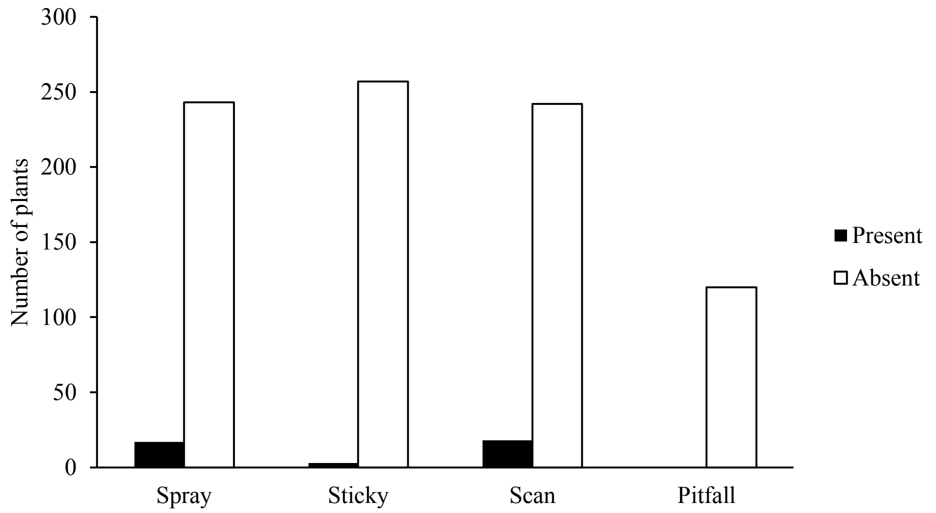


Figure 5.9: The numbers of targeted banana plants sampled using the spray, sticky trap, scan or pitfall method that contained Chrysomelidae.

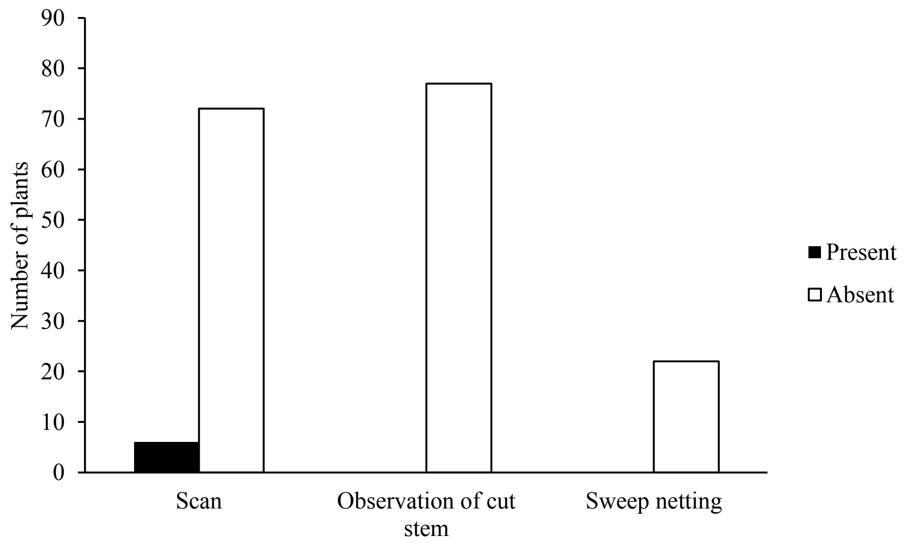


Figure 5.10: The numbers of plants sampled opportunistically using the scan, observation cut stem and sweep netting methods that contained Chrysomelidae.

The proportions of samples containing Chrysomelidae varied significantly with sampling method on banana plants (logistic regression, deviance = 25.7077, df = 3; $P < 0.001$) and for opportunistic sampling (logistic regression, deviance = 10.1014, df = 2; $P < 0.01$).

Although detectability was low, scanning methods (both on banana plants and opportunistic) were the best for finding chrysomelids, which were present in about 7% of both kinds of samples.

5.4.6 *Basilepta subcostata*

The influence of sampling type on the detectability of the pest species *Basilepta subcostata* is shown for sampling on banana plants and for opportunistic sampling in Figures 5.11 and 5.12.

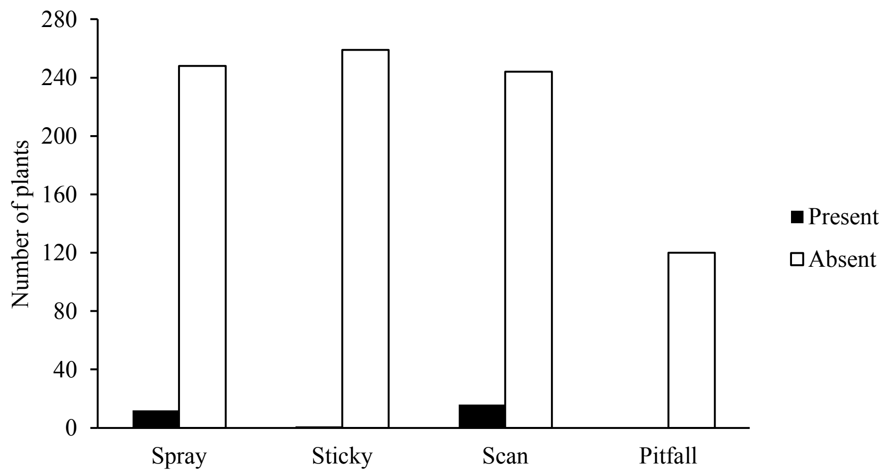


Figure 5.11: Numbers of targeted banana plants sampled using the spray, sticky trap, scan or pitfall method that contained *Basilepta subcostata.*

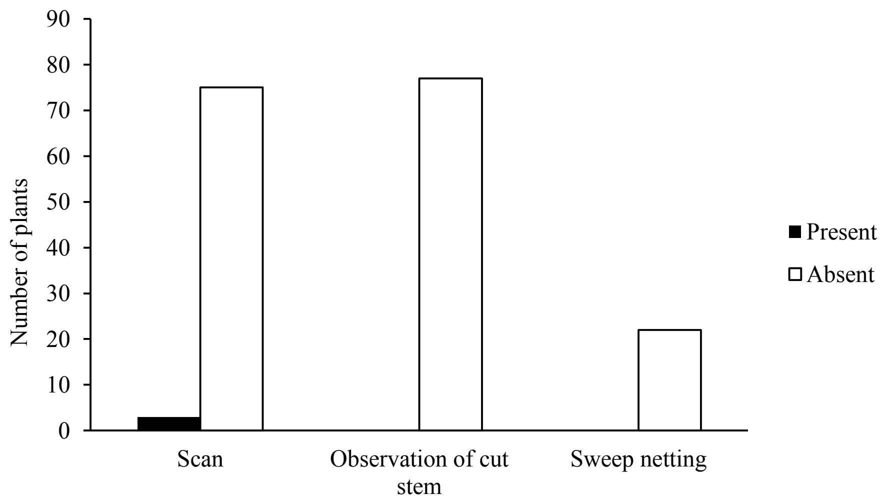


Figure 5.12: Numbers of plants sampled opportunistically using the scan, observation of cut stem and sweep netting methods that contained *Basilepta subcostata.*

Proportions of samples containing *Basilepta subcostata* varied significantly among methods for sampling on banana plants (logistic regression, deviance = 25.7040, df = 3; $P < 0.001$) but not for opportunistic sampling (logistic regression, deviance = 4.982401, df = 2; $P = 0.0828$).

Basilepta subcostata was much more likely to be detected by sampling on banana plants rather than opportunistic sampling. Although present in few samples, scanning or observation methods were the most likely to detect this species.

5.4.7 Tephritidae

The influence of sampling type on the detectability of pest *Tephritidae* is shown for sampling on banana plants and for opportunistic sampling in Figures 5.13 and 5.14.

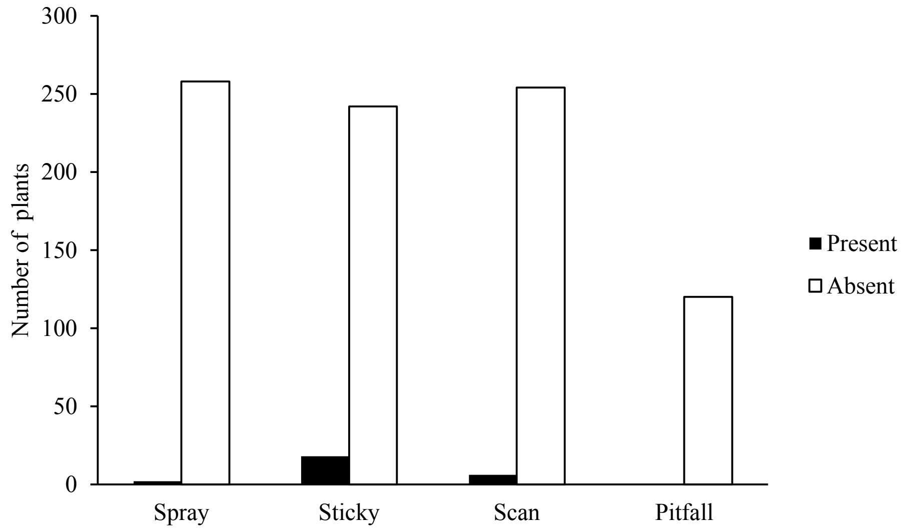


Figure 5.13: The numbers of targeted banana plants sampled using the spray, sticky trap, scan or pitfall method that contained Tephritidae.

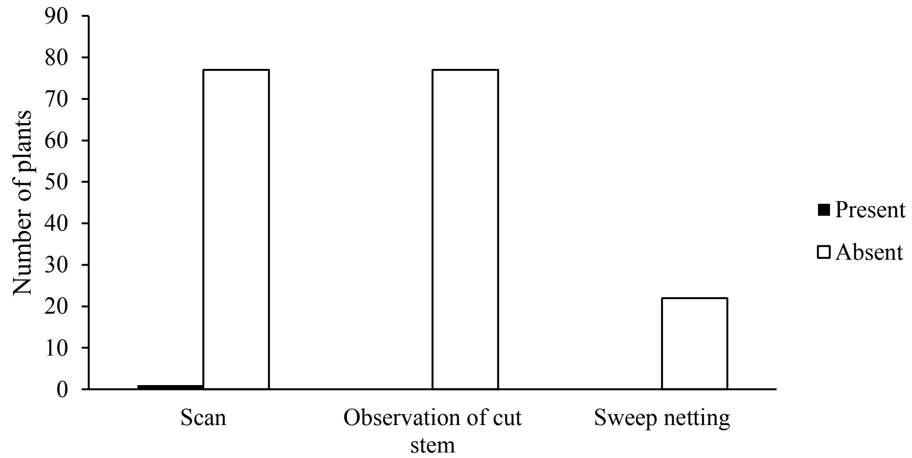


Figure 5.14: The numbers of plants sampled opportunistically using the scan observation of cut stem and sweep netting methods that contained Tephritidae.

The proportions of samples on banana plants containing Tephritidae varied significantly with sampling method (logistic regression, deviance = 24.1476, df = 3, P <0.001), but not for opportunistic sampling (logistic regression, deviance = 1.6460, df = 2, P = 0.4390). Sticky traps were most successful, with 6% of these yielding tephritids.

5.4.8 *Cosmopolites sordidus*

The influence of sampling type on the detectability of the pest species *Cosmopolites sordidus* is shown for sampling on banana plants and for opportunistic sampling in Figures 5.15 and 5.16.

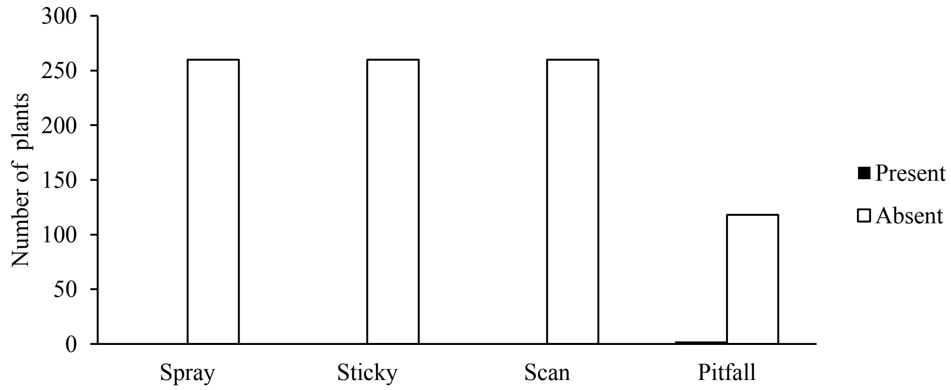


Figure 5.15: The numbers of targeted banana plants sampled using the spray, sticky trap, scan or pitfall method that contained *Cosmopolites sordidus.*

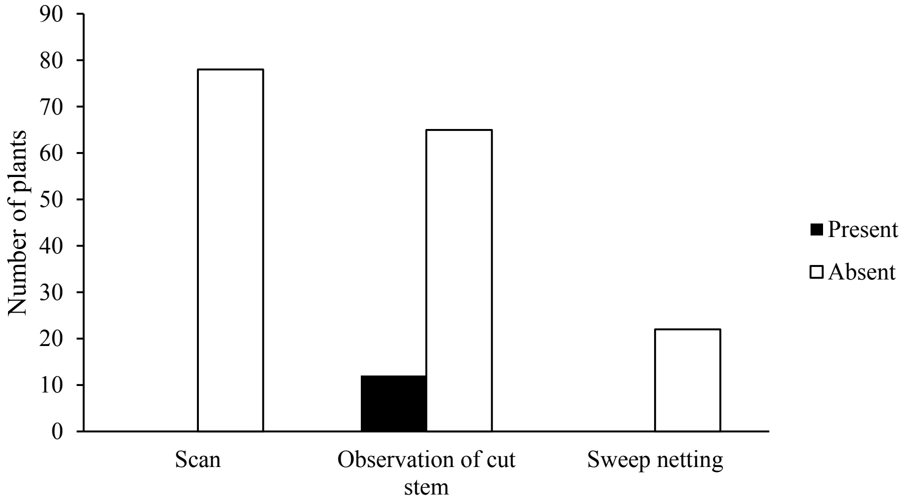


Figure 5.16: The numbers of plants sampled opportunistically using the scan, observation of cut stem and sweep netting methods that contained *Cosmopolites sordidus.*

The proportions of samples on banana plants containing *Cosmopolites sordidus* varied significantly with sampling method (logistic regression, deviance = 8.088648, df = 3; $P < 0.05$) and for opportunistic sampling (logistic regression, deviance = 21. 11931, df = 2; $P < 0.001$).

Although relatively small numbers were detected, *C. sordidus* was most likely to be caught in scanning cut samples from decayed pseudostems and corms (15% of samples contained this pest). In contrast, only 1% of pitfall traps contained this species.

5.8.9 *Erionota thrax* and *Bactrocera dorsalis*

The influence of sampling type on the detectability of the pest species *Erionota thrax* and *Bactrocera dorsalis* are shown opportunistic sampling in Figures 5.17 and 5.18 respectively.

The proportions of samples containing *Erionota thrax* (Figure 5.18) did not significantly differ according to sampling method for opportunistic sampling (logistic regression, deviance = 4.2107, df = 2; $P = 0.1218$).

For *Bactrocera dorsalis* (Figure 5.19) this was also the case of sampling on banana plants (logistic regression, deviance = 2.4861, df = 3; $P = 0.4777$). In each of these classes of sampling method, only a single sample contained this species.

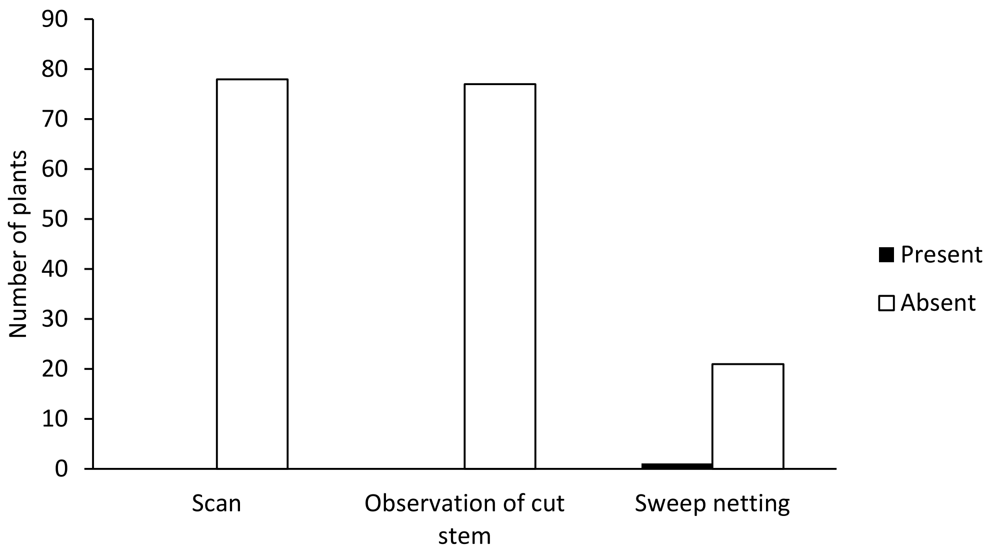


Figure 5.17: The numbers of plants sampled opportunistically using the scan, observation of cut stem and sweep netting methods that contained *Erionota thrax.*

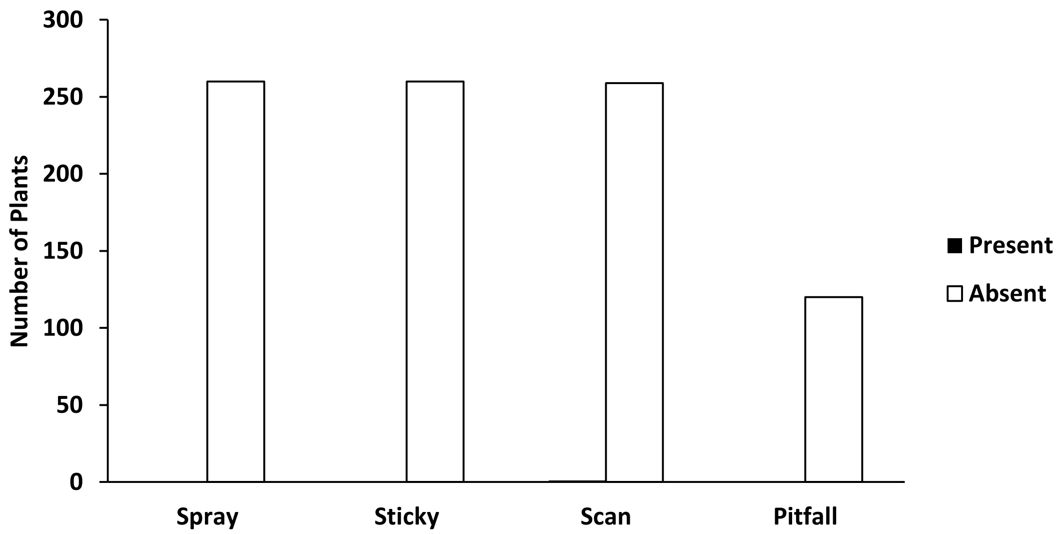


Figure 5.18: The numbers of targeted banana plants sampled using the spray, sticky trap, scan or pitfall method that contained *Bactrocera dorsalis.*

5.5 Discussion

Pest monitoring is vital prior to selecting appropriate management approaches. In this study, comparisons were made of the different sampling methods for capturing nine known pests of banana (Table 5.6).

Table 5.6: A summary of the best sampling method for detecting each of the nine banana pest species.

Overall rank	Taxon	The best sampling methods
15	*Odoiporus longicollis*	Observation of cut stem
16	Acrididae	Scanning (observation)
17	*Stephanitis typica*	Spraying
20	Chrysomelidae	Scanning
22	*Basilepta subcostata*	Scanning
27	Tephritidae	Sticky trap
38	*Cosmopolites sordidus*	Observation of cut stem
106	*Erionota thrax*	None
139	*Bactrocera dorsalis*	None

The sampling methods used in this study varied greatly in their efficacy in detecting different pests. Two species, *O. longicollis* and *C. sordidus* were best sampled using the rapid method of cutting pseudostems and corms. Life-cycle stages of borers, living inside the tissues of the banana tree, were best sampled by examination of roots (Azam, 2010; Fogain, 2001; Gold et al., 2002). This destructive approach depended on the availability of decayed, rotten and aged or falling-down pseudostems that were no longer capable of banana production. Furthermore, cutting and examining the decayed pseudostem was more likely to reveal that a rotten pseudostem acts as a natural olfactory attractant for borers and found that the most abundance of borer was between 4-8 weeks after cutting (Masanza et al., 2005), while Sahayaraj (2009) mentioned borers start being attracted to a decayed stem after 7 days of trap setting. The ability to detect borer may depend on many factors such as type of banana pseudostems, the pseudostem length, time of year, shading and soil moisture (Ogenga-Latigo, 1993; G. Reddy et al., 2008). Length of time after cutting a pseudostem might be important. Masanza *et al*. (2005)

found that the highest abundance of borer between 4-8 weeks after cutting, while Sahayaraj (2009) mentioned borers start being attracted to a decayed stem seven days after trap setting. Non-destructive methods, such as the use of the disc-on-stump approach with attractants such as pheromones and semiochemicals, are well studied, but tend to be time-consuming (Palanichamy, Padmanaban, Fazal Mohamed, & Mustaffa, 2011; Prasuna et al., 2008; G. Reddy et al., 2008; Gadi V. P. Reddy & Raman, 2011; Rhino, Dorel, Tixier, & Risede, 2010). Therefore, detection of banana borers in Laos depends on targeted sampling and the availability of materials for doing this. Cutting is a fast and inexpensive way to search for borers, especially on small farms. Non-destructive methods using attractants can be an option for monitoring. However, this may be costly and suppliers of attractants were not found locally.

Scanning or direct observation was the best way to detect Acrididae (grasshoppers), an important generalist and highly mobile pest taxon. Unlike previous studies, sweep net and spray were also reasonably successful at sampling acridids. Differences from previous studies may depend on location and vegetation types. These studies focused on biodiversity and occurrence of grasshoppers in Pakistan (Gul-e-Shadab *et al*. 2010), patterns of vegetation and grasshopper communities in the USA (Kemp *et al.* 1990) and sweep sampling for grasshopper in the USA (Whipple *et al.* 2010). In summary, observation around crops and surrounding habitats is the first step in grasshopper collection, followed perhaps by the use of the sweep nets. Further studies will be required to determine in the best sampling regime for estimating abundances of different grasshopper species.

Sampling using pyrethroid spray was the most likely to detect *Stephanitis typica* on the banana plant. The method was applicable for sampling insects on vegetation, as mentioned by Leather (2008). There have been no specific studies of the method for banana crops but other combination methods were mentioned in the Philippines where sweep netting, pitfall traps, flight interception traps and visual inspection were examined for the presence of *S. typica* and other banana pests (Aguilar *et al.* 2014). Although *S. typica* was recognized as a pest of banana plants in Laos, Thailand and the Philippines (Wongsiri 1991; Waterhouse 1993; Aguilar *et al*. 2014), most studied reported on this pest were on other crops especially coconut palm, ginger and turmeric. This pest is known to transmit coconut root wilt (Mathen & Kurain, 1980; Rekha & Sreekumar, 2004), and other potential diseases of ginger and turmeric (Patil, Thakur, & Mohalkar, 1988; Tigvattnanont, 1990). The spraying method is an appropriate option for detecting *S. typica* in Laos due to the availability of chemicals on the market. However, handling and using chemicals safely are important issues for environmental and human health. Furthermore, the height of banana trees and the rinsing action of rain are considerable problems when spraying.

Chrysomelidae comprise a large family of leaf-feeding beetles (Lawrence & Britton, 1991). These were best detected using scanning methods. Chrysomelids are pests of diverse crops. One identified species recently found to be an important pest in banana production in Laos was *B. subcostata* (scarring beetle). This report was based on internal and unpublished data from the agriculture sector and growers. Scanning methods remain the best option to detect them, especially on new leaves. There is very little literature on their biology, occurrence and pest status. Existing studies include one from India on *B. subcostata* populations (Ahmad *et al.* 2010) and the taxonomy of the Eumopinae subfamily for Laos, Thailand, Cambodia and Vietnam (Kimoto and Gressitt 1982). Searching on leaves, especially newly emerged leaves, was recommended. Although cheap, this is time-consuming, something that must be taken into account in any cost-benefit analysis.

In this study, Tephritidae were mainly caught on sticky traps. Nowadays, sticky traps tend not to be used widely to sample species such as the oriental fruit fly (Chuang *et al*. 2014). This is mainly because the glue damages specimens, hindering identification. The use of pheromone traps (Barclay & Hendrichs, 2014; Dhillon et al., 2005; Drew, 1989; Mararuai, 2010; Shelly, 2010) and traps containing artificial food or protein bait (ACISAI, 2010a; Pinero, Mau, & Vargas, 2009; Zhang, He, & Chen, 2014) is increasing. Although valuable in monitoring for banana pests, the cost of such traps limits their deployment in the case of small-scale farms in Laos.

Detection of two recognized pests, *E. thrax* and *B. dorsalis*, did not vary significantly according to method of sampling. However this was mainly due to their rarity. It is possible that abundances of these species fluctuate according to factors such as season, banana phenology, and their food foraging behaviour. In this study, surveys were done only during the dry season, a time when bananas are not growing rapidly. The majority of farms relied on rain for their banana production. Therefore, fruiting and vegetative growth are greatest in the wet season, and likely to enhance populations of fruit flies which feed on banana fruits and skippers (*E. thrax*).

Although the top nine key banana pest species presented in Chapter 4 were found during this study, it is notable that they did not score highly on a list of pest species ranked by the number of times they were found on banana farms (Table 5.3 and Figure 4.1). There are at least three possible reasons for this discrepancy. The first is that the survey results presented in this thesis were only carried out during a single season (dry season). Pests may be more abundant during the wet season. Extended sampling of banana pests over multiple seasons would provide further clarity and confirmation of appropriate sampling methods. The second is that the overall abundance of an individual species, even at a single period of time, may have little association with their ability to damage bananas over a longer term period such as an entire year. Thirdly different sampling methods (for both banana and opportunistic samples) were biased towards detecting both ‘known pest species’ as a whole (Table 5.4) and individual pest species. *Odoiporus longicollis* for example, were only ever associated with bananas using sticky, scan or pitfall traps (Table 5.6), and they were restricted entirely to ‘observation of cut stems’ as part of an opportunistic sampling approach. Similarly, *Stephanitis typica* were never detected with scan or pitfall traps as part of a banana sampling method: they were only found with spray and/or sticky methods. Sampling methods targeted more towards these nine key species may well have provided a greater detection probability, placing them higher on the list of pest species based on abundance alone.

CHAPTER 6: Farmers’ perceptions on banana pests and their influence on pest management

6.1 Abstract

A survey of farmers was conducted in Laos, between January and November 2012, in three provinces; Vientiane, Bolikhamxay and Saravan to investigate farmers' perceptions on banana pests and farm management. Most farmers fell into two age groups, 51-61 years old (27.7%) and 41-51years old (26.5%). More than half of the respondents had attended primary school (54.2%). Banana farms were typically small-scale, around 0.25 hectares (44.6% of total respondents). Farms were generally on land owned by the farmers themselves (95.2% of total respondents). The most common banana variety grown in their farms was Kuay Nam (KN), which was planted on about 51.7% of the total farm area. Farmers perceived that the main pest on their farms was *Erionota thrax* (approximately 44.8% of total respondents), while other significant pests causing economic losses included scarring beetle, thrips, fruit fly, grasshopper, termite, and unidentified diseases (56.3% of total respondents). Although farmers thought that major economic pests were present in their farms, more than half of the respondents (55.3%) did not try to control these pests. Of the farmers who applied any pest management strategies (44.7%), only a small number (18.4%) used chemicals for this, while the majority employed a variety of manual approaches. There was a relationship between the farm size and the type of pest management used by farmers in different locations. If the farm was larger than 0.75 ha, control methods were generally applied for unidentified disease and scarring beetle. Management of unidentified diseases and scarring beetle differed between the three provinces of Laos. Farmers in Bolikhamxay and Saravan provinces applied disease management on larger farms (>0.75-100 ha). In contrast, farmers in Vientiane province tended to control pests on smaller scale farms (0-<0.75ha). Scarring beetle management was applied on larger farms in Vientiane and Bolikhamxay provinces, but not in Saravan province. Farmers correctly recognized some banana pest taxa, but these were a subset of the probable pest taxa found during the farm sampling.

6.2 Introduction

Agricultural production is the main source of domestic products in the Lao People's Democratic Republic (Lao PDR), and contributed 18 021372 million Kip (about $3 billion AUD) towards GDP in the year 2011 (Lao Statistics Bureau, 2011). Agricultural land holdings cover a total of 1 047 700 ha (FAO, 2010). This is predominantly (80%) under rice production, because rice is the most essential staple food of the Lao people. Glutinous rice is the preferred variety, occupying 91% of the total area of rice production in 2003 (Douangphrachanh, 2007) and making up 80% of daily dietary intake (Appa Rao, Bounphanousay, Schiller, & Jackson, 2002). Other common crops, important for domestic and international markets, include coffee, tea, cardamom, banana, pineapple, tamarind, abaca, coconut, papaya, jackfruit, orange, mulberry, custard apple, longan, lemon and jujube (FAO, 2010). In the past, some of these crops, such as coffee, tea and banana, were commonly grown on small- scale farms scattered over the whole country. Nowadays, there have been increases in production of these crops, including banana on large plantations, which also export to different countries. The expansion of farming systems is supported by government policy to improve rural livelihoods, reduce poverty and enhance self-sufficiency. This reform strategy has increased production for export (Alexander, Millar, & Lipscombe, 2010; Ministry of Agriculture and Forestry, 1999). Banana has the potential to be a new commercial crop. A total harvest area of 755 ha was estimated in 1961, but this had expanded to 13 590 ha by 2005 (CABI, 2005; DOA, 2009). Investment in large-scale banana production for export to international markets has recently become attractive. Commercial-scale cultivation has occurred in Bolikhamxay, Bokeo and Phongsaly provinces (Douangphrachanh, 2007; DPI, 2012; Ministry of Agriculture and Forestry, 2010a; SDC, 2014).

Damage to crops by insect pests is a key problem worldwide, and the need to apply control measures that take into account the knowledge, perceptions and experience of farmers is well established (Gurung, 2003; Tefera, 2004; Van Mele, Cuc, & Van Huis, 2001). Farmers' perceptions of banana pest problems and management have been studied in the Philippines and Ghana (Aguilar et al., 2014; Schill, Afreh-Nuamah, Gold, & Green, 2000) and most of this research focused on pesticide use (Barraza et al., 2011; Polidoro et al., 2008). Farmers' knowledge of specific pests, especially root borer (Dahlquist, 2008) and stem weevil (Tiwari, Thapa, Gautam, & Shrestha, 2006) has also been investigated. Consumer perceptions of pests were the subject of a study by (Scriven & Seaman, 1990).

In Laos, farmers' perceptions of pests and their management, in particular integrated pest management (IPM), has been researched for the main crop foods, rice and vegetables (FAOIPM, 2008). Banana crops have not yet received much research attention. There is still a lack of adequate accessible information for banana pest recognition and management. To develop integrated and sustainable pest management, it is vital to have adequate information about farmers' perceptions and knowledge of banana pests and their management. Therefore, the aim of the survey was to provide information on how farmers perceive banana pests and factors which influence pest management.

This chapter presents information from field sampling of insects, farmers' perceptions and references that were available about Laos (Dean, 1978), Thailand (Wongsiri, 1991), Malaysia (Wahad, 2000), the Philippines (Aguilar et al., 2014), Southeast Asia (DF. Waterhouse, 1993);

CABI 2005), Australia (Pinese, 1994; Tenhaj, 2008), Pacific Islands (Nelson et al., 2006) and America (Gilman & Watson, 1994; Peno, 2006), many countries (Gold et al., 2002) and world pests of banana (Ostmark, 1974), to produce a list of key banana pest of Laos. This list is important because under the world trade legislation, trading partners are obligated to establish pest lists for any commodity to be imported or exported. No current list of banana pests exists in Laos. The list will help banana production management and planning for farmers as well as providing a basic tool that can be improved in the future.

6.3 Methods

6.3.1 Description of the study site and survey

The survey of farmers' perceptions of insect pests of banana was conducted in Laos. The data were collected from four districts of three provinces, namely Hadxayfong (17°48' 40"N, 120° 41' 44"E, 164 m.a.s.l) in Vientiane province, Pakxane (13 °25'43.4"N, 103° 42'47.5"E, 155 m.a.s.l) and Pakkading (18°14'30.2"N,104°12'42.3"E, 168 m.a.s.l) in Bolikhamxay province, and Lao-ngam district (15°29'35.5"N, 106°09'23.8"E, 505 m.a.s.l) in Saravan province. These are the main areas of banana production (Figure 6.1) (FAO, 2014). The interviews were carried out between January and November 2012, and involved a total of 83 farmers. Farmer selection was based on the field sampling of insect pests on their farms and their availability for interview. Individual farmers were interviewed for approximately 30-40 minutes, using the appropriate national language, and some farmers were addressed in the local dialect with the help of a translator. There were 25 questions and a set of pictures of the significant insect pests of banana plants (Figure 6.2), derived from the publication of Dean (1978). The images were obtained from available sources based on scientific names listed by Dean (1978) with the intention of helping farmers' recognition of pests. The survey was designed to obtain useful information about on farmer profiles, how farmers perceived the banana pests, and factors that influenced farmers' management of pests. Each question was summarized in terms of a percentage of responses, diagrams and tables.

Figure 6.1: Location of the three Provinces in Laos involved in the farm survey study.

6.3.2 Farmer Questionnaire

The following questionnaire and images along with Figure 54 were presented to farmers.

1. How long have you been living on this land and farming bananas?
   Are you the owner of this farm?
   Are you renting this farm?
2. How large is your banana farm?
3. What are the major pests of banana on your farm?
   (Refer to list of pictures Fig.6.2)
4. What is the most harmful pest on your farm that causes economic loss (through yield loss)?
5. Can you always identify which pest is causing damage to your crop?
   Yes, How?
   No, please describe the characteristics in general
6. What month do you find the most pests?
7. Have you noticed any particular parts of the tree being attacked more often? (fruit, leaf, trunk, corm)
8. How severely do major pests affect your crop?
   Level 1 low
   Level 2 moderate
   Level 3 high
9. What factors do you think contribute to high levels of pest damage on your farm?
   Rainfall
   Poor soil
   Weeds
   Age of tree
   Variety
10. Do you try to control them/it?
    Yes
    No (why?)
11. If yes, what practices do you employ to manage those pests?
    Manually
    Using chemical
    Others

12. If using pesticides, what are the names of chemicals and how are they applied?
13. Do you have access to sufficient labour for effective management of your crops?
14. How do you handle chemical spraying? (Do you use protective clothing)?
15. What is your highest level of education?
16. Do you talk to other banana farmers about how they manage their pests?
17. Do you talk to government representatives about how to manage your pests?
18. Where do you mostly learn about how to manage pests on your banana crops?
19. What varieties of banana do you grow in your farm and why did you choose them? (Please describe the different varieties of banana in relation to their use)
20. Where did you get the varieties? (Friends, government, market.)
21. Are different varieties of banana more or less susceptible to pests? (resistance, fewer pest)
22. If yes, why do you grow banana varieties that are susceptible to pests?
23. How many bananas do you get from the tree per year (seasons, times) or what average yield do you get from your farm per year?
24. Do you measure spacing before planting bananas? Yes, No

    If yes, what is the spacing between banana trees?

    If No, how do you estimate the spacing?
25. How old are you?

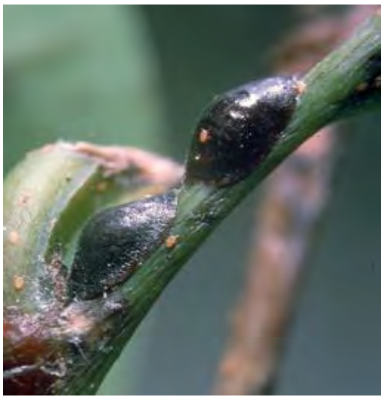
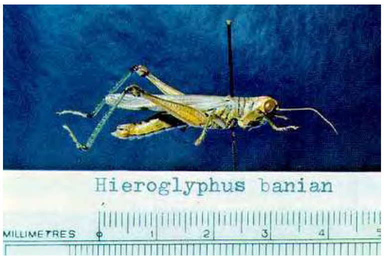
Names	Pictures	Sources of image
Parasaissetia nigra (Black scale)		http://www.forestryimages.org/browse/detail.cfm?imgnum=1263055 (Central Science Laboratory, 2008)
Hieroglyphus banian (Rice grasshopper)		http://ecoport.org/ep?SearchType=pdb&PdbID=2422 (Rice Diseases and Pest of Thailand, 2006)
Patanga succincta (Bombay locust)		http://www.thaibugs.com/?page_id=854 (Thaibugs, 2011)
Erionata thrax (Banana skipper, palm redeye skipper) (Larva)		http://www.starrenvironmental.com/resources/ (Forest Starr & Kim Starr, 2002)
Gangara thyrsis (Giant redeye skipper)		http://www.ifoundbutterflies.org/294-gangara/gangara-thyrsis-dp1 (Saji, Kunte, & Manoj, 2011)

Figure 6.2: List of target pests cited by Dean (1978) (with images from various sources).

Names	Pictures	Sources of image
Cosmopolites sordidus		(CABI, 2005)
Odoiporus longicollis		(CABI, 2005)
Sphaeroderma veripennis	See *Sphaeroderma* spp	
Sphaeroderma spp		(WCG, 2011)

Figure 6.2 (continued): List of target pests cited by Dean (1978) (with images from various sources).

6.3.3 The influences of farmers and farm characteristics on management of pests

Factors influencing farmers' pest management decisions were examined. These factors were gleaned from information concerning farm characteristics (e.g. farm size, banana variety used and plant spacing and location) and demographic details about the famers (e.g. age, length of time in farming and educational level reached).

The factors influencing pest management were analysed using S-Plus statistical software to assess the association between responses to questions (TIBCO software Inc, 1997). In particular, Fisher's exact test and logistic regressions were used for comparing two or more categorical variables. Simple linear regressions were conducted to determine relationships between farmer traits, farm characteristics and pest management.

6.3.4 The link between farmers' perceptions and field sampling

Farmers' knowledge of banana pests was compared to results from field sampling in Laos, which were presented in Chapter 5. The comparison was focused only on the known pest species.

6.3.5 The list of banana pest of Laos

The list of key banana pests was compiled by creating an overview table of banana pests derived from farmers' knowledge of banana pests (this Chapter), the results from field sampling in Laos (Chapter 5) and references relating to banana insect pests locally, regionally and globally. To this was added my own contribution of knowledge and experience of pest-species biology.

6.4 Results

The results are organized into three sections: (1) questionnaire interpretation, (2) influences of farm characteristics and farmer demographic features on pest management, and (3) comparison between farmers' perceptions and results from field sampling.

6.4.1 Questionnaire interpretation

A total of 83 respondents were interviewed; 46 respondents from Vientiane, 22 respondents from Saravan and 15 in Bolikhamxay province.

1. **How long have you been living on this land and farming bananas?**
   Are you the owner of this farm?
   Are you renting this farm?

The farmers generally responded to this question by providing the age of the current banana plantation, rather than the length of time they had been living on the farm. The largest class of respondents (36.1%) reported having farmed for four years. The second most frequent response was one (or less than one) year. This was because some farmers were new owners, and others had recently re-planted and were waiting for new shoots from the stool (Figure 6.3).

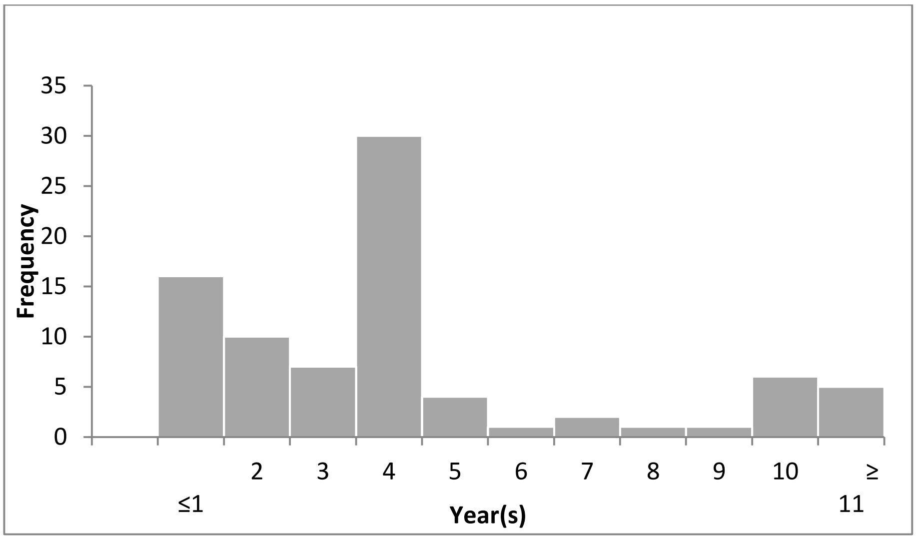


Figure 6.3: The length of time individuals have been banana farmers.

In most cases (79/83, ~95%), the land farmed belonged to the farmers. Remaining respondents were renting the land, or were the son or employee of the owner (Table 6.1).

Table 6.1: The ownership status of banana farmers.

Answer	Frequency	Percentage (%)	Cumulative percentage (%)
Owner	79	95.2	95.2
Foreign agriculture	1	1.2	96.4
Provincial Agriculture and Forestry Office	1	1.2	97.6
Renting	1	1.2	98.8
Son of owner	1	1.2	100.0
Total	83		

2. How large is your banana farm?

Farms varied in size from back-yard gardens to large-scale commercial cultivations. In general, smallholder farms are typical for banana production. Many respondents (44.6%) had banana cultivated areas less than or equal to 0.25 ha. Areas of 0.25-0.5 ha were the next commonest category (18.1%). Few respondents (2.4%) had farm sizes larger than 4 ha (Figure 6.4). This included the commercial farm, owned by the Banana Company, in Bolikhamxay province, which covers 100 ha.

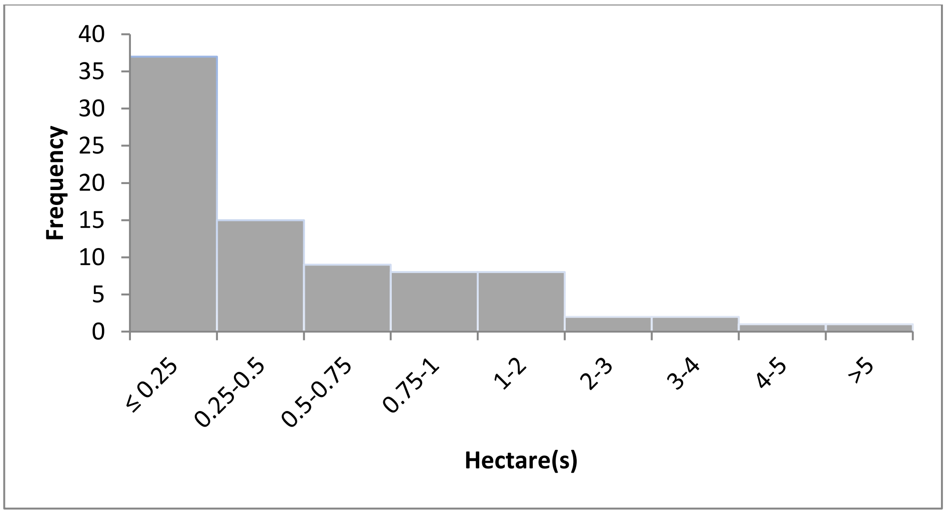


Figure 6.4: The size of banana farms.

3. What are the major pests of banana on your farm?

(Refer to lists of pictures shown in Fig. 6.2)

Respondents were asked the local name of the major pests on their farms. Insect pests mentioned by the respondents and that were not reported in Figure 6.2, were placed in the "Others" category. The most commonly reported pest (44.8% of respondents) was *Erionota thrax* (Group 1) while others (disease, scarring beetle, thrips, termite, fruit fly and grasshopper) were mentioned by 42.5% of total respondents (Group 2). Only 12.7% of respondents reported borer pests (*C. sordidus and O. longicollis*) on their farms (Group 3) (Figure 6.5).

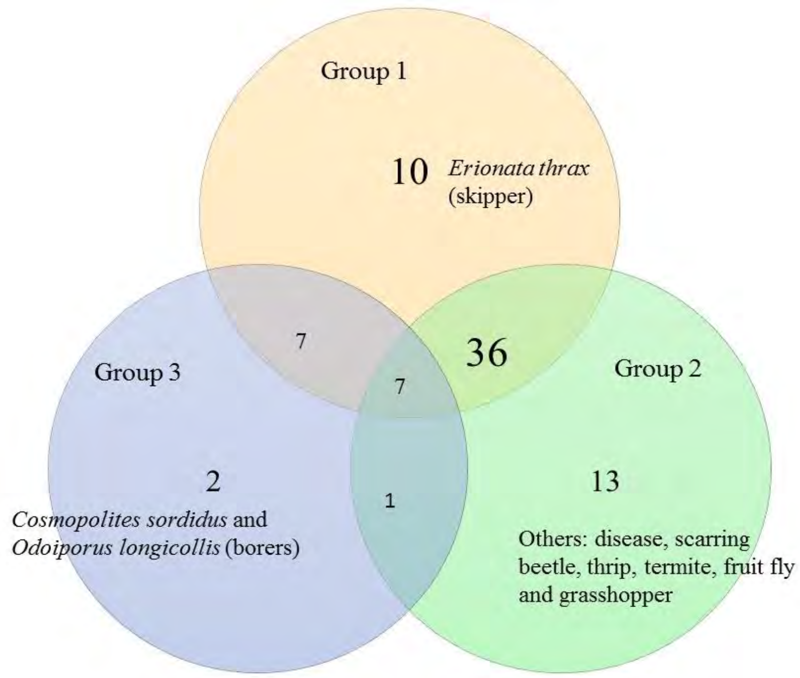


Figure 6.5: Venn diagram of the most important pests of banana, as reported by farmers.

4. What is the most harmful pest on your farm that causes economic loss (through yield loss)?

Aside from the major pests that are commonly found on their farms, the most harmful pests that cause economic loss were also emphasized. The most frequent answers (56.3%) on the economic pest question mentioned pests from the 'others' category (disease, scarring beetle and beetles) (Group 1). *Erionota thrax* was only placed in this category by approximately 29.2% of total respondents (Group 2) and followed by borers (Group 3) (Figure 6.6).

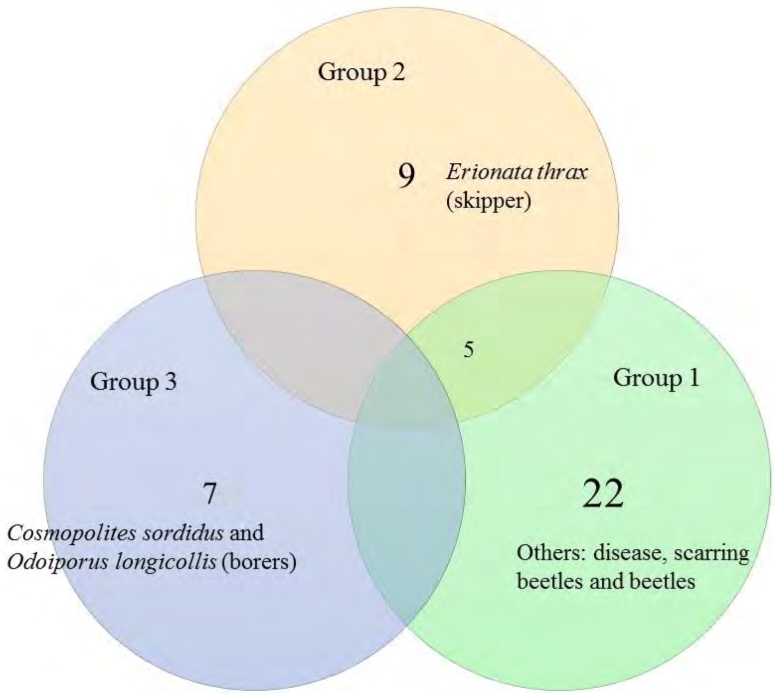


Figure 6.6: Venn diagram of the economic pests of bananas, as perceived by farmers.

5. Can you always identify which pest is causing damage to your crop?

Yes, How?

No, please describe the characteristics in general

More than half of the respondents (51.8%) were able to identify those pests present based on visual symptoms on the banana plants. However, 39.8% of respondents could not provide the correct names. On the other hand, the plantation company employed an experienced agriculturist from overseas who has specialist knowledge and information from local farmers in Laos. The foreign agriculturist was able to identify the pests using visual analysis or symptoms on the plants, but was also able to identify pests based on his overseas knowledge and literature resources (Table 6.2).

Table 6.2: A summary of the pest identification skills of banana farmers.

Pest identification	Frequency	Percentage (%)	Cumulative percentage (%)
Yes	43	51.8	51.8
No	33	39.8	91.6
No pest noted on their farms	7	8.4	100
Total	83		

6. In what month do you find the most pests?

Farmers reported that the most critical season for pest-induced damage was the dry season (Nov-May) (55.8%), when compared to the wet season (June-Oct) (15.6%). Farmers also indicated that although pest infestation occurred year-round, banana plants were still able to produce fruit and new shoots in the wet season, but not in the dry season (Figure 6.7).

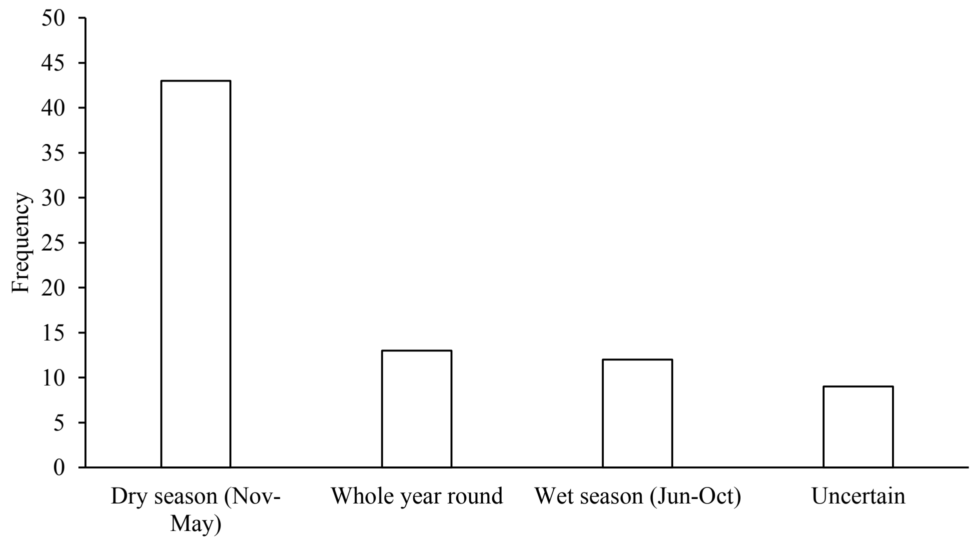


Figure 6.7: The relationship between seasons and banana pest detection by farmers.

7. Have you noticed any particular parts of the tree being attacked more often? (Fruit, leaf, trunk, corm)

The most frequent responses were that leaves were the most common part of the plant being attacked (42.7%), followed by the stem (pseudostem) (19.8%). The leaf part had obvious and recognizable symptoms, which might be the reason why many responses focused on this part of the plant. A few respondents (6.3%) found either new young leaf or the whole tree was being attacked. However, 15.6% of respondents did not know where the major pest infestation was occurring (Figure 6.8).

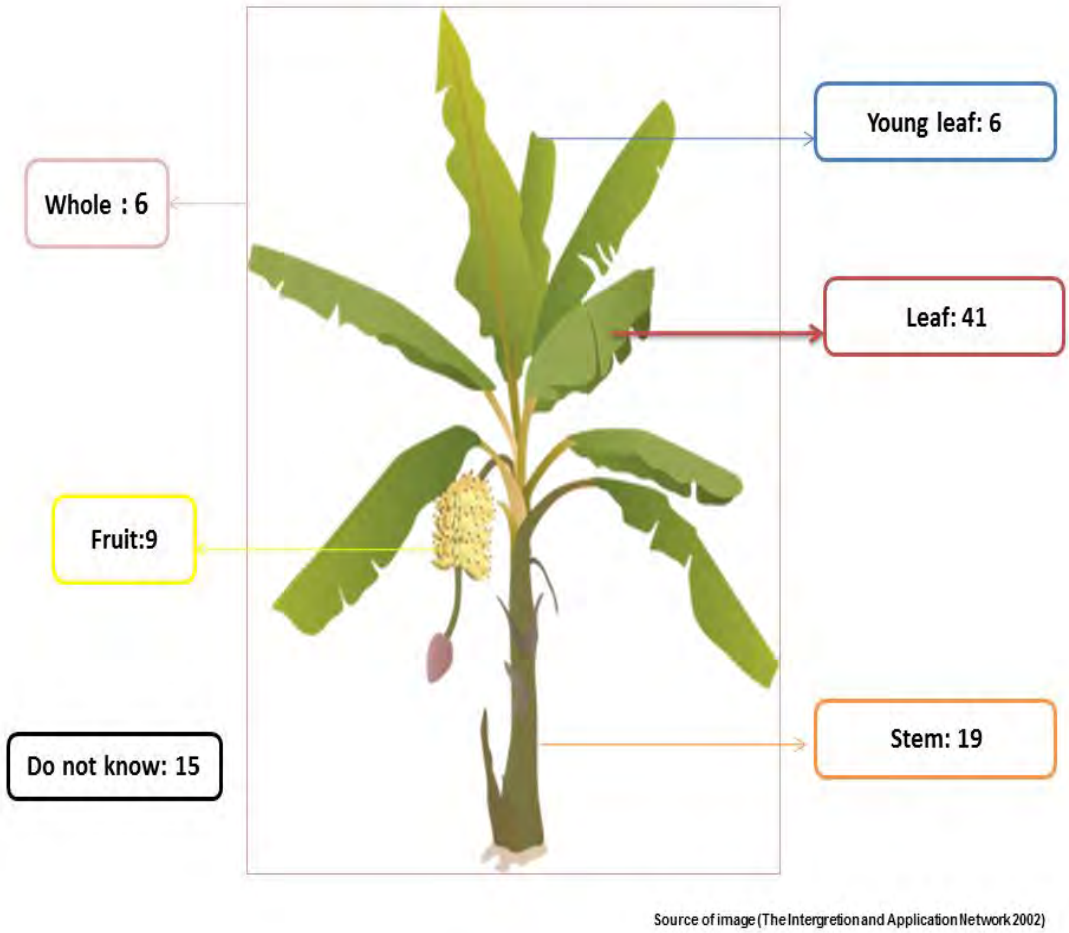


Figure 6.8: Diagrammatic representation of the sites of pest attack on banana plants as identified by farmers.

8. How severely do major pests affect your crop?

Level 1 low

Level 2 moderate

Level 3 high

A low level of infestation was reported by 58.2% of the respondents. Perceived medium and high levels of infestation were reported by 25.3% and 13.9% respectively (Figure 6.9).

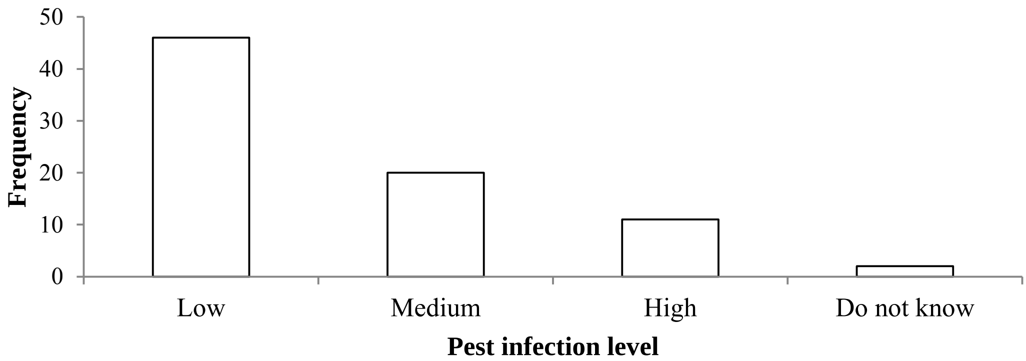


Figure 6.9: The perceived levels of pest infestation by banana farmers.

9. What factors do you think contribute to high levels of pest damage on your farm? (Rainfall, Poor soil, Weeds, Age of tree, Variety)

Other factors (do not know, climate, season of occurrence or from neighbour) were categorized due to respondents adding more information than that listed. It is interesting to note that more than half of respondents (67.5%) did not know what factors encourage high infestation of pests. Climate, rainfall and age of the crop were considered by some respondents (6.5% for each factor) to evenly contribute to the problem (Table 6.3).

Table 6.3: Factors contributing to high level of pest damage on bananas.

Answer	Frequency	Percentage (%)	Cumulative percentage (%)
Rainfall	5	6.5	6.5
Age of tree	5	6.5	13
Weeds	0	0	13
Poor soil	3	3.9	16.9
Variety	3	3.9	20.8
Others (list below)	61	79.2	100
Do not know	52	67.5	
Climate	5	6.5	
Season occurrence	3	3.9	
From neighbour	1	1.3	

10. Do you try to control them/it?

Yes

No (why?)

More than half of respondents (55.3%) did not apply any control methods for the pests (Table 6.4).

Table 6.4: Numbers of banana farmers who used pest control measures.

Answer	Frequency	Percentage (%)	Cumulative percentage (%)
No	42	55.3	55.3
Yes	34	44.7	100
Total	76		

11. If yes, what practices do you employ to manage those pests?

Manually

Using chemical

Others

The majority of farmers (55.3%) did not apply any kind of method for controlling pests when an infestation problem occurred on their farms. The remaining 44.7% of respondents stated that they managed the pests when they found any infestations. Manual approaches for pest management were the most commonly used (78.9%). These include weeding, cutting, uprooting, killing, burning, removal of debris from the base of the stool, crop rotation, turning over the soil and cooking caterpillars (skipper). Chemical application was a less popular method, accounting for 18.4% of respondents (Figure 6.10). Specifically, chemical applications were classified as pesticides, herbicides and mineral supplements. In addition, 2.6% of respondents reported use of neem extract to control pests.

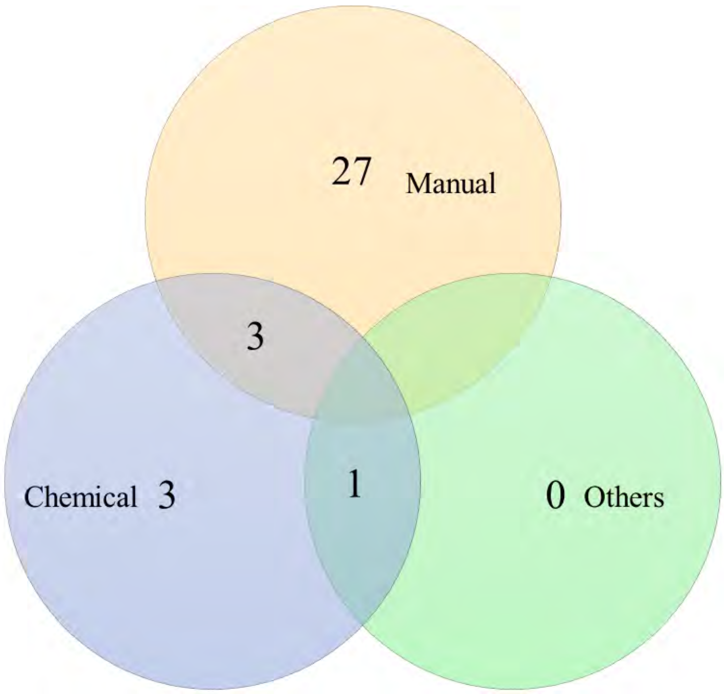


Figure 6.10: Venn diagram of pest control methods used by banana farmers.

12. If using pesticides, what are the names of chemicals and how are they applied?

When questioned farmers reported a variety of general chemical names such as ‘herbicides’ or ‘pesticide’ rather than the name of the actual product used (Table 6.5). In all cases they indicated they applied the chemicals using the instructions provided on the chemical container.

Table 6.5: List of chemicals reported by banana farmers as used for control of pests.

Name of Chemical	Frequency
Calcium sulfate	1
Cypermethrin (folidol)	1
Furadan	1
Herbicide	1
Pesticide	1
Total	6

13. Do you have access to sufficient labour for effective management of your crops?

Only 2.4 % of the total respondents said that they did not have access to sufficient labour. The majority of farmers (95.2%) reported utilizing family members for labour. The critical periods were when the bananas were beginning to grow and when due to be harvested; the rest of the season required less extensive care. On the other hand, the commercial farm had a sufficient labour force all year round. They have routine management procedures from growing until delivery to markets (Table 6.6).

Table 6.6: Summary of labour sources used by banana farmers to implement pest management strategies.

Answer	Numbers of farmers	Percentage (%)	Cumulative percentage (%)
Family	79	95.2	95.2
Yes	2	2.4	97.6
No	2	2.4	100
Total	83		

14. How do you handle chemical spraying? (Do you use protective clothing)?

All six respondents who applied chemicals indicated they used protective equipment.

15. What is your highest level of education?

The majority of farmers had attended primary school, (54.2% of total respondents), followed by 24.1% who had graduated from secondary or had tertiary qualifications, while 12% had no schooling (Figure 6.11).

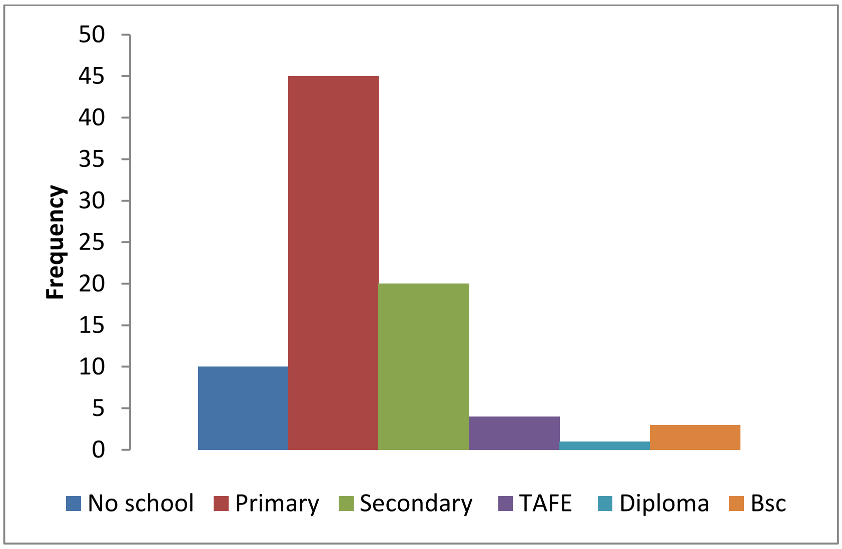


Figure 6.11: Highest educational level reached by banana farmers.

16. Do you talk to other banana farmers about how they manage their pests?

The majority of farmers (82.9%) did not discuss pest management with other farmers.

17. Do you talk to government representatives about how to manage your pests?

The majority of farmers (94%) did not ask government representatives for advice on pest management (Table 6.7).

Table 6.7: Summary of numbers of farmers who seek government advice on how to manage banana pests.

Answer	Numbers of farmers	Percentage (%)	Cumulative percentage (%)
No	78	94	94
Yes	5	6	100
Total	83		

18. Where do you mostly learn how to manage pests on your banana crops?

Of those respondents who had a pest problem on their farm (95.2%), most tended to self-study and depend on their own knowledge and experience to manage the problem, not seeking advice. A minority learned from villagers, friends, books and international experts (Figure 6.12).

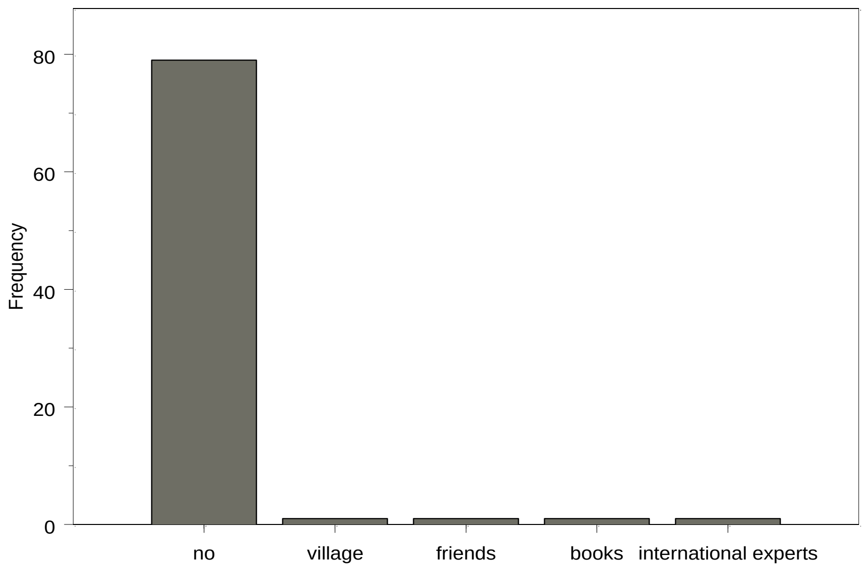


Figure 6.12: Summary of where farmers seek advice concerning the management of pests on banana farms.

19. What varieties of banana do you grow in your farm and why did you choose them? (Please describe the different varieties of banana in relation to their use)

In total, 16 varieties of banana were grown by respondents. With the exception of the imported variety, Cavendish, which is well-known in the banana industry, the common names (in Lao language) are: Kuay Nam (KN), Hormthong (HT), Khai, Horm, Khai pan, Ngao, Thany, Kuay Kean, Teep, Musy, Horm khai (HK), Som (hormfarang), Buasy, Horm pan and Teep mong. There are six major varieties, which 86.4% of total respondents grow. KN is the most widespread and commonly grown in Laos, accounting for 51.7% (33 out of 83 respondents), while others included 14.4% HT, 8.5% Khai, 4.2% Horm, 4.2% KP and 3.4% Cavendish (Figure 6.13). Only one respondent planted four varieties together (KN, Musy, Ngao and HK). Farmers perceived that these varieties did not differ in their susceptibility to pests.

The rationale for growing bananas appears to be evenly divided between income generation and home consumption. Many respondents (45.7%) grew bananas with the aim to sell, while 44.7% grew them for home consumption only.

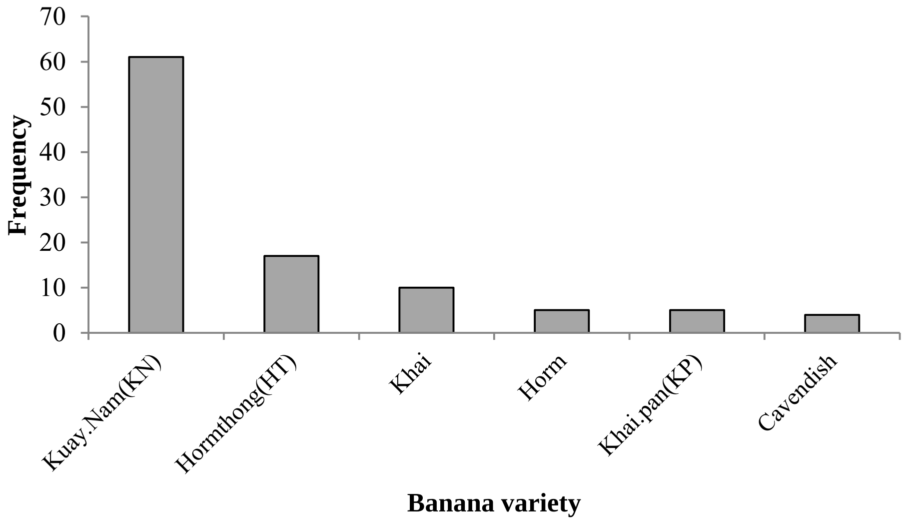


Figure 6.13: A summary of the relative frequency of cultivation of the six most frequently grown varieties of banana.

20. Where did you get the varieties? (Friends, government, market)

Most of varieties were from local domestic sources, such as inside villages, from neighbours and/or their own traditional varieties. Only the Cavendish variety was imported (from the Philippines) by a company to be grown in Laos with the purpose of exporting to international markets (Figure 6.14).

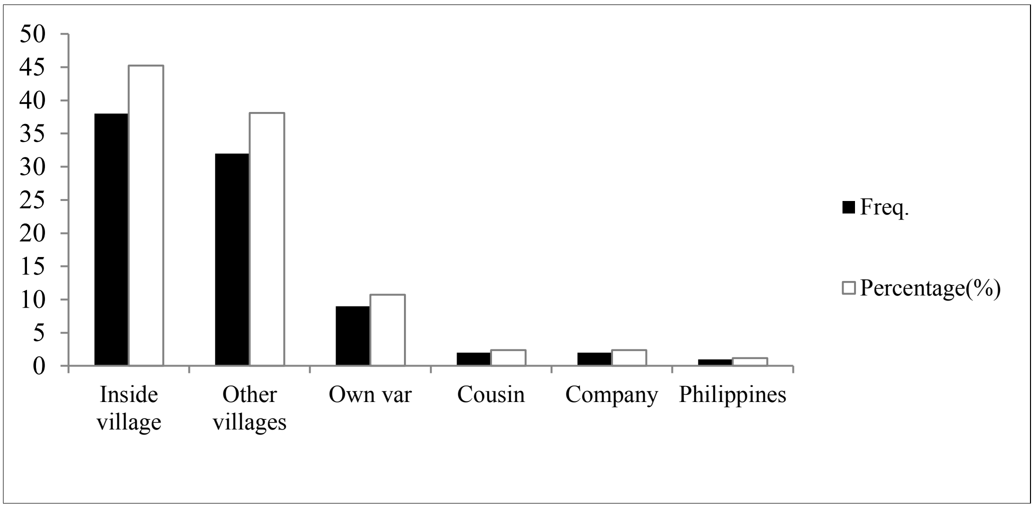


Figure 6.14: A summary of the sources used to obtain bananas for farming.

21. Are different varieties of banana more or less susceptible to pests? (Resistance, fewer pests)

The majority of farmers (98.9%) reported that there were no differences between varieties in susceptibility to pests (Table 6.8).

Table 6.8: A summary of farmer perceptions of susceptibility of different banana varieties to pest attack.

Answer	Frequency	Percentage (%)	Cumulative percentage (%)
No difference	82	98.8	98.8
Yes	1	1.2	100
Total	83		

22. If yes, why do you grow banana varieties that are susceptible to pests?

One respondent answered that Kuay Kean was less susceptible to pests than Kuay Nam.

23. How many bananas do you get from the tree per year (seasons, times) or what average yield do you get from your farm per year?

Responses varied greatly, depending on farms size, season and banana productivity. Many respondents (54.4%) harvested between 0-1000 bunches/year from their farm as a whole (Figure 6.15).

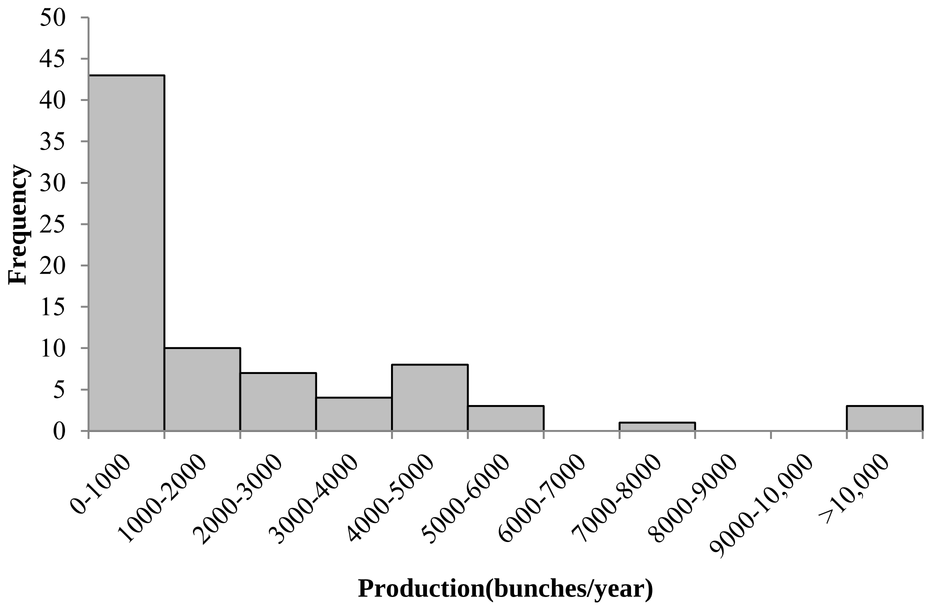


Figure 6.15: Banana production (bunches/year) on a per farm basis.

24. Do you measure spacing before planting bananas? Yes, No

If yes, what is the spacing between banana trees?

If No, how do you estimate the spacing?

Some respondents (38.6%) applied measurement, while many did not (61.4%) (Table 6.9).

Table 6.9: A summary of the whether farmers space out bananas when planting them on farms.

Answer	Frequency	Percentage (%)	Cumulative percentage (%)
No	51	61.4	61.4
Yes	32	38.6	100
Total	83		

Respondents, who did not apply standard measurements, applied an estimation for spacing by footsteps, nylon rope and arm-lengths (Table 6.10).

Table 6.10: Methods used to space out planted bananas used be farmers who did not apply standard measuring techniques.

Answer	Frequency	Percentage (%)	Cumulative percentage (%)
Did not use tools	38	74.5	74.5
Foot steps	10	19.6	94.1
Nylon rope	2	3.9	98.0
Arm lengths	1	2.0	100.0
Total	51		

Spacing between plants: the area allocated to individual banana trees varied from 1.5 x 1.5 m to 10 x 10 m (100 m^2). An area per plant below 20 m^2 was the most preferred by respondents (71.82%), especially for growing the Horm variety. The least common space allocation was more than 40 m^2 accounting for approximately 5 % of respondents (Figure 6.16).

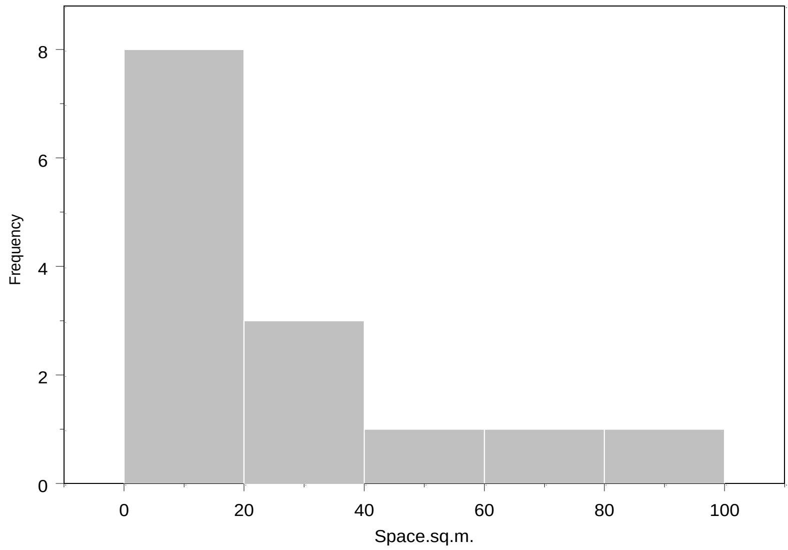


Figure 6.16: Observed space allocation for banana plants.

25. How old are you?

Farmers interviewed ranged in age from 21 to 98 years. The average farmer was 53 years old with the most commonly occurring age group was 51-61 years (27.7%), followed by 41-51 years (26.5%, Figure 6.17).

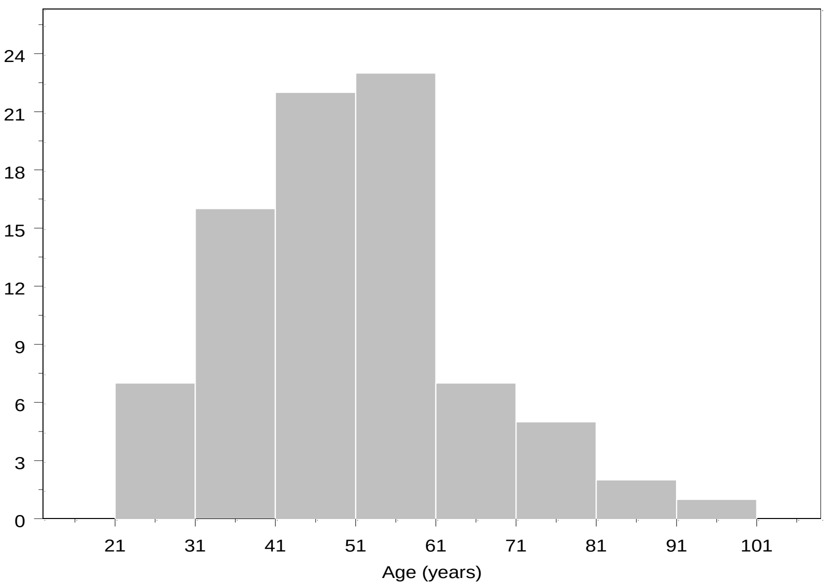


Figure 6.17: The age frequency distribution of banana farmers.

A summary of the key attributes of a typical banana farmer and a typical banana farm in Laos is provided in Table 6.11.

Table 6.11 Key attributes of a typical banana farmer and farm in Laos.

Attribute	**Mode**
Duration of farming	4 years
Size of farm	≤ 0.25 ha
Farm possession	Owned by farmers
Major pest	Skipper (*E. thrax*)
Harmful pest that cause economic loss	Others (Disease, scaring beetle, thrip, termite, fruit fly and grasshopper)
Identification/Recognition	Visual symptoms
Time of severe pest occurrence	Dry season (Nov-May)
Part of the plant being attacked	Leaves
Severe pest level	Low
Factors contributing to severe damage	Others (Unknown, climate, season, neighbour)
Pest management	Pest control not employed, or manual in nature. Family members as labour
Exchanging information on pest management	Self-learning and practice
Variety	Kuay Nam
Spacing	Below 20 m^2
Age	Varied age groups (41-51) and (51-61) years of age
Education	Primary school

The testing of relationships between farmer and farm characteristics and the management of key pest species

The statistically significant results are shaded in bold (Tables 6.12 - 6.14). Although unidentified disease was not the focus of this study, many respondents mentioned this as a significant problem. Therefore, reports of disease have been collected as additional information. 'Disease' probably represents a diverse range of plant pests and pathogens.

Table 6.12: Test of association between farm variables (categorical variables: duration of farming, farm size, education, space between plants, farmer age and location) and pest management (Fisher's exact test, a probability less than 0.05% indicates a significant association between the farm variable and pest management parameter).

Variable (category)	Skipper control (No, Yes)	Borer control (No, Yes)	Scarring beetle control (No, Yes)	Disease control (No, Yes)
Duration of farming (year(s)) (0-2.01, 2.01-4.01, 4,01-50)	0.26	0.09	0.2	0.73
Farm size (hectare (s)) (0-.075, 0.75-100)	1	0.67	0.05	**<0.05**
Education (no school, primary, secondary, TAFE, diploma, Bsc)	0.47	0.28	0.35	0.68
Space between plant (sq.m) (0-6.26, 6.26-25, 25-100)	0.50	0.89	0.34	0.12
Farmer age (year (s)) (20.99-40, 40-98)	0.57	0.67	1	0.57
Location (province) A:Bolikhaxay, B: Saravan, V: Vientiane	0.13	0.41	0.52	0.20

Table 6.13: Test of association between farm size, location and pest management (scarring beetle and disease) (General Linear Model: Logistic regression).

Dependent variable	**Independent variables**	**Deviance Resid.**	**Df**	**P**
Scarring beetle control	Farm size	4.33	1	**<0.05**
	Location	8.22	2	**<0.05**
Disease control	Farm size	5.18	1	**<0.05**
	Location	0.64	2	0.72

Table 6.14: Test of association between banana varieties and pest control.

Pests / **Banana variety**	**Skipper control (No, Yes)**	**Borer (No, Yes)**	**Scarring beetle (No, Yes)**	**Disease (No, Yes)**
Kuay Nam (KN) (No, Yes)	0.78	0.67	0.28	0.78
Horm thong (HT (No, Yes)	0.77	0.19	0.57	1
Khai (No, Yes)	0.72	1	0.41	1
Horm (No, Yes)	0.13	0.07	1	0.6
Cavendish (No, Yes)	0.57	1	0.18	1

Farmers and farming characteristics; time length on farming, farm size, educational level attained, variety, space, age of farmers and location were possibly important factors to investigate for pest management (skipper, borer, scarring beetle and disease).

The survey results found no significant relationships among application of pest management and farmers' demographic features (duration of farming, education and age of farmers) or most farm characteristics (banana variety grown, plants spacing) (Table 6.12, 6.14). However, there was a significant relationship between the size of the farms, location and scarring beetle management. Disease management showed a relationship with farm size but there was no relationship with location (Table 6.12, 6.13).

Firstly, farmers who applied disease management used different forms of management depending on the size of the farm. The proportion of farmers applying pest management methods differed significantly with increasing size of the banana farm (Fisher's exact test, $p < 0.05$) (Figure 6.18). If the farm was more than 0.75 ha, 45% of farmers applied pest management, as opposed to only 20% if the farm was smaller than 0.75 ha. A larger proportion of farmers in Bolikhamxay and Saravan provinces controlled disease in farms larger than 0.75 ha than was the case in Vientiane province. Conversely, in Vientiane province, farmers who had larger farms did not practice any management whereas those with smaller farms did do so (Figure 6.19).

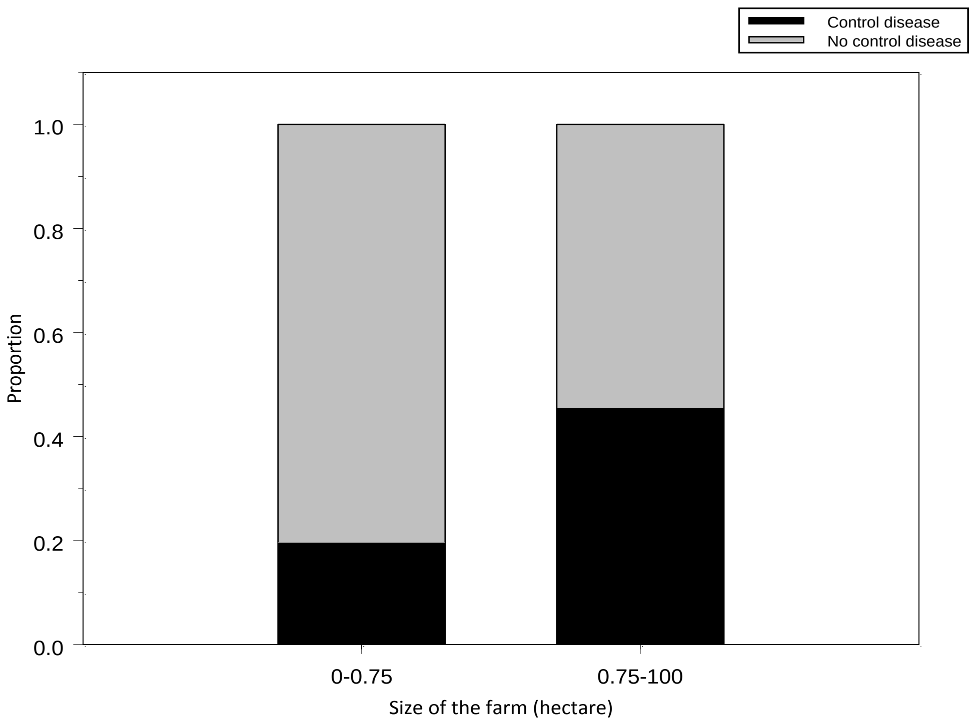


Figure 6.18: The relationship between disease management and banana farm size in Laos.

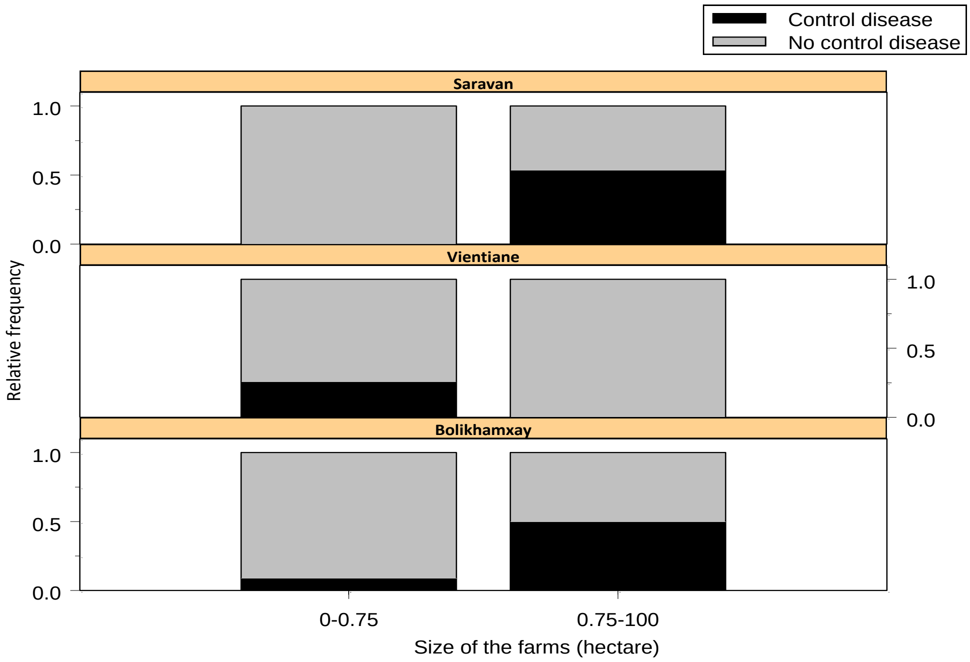


Figure 6.19: The relationship between disease management and banana farm size for three different locations in Laos.

Secondly, there is a significant relationship between scarring beetle management by farmers and the size of banana farm (logistic regression, deviance = 4.333, df = 1, $p < 0.05$) and location (provinces) (logistic regression, deviance = 8. 221, df = 2, $p < 0.05$). Farmers who have farms of more than 0.75 ha tried to control scarring beetle, while owners of smaller farms did not. Farmers in Bolikhamxay and Vientiane provinces used controlling methods for scarring beetles on the larger farms, with the proportions 0.50 and 0.33 respectively. While in Saravan province, farmers did not apply any control measurements for the pest (Figure 6.20).

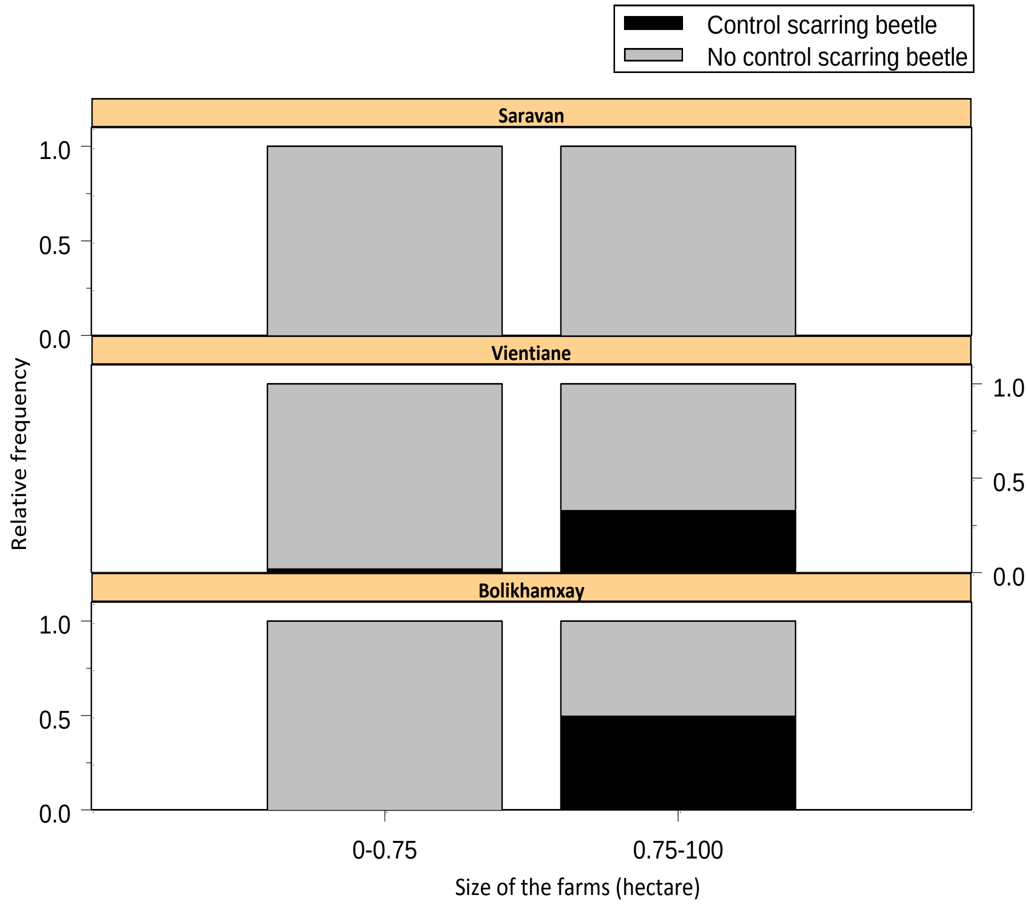


Figure 6.20: The relationship between control management strategies for scarring beetle and banana farm in three provinces of Laos.

6.4.2 The link between farmers' perceptions and field sampling of banana pests

A comparison of farmers' perceptions and the on-farm sampling data from their banana fields revealed that the pests most commonly reported by farmers constituted a subset of those found during the field sampling and were in relatively low abundance (The first 4 columns of table 6.15). Farmers mentioned eight pests of banana they perceived as important.

The pests most commonly cited by banana farmers were *Erionata thrax* (skipper), borers, and others (unidentified disease, scarring beetle, thrips, termite, fruit fly and grasshopper). A comparison of each pest mentioned by farmers relative to results of field sampling is shown below.

Skipper (Erionata thrax)

Skipper was the only kind of butterfly pointed out by farmers due to their characteristic behaviour as leaf rollers and shredders. On the other hand, in field sampling, skipper was ranked number 106 in abundance and only a single specimen was found. Apart from skipper (Hesperiidae), other butterflies and moths were detected, some of which were identified to family level (Bombicidae, Limacodidae, Nymphalidae, Pterophoridae, Saturnidae, Lycaenidae, Pieridae, Arctiidae, Psychidae).

Borers (Cosmopolites sordidus and Odoiporus longicollis)

Banana borers were also a significant insect taxon identified by farmers. The damage caused by these is clearly seen after cutting rotten stems. All local farmers were able to describe the borer using the Lao common name, and they thought there was only one species. In fact, there were two different species that belong to the same family of Coleoptera; Curculionidae. They are very similar to each other. Stem borer (*O. longicollis*) ranked 15th in abundance and root borer (*C. sordidus*) ranked 38th, from the field sampling. Aside from this family of borer, more species of Curculionidae and other families were found in the field, all of which have different characteristics. Among these are Anthribidae, Bostrychoidae, Lycidae, Rhipiphoridae, Tenebrionoidea, Cerembicidae, Cucujoidea, Lucanidae, Staphylinidae, Carabidae, Coccinelidae, Hydrophiloidae, Scarabaeidae, Elateridae, Chrysomelidae, Cleridae and other unidentified coleopterans.

Others

The next group includes 'others' (unidentified disease, scarring beetle, thrips, termite, fruit fly and grasshopper) that were recognized by farmers. Farmer's knowledge of disease was less extensive and there was no further identification carried out for disease in the field survey.

Scarring beetle activities were identified on the commercial farms, but were less obvious on local farms and were most easily identified visually by symptoms on leaves and fruits. The scarring beetle was ranked number 22 in abundance from the field surveys and was not the only chrysomelid beetle found. A number of leaf-eating chrysomelids were collected during the field survey but have not yet been classified to any level lower than family.

Thrips (Thripidae) was mentioned by a few of the farmers, as a cause of banana fruit rust and scar. The field survey found few thrips that might be the pest causing the damage, but another family of thrips (Phlaeothripidae) was found in high numbers. These are fungus-feeders and mostly found on dry leaves. A possible reason for there not being many flower-feeding thrips found is because sampling was done during the dry season when fewer banana plants were flowering and fruiting.

Fruit flies belonging to family Tephritidae and order Diptera are considered to be important pests. The field sampling ranked Tephritidae 27th and 139th (*Batrocera dorsalis*), and also detected additional fly families such as Cephylidae, Syrphidae, Mycetophilidae, Tipulidae, Sciadae, Culcilidae and other non-identified families.

Grasshoppers are a generalist pest, which mostly feed on leaves found on the ground, and they were identified into two families: Acrididae and Gryllidae. Termites were not the target of field sampling but were also found.

6.4.3 The list of key banana pest of Laos

The list of key banana pests of Laos is very important to farmers in their day-to-day work. It is also important for Laos given the need to establish a pest list before large-scale export of bananas can commence. Currently, no list of banana pests exists. Here, such a list has been derived from the results of field sampling (Chapter 5), farmers' perceptions of the most important pests and harmful pests (causing economic losses) (Chapter 6), and the available literature sources as well as my biological knowledge and experience (Table 6.15).

Table 6.15 provides an overview of the possible insect pests of bananas in Laos. In includes the results of this thesis based on farm samples and discussions with farmers and previous studies, which together are used to justify the selection of the most relevant banana insect pests. The list of insects includes the top 20 in abundance from the field surveys, and other recognized pest species that fell outside the top 20. Insect species/taxa reported as pests in the literature were also included. Major references are listed, and for each, mention of a particular pest species is indicated by a tick **(✓)**. From this, a list of nine most important banana pests was developed: *Odoiporus longicollis* (stem borer), Acrididae (*Heroglyphas banian,* grasshoppers, *Stephanitis typica* (Lace bug), Chrysomelidae (*Sphaeroderma* spp, leaf beetle), *Basilepta subcostata* (scarring beetle), Tephritidae (*Bactrocera* spp) (fruit fly family), *Cosmopolites sordidus* (root borer), *Erionota thrax* (skipper) and *Bactrocera dorsalis* (fruit fly).

Some insect species/taxa were not placed among the nine important insect pests due to low detection during the survey. Some common insects were not considered as pests based on knowledge of their general ecology and likely lack of impact on banana. These included Phlaeothripidae (fungus feeders), Cleridae (predators), Gryllidae (crickets) and Formacidae (ants). Some taxa could not be identified to species level and their potential as pests therefore cannot be assessed. Those unidentified insect taxa are the subjects of on-going taxonomic work.

Table 6.15: An overview of the status of banana insect pests in Laos.

Insect species/taxon	Rank based on field sampling (Chapter 5)	Rank based on farmers' perception of important pests (Chapter 6)	Rank based on farmers' perception of harmful (Economic losses) (Chapter 6)	References											The target lists of nine most important insect pests
				(Dean, 1978) (Laos)	(Wongsiri, 1991) (Thailand)	(DF. Waterhouse, 1993) (Southeast Asia	(CABI, 2005) (database for Laos)	(Aguilar et al., 2014) (Philippines)	(Wahad, 2000)	(Nelson et al., 2006) (Pacific Islands)	(Peno, 2006) (USA)	(Pinese, 1994; Tenhaj, 2008)(Australia)	(Gold et al., 2002) (different parts of the world)	(Ostmark, 1974) (world pests of banana)	
Diptera_a	1														
Diptera_a.1	2														
Diptera_x2	3														
Hemiptera_ Miridae	4														
Diptera_j	5														
Hymenoptera_Fo rmicidae	6														
Diptera_m	7														
Coleoptera_ Cleridae	8														
Coleoptera_h	9														
Thysanoptera_Ph laeothripidae	10														
Coleoptera_m	11														
Orthoptera_ Gryllidae	12														
Coleoptera_c	13														
Diptera_b	14														
Odoiporus longicollis	15	3	3	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
Acrididae (*Heroglyphas*	16	2	1	✓	✓	✓									✓

Insect species/taxon	Rank based on field sampling (Chapter 5)	Rank based on farmers' perception of important pests (Chapter 6)	Rank based on farmers' perception of harmful (Economic losses) (Chapter 6)	References											The target lists of nine most important insect pests
				(Dean, 1978) (Laos)	(Wongsiri, 1991) (Thailand)	(DF. Waterhouse, 1993) (Southeast Asia	(CABI, 2005) (database for Laos)	(Aguilar et al., 2014) (Philippines)	(Wahad, 2000)	(Nelson et al., 2006) (Pacific Islands)	(Peno, 2006) (USA)	(Pinese, 1994; Tenhaj, 2008)(Australia)	(Gold et al., 2002) (different parts of the world)	(Ostmark, 1974) (world pests of banana)	
banian)															
Stephanitis typica	17				✓	✓		✓						✓	✓
Coleoptera_g	18														
Diptera_h	19														
Chrysomelidae (Sphaeroderma spp)	20	2	1	✓		✓								✓	✓
Basilepta subcostata	22	2	1			✓									✓
Tephritidae (Bactrocera spp)	27	2	1		✓				✓	✓				✓	✓
Cosmopolites sordidus	38	3	3	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓
Erionota thrax	106	1	2	1	✓	✓	✓			✓			✓	✓	✓
Bactrocera dorsalis	139	2	1		✓	✓	✓			✓					✓
Group 2: Others: disease, scarring beetle, thrip, termite,fruit fly and grasshopper)		2	1												
Parasaissetia nigra	Not found			✓											
Gangara thyrsis	Not found			✓											

6.5 Discussion

6.5.1 Farmers' perceptions concerning banana pests

Banana pests are important worldwide, especially in tropical and subtropical regions (Gold et al., 2002; Ostmark, 1974; DF. Waterhouse, 1993). In Laos, the most recent publication on banana pests appeared in 1978 (Dean 1978). However, there has been no research into farmers' perceptions of banana pests and how they manage these in Laos. This study is the first to document how Lao local farmers and commercial farms manage their banana farms and their responses to pests.

The analysis of data revealed that the majority of farmers perceived the most troublesome pest to be *Erionota thrax* (skipper), and the pests causing the greatest economic losses were in the group of "others" (scarring beetle, thrips, fruit fly, grasshopper, termite and disease). Pests were placed in the 'others' category if they had not been reported in Laos by the previous study by Dean (1978). Many farmers mentioned *E. thrax* as the major pest on their farms due to its relatively large size and the obvious infestation on the banana leaves. Similar studies have shown that the body size of pests can influence farmers' perceptions. In Guatemala, this is the case for the traditional knowledge of crop pests under the polyculture cropping system; maize, bean and squash (Morales & Perfecto, 2000) and in the Philippines for rice production (Joshi, Matchoc, Bahatan, & Pena, 2000). Farmers frequently reported the pests that are obvious and larger on their crops, compared to the tiny species.

Disease was the most frequently mentioned by farmers, due to the whole plant being damaged and resulting in no fruiting and growth, and farmers have less knowledge about diseases than about insects (Kiros-Meles & Abang, 2008; Van Mele et al., 2001) (Van Mele *et al*. 2001; Kiros-Meles & Abang 2008). There was no further identification carried out for disease in the field survey.

Some farmers reported borers (*Cosmopolites sordidus* and *Odoiporus longicollis*) as being the third most important pest on their farms and were found by cutting the infested stems. This may be due to the life-cycle of the borer, which occurs mostly inside stems and corms thus attracting less attention from farmers. Some farmers thought that banana borer caused the whole plant to become yellow and collapse. This misperception is also similar to findings in the case study of a rapid appraisal of pest management of plantains and bananas in rural Costa Rica (Dahlquist 2008). Many of the farmers did not notice whether there was more than one species of borer.

Aside from banana borer, scarring beetles were reported to be important pests by Lao farmers. The damage was reported based on symptoms on leaves and fruits. The beetles were rarely found in local farms, but were present on commercial farms. Scarring beetle infestation was reported internally to the Department of Agriculture before this survey was conducted and found to be obvious during this survey. The scarring beetle was not the only chrysomelid beetle found. A number of leaf-eating chrysomelids were collected during the field survey but have not yet been classified to any level lower than family due to limitation of the taxonomic keys used, with respect to genera and species of this family.

Although farmers reported a total of 16 banana varieties, some of which were already mentioned by Callaghan (2004), the most common variety grown in Laos is Kuay Nam (KN). This variety is not a cooking banana or plantain, but is consumed ripe and has a sweet flavour. There have been studies on the characteristics and usage of KN in Thailand (Kasetsate University, 2014; Plant Genetic Conservation Project Office, 1996). Although farmers reported the same name (KN) from the three locations, the banana characteristics and phenology are visibly different across areas. This difference does not only occur in Laos, but more widely in Southeast Asia, which is a centre of banana diversity. The names of banana varieties are confusing, as they vary across countries and regions (KEW, 2015; Valmayor, 2000). Therefore, there is a need to document and classify the banana varieties in Laos.

A few questions from the questionnaire were not well understood and were interpreted differently by different farmers. These questions related to duration of farming and availability of labour. The misinterpretation may be related to the translation of the questionnaire into the Lao language, and the later translation of responses into English. Some questions may have been ambiguous when translated into Lao. Farmers preferred to expand on answers, rather than give simple yes or no answers, which made interpretation more difficult.

6.5.2 Factors influencing pest management

Many of the characteristics of farmers and farms measured showed no obvious relationship with pest management strategies. However, the size of banana farms in three provinces showed a relationship with management of disease and scarring beetle. Disease management practices by farmers on larger farms are different to those with smaller farms, and can involve chemical or manual methods. Farmers in two provinces, Bolikhamxay and Saravan, applied methods for controlling disease on larger farms. A possible reason for this is that large farms are often separately located from the owner's house and generate more income to the farmers than smaller farms. The commercial farms are located in Bolikhamxay province, and have a management system differing from local Lao farmers in terms of crop production, labour, pest management, machinery and postharvest system for exporting. On the other hand, farmers in Vientiane tended to manage pests, even on smaller farms. This may be because Vientiane is the capital city of Laos and the banana production areas are along the Mekong River, which is not far from the centre of the city. The central urban area is expanding, and the farm size tends to be smaller than in other provinces. Farmers are able to access information, markets and tools for pest management.

There is a relationship between the management of scarring beetles with increasing farm size, and location (province). In two provinces (Vientiane and Bolikhamxay) farmers applied methods for controlling the beetles, while farmers in Saravan did not. This may be because farmers who live in Saravan province never have any problem with scarring beetles on banana fruits, and the markets for this area are only local. This area has old volcanic soil promoting plant growth with larger banana fingers and bunches.

Although farmers reported that there were specific pests causing economic losses, many of farmers were not controlling these pests. This is different from perceptions in various other countries, such as the Philippines (Aguilar *et al*. 2014), Ghana (Schill *et al.* 2000), Uganda (Gold *et al.* 2006) and in East Africa (Rukazambuga *et al*. 1998). This may be because Lao banana farmers feel that their farms do not need extensive care. Some farmers pay little or no attention to pests, especially in the rainy season, because rainfall can help generate new plant growth and fruiting which can mask pest problems. In the dry season, however, pests are more apparent.

Farmers largely rely on self-study for learning how to manage pests, and they did not exchange the pest information amongst themselves, nor did they ask government representatives. This could be because small-scale back-yard farms did not need extensive care. Competition between farmers may also account for their unwillingness to communicate their own management methods (Van Mele *et al.* 2001).

In, general, farm management by local farmers involves little or no input and less maintenance than larger farms. Most methods of control are manual; weeding, hand picking, removing the whole plant, etc. This may be modelled on the growing technique for rice in Laos - "Thammasat" - which involves a low level of input and utilizes traditional skill (Tanaka, 1993).

In the Philippines, it has been suggested that in the future banana production may move toward organic production, moving from chemical pesticide use to botanical pesticides and fertilizer in long-term management (Aguilar *et al*. 2014). In contrast, in Laos some local farmers and all commercial farms applied chemicals to control pests. Pesticides presently are accessible in the local markets. The chemicals used by some farmers for controlling pests were not specific for these. This makes local farmers at high risk of pesticide misuse, which could be the same scenario as in a previous study of rice production in Laos (Heong *et al*. 2002).

In many developing countries, there is a shortage of adequate information, training, and specialists in many agricultural fields and there is a poor top-down flow of information (Schaefer, 1996). Similarly, Laos also lacks agriculture specialists, facilities and equipment. For vegetables in Laos, integrated pest management (IPM) has been widely adopted (Douangphrachanh 2007). Therefore, there is a need to educate farmers to be aware of the various pesticides on the market and their correct use (Banjo, Lawal, Fapojuwo, & Songonuga, 2003) and Development of integrated pest management (IPM) specific to banana will be beneficial for Lao farmers. As part of this development, there is a need to educate farmers to be aware of the various pesticides on the market and their correct use (Banjo et al., 2003).

Aside from insect pests, farmers also found disease played an important role on their farms. There is little knowledge on the pathogens involved, due to there being many agents, such as viruses, fungi and bacteria, which can contribute to reductions in banana production (Gold et al., 2002; Nelson, 2009; Pinese, 1994). Further study of particular diseases is important for management of the banana production industry.

6.5.3 The list of key banana pests of Laos

Farmers recognized pests by obvious visual symptoms on the plants. On the other hand, on-farm insect sampling used a range of different sampling methods, resulting in many insect taxa being found. A total of 2 952 insect samples were examined and identification attempted. Priority was given to identification of insect pests of banana previously reported in the literature. Survey results, farmers' perceptions and published information were combined to assemble a list of the nine most important banana pest insect taxa in Laos. The unidentified specimens will be kept in the Entomology unit of the Plant Protection Centre in Laos and will be valuable in future research on banana pests.

While this study has highlighted the significance of the nine key banana pests in Laos, ongoing studies of the management and economic impact of these pests would be invaluable.

CHAPTER 7: General discussion

7.1 Summary

Banana is an important food crop and native to the Asian, Indo-Malaysian and Australian tropics (CABI, 2005; Nelson et al., 2006; Ortiz, 1997). In Laos, banana has long been an essential food source. The amount of land under banana production in Laos has increased recently with the recognition of the commercial and export potential of large-scale plantation investment. Banana can complement the supply by Laos of coffee, maize, wood and wood products to international markets (Douangphrachanh, 2007), improving livelihoods and generating more income for Lao farmers. Insect pests need to be considered in line with international phytosanitary measures when any agricultural product is offered to international markets. The first steps are to characterize Lao traditional banana cultivation practice and the pests associated with this. Since the species list produced by Dean (1978) and Waterhouse (2003), there have been no current studies on banana insect pests and only very limited information on banana cultivation, varieties used and management in Laos. The work in this thesis, therefore, provides updated information on Lao banana pests and their management, and reports the perceptions of Lao banana farmers regarding these pests. A summary of the thesis results and future directions are given below.

Banana growing areas in two provinces, Bolikhamxay and Saravan were surveyed. These provinces differ in many respects. Bolikhamxay is located not far from the capital city. Natural environments are rainforest and wetlands. Two commercial large-scale farms (~100 ha) have been established here and grow the Cavendish variety. Remaining farms in the province are small holdings and grow mainly the KN variety. The soil is fertile, sandy loam which is well-drained, is white grey in colour and finely granular. Saravan province is located in the south of Laos. The selected banana farms were on Bolaven Plateau, which is a highly fertile area with extensive agricultural production. Saravan is an important area for biodiversity, with dense forests and is home to many minority groups and animal species. All farms in the area are small holdings growing the KN variety. Individual banana plants exhibit far more exuberant growth than those in Bolikhamxay, with many pseudostems and more bunches and fruits. The soil is highly fertile, with a dark orange reddish colour.

The list of nine major pests was developed from field surveys along with a study of the perception of banana farmers concerning which insects are the most important to them. These sources were combined with published references, both country-specific and global in scope. These pests are *Cosmopolites sordidus* (root borer), *Odoiporus longicollis* (stem borer), *Basilepta subcostata* (scarring beetle), *Sphaeroderma* spp (leaf beetles, representing various chrysomelids), *Hieroglyphus banian* (rice grasshopper, representing various acridids), *Erionota* *thrax* (banana skipper), *Bactrocera cucurbitae* (melon fruit fly), *Bactrocera dorsalis* (fruit fly) and *Stephanitis typica* (lace wing bug). Information is provided concerning these pests that will be useful for farmers and provincial agricultural staff, including those with a non-specialist background. The information includes primary identification, lifecycle, distribution, damage caused, host range, monitoring and control options for each species, as well as references.

Insects collected during the study included 2 925 identified specimens. These were collected using different sampling methods: pyrethoid spray, sticky traps, visual scanning and pitfall traps, sweep net and destructive methods (observation of cut stems). Different sampling methods differed significantly in their abilities to detect the known pests. The two borers (*Odoiporus longicollis* and *Cosmopolites sordidus*), were best detected by examination of cut pseudostems. Scanning methods were best for detecting Acrididae, Chrysomelidae and *B. subcostata*. Pyrethroid spray was more likely to reveal *Stephanitis typica* on the banana plant and Tephrititidae were most easily caught on sticky traps. In terms of the total numbers of insects collected, the nine pests formed only a small proportion. Many factors need to be considered in understanding this, such as season, sampling methods, diversity of insects and vegetation, and the fact that there were many unidentified insects which may potentially be pest species or beneficial species. Therefore, detection of known pests was dependent on the sampling methods used.

In this research, farmers' perceptions of the existence and importance of pest species were evaluated as a step towards further development of pest management. Typically, farmers interviewed were aged between 41 and 61 years and more than half of the respondents had attended primary school. Most banana farms were small-scale, typically around 0.25 ha, and were owned by the farmers themselves (95.2% of total respondents). The most common banana variety grown in their farms was Kuay nam (KN), while large-scale farms cultivated the Cavendish variety. Farmers only perceived pests to be present if they produced clear visual signs on their plants.

Although farmers thought that harmful pest species, that may cause economic loss, were present on their bananas, more than half of the respondents (55.3%) did not try to control the pest. Of those farmers who applied pest management (44.7%), this was generally manual removal of damaged plant material and pests, as well as weeding and cleaning around plants. Only a small number of respondents (18.4%) used chemicals to control pests.

7.2 Future directions

Production of the list of nine key banana pests of Laos was an initial step facilitating a potential banana export market. However, of the 2 952 insect specimens examined, many taxa could not identified to species level. Some of these may be pests of banana. Further identification is essential to catalogue all the pests associated with bananas in Laos. This will also support the Lao Government's intentions of promoting banana fruit as an export commodity, and adhering to International Phytosanitary guidelines on market access (IPPC, 2013).

Although these nine major insect pests were detected in Laos during this study, quantitatively they comprised only a small proportion of the total number of insects collected. Therefore, there is a need for further in-depth study of the pests in terms of crop infestation and economic impact monitoring. Further investigation of the economic impact of each of the major pests is needed to aid cost-benefit analysis.

Extended sampling of banana pest over multiple seasons per year would provide further clarity and confirmation of appropriate sampling methods. Further investigation of farmers' perceptions and management concerning specific significant banana pests is needed to inform development of cost-effective tools for pest management. The main banana varieties grown in Laos are Cavendish (large-scale farms growing for export) and Kuay Nam (KN) grown locally. KN has not been properly characterized and even the scientific name is undetermined for this and other banana varieties in Laos, including wild plants, ornamentals and medicinal species. There is a need to identify them properly and document their phenology and characteristics.

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