BANANAS

INSECT & MITE MANAGEMENT

DPI
QUEENSLAND
DEPARTMENT OF PRIMARY INDUSTRIES

HRDC

Queensland Fruit & Vegetable Growers

Bruno Pinese

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Cover: *Stethorus* larva: bunch of Cavendish bananas within a protective polythene sleeve

CONTENTS

FOREWORD

Bananas are the largest fruit crop grown in Queensland. With a gross value of production of $182 million, Queensland is Australia's largest supplier of bananas and plays a vital role in both State and regional economies.

The key to success for any industry or business is in providing consumers with what they want. People are demanding high-quality fruit free of blemish; they also want fruit produced using the minimum amount of chemicals. Growers who give consumers what they want will find that their bananas are sold faster and attract higher prices.

The Queensland industry is putting a high priority on the development of quality management systems to improve farm efficiency and profitability, and to deliver consistent, high-quality bananas to consumers.

Management of insect pests is a key operation in banana production. The Queensland banana industry is committed to integrated pest management (IPM) and other means of reducing chemical use. The banana industry, the Horticultural Research and Development Corporation (HRDC) and the Department of Primary Industries, Queensland have collaborated over the past four years in a research program specifically focused on developing an IPM system for bananas.

The industry is now ready to spread the word about the success of the research project. It is hoped that this book, *Bananas: insect and mite management*, will encourage the adoption of IPM strategies and techniques throughout the State. With financial assistance from the Banana Sectional Group Committee and HRDC, it is being distributed to all Queensland banana growers.

Many people have contributed to the preparation of this book, but I would particularly thank Bruno Pinese and Richard Piper for their efforts.

Banana growers have much to gain from putting IPM into practice on their farms. I recommend this book as a guide and hope that all growers will join in moving the Queensland banana industry into an exciting new era.

Len Collins
Cbairman
Banana Sectional Group Committee
Queensland Fruit and Vegetable Growers

ACKNOWLEDGEMENTS

This project would not have been possible without the generous cooperation of the following growers who allowed us to undertake studies on their farms and who kept valuable records of rainfall, chemical applications and crop management: Mr G. Bush (Kennedy), Messrs J. and A. Deluca (Tully), Messrs V., M., M., and R. Gallagher (East Palmerston), Mr H. Henry (Murray Upper), Messrs J. & L. Horsford (Utchee Creek), Messrs R., J., S. & G. Mackay (Tully), Mr A. Sellars (Mission Beach), Messrs A. & D. and Mrs L. Sly (East Palmerston and Mr P. Watson (Murray Upper).

We would also like to thank the following people who have assisted with identifying specimens: Dr A. Austin (Waite Agricultural Research Institute, Adelaide) (borers), Dr B. Cantrell (DPI) (Anthomyzidae, Tachinidae), Mr J. Donaldson and the late Mr K. Houston (both DPI) (various groups), Dr R. Halliday (CSIRO) (Uropodidae), Dr D. Holdom (BSES, Indooroopilly) *(Cladosporium* and *Erynia)*, Dr D. McAlpine (Australian Museum) *(Stenomicra)*, Mr R. Storey (DPI) (*Coleoptera)*. Mr D. Meiklejohn and Mr A. Lisle (both DPI) kindly provided assistance with computer programming and data analysis for which we are grateful. Ms J. Grimshaw and Mr J. Daniels (DPI) and Mr L. Wilkie (James Cook University) kindly supplied photographs of spiralling whitefly, banana skipper and scab moth respectively. The photograph on the back cover is courtesy of the QFVG.

The financial support of the Queensland Fruit and Vegetable Growers (QFVG) (formerly COD) and the Horticultural Research and Development Corporation (HRDC), who provided matching funding for the project, is gratefully acknowledged.

ABOUT THE AUTHORS

Bruno Pinese

Bruno Pinese is an entomologist with the Queensland Department of Primary Industries and is based in Mareeba. He has been closely involved with the development of control strategies for banana pests to reduce the overall dependence on chemical control. His research in 1988 into the use of bunch injection for control of banana scab moth has led to a major reduction in chemical use and has provided the impetus for the development of integrated pest management for bananas. Bruno is currently developing economic injury levels for banana weevil borer and mites as well as investigating biological control and efficient pesticide application methods against avocado pests. Previously, he researched effective control measures for the prevention of aphid-transmitted viruses in cucurbits with the result that his methods are now recognised controls within these crops.

Richard Piper

Richard Piper has worked in tropical entomology in northern Australia for the past ten years. In 1990 he was employed on a three-year project, funded by the banana industry and HRDC, to develop integrated pest management (IPM) in bananas. Richard is currently working privately in north Queensland, providing assistance to banana growers with the implementation of IPM and other aspects of crop management.

1 THE INTEGRATED PEST MANAGEMENT CONCEPT

What is integrated pest management?

The main objective of IPM is to change from a pesticide-dependent system of pest control to a sustainable program which utilises a range of pest-management options. These include biological control (such as beneficial parasites and predators), cultural control (hygiene, crop management) and the targeted use of selective chemicals, if necessary.

IPM systems aim to manage pests so that populations remain below economic injury levels (EIL). The EIL is the level of a pest population at which the damage it causes is equal to the cost involved in its control. Because the price of fruit is always changing and production is not always the same, the EIL also changes. However, a standard EIL can serve as a useful guide when deciding on a range of control options. The main components of an IPM system are shown in figure 1.1.

- *Equilibrium I*: Pest numbers fluctuate around the equilibrium. The pest numbers are always above the EIL and therefore significant economic losses are incurred.
- *Equilibrium II*: Following the introduction of primary management components (parasite/predator/management change) the new equilibrium is below the EIL and damage is no longer of economic significance. If pest populations exceed the EIL then remedial measures such as strategically timed applications of insecticides can be used.

The main steps required to establish an IPM program are shown in figure 1.2 (over page).

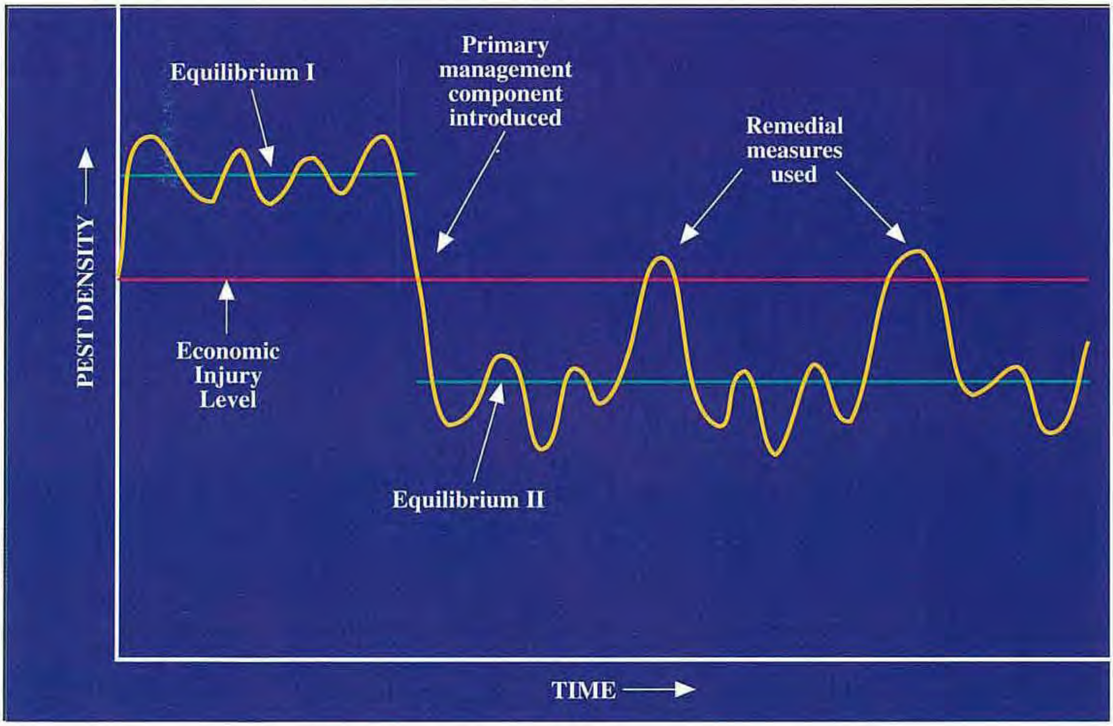


Figure 1.1: Population changes of a hypothetical pest, illustrating the principles of IPM (after Rabb, R.L. 'A sharp focus on insect population and pest management from a wide-area view', 1978, *Bulletin of Entomological Society of America*, Vol. 24(1): 55–61)

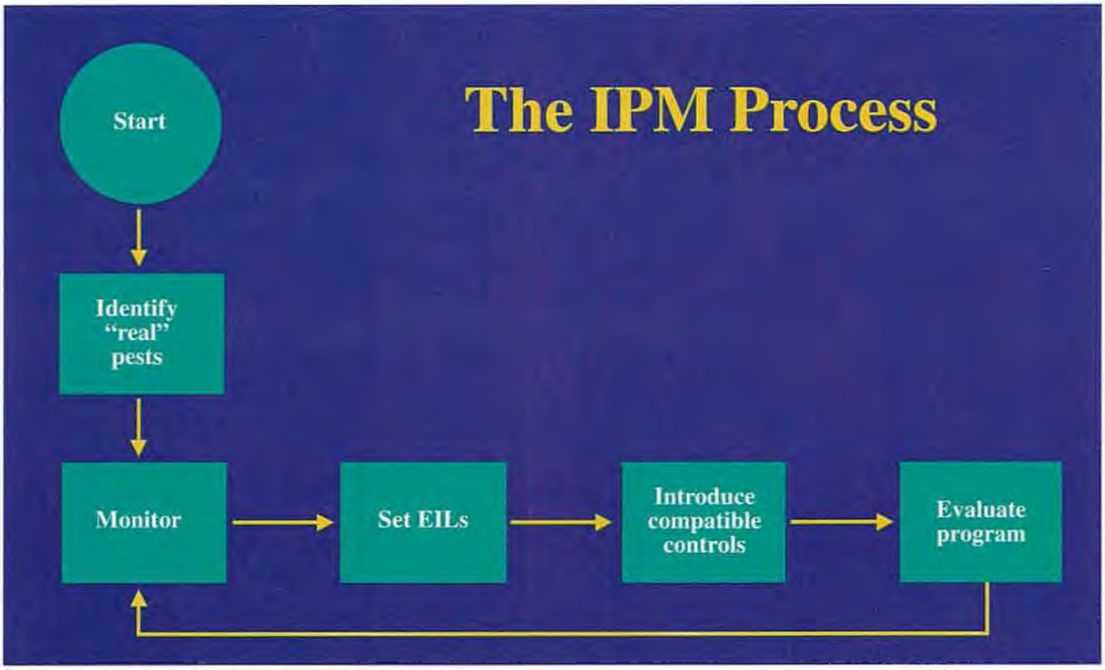


Figure 1.2: Steps in a typical IPM program

As the flow chart illustrates, IPM goes through a number of important steps and is a dynamic process. Improvements in pest management are achieved through constant evaluation and modification of the program.

Pest-management decisions are based on regular monitoring of pests and beneficial parasites and predators. Monitoring is best carried out by a competent professional pest scout but can also be done by the grower. Results from regular scouting are recorded on field sheets, the information from which, subsequently, can be entered into a computer. Recommended monitoring frequencies, methods, and sample data sheets are included in this manual for each major pest (see chapter 3 and Appendix 4).

The accurate identification of both pests and beneficials is the essential first step in IPM. To use IPM successfully, it is necessary to be able to identify each pest (including the main stages in the pest's life cycle) and the major parasites and predators of that pest. Colour photographs, line drawings and life-cycle descriptions of each major pest are included in later chapters of this book to assist in this learning process.

PREFACE

This manual summarises the current knowledge of insect and mite pests of bananas and how they are managed in Queensland. Its intention is to provide practical advice to growers, horticultural advisers, future pest scouts and other interested persons in the implementation of integrated pest management (IPM) in bananas. IPM methods aim to provide sustainable pest management by exploiting biological and cultural methods of pest control and reducing dependence on insecticides.

The manual explains the biology, economic importance, biological control potential, and both cultural and chemical control options for all pests likely to be encountered in bananas; these are grouped as major and minor pests. Detailed monitoring procedures are outlined for the major pests. Whenever possible, photographs and line drawings have been included to assist in positive identification, the first step towards successful pest management.

Although this book deals only with insect and mite pests, a similar manual will be produced at a later date to provide information about diseases, nematodes and weeds.

NOTES TO GROWERS

Note 1

The chemical recommendations given in this book are correct for Queensland at the time of printing. Check with your local departmental officers for any variations from these recommendations.

Note 2

Chemical names used in this book are common names only. Refer to Appendix 1 (pp. 67–68) for a list of trade names.

2 BIOLOGICAL CONTROL OF BANANA PESTS

A large number of beneficial organisms (parasites and predators) occur naturally in banana plantations and provide a degree of pest control. Many are small insignificant insects and spiders, and some are active at night, preferring to hide during the day. Hence they go largely unnoticed and their real value is only appreciated when they are destroyed by inappropriate use of insecticides. For example, general cover sprays of insecticides from the ground or the air must be avoided if the full benefits from beneficials are to be realised.

Predatory ladybird beetles, lacewings, bugs, ants, and parasitic flies and wasps are the main beneficial insect groups active in banana plantations. Spiders are also a major group of predators which have been found to be very effective. Cane toads have been shown to feed on beetle borer and on other insects near the ground. Tree frogs which frequent the banana plants also feed on insects.

Within a banana plantation different species of pests and beneficials tend to occupy different habitats. Some prefer the leaves; others are more common on bunches; while others are found amongst the trash on the ground.

Figure 2.1: The green lacewing (left) and the *Stethorus* beetle (right) are valuable predators of some banana pests.

Figure 2.2: The lacewing eggs are laid in clusters and are held above the surface by fine white threads.

Figure 2.3: The larva (left), pupa (bottom right) and adult ladybird beetle (top right), of *Stethorus*

Figure 2.4: A colony of the ant *Tetramorium bicarinatum*. This ant is an aggressive coloniser and is very common in banana plantations where minimal insecticides are used. *T. bicarinatum* is useful in reducing scab moth, weevil borer and other pests.

Figure 2.5 (a-d): Spiders are common predators in banana plantations. Many spiders are found in rainforest and natural bushland which provide a good supply of spiderlings to move into adjacent banana plantations.

(a) Jumping spider *(Salticid)*

(b) Huntsman spider *(Heteropoda sp.)*

(c) Jumping spider feeding on cluster caterpillar larva

(d) Sun or Christmas spider *(Gasteracantha sp.)*

3 MONITORING PROCEDURES

Frequency of monitoring

Insect pests are managed more effectively if control measures are applied before populations rise to damaging levels. Regular and frequent monitoring is recommended to gain a thorough understanding of pest dynamics in each block/ property. Accurate monitoring will allow more efficient implementation of control measures and minimise crop losses.

The frequency of monitoring for any pest species varies and depends on a large number of factors including:

- mobility of the pest
- length of its life cycle
- severity of potential damage
- climatic conditions.

Because most pests are more active when temperatures are warm, monitoring needs to be more frequent during spring and summer. The most practical monitoring frequencies have been determined through DPI research on the biology of the pests, their natural control agents and potential crop damage.

Monitoring techniques

Different monitoring techniques are needed for different pests. Monitoring relies on examining a small proportion of a crop to provide information which will allow a management strategy to be applied to the whole crop. Monitoring techniques are easily learned and observations can be made quickly without specialised equipment.

Knowledge of pest distribution throughout the farm will increase the efficiency of sampling. For example, on the plantation, you should determine whether the insect is:

- distributed uniformly throughout
- confined to plants on, or close to, the margins
- found regularly in certain locations ('hot spots').

Sampling should be planned to include 'hot spots' since these areas provide early warning of potential and more widespread pest outbreaks.

Quality assessment of harvested fruit

An integral part of the monitoring program should be regular assessments of harvested fruit in the packing shed. Such assessments will indicate the ultimate effectiveness of pest management practices. Harvest assessments may at times underestimate damage caused by insect pests. For example, scab moth-infested bunches may be cut off and left in the field, and therefore not recorded at harvest. Similarly, losses due to plant fall-out from banana weevil borer and/or nematode damage are also difficult to quantify from harvest assessments. Nevertheless, harvest assessments do provide valuable information on the causes of poor fruit quality that can be immediately rectified to minimise future fruit losses.

Packing-shed assessments will also expose other factors that may be affecting fruit quality — for example, mechanical damage caused by mishandling during harvest and transport from the field, and during dehanding. Action can then be taken to reduce or prevent this type of damage. Other causes of poor fruit quality are:

- chemical burn
- sunburn
- fruit diseases
- rat and bird damage.

Frequency of harvest assessments

In the first year following adoption of IPM, harvest assessments should be undertakeu at least monthly. This will quickly identify the major sources of damage at different times of the year. In subsequent years, the assessments

TABLE 3.1: Suggested monitoring frequency for the main pests

PEST	MONITORING INTERVAL (WEEKS)	
	Spring/Summer	Autumn/Winter
Banana scab moth	1	2
Banana weevil borer	4	6-8
Banana rust thrips	2	4
Banana flower thrips	2	4
Sugarcane bud moth	2	4
Mites	1-2	2-3

can be made less often. Three-monthly intervals should be adequate to ensure that quality standards are maintained and to detect any new sources of damage.

Suggested method of harvest assessments

At the required interval, select one trailer-load of fruit at random and assess the fruit for blemishes. The following procedure needs to be followed. A suitable form to record the information is shown in table 3.2.

1. Record the total number of bunches.
2. Record the total number of cartons within each fruit grade packed to determine individual and total packout.
3. Separate fruit discarded during cutting and packing. Sort into categories according to damage — for example, insect and non-insect damage.
4. Individually weigh all damaged fruit and record the weights.

Personal computers in data storage and presentation

Personal computers are a valuable aid in integrated pest management programs. They provide an effective method for data storage and manipulation and can be used to generate pictorial representation of the data. This simplifies the interpretation of results and aids decision- making.

The following information can be stored and retrieved using a personal computer:

- insect counts
- spray information
- weather records
- harvest data
- crop growth measurements.

Software packages — for example, EXCEL, LOTUS 1-2-3 — are available that allow data to be recorded on files known as spreadsheets. To transfer data easily, the format of the sheet used for field recording should be the same as that of the spreadsheet set up on the computer (see Appendix 4).

Spreadsheet/graphics packages are useful for plotting charts of insect numbers (as determined by monitoring) over time. They provide information on whether the population is increasing, remaining stable, or decreasing. In the case of a pest species, this information enables rapid assessment of the ueed to undertake control measures and also the evaluation of any that may have already been implemented.

An example of a graph produced from a spreadsheet containing information on mites and *Stethorus* counts at various times is presented in figure 3.2 (p. 8). (See p. 62 for field data sheets.)

The presentation of spreadsheet information can be easily changed, so that different types of graphs and colours can be used to highlight different information. An example of a pie chart using different colours to show the damage to harvested fruit from various sources is presented in figure 3.1 (page 8).

TABLE 3.2: A suggested format for recording information from harvest assessments

HARVEST ASSESSMENT

Farm: Nerada Paddock: B4

Total Bunches Assessed: 10 Date: 15.3.93

Cause of damage	**Weight of damaged fruit (kg)**
Non-insect damage	
Mechanical — Pre-harvest	—
Mechanical — Post-harvest	—
Mechanical — Injection marks	10.3
Sunburn	1.7
Maturity bronzing	83.8
Doubles	—
Smalls	6.8
Chemical burn	—
Rat	2.1
Other	—
SUB-TOTAL (a)	104.7 kg
Insect damage	
Scab moth	34.2
Sugarcane bud moth	20.5
Mites (red spider)	—
Banana fruit caterpillar	—
Flower thrips	8.6
Rust thrips	3.0
Other	—
SUB-TOTAL (b)	66.3 kg
Waste unsorted	
TOTAL WEIGHT ALL WASTE (c)	171.0 kg

Fruit weight/carton = 14 kg

Total cartons packed = 21.5 (18 XL, 3.5 L)

Total weight packed fruit = 301 (d)

Total weight of harvested fruit = 472 (c + d)

% Waste fruit (of total harvest) = $\frac{c}{c+d} \times 100 =$ 36.2 %

% Insect damaged fruit (of total harvest) = $\frac{b}{c+d} \times 100 =$ 14.0 %

% Insect damaged fruit (of total waste fruit) = $\frac{b}{c} \times 100 =$ 38.8 %

Waste categories from fruit harvest assessment

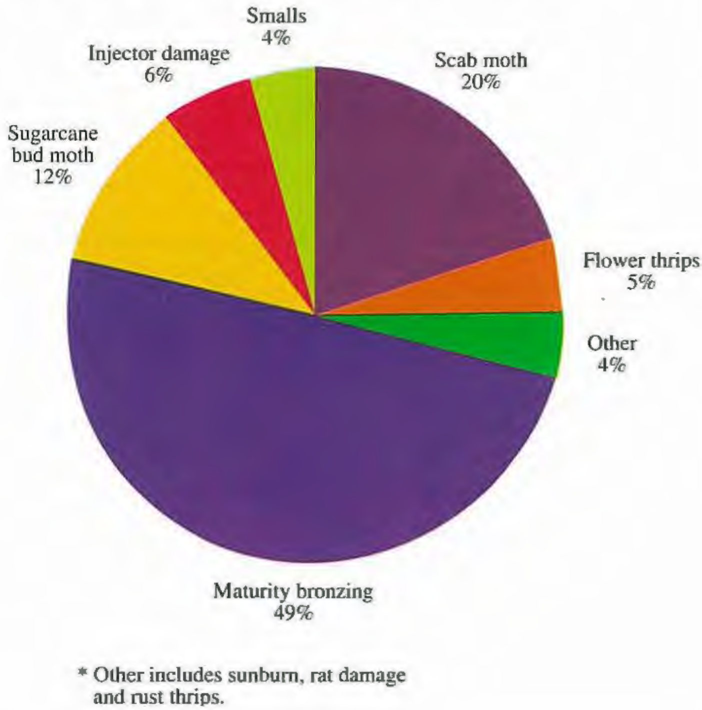


Figure 3.1: Data from table 3.2 presented as a pie chart. This form of presentation provides a very useful visual aid to show the main sources of fruit waste. In this example, maturity bronzing (49%) and scab moth damage (20%) were the main contributors. This indicates that fruit may have been allowed to overfill promoting maturity bronzing, and that scab moth control measures were inadequate at bunch emergence.

Population changes of mites and the predator *Stethorus*

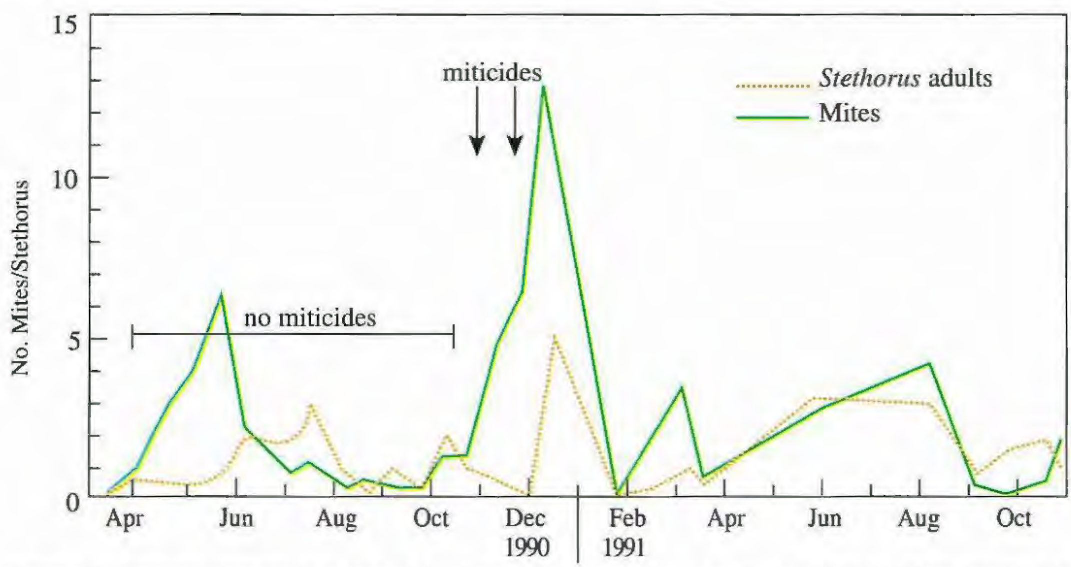


Figure 3.2: Seasonal changes in mites and *Stethorus* in a banana plantation during 1990-91. Note that the May 1990 mite build-up was controlled by an increased *Stethorus* population. Two miticide applications were needed in early and mid-December to assist *Stethorus* during the very hot and dry period which favoured the mites. Up to mid-1991 no miticides were needed since *Stethorus* provided adequate control.

4 MAJOR PESTS

Banana scab moth (Nacoleia octasema)

Occurrence

In Queensland, banana scab moth occurs only in areas from Ingham northwards. Although banana is the preferred host, larvae also have been recorded feeding on pandanus flowers.

Damage

Damage is primarily confined to the flowering period. Feeding by young larvae starts as soon as the first bracts lift and usually increases in severity as the larvae grow and move progressively down the bunch as subsequent bracts open. Damage is confined to the outer curve of the fingers (the area nearest to the bunch stalk) but, in more severe cases, damage can extend to areas between touching fingers, or even extend to cover the whole fruit surface.

Figure 4.1: Characteristic fruit damage to a newly emerged bunch

The surface feeding by larvae results in scars which quickly turn black. While damage is usually only superficial, affected fruit is downgraded or is unsuitable for market.

Seasonality

Scab moth favours moist and warm conditions; therefore, the period of greatest potential damage is during the wet season. Bunches which emerge from December through to the end of May are most at risk of attack. The cooler and drier winter months are relatively free of scab moth but damage can flare up if unseasonal rain occurs at this time.

Description and life cycle

The tiny (1.2–1.5 mm) flattened eggs are laid in clusters which resemble miniature overlapping fish scales. Because of their small size and the fact that they are laid near the throat of the plant, egg clusters are very difficult to locate. Eggs are usually laid on the emerging bunch and the surrounding leaves and bracts, but eggs have occasionally been found on the pseudostem below the new bunch. The pink to brown larvae range in length from 1.5 mm when first hatched to about 25 mm when fully developed. If disturbed, larvae wriggle violently and drop on silken threads. When fully mature, the larvae pupate in the trash at the base of plants or on the bunch. The brown pupae range in length from 9–13 mm.

The adult moths are rarely seen because they hide by day and their small size (22 mm wingspan) and dull brown/grey coloration makes them difficult to see. The adults do not appear to be attracted to lights.

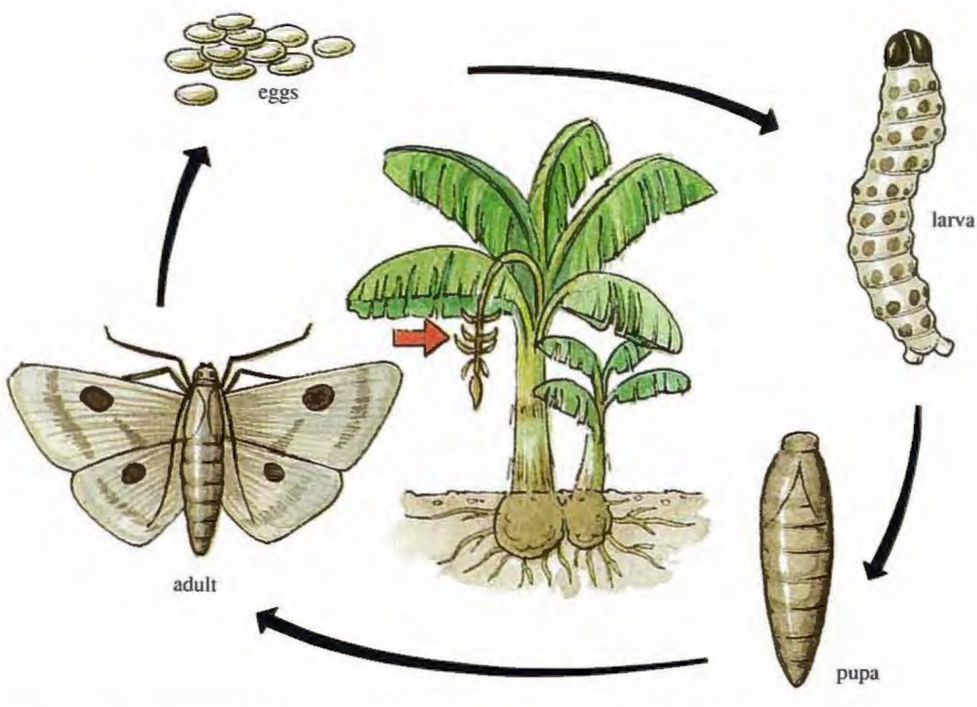


Figure 4.2: Life cycle of banana scab moth. Under suitable conditions, the life cycle is completed in approximately 28 days (arrow indicates part(s) of plant affected).

Figure 4.3: Banana scab moth larva feeding on immature fruit

Figure 4.4: Damage on mature fruit — this damage was done soon after bunch emergence.

Figure 4.5: Eggs of banana scab moth (× 15)

Figure 4.6: Adult banana scab moth (× 3)

Monitoring

The only practical method of monitoring for scab moth is to examine a number of freshly emerged bnnches (Growth Stage 6 = GS6) for the presence of damage and/or larvae. Begin by checking the undersurface of the fingers in each hand (closest surface to the bunch stalk) and the cushion area. In very young bunches, it may be necessary to lift the developing hand away from the bunch stalk to reveal any larvae and fresh damage.

Another larval feeding site is at the base of the bunch stalk where the larvae enter the throat of the plant. Larvae can be detected by separating the base of the flag leaf and removing the bract that is attached to the stalk. Often a clear jelly-like substance, which appears to be associated only with scab moth feeding, is present at these sites.

A total of at least ten freshly emerged bunches at GS6 (bract fall) should be checked for both scab moth larvae and damage at each sampling site. Known 'hot spots', such as border rows adjacent to scrub or creeklines, should be monitored closely. Two sampling sites (twenty bunches) per hectare should be monitored, if possible, to provide an accurate picture of scab-moth activity. During periods of bunch emergence, monitoring should be carried out on a weekly basis, especially during warm rainy weather when scab moth is most active. During cold or dry weather this can be reduced to a fortnightly schedule.

A field monitoring sheet is presented in Appendix 4 (p. 64) which can be used to record scab moth presence on hands as well as potential beneficials. Since flower thrips are also monitored at this stage, thrips numbers can also be recorded on the same sheet

Note: Monitoring for scab moth eggs is very difficult because the eggs are very small and they are laid at the top of the plants where access is difficult. Adults cannot be monitored because no method is available for attracting them, and their nocturnal habits and good camouflage makes detection very difficult.

Management guidelines

Because scab moth damage results in immediate downgrading or rejection of fruit, treatment should be commenced as soon as damage is detected on any of the GS6 bunches monitored. This is particularly important if heavy bunching is anticipated and/or conditions suitable for scab moth (hot and wet) are being experienced or forecast.

Chemical

The preferred and recommended control method is bell (bunch) injection. Chlorpyrifos and bifenthrin are registered for use in bell injection.

One injection at bunch emergence using 20-40 mL of chlorpyrifos mix or 40 mL of bifenthrin mix will provide protection scab moth. Refer to product table in Appendix 1 for rate of use. The accurate targeting of insecticide using injection will not harm beneficial insects on other parts of the plant. Beneficial insects may be providing some control of other pests; therefore, this method is preferred to the less-precise application methods of dusting, bunch spraying and broadcast applications from the ground or air.

The correct site for injection is in the top one-third of the emerging (upright) bunch. Injection below this area will damage fruit. The lower position for injection can be confirmed by the distinct swelling caused by the bottom hand of fruit. Injection just above this site will allow rapid entry of liquid and cause minimal or no damage to the fruit. Injection near the tip of the upright bunch will result in reduced entry of liquid due to the solid 'bell'.

Aerial application using 0.5–1.0 L of chlorpyrifos per hectare should be used only if labour shortages or other factors prevent injection from being carried out. Aerial application is not as effective as injection and is detrimental to most beneficial insects in the crop. For similar reasons, airblasting or misting with ground rigs should not be carried out.

Figure 4.7: Emerging bunch showing the site for injection — slightly above one-third from the top

Figure 4.8 Injector damage to fruit caused by incorrect (too low) injection

Dusting with a 1% chlorpyrifos dust or bendiocarb (Ficam banana dust) can be used for scab moth control but is not as effective as injection, and dust residues can detract from fruit appearance.

Note: 1% chlorpyrifos dust is made by thoroughly mixing 1 kg of Lorsban 250W with 24 kg of talc or 1 kg of Lorsban 500W with 49 kg of talc.

To be effective, dust must be applied just prior to bunch emergence to prevent entry of the young larvae into the bunch. Once the larvae move beneath the bracts they will not be controlled by dusting unless the bracts are lifted by hand to expose the larvae.

Cultural

Followers of equal size should be selected in order to concentrate bunch emergence. Control

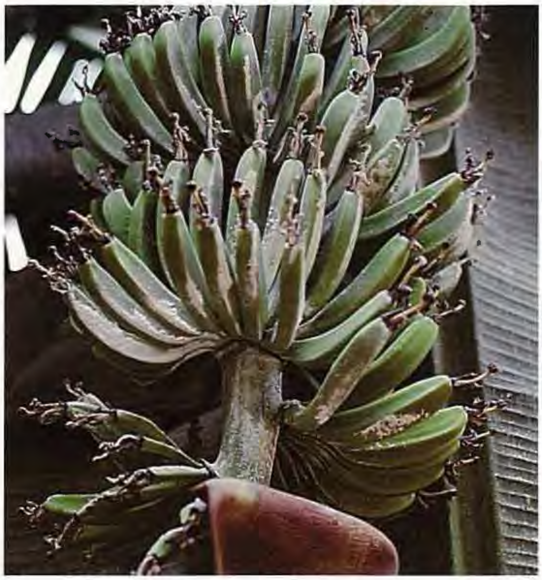


Figure 4.9: Heavy dust deposits on fruit are unsightly and lead to excessive chemical residues. Correct calibration of the duster (refer chapter 7) is essential to provide only a fine coating of dust.

TABLE 4.1: Impact of various pesticide application methods on scab moth and other major pests

	Scab moth	Mites	Flower thrips	Rust thrips	Sugarcane bud moth
Bunch injection	Very effective	Nil	Very effective	Very effective[1]	Unknown
Bunch dusting	Effective	Nil	Partly effective	Very effective	Very effective[2]
Cover sprays	Not effective	Adverse[3]	Not effective	Partly effective	Unknown
Aerial sprays	Effective	Adverse[3]	Not effective	Partly effective	Unknown
Butt sprays	Unknown	Nil	Nil	Effective	Nil

[1] Bunch injection is only effective against rust thrips at the time of bunch emergence and further treatments are necessary to provide protection during fruit development.

[2] Requires a follow-up treatment at time of bunch covering to give longer-term protection.

[3] These treatments reduce the effect of beneficial predators resulting in mite increase.

treatments are more efficient when bunch emergence is synchronised through careful selection of followers.

Biological

No major specific parasites or predators of scab moth have been found but a number of wasp parasites, spiders and other general predators do provide a low level of natural control. The ant, *Tetramorium bicarinatum* is very common on plants and bunches and evidence indicates that it suppresses scab moth.

Banana rust thrips (*Chaetanaphothrips signipennis*)

Occurrence

Banana rust thrips has been a serious and frequent pest since bananas were first grown in Queensland. Damage occurs in all areas but is more severe in bananas grown in the well-drained red soils.

Damage

Fruit damage is caused during feeding by the larval and adult stages of the thrips. The damage first appears as a dusty water-soaked

Figure 4.10: Early development of damage. Note the dusty, water-soaked appearance between the adjacent fingers.

Figure 4.11: Typical 'rust' on mature fruit.

Figure 4.12: Severe 'rust' on a mature hand. Heavy pest pressure will lead to damage spreading past the areas between adjacent fingers.

mark between the fingers in the area where two adjacent fingers touch. This later develops into typical reddish-brown 'rust' areas. Severe damage can result in skin cracking.

The superficial damage does not reduce the fruit eating quality. However, 'rusty' fruit can be downgraded or rejected, depending on the severity of damage and the current market supply conditions.

Note: Rust thrips damage should not be confused with maturity bronzing, which produces a rusty reddish discolouration on the fingers. While it appears similar to rust thrips damage, matnrity bronzing occurs on the exposed outer curve of the fruit and is not confined to areas where fingers are touching.

Seasonality

Rust thrips can damage fruit throughout the year but the period from November to April is the period of greatest activity. Experience has shown that unusually dry periods at this time encourage heavy build-up of thrips and subsequent damage. Wet conditions are thought likely to cause high mortality of the soil-dwelling pupal stage, either directly from drowning or by encouraging the development and spread of diseases.

Description and life cycle

The extremely small eggs are inserted by the female just below the surface of the fruit or other plant tissues. The small (0.5–1.0 mm long) white slender larvae do not have wings and can be seen moving when areas of infestation are exposed by separating touching fruit.

When fully developed, the larvae drop to the ground and pupate just below the soil surface, near the base of the plant and suckers. The white pupa is about 1 mm long and can be very difficult to find. Two distinct pupal stages are known to occur.

The adult has small feathery wings and is a slender (1–1.5 mm) straw-coloured insect. The wings are fringed with a line of dark scales and, when at rest along the body, these scales form a characteristic black longitudinal line running the length of the abdomen. Two eye-like dark patches at the base of the wings are characteristic of rust thrips adults. These patches help distinguish them from the smaller males of banana flower thrips.

Figure 4.14: Adult banana rust thrips on banana fruit. Note the distinct black line formed by the folded wings and the two eye-like black patches over the thorax.

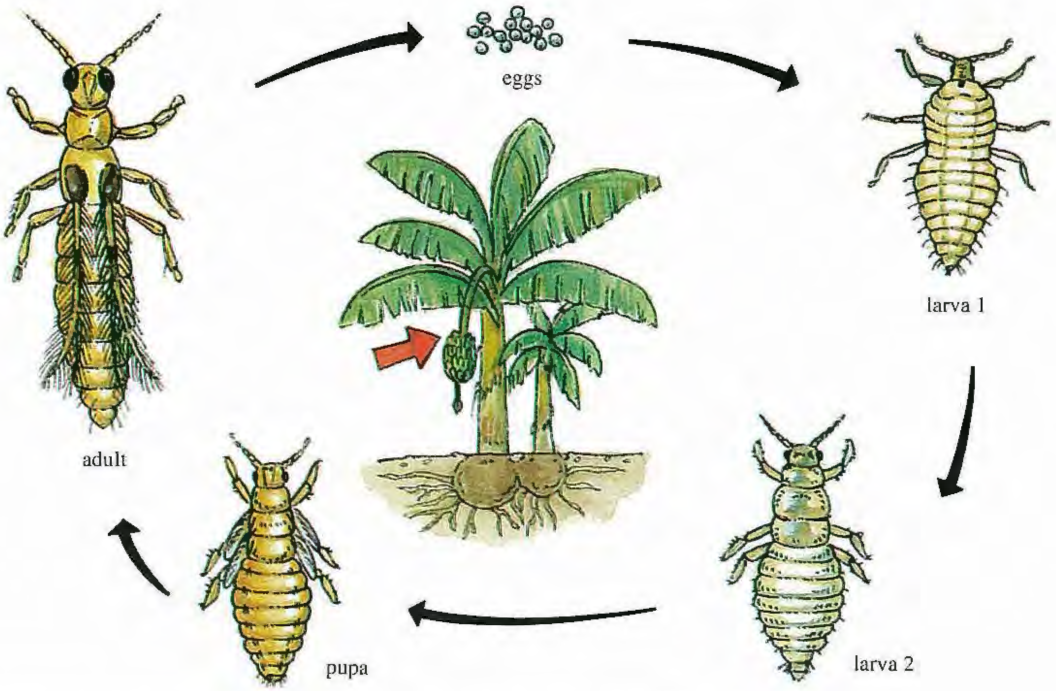


Figure 4.13: Life cycle of rust thrips (arrow indicates part(s) of plant affected)

Monitoring

Five bunches per hectare at GS7 (the same as those used for monitoring corky scab) should be examined for rust thrips on a fortnightly basis throughout the year. Using a ladder to gain access to the top of the bunch, select five central fingers from the top row of the top hand. The number of adult thrips on one side of each finger and the level of red discolouration (rust) present on the same side are recorded using the rating scheme in table 4.2 and recorded in the field sheet (see Appendix 4).

Rust thrips can occur on unbunched plants and their presence can be determined by monitoring established plantations fortnightly throughout the year. New plantings should be inspected prior to bunching in order to determine both the presence and severity of rust thrips infestations so that control measures, if required, can be carried out before fruit damage occurs.

TABLE 4.2: Rating scheme for banana rust thrips damage on fruit

Rating	Level of damage
0	No damage
1	Minor localised damage (up to 4 cm across)
2	Damage extending beyond 4 cm (fruit could be marketed as second grade)
3	Severe and extensive damage with skin cracking (fruit unmarketable)

Under heavy infestations, rust thrips can produce characteristic V-shaped rust coloured markings on pseudostems as a result of their feeding where the petiole meets the pseudostem. If these markings are observed, the presence of thrips should be confirmed by gently pulling the

Figure 4.15: V-shaped rust markings on the upper pseudostem indicate the presence of high rust thrips populations.

leaf petioles away from the stem and inspecting these sites with a ×10 hand lens.

Management guidelines

Chemical

Chemical control should be directed at both the soil-dwelling pupal stage and the adults and larvae on the fruit and plant. Failure to control the pest at both sites will result in continuous reinfestation, especially during the hot, humid periods of the year.

Soil treatments: The treatments aimed at banana weevil borer (see p. 25) will provide temporary control of rust thrips. Prothiofos (Tokuthion) has been found to be the most effective, followed by chlorpyrifos (Lorsban). Treatments applied in September/October for weevil borer should provide partial protection during November/ December and into the early part of the following year.

If the September/October treatment against weevil borer has not been used, and monitoring indicates the presence of rust thrips, then a specific soil treatment against rust thrips should be applied in December using the rates and application methods specified for weevil borer.

Figure 4.16: Damage to fruit ('burn') caused by spray run-off coalescing on the undersurface of the fingers

Fruit/plant treatments: All bunches, the pseudostem and the suckers should be sprayed with diazinon 40 g per 100 L. **Note:** Do not use a rate higher than 40 g per 100 L as this will cause severe fruit 'burn'. (40 g of diazinon is contained in 50 mL of Diazinon 800 etc.)

Diazinon treatments should commence when all bracts have fallen and continue every 14 days if bunch covers are not used. Treatments must not be made less than 14 days prior to harvest. Bunch and pseudostem sprays of diazinon must only be used in extreme cases since these will disrupt beneficials. The early application of bunch covers in conjunction with dusting inside the bag (as for control of sugarcane bud moth) is the preferred method of control.

Injection treatments for scab moth (see pp. 11–12) provide early bunch protection against rust thrips. Extended protection up to harvest should then be provided by one insecticide dust application at the time the bunch cover is applied. New management techniques using controlled release chemicals to replace dust and sprays are being evaluated.

Cultural

Obtain thrips-free planting material and, if possible, hot water treat prior to planting out. Destroy all volunteer plants and old neglected plantations which harbour the pest and which could act as a source of thrips to spread to other plantings.

Sound (unbroken) bunch covers (which cover the full length of the bunch) do provide some protection if applied very early. These cannot be relied upon to fully protect fruit, particularly during severe infestations. Regular checking of fruit under the bunch covers is essential to ensure that damage is not occurring. Ensure treatments are applied immediately after detection to prevent further damage.

Biological

General predators such as lacewings and ladybird beetles may exert some control of rust thrips on the plant, and ants may be effective in removing some of the pupae in the soil.

Mites

Banana spider mite (Tetranychus lambi)
Two-spotted mite (Tetranychus urticae)

Occurrence

The banana spider mite (also known as the strawberry spider mite) and the two-spotted mite are common pests of a broad range of crops and are widely distributed. Both species are often referred to simply as 'red spider'. In bananas, the banana spider mite is the more prolific of these two pests.

Damage

Damage is mainly confined to the underside of the leaves; however, in severe outbreaks the mites can move to the bunches and damage fruit. Leaf damage appears at first as isolated bronzed rusty patches, which later coalesce along the leaf veins as the infestation increases.

Figure 4.17: Severe leaf damage causes edge scorching and death of the leaf.

Eventually the whole leaf turns dark brown-grey and, in extreme cases, the leaves wilt, with partial or total collapse of the leaf lamina. Leaf wilting and collapse result in sunburnt bunches and reduction in plant growth.

Fruit damage by banana spider mite is found mainly on the cushion end of the fingers. Feeding in this area causes a red to purple-black discolouration of the fruit surface which may later dry out and crack.

Figure 4.18: Damage caused to a hand of bananas by the banana spider mite

Figure 4.19: Damage by the two-spotted mite. Note the silvery-grey damage to the tip of fruit fingers and webbing.

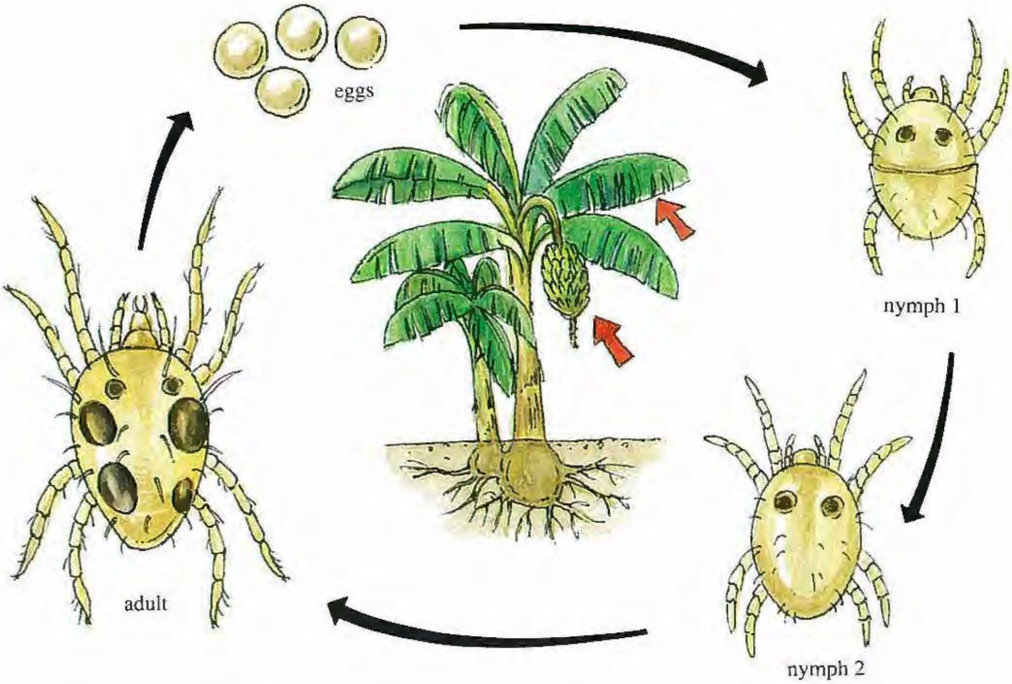


Figure 4.20: The life cycle of the mite (arrows indicate parts of plant affected)

Two-spotted mite damage to fruit is usually confined to the top hands of bunches, and develops as silvery-grey patches on the tip of the fruit fingers. This damage is associated with conspicuous fine webbing bridging infested fingers.

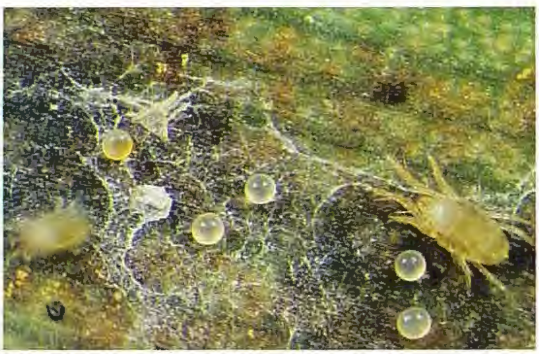


Figure 4.21: Adult mite and its spherical eggs. Note the dark leaf tissue, an indication of dead leaf cells caused by mite feeding.

Seasonality

Mites are most abundant during hot dry periods — for example, from September to December. High humidity does not favour mites and mite pressure in north Queensland reduces accordingly during the wet season.

Because mites have a very short life cycle, under favourable conditions rapid flare-up of mites can occur. This can be avoided by regular monitoring and application of well-timed miticide sprays when necessary. Miticides are specifically aimed at eradicating mites and can be used safely in an IPM system with natural predators.

Description and life cycle

The life cycle and appearance of the banana spider mite and two-spotted mite are similar. The main distinguishing feature between them is the relative lack of fine webbing in infestations of the banana spider mite, whereas high

TABLE 4.3: Mite damage assessment category (overall plant)

Categories	Indicators
1 = Low	Few mite colonies evident on leaves and minor localised bronzing on undersurface of leaves.
2 = Medium	Mite colonies scattered but numerous; bronzing clearly evident on leaves (patchy but starting to coalesce) but damage contained within the interveinal areas.
3 = High	Mites colonies coalescing, and bronzing damage over most of the leaves. In extreme cases, leaves wilting with possible edge scorching.

populations of the two-spotted mite are always associated with webbing.

The tiny straw-coloured or greenish mites are best seen with the aid of a ×10 lens. Under good light conditions, the adults can just be seen with the naked eye.

The minute colourless to yellow, spherical eggs are laid singly on the leaf surface and, upon hatching pass through two nymphal stages before becoming adults. In hot conditions, the life cycle (figure 4.20) can be as short as eight days.

Monitoring

During hot and dry weather conditions, monitoring of mite populations should be carried out at least fortnightly. During cold and/or wet conditions, which are less favourable to the mites, the monitoring interval can be extended to three weeks.

Method

1. Overall plant damage assessment

Five plants at GS6 (the same as used for scab moth monitoring) are examined and each plant is rated according to the level of mite damage (bronzing). Damage categories are assigned for

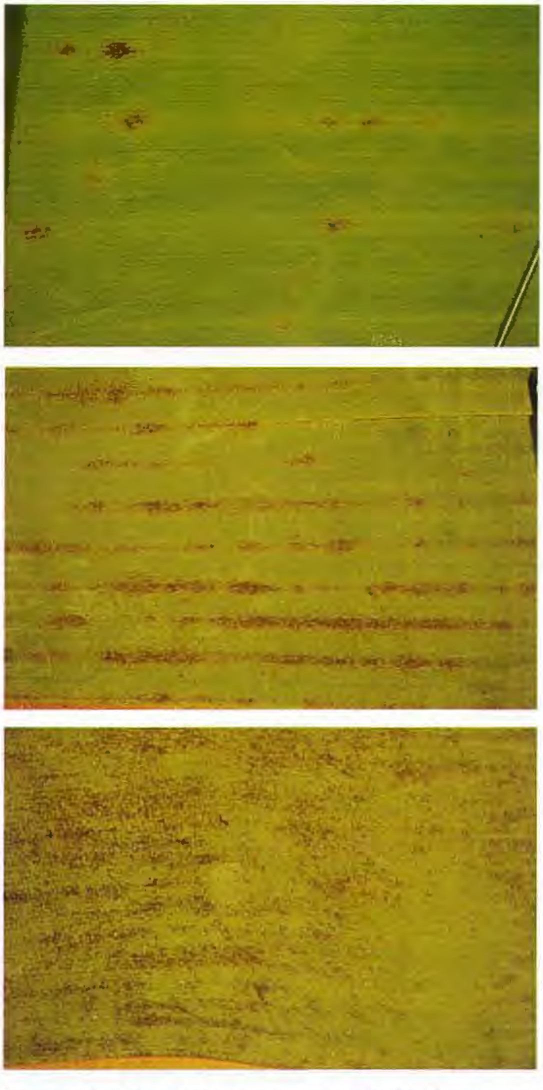


Figure 4.22 (a-c): Three categories of mite damage as described in table 4.3.

each plant according to information provided in table 4.3 (1= Low, 2 = Medium, 3 = High) based on the overall appearance of the leaves.

2. Detailed mite/predator count

Each of the five plants is then more closely examined by using a ladder to gain access to the top of the plant where the youngest leaf with bronzing and/or mite colonies is recorded. The third leaf down from the youngest mite- infested leaf is cut and carefully lowered to the ground, being careful not to dislodge predators. The leaf is placed upside down on the ground and the entire leaf undersurface immediately inspected for the presence of the main mite predator *Stethorus* and other minor predators. (See section on biological control of mites, pp. 21–23.)

A section of leaf approximately the length of a long-handled cane knife (38 cm) on one side of the midrib only, is then examined for mites. Ideally, this section should be taken from the centre of the leaf; however, where the leaf blade has been split excessively by wind, it may be necessary to choose an area closer to the petiole where it is less divided.

The number of discrete mite colonies causing bronzing (damaged area) is recorded using a 0–4 rating scale where:

0 = no areas damaged

1 = 1–10 areas damaged

2 = 11–50 areas damaged

3 = 51–100 areas damaged

4 = >100 areas damaged.

Five colonies are selected at random and examined closely using a ×10 hand lens. The number of eggs and other stages (nymphs, resting stages and adults are included under other stages) for each of the five areas are counted and recorded. At this time, predatory mites, *Stethorus* eggs and other mite predators which may be present on the five selected sites are also recorded on the data collection sheet (see Appendix 4).

Note: Mite monitoring is best carried out between 9 a.m. and 2 p.m. when any dew has evaporated and there is more available sunlight to assist examination of the leaves. Mite monitoring is not feasible during rain or if leaves are wet from overhead irrigation.

Management guidelines

Chemical

Good mite control can be achieved by well-timed miticide treatments using correctly calibrated airblast sprayers or misting machines. Sufficient volume (up to 500 L/ha) has to be

TABLE 4.5: Recommended miticide use

Pesticide (common name)	Trade name	Commercial formulation	Withholding period (days)	Rate		Rate of active ingredient
				per 100 mL	per ha	
dicofol	Kelthane	240EC 179EC 480MF	7	250 mL 250 mL 100 mL	2.5–3.0 L 2.5–3.0 L 1 L	0.06%
fenbutatin oxide	Torque	550EC	1		370 mL	NA
clofentezine	Apollo	500SC	0		250 mL	NA
propargite	Omite	300WP&WG	7	100 g	1.25 kg	0.03%
bifenthrin[5]	Talstar	100EC	8	40 mL	NA	0.004%

Notes

1. Do not apply clofentezine more than once per season. More frequent use is likely to lead to the rapid development of resistance in the mite population.
2. Avoid high volume coverage (to runoff) of bunches, as this may cause fruit burn. Use of bunch covers will avoid this damage.
3. When treating established (medium to high) populations, use a knockdown miticide (dicofol, propargite, fenbutatin oxide) in conjunction with the ovicide clofentezine.
4. Monitor eggs and motile mites about 10 days after the initial treatment to determine if a follow-up treatment is needed (approximately 14 days after the initial spray).
5. Talstar is harmful to the mite predator, *Stethorus*, and should not be used if prior monitoring had shown it to be active. If in doubt, use other specific miticides listed.

applied to obtain good coverage of leaf undersurfaces where the mites occur.

Treatments during the hot part of the day, when leaves are wilted, should be avoided because of difficulty in obtaining coverage under the leaves. If possible, double spraying (in opposite directions) using 250 L/ha at each run is recommended to increase spray coverage. In most situations a second application 14 days later should also be applied, especially if monitoring indicates a carryover of mites. This second treatment may not be required if a thorough first application of the ovicidal miticide clofentezine was applied, or if high populations of *Stethorus* are found during monitoring after the first treatment.

Cultural

Reduce dust on roadways as much as possible because dusty conditions favour the build-up of mites. Broad-leafed weeds act as reservoirs for mites, which can then reinfest banana leaves following treatment. Ensure a good level of weed control is maintained to reduce this.

Good water management, especially during dry conditions, will reduce water stress to plants, allowing them to better withstand mite damage.

Regular desuckering, leaf trimming and maintenance of correct plant densities will assist in achieving good spray coverage and thus increase the level of control obtained with miticides.

Biological

The small, shiny, black mite-eating ladybird beetle or *Stethorus* is the most important predator of mites in bananas. (See following section.) Other predators include other ladybird beetles, native predatory mites, predatory thrips and rove beetles.

Cover sprays with broad-spectrum insecticides are the major cause of mite flare-up because they destroy the beneficial predators. Use of such chemicals is not recommended. Where non-disruptive (pest-selective) pesticide treatments are used, natural predators usually provide sufficient control and miticides should not be required.

Biological control

The mite-eating ladybird (Stethorus)

The most important biological control agent of mites in bananas is the ladybird beetle — *Stethorus*, or mite-eating ladybird. Three species of *Stethorus* occur in bananas, but the main species is *Stethorus fenestralis*. All three species appear identical to the naked eye.

Stethorus numbers build up following mite population increases and eventually bring the mites under control. Both the adult and larval stages of *Stethorus* feed almost exclusively on mites.

Most insecticides, if applied to the leaves, destroy *Stethorus* and upset the delicate balance between this predator and its prey,which can result in serious mite outbreaks. Fortunately, the most effective method of control of insect pests in bananas is to apply chemical treatments to the bunch (bunch injection, bunch spraying or dusting) thus avoiding the leaves where the mites and *Stethorus* live.

Broadcast spraying of insecticides by aerial or ground-based equipment should be replaced by bunch injection, bunch spraying or dusting to preserve *Stethorus* and other mite predators. Since adopting the bunch injection technique a number of years ago, many banana growers in north Queensland have relied entirely on *Stethorus* and other natural controls to suppress mites.

Stethorus occurs naturally in all banana-growing areas. Although they are not available commercially, *Stethorus* are active fliers and have the ability to rapidly locate mite infestations and quickly disperse in search of new ones when food becomes scarce.

Life cycle

There are three distinct stages in the life cycle of *Stethorus* and it is important to recognise each of these stages. The elongated, translucent to pale brown eggs are laid singly under the leaves, either on or close to mite colonies. The eggs are about 0.2 mm long and can easily be

TABLE 4.6: Impact of various pesticide application methods on mites and other major pests

	Mites	Scab moth	Flower thrips	Rust thrips	Sugarcane bud moth
Cover sprays	Effective	Not effective	Not effective	Partly effective	Unknown
Bunch injection	Nil	Very effective	Very effective	Very effective	Unknown
Bunch dusting	Nil	Effective	Partly effective	Very effective	Very effective
Aerial sprays	Adverse	Effective	Not effective	Partly effective	Unknown
Butt sprays	Unknown	Unknown	Not effective	Effective	Nil

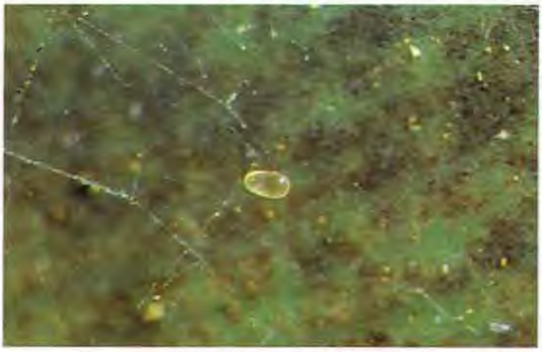


Figure 4.23: *Stethorus* egg: this egg is elongated and is about twice the size of the spherical mite eggs.

distinguished from the smaller spherical (and usually more numerous) mite eggs (figure 4.21).

Four active larval stages are each separated by a moult. Larvae are hairy and vary in colour depending on their age. Young larvae are pale cream becoming dark grey at maturity. Fourth-stage larvae (figure 4.24) eventually stop feeding when they are about 2 mm long and attach themselves to the leaf where they pupate.

The pupae are black, hairy and about 1 mm long (figure 4.25). Pupae may be found anywhere on the leaf undersurface; however, they tend mostly to be found close to or on the midrib. The pupa is the most easily observed stage because it is attached to the leaf. The pupal skin remains attached after the adult emerges. To determine if a pupa is alive or simply an empty pupal skin, smear it gently with a finger. A wet streak will indicate it was alive and if no such streak is produced it was an empty skin.

Adults are shiny black, almost circular beetles and are about 1 mm long (figure 4.24). They also occur on the undersurface of the leaf. Where there is a high incidence of mite infestation, there may be more than fifty adults under one leaf, although they usually number less than ten.

Figure 4.24: *Stethorus* larva with adult feeding on a mite

Figure 4.25: *Stethorus* pupa — the resting stage between the larva and adult

Monitoring

Monitoring *Stethorus* is easily combined with the monitoring of mite populations, so that both mites and *Stethorus* are counted at the same time. The same five plants assessed for mites are used for this purpose. The technique used for assessing *Stethorus* involves close examination of the undersurface of the leaf which has been cut from the plant to assess for mites. This leaf is carefully removed from the plant, in order to avoid dislodging the adults and larvae, and then carefully placed upside down on the ground for counting.

The leaf should be examined immediately before the adults fly off. Adults, pupae and larvae are counted by examining the leaf with the naked eye and the totals recorded on the mite assessment sheet (Appendix 4). The eggs of *Stethorus* will only be detected when the mite colonies are closely examined with a ×10 hand lens. Egg numbers are also recorded on the sheet.

Banana weevil borer (Cosmopolites sordidus)

Occurrence

Banana weevil borer is found in all major banana growing areas throughout the world. Bananas and other species of the genus *Musa* are the only known hosts. First recorded at Mackay in 1896, the banana weevil borer has since spread to all major banana-growing areas in Australia.

Figure 4.26: Extensive larval tunnelling in old corm just above the soil surface

Damage

Most of the damage is done by the tunnelling of the larvae which develop exclusively within the corm. No evidence of larval tunnelling is noticeable since all the tunnelling is confined to the corm below the soil surface. In heavy infestations, tunnelling will extend for a short distance up the pseudostem; the presence of tunnels can be seen if the pseudostem is cut close to the soil surface.

Healthy, fast-growing plants can withstand considerable infestation without showing obvious signs of reduced vigour. However, under different growing conditions, observations have indicated significant differences in plant tolerance to weevil borer attack. In situations where plant growth is reduced as a result of environmental stress, plants appear to suffer more from weevil infestation than in areas of active growth. Typical symptoms of a severe infestation are reduced plant growth, choking, yellow leaves and weak or dying suckers. Plants under attack are also prone to falling out (particularly in windy weather) but the root system of fallouts must be inspected carefully to ascertain the

Figure 4.27: Banana root showing different levels of burrowing nematode damage (reddish-brown lesions); healthy root (top) with increasing damage towards the bottom roots

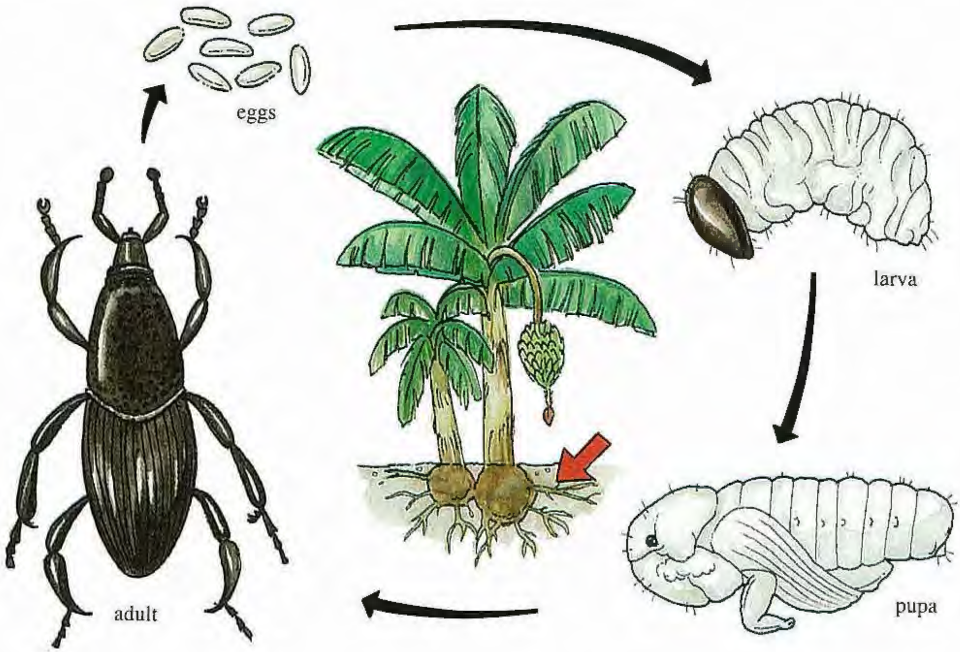


Figure 4.28: Life cycle of a banana weevil borer (arrow indicates part(s) of plant affected)

Figure 4.29: Adult and larva in banana corm

actual cause. In many circumstances, fallouts may be the result of root damage by the burrowing nematode, *Radopholus similis*.

Seasonality

Two peaks in adult emergence and activity have been noted — the first in spring during September and October, and the second during March and April. These peaks are particularly evident in South-east Queensland where activity almost ceases during winter. In North Queensland, where winter temperatures are not as low, activity continues throughout the year although at a reduced rate in winter. In North Queensland, dry conditions greatly reduce adult activity, whereas rainfall may be a major factor in increasing adult activity (as determined by weevil borer traps).

Description and life cycle

The pearly white 2 mm elongated eggs are laid singly in a shallow pit made by the female weevil at the base of the pseudostem. The eggs are very hard to find because the oviposition site becomes covered by congealed sap. The incubation period can be as short as four days in hot summer conditions but, at low temperatures, this period can extend to more than 30 days. An average incubation time is eight days.

On hatching, the small white larva immediately tunnels into the corm where it subsequently undergoes a number of moults before moving to the outer edge of the corm to

TABLE 4.7: Rating scheme for evaluation of banana weevil borer damage to banana corms (harvested plants)

Rating	Tunnels visible at soil level. (cross-section of lower corm)	Percentage of corm circumference with tunnels (at soil level)
0	nil	nil
1	1–4	1–25
2	5–8	26–50
3	9–15	51–75
4	>15	76–100

pupate. When fully grown, the soft-bodied legless larva is about 12 mm long and is creamy white with a hard brown head. The larval period varies greatly according to temperature, and may be as short as three weeks in hot conditions but may extend to several months during the colder winter months. The pupal stage lasts for about eight days.

Newly emerged adults are reddish brown but quickly assume their characteristic shiny black appearance. The adults are sluggish and feign death if disturbed. Although they have functional wings, they seldom fly. Extension of wings has been noted when the insect is under severe stress — for example, exposure to insecticide-treated soil. Releases of adults under controlled conditions have shown the rate of natural spread to be very slow. Dispersal is primarily by the introduction of infested suckers and bits at planting.

Monitoring

Adult weevil borer numbers can be monitored by baiting (trapping). Baits are made by cutting a fresh pseudostem into slices about 10 cm thick. The pseudostem material selected for making baits should ideally be taken from the lower portion of the stem of freshly harvested plants. One bait is placed close to the base of each plant, with one cut surface in full contact with the ground, and covered with leaves to prevent the bait drying out. Twenty or more baits should be used in known hot spots to obtain a good indication of weevil borer numbers. The ground directly beneath the bait should be cleared of any weeds or plant remains which can shelter adult weevil borers and hinder rapid checking of the baits. After three to four days, the baits are turned over and the adult weevils counted.

Adult weevil borer numbers are recorded from each bait and, knowing the total number of baits set and weevils counted, the average number of adults per bait can be calculated by dividing the total number of weevils by the number of baits set. A suitable field recording sheet is provided in Appendix 4. The field sheet allows for the recording of trap counts and a range of potential predators.

Adult weevil monitoring should be carried out on a monthly basis, except during the colder months when the time frame can be extended to six weeks.

Adult weevil activity increases during warm and/or wet weather and decreases during cold and/or dry conditions. Consequently, weevil borer numbers at baits placed during adverse conditions may not accurately reflect actual adult population levels. Periods of greatest adult activity are in spring (September-October) and late summer (March-April). Trapping should concentrate on these times to ensure the correct timing of chemical treatments if needed.

Regular monitoring of adults will give information on weevil borer population trends which can be useful in targeting the correct times for treatment. Chemical control measures will achieve the best result if applied during periods of high adult activity, because more weevil borers will come into contact with the lethal dose of insecticide.

Management guidelines

Chemical

If average weevil borer counts from trapping are more than two per trap (South-east Queensland) or more than four per trap (North Queensland) chemical treatments should be applied according

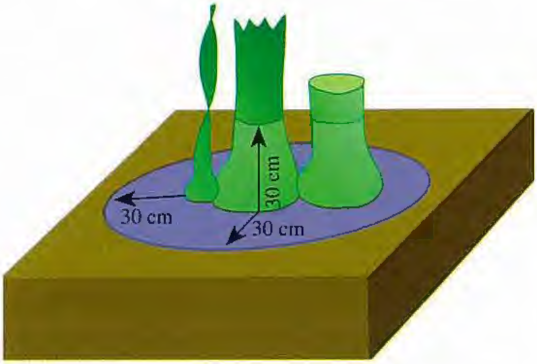


Figure 4.30: Diagram showing area to be treated in butt spraying for weevil borer

to label directions. If average counts are less than these, treatment is not considered necessary.

Note: Various formulations of chlorpyrifos and prothiofos are registered for use as well as ethoprophos, cadusafos and pirimiphos-ethyl. Select the most appropriate for your area, based on known resistance history. Mocap (ethoprophos) and Rugby (cadusafos) are dual purpose insecticides/nematocides and must be applied over a larger area than other chemical butt treatments in order to cover the root zone (refer to the labels). Mocap has a short residual activity against banana weevil borer and, in North Queensland, its effectiveness is greatly reduced by heavy rain.

Cultural

The use of clean (weevil borer-free) planting material and the maintenance of trash and weed-free areas near plants are two important factors in reducing the impact of this pest in bananas. Ideally, planting material should be obtained from weevil-free blocks, plant nurseries or from tissue-cultured plantlets.

If using slightly infested material, all corms and suckers must be carefully trimmed to remove all traces of tunnels and eggs and larvae.

When planting into old banana land, allow at least six months of fallow after all old banana material has rotted down to prevent a carryover of weevil borer adults. Cut up all fallen and harvested pseudostems to prevent weevil borer breeding. This is particularly important in South-east Queensland where drier, cooler conditions result in slow breakdown of plant material.

Biological

A large range of general predators including ants, beetles and cane toads assist in reducing weevil borer numbers. Research is being undertaken to determine the effectiveness of insect parasitic nematodes, which could prove suitable as biological control agents for weevil borer control.

Sugarcane bud moth (Opogona glycyphaga)

Occurrence

Sugarcane bud moth (SCBM) has been recorded damaging bananas in Queensland, northern NSW and at Kununurra and Carnarvon in Western Australia.

Damage

Larvae commence feeding on the surface of fruit after all the bracts have fallen. Damage is

Figure 4.31: Damage from sugarcane bud moth, and black frass pellets deposited by the larvae

confined primarily towards the tip of fingers. A preferred feeding site is the area where flowers from a lower hand touch the outer curve of fruit in the hand immediately above.

In severe cases, feeding sites can extend to areas between neighbouring fruit. This damage is very similar to scab moth damage.

Seasonality

This pest is most prevalent between December and April. Its importance has increased since DDT/BHC dust was withdrawn, due to the decreased residual activity of the organophosphate insecticides currently in use.

Description and life cycle

The minute eggs have not been detected but are most likely laid singly on the fruit. The pink-yellow to dark grey larvae moult a number of times and, when fully grown, are approximately 16 mm long.

The pupa is found under a tough silken cocoon spun by the larva and is attached to the fruit near the feeding sites and completely covered by black pellets of excreta.

The adult is a small (10 mm long and 2 mm wide) colourful moth with golden yellow and purple wings. During the day, adults rest with wings folded on banana leaves, leaf petioles and on fruit but because of their small size they are seldom seen.

Although the length of the life cycle is not known, during the summer months it is expected to be approximately one month in duration.

Figure 4.32: Adult sugarcane bud moth

Monitoring

Sugarcane bud moth damage will be detected during examination of GS 7 bunches for rust thrips and corky scab. The number of damaged hands within each of five bunches should be recorded on the field sheet presented in Appendix 4.

Adult sugarcane bud moths are attracted to light and it should be possible to monitor activity using light traps.

Management guidelines

Chemical

Dust with 1% chlorpyrifos dust at the time the bunch cover is applied. Minimise dust deposits on fruit by aiming the dust delivery tube toward the inside of the plastic bag.

Note: 1% chlorpyrifos dust is prepared by thoroughly mixing 1 kg of Lorsban 250W with 24 kg of talc or 1 kg of Lorsban 500W with 49 kg of talc.

One light dusting using up to a maximum of 5 g of dust per bunch, is adequate for control of SCBM and further treatments are not required. Further dusting closer to harvest should be avoided because it may result in higher than permitted residue on fruit.

Note: Chemical treatment of bunches to be bagged is only warranted if careful examination of 100 hands from half-filled (Stage 7) bunches shows more than 5% of them damaged. The decision to treat or not will also be influenced by the time of year and the incidence of SCBM during the previous seasons.

Cultural

Currently, there are no known practical cultural management methods which can be adopted.

Biological

A wasp parasite has been recorded from SCBM but the level of parasitism is very low and is not expected to influence the populations. General predators such as spiders contribute to natural control.

Banana flower thrips (Thrips hawaiiensis)

Occurrence

Banana flower thrips is common in the flowers and among the fingers of newly emerged hands. This pest is found whenever bananas are grown but its damage is more significant in South-east Queensland and northern New South Wales.

Damage

Damage to fruit is the result of the superficial scarring caused by feeding and ovipositing. Extensive feeding damage causes 'corky scab' which produces a slightly raised grey corky skin covering. This damage is patchy and usually confined to the cushion end of the fruit on the lower hands and adjacent to the bunch stalk but, in severe cases, this damage can extend along the outer curve of the fruit.

Oviposition damage resembles minute raised pimples on the young immature fruit skin. These are readily seen because of a dark raised centre and can be confirmed by lightly touching the raised area with the finger tips. These oviposition marks are not important since they almost disappear as the fruit mature.

Seasonality

Flower thrips are active throughout the year, with increased activity in January through to April.

Description and life cycle

Female flower thrips are 1 mm long with a pale brown head and thorax and black abdomen. They are generally found sheltering under the bracts or inside the flowers. Male flower thrips are smaller (about 0.75 mm long), uniformly cream coloured and tend to occur on the outer surface of the bracts.

Adults and nymphs are found on newly emerged bunches and invade the fruit early when the bunch is still covered by its bracts. Feeding and oviposition is usually more severe on the lower hands. As the bracts lift progressively from the top of the bunch, the thrips move down to the next hand until most thrips are found on the male flowers of the 'bell'.

Figure 4.33: Severe 'corky scab' damage to a hand of bananas

Figure 4.34: Male (lower centre), females (left and right) and nymphs (centre) of flower thrips

The entire life cycle takes about three weeks in summer. with full development from egg to adult taking place on the bunch or in other parts of the plant. Unlike banana rust thrips, banana flower thrips do not spend a period of time in the soil.

Monitoring

Monitoring for flower thrips numbers and fruit damage is carried out simultaneously on ten bunches (GS6) in each paddock. When large numbers of thrips are present in a bunch, their feeding activity can result in speckling on the bracts. These markings are usually more pronounced towards the edge of the bracts and can be seen from a distance (up to 2 m) when sufficiently extensive.

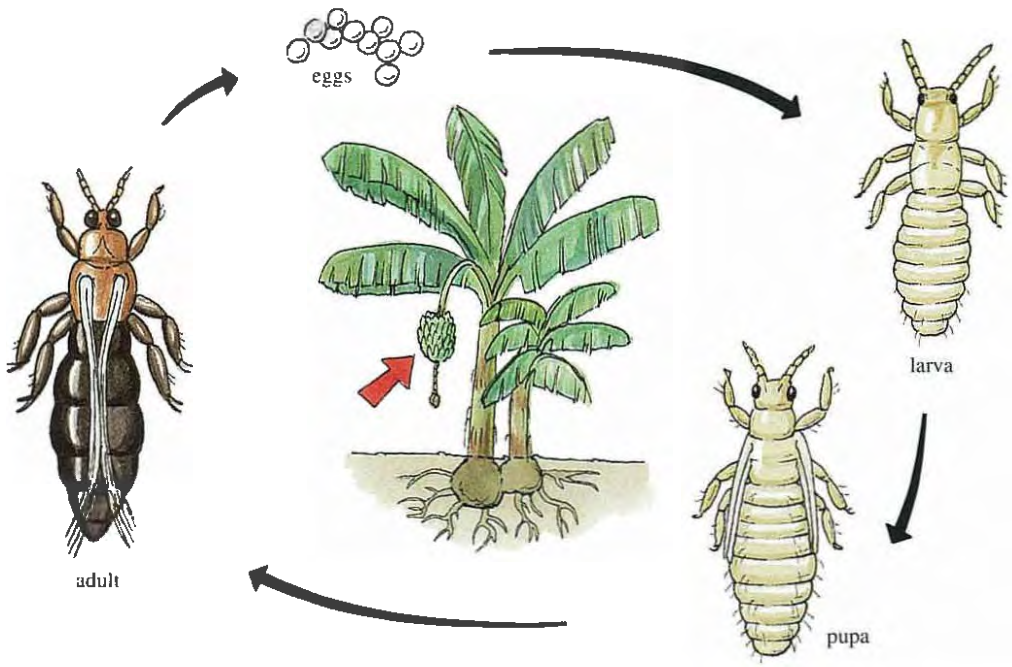


Figure 4.35: Life cycle of banana flower thrips (arrow indicates part(s) of plant affected)

Flower thrips counts

Each fortnight, ten GS6 bunches should be inspected for the presence of flower thrips. For convenience, these bunches could be the same as those used for scab moth monitoring with both pests being monitored together.

The technique used to determine the actual numbers of thrips present involves removing the uppermost (i.e., the oldest) hand of male florets covered by a bract. If the bract is still tightly attached to the bell and there are no gaps for the thrips to move into the underlying florets, the next available hand of male florets should be carefully removed and used for the assessment.

Once removed, the hand should be examined quickly in order to count thrips before they fly away or hide inside florets. Only those thrips on the surface of the male florets are counted as the florets are parted. (The petals of individual florets are not opened). Male and female thrips are counted separately.

The rating scheme shown in table 4.8 is used for recording the number of thrips present:

TABLE 4.8: Rating scheme for flower thrips numbers on male florets

Rating	No. of flower thrips
0	0
1	1–10
2	11–25
3	26–50
4	>50

Flower thrips damage

The number of oviposition marks on one face of a central finger from the lower row of the last true female hand of each bunch is recorded. The face used for the count is the flat face immediately adjacent to another finger on either side in the same row. The same rating scheme as for thrips numbers is used (table 4.8).

Corky scab is assessed on five of the ten bunches by examining five central fingers on the lower row of the second true hand from the bottom. The rating scheme is the same as that used for assessing rust thrips damage (table 4.2 page 15).

To determine corky scab development on more mature fruit, five randomly selected bunches at GS7 (half-filled) are also rated using the same method and rating scheme used for GS6 bunches. If bunch treatments such as bagging, spraying and dusting have been applied, these should also be noted on the monitoring sheet (Appendix 4).

Management guidelines

Chemical

Specific treatments such as cover sprays (ground or aerial) have not always been successful and should be avoided as they disrupt the IPM program. 'Throat' applications of omethoate (Folimat) using 500 mL per plant of a 125 mL Folimat in 100 L mix at bunch emergence have only proved partly effective.

Bunch injections to control scab moth (page 11) have also provided almost total control of flower thrips. This technique is recommended for specific control of flower thrips in areas where scab moth is not a problem — for example, in South-east Queensland and northern New South Wales.

Cultural

Early removal of the 'bell' to discourage thrips from developing within the male florets has not been evaluated but should be tried as a means of reducing thrips. Some evidence suggests that by maintaining moist plant conditions with overhead irrigation, corky scab development can be greatly reduced.

Biological

A range of predatory bugs, ladybird beetles and lacewings have been detected and these assist in reducing the build-up of flower thrips.

5 MINOR PESTS

Banana aphid (Pentalonia nigronervosa)

Occurrence

Banana aphid occurs throughout Queensland. Cultivated bananas and other *Musa* species are its main host but it also attacks a range of ornamental plants such as *Strelitzia* (bird of paradise) and flowering gingers. Aphids can be found in the unfurled leaves of young suckers throughout the year but increased activity, which leads to fruit spoilage, is more common during cooler weather in autumn and spring.

Damage

Because it is the vector of bunchy top virus, banana aphid is a serious pest in South-east Queensland where the virus is present. In North Queensland, occasional high populations build up in bunches resulting in the appearance of honeydew and sooty mould. Sooty mould is difficult to remove and fruit looks less appealing.

Figure 5.1: Sooty mould develops on the honeydew excretions of the aphids. Such heavy mould development is difficult to remove.

Description and life cycle

Aphids, both winged and wingless, are found in dense colonies and are usually attended by ants. The small (1.5-2.0 mm long) winged aphids have distinctive clear smoky wings with conspicuous black veins. Wingless forms are dark brown/ black and vary in size, depending on their stage of development.

Figure 5.2: Young sucker showing symptoms of bunchy top and numerous white cast skins of banana aphid

Figure 5.3: Colony of wingless banana aphids on a young banana hand

This aphid species has no males, and the females reproduce without fertilisation by giving birth to live nymphs. Dispersal is by flight or by moving aphid-infested planting material. Colonies can be found on young emerging suckers and at the base of the pseudostem at, or just below, soil level. Therefore, they can easily be carried on bits and suckers.

Monitoring

No specific monitoring is required but the incidence of banana aphids on suckers and in bunches can be determined by observation during monitoring for the major pests. Fruit damage from sooty mould growth occurs only in very heavy infestations and, therefore, the more usual minor outbreaks are of little importance. Regular observation during monitoring will give early warning of possible heavy build-up, and treatments can then be applied at an early stage.

Management guidelines

Chemical

Treatments are seldom required and should only be used if heavy populations are causing sooty mould on fruit. Sprays to control aphids in an attempt to reduce bunchy top transmission are not effective. If required, spot spray with dimethoate using 0.03% active ingredient*.

Cultural

Hot-water treatment of planting material (to control nematodes) will kill aphids, thereby reducing the spread of colonies. Efficient weed control in plantations will also reduce the incidence of aphids.

Biological

A number of predators feed on the banana aphid, including ladybird beetles, hoverflies, lacewings and wasp parasites. The usefulness of these beneficials is usually hindered by ants which are attracted to, and feed on, the honeydew. Natural controls are usually adequate to prevent fruit spoilage from sooty mould, which develops on honeydew-covered fruit. However, natural controls do not suppress bunchy top transmission, and the best method of preventing this is to immediately rogue out any plants showing symptoms.

*A spray solution of 0.03% dimethoate is produced by mixing 75 mL of a product containing 400 g/L dimethoate with 100 L of water.

Redshouldered leaf beetle (Monolepta beetle) (Monolepta australis)

Occurrence

Redshouldered leaf beetles swarm in spring and summer. Adult beetles can cause severe damage to a range of horticultural tree crops, but no severe damage has been noted in bananas even after very heavy populations have been observed on young bunches and plants.

Damage

On banana bunches, the beetles apparently go in search of nectar from the flowers and, even when present in plague proportions, do not appear to feed on the fruit. Often, feeding will occur on the inner and outer surfaces of the bracts.

Figure 5.4: Severe 'shot hole' damage to a leaf of a non-commercial banana variety susceptible to redshouldered leaf beetle

No significant leaf damage has been seen on cavendish bananas but considerable 'shot hole' effect has occurred on introduced, experimental varieties. Beetles feeding in the unfurled 'cigar leaf' of these varieties produced many small holes in the leaf lamina. Adjacent cavendish plants were not affected.

Figure 5.5: *Monolepta* or redshouldered leaf beetles. Note the characteristic bright red colour just behind the head of the beetle from which it gets its common name.

Description and life cycle

The predominantly creamy-yellow beetles are about 6 mm long and have two distinctive bright red areas at the base of the wing covers, which give the beetle its common name.

Females lay eggs in the soil and the larvae feed on the roots of grasses. Adults emerge in masses in spring following a storm or soaking rains. The adults fly to suitable bost trees where they feed and breed.

Management guidelines

No specific control is required or recommended since swarms of redshouldered leaf beetle are not known to damage commercial hananas.

Banana silvering thrips (Hercinothrips bicinctus)

Occurrence

Banana silvering thrips mainly affects bananas in South-east Queensland with only a single incidence recorded from bananas at South Johnstone in North Queensland. Infestation is usually patchy. Other hosts of silvering thrips are passionfruit, choko and weeds, including cobbler's peg (*Bidens pilosa*). In Southern Queensland, this thrips can be active all year round although it tends to build-up to damaging numbers during spring and early summer.

Damage

Fruit infested with banana silvering thrips develops irregular silvery areas which, on close examination, can be seen to be speckled with dark excrement. In some instances, browning of fruit can occur and deep longitudinal cracks may appear as a result.

Description and life cycle

The banana silvering thrips takes its name from the silvery discolouration which results when the thrips feed on fruit.

The life cycle is similar to the banana rust thrips (see page 14) with eggs, nymphs and adults found on the pseudostem and fruit. The mature larvae are also thought to pupate in the soil at the base of the banana plant.

The adult thrips is 1.5 mm long, and is brown with a darker abdomen. On fruit, the adults appear dark with a pale yellow line down the middle of the body formed by the yellow hindwings. The yellow-white larvae are often observed with a globule of black excrement at the tip of the abdomen.

Monitoring

No specific monitoring technique for banana silvering thrips is suggested. If required, the monitoring system used for rust thrips can be adopted for the banana silvering thrips.

Management guidelines

Chemical

Chemical treatment should not be required because this pest is sporadic and minor. If damage becomes excessive, spot-spray infested plants and fruit with dimethoate using 0.03% active ingredient.*

*Use 75 mL of 400 g/L dimethoate in 100 L of water.

Figure 5.6: Fruit damaged by silvering thrips

Figure 5.7: Adult silvering thrips: note the dark abdomen and light-coloured feathery wings.

Cultural

To prevent tbis pest spreading, do not use planting bits and suckers from areas infested with silvering thrips. Infestations can be reduced by controlling weed growth in plantations, especially important weed hosts such as cobbler's pegs.

Biological

General predators such as ladybird beetles and lacewings help keep silvering thrips in check.

Banana fruit fly (Bactrocera musae) *Queensland fruit fly* (Bactrocera tryoni)

Occurrence

Banana fruit fly occurs in coastal areas north of Townsville and is a pest of cultivated and wild bananas. Queensland fruit fly is a pest of a wide range of horticultural crops throughout Queensland and other areas of Australia, but only rarely damages bananas.

Damage

With regard to bananas, the banana fruit fly is the more important of the two fruit fly pests. The banana fruit fly will occasionally lay eggs (sting) into green fruit while the Queensland fruit fly will lay eggs only into ripening or yellow ripe fruit.

Description and life cycle

These two fruit flies resemble each other and are wasp-like in appearance with red-brown and yellow markings. The wings are held outstretched when walking on fruit or leaves and are moved in a characteristic forward and back 'rowing' motion.

Batches of up to a few hundred pearly-white banana-shaped eggs are laid between the skin and the pulp. Eggs laid into green fruit remain dormant until the fruit begins to turn yellow at which time the eggs begin to develop. The

Figure 5.8: Fruit fly on ripening fruit

Figure 5.9: Overripe bunch left hanging: this provides an ideal situation for fruit fly breeding.

maggots feed on the pulp and, when mature, emerge from the rotting fruit and drop to the ground to pupate. Under warm conditions, the life cycle is completed in less than three weeks.

Monitoring

Adult fruit flies can be monitored by using fruit fly traps baited with the attractant methyl eugenol (Me). Because only males are attracted, the traps serve only as an indicator of fly activity and do not provide a means of fruit fly control.

In addition to the banana fruit fly, several other species of fruit flies (not known pests of banana) are also attracted to Me-baited traps. Therefore, captured flies must be sorted into species to determine the actual numbers of fruit fly which can damage banana fruit. Because fruit flies look similar, it is important to be able to identify each species to effectively monitor fruit flies in this way.

Management guidelines

Chemicals

Chemical treatments should not be required and are not generally recommended because their use will disturb the effectiveness of beneficial insects. If treatment is required (especially during the wet summer months), concentrate on areas bordering standing scrub because these are the most susceptible areas of a plantation. Spot spray with dimethoate using 0.03% active ingredient.*

Cultural

Ensure that no ripening bunches are left hanging in the field as these will attract female Queensland fruit flies to lay eggs, and subsequent breeding will rapidly lead to a heavy local build-up. Another form of control is to maintain good growing conditions to avoid 'mixed ripe' bunches. Damaged fruit will also attract fruit fly and care should be taken to minimise damage during plantation operations. Bunches which are unsuitable for harvest (scab moth damage, fallouts, etc.) must be cut up into several pieces when still green to ensure rapid breakdown of fruit and must not be left intact to be used as breeding sites by the flies.

Neglected plantations, which can rapidly become breeding sites for fruit fly, should be destroyed.

Banana fruit caterpillar (Tiracola plagiata)

Occurrence

Banana fruit caterpillar is found throughout coastal Queensland. Damage is usually patchy and normally confined to rows adjacent to standing scrub or rainforest. Larvae also feed on a range of cultivated and wild plants as well as weeds. Damage can occur throughout the year but is more prevalent during the hot summer months and after the wet season.

* Use 75 mL of 400 g/L dimethoate in 100 L of water.

Damage

Larvae feed on both foliage and fruit. Large larvae feed deep into the fruit while smaller, younger larvae feed on the rind of immature fruit, causing irregularly shaped patches of damage to the exposed fruit surfaces. The damage is more severe and visible than that caused by the banana scab moth — damage which tends to be shallower and confined to the underside of the fruit where it joins the bunch stalk. Because of their large size, one or two larvae can destroy all the fruit on a bunch.

Figure 5.10: Larva of the banana fruit caterpillar feeding on young fruit

Description and life cycle

The drab grey-brown larvae have two pairs of black marks on the top of the body and grow to about 6 cm when fully grown. Mature larvae move off the plant and seek a secluded area among trash at the base of plants in which to pupate.

Adults are medium to large moths measuring 5–6 cm across the wings. The darker forewings are dull grey-brown in colour with a dark brown V-shaped area on the fore margins. The hind wings are uniformly light brown-grey.

Management guidelines

Damage is sporadic and rarely sufficient to warrant specific treatment. If monitoring indicates that more than five bunches out of 100 are attacked, treat new and old bunches in the infested area with endosulfan using 150 mL per 100 L. As damage is usually seasonal and confined to known 'hot spots', concentrate monitoring to these situations.

Cluster caterpillar (*Spodoptera litura*)

Occurrence

Cluster caterpillar occurs in all banana-growing areas of Queensland. It has been recorded feeding on more than one hundred different species of plants belonging to forty-four families.

This insect is present in Queensland througbout the year, although it becomes less abundant during winter.

Damage

Young larvae feed on leaves in groups or clusters (hence the common name) of up to a few hundred individuals. Feeding is confined to either the top or bottom of the leaf and the opposite side of the leaf is left intact. These damaged areas rapidly turn brown and shrivel.

Figure 5.11: Young cluster caterpillar larvae feeding on the surface of the leaf

Figure 5.12: Characteristic evenly spaced holes caused by larger cluster caterpillar larvae feeding within the upright candela

Older larvae become solitary and feed on the entire leaf surface. These larvae will feed on the young rolled up candela, or 'cigar' leaf, producing characteristic evenly spaced holes when the leaf expands.

Solitary mature larvae will also feed on fruit, causing large irregular superficial or deep damage which resembles that caused by the banana fruit caterpillar (*Tiracola plagiata*).

Description and life cycle

The eggs are laid in clusters of 100-300 on the plant, often on leaf surfaces.

The eggs hatch after a few days, and the young larvae (about 1.5 mm long) cluster together near the egg mass and commence feeding on the surface tissues of the leaf. Young larvae range in colour from light shades of grey and green through to almost black. They are darker towards the front of the body.

Older larvae become more solitary, wandering over the plant and often moving to the youngest leaves. The large larvae have a number of shiny black triangular marks on each side of the body. When disturbed, the larvae contract into a C-shape and may drop from the plant.

Large larvae often hide during the day in the channel of the midrib of the leaf where it meets the stem.

The mature caterpillars pupate in the ground. The adult moths have a wingspan of between 3.5-4.0 cm.

Figure 5.13: Solitary mature larva of a cluster caterpillar

Figure 5.14: Adult moth and egg mass of a cluster caterpillar. Moths are attracted to lights and are commonly found near them on warm nights.

The forewings are brown with white markings and the hindwings are grey.

Adult moths live for about seven days and are night-flyers. The complete life cycle takes four to five weeks during summer.

Monitoring

The egg masses of cluster caterpillar can be seen during monitoring activities for other pests and diseases. The masses are usually laid under the leaf and can be seen as a dark patch on the leaf when viewed from below.

To determine if egg masses have already hatched, gently rub the surface of each mass with a finger tip. If a wet smear is produced then the eggs have yet to hatch. If the egg mass rubs easily off the leaf and is dry, then the eggs have already hatched.

Management guidelines

Chemical

Chemical control is seldom required to control cluster caterpillar. Leaf damage is rarely so severe that plant growth is reduced, and banana plants can rapidly compensate for leaf loss caused by this pest.

If required, spot-spray infestations with chlorpyrifos.* Treat early to control young larvae.

* Use 150–200 mL of 500 g/L chlorpyrifos, or 300–400 g of 250 g/kg chlorpyrifos or 150–200 g of 500 g/kg chlorpyrifos in 100 L of water.

Cultural

Control weeds within and immediately adjacent to plantations to reduce breeding sites.

Biological

Cluster caterpillar is controlled naturally by a wide range of organisms including diseases, parasitic and predatory insects, spiders and birds.

Occasionally, large infestations may develop, especially in young plantings. However,in most instances, these outbreaks are brought under control naturally and specific chemical controls are not required or recommended because they interfere with natural controls.

Transparent scale
(Aspidiotus destructor)

Occurrence

Transparent scale is found throughout Queensland banana-growing areas. Infestations are usually patchy and concentrated on the undersurface of leaves of a few individual plants. In severe infestations, transparent scale can occur in high numbers on the bunch stalk and fruit, especially on or near the the cushion.

Scale insects may be present all year round but the warm summer period is more suitable for scale development.

Figure 5.15: Numerous transparent scale form a dense population on the undersurface of the leaf.

Description and life cycle

The waxy, flattened scale covering is transparent and the surface of the leaf can be seen quite easily through it.

Male scales are oval, females are round, and both can vary in size according to the instar. Adult female scales are from 1.5 mm to 2 mm in diameter. The male adults have translucent wings and can fly whereas the female is unable to move.

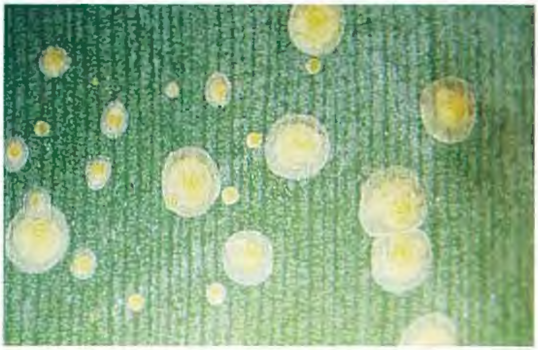


Figure 5.16: Close-up of male (oval) and female (round) scales showing an almost transparent outer-scale covering. Different size denotes a different instar.

Adult female scales produce large numbers of young, known as crawlers which move out from beneath the scale onto the leaf blade. They may be dispersed by wind to another leaf or settle on the same leaf close to the female scale.

Once the crawler attaches itself to the leaf and starts feeding, it can no longer move. As it grows, it produces its own wax coating, or scale, and undergoes a number of moults.

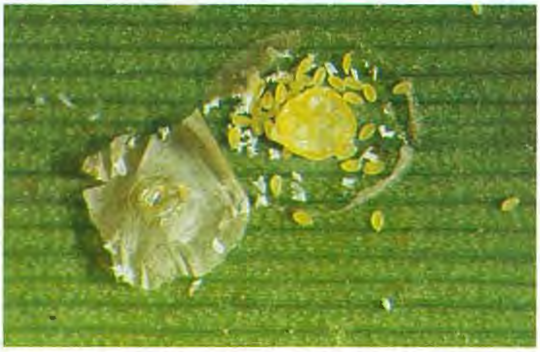


Figure 5.17: Female scale surrounded by crawlers; the protective scale covering has been removed.

Figure 5.18: Adult and larvae of *Chilocorus baileyi*, a predatory ladybird beetle, feeding on transparent scale

Monitoring

Scale populations can be detected during the course of monitoring mite activity on leaves. No specific monitoring is required for transparent scale; however, the presence and severity of scales on plants should be noted.

If scale insects are observed on fruit at the packing shed, it could be an indication that severe scale infestations are present in the plantation.

Management guidelines

Scale insects are controlled by a large range of biological agents, especially wasp parasites and predatory ladybird beetles. Undertree spraying with oil for disease control assists in the control of transparent scale.

Greyback cane beetle (Dermolepida albohirtum)

Occurrence

Cane beetles occur throughout the banana-growing areas of Queensland. The greyback cane beetle is currently the only species known to attack bananas but it is likely that larvae of other species may also feed on banana roots.

Cane beetles emerge from the soil following the first good summer rains, usually between October and December. Large fluctuations in adult populations may occur from one year to the next. Cane grubs can be present in the soil all year round, depending on the species.

Damage

Leaf damage caused by feeding adults is seldom severe, but extensive feeding on the preferred older leaves (particularly on bunched plants) can lead to sunburnt fruit.

Larvae feeding on the roots can, under heavy attack, cause plants to topple because the root systems have been reduced. Poor growth, leaf yellowing and retarded sucker development may also be the result of greyback cane beetle larvae feeding on the roots. Careful observation is required to ensure that other pests, such as nematodes and banana weevil borer, or poor growing conditions are not the primary cause, because these can produce similar symptoms.

Figure 5.19: Severe defoliation caused by greyback cane beetle.

Description and life cycle

Greyback cane beetle obtains its name from the dull grey hairs on the surface of the thorax and wing covers of the adult beetle, and the feeding habit of the larva on the roots of sugarcane. The grey hairs often rub off when the adults tunnel up from the ground to emerge so the appearance of adults may vary considerably from uniformly grey through to uniformly brown, depending on the degree of hair removal. Greyback cane beetles are about 35 mm long and can be distinguished from other species of cane beetle by the bare, shiny black area in the middle of the underside of the abdomen.

The cane larvae are C-shaped, grey-white soft grubs with the rear third darkened. Each has six brown legs, a smooth, shiny tan-coloured

Figure 5.20: Adult beetle feeding on banana leaf

Figure 5.21: Larvae of greyback cane beetle; note the distinct head capsule and C-shape.

head and two well-developed mandibles. They can grow to 50 mm or more in length.

After mating, females lay their eggs in the soil. The eggs hatch after about two weeks; the larvae moult three times becoming mature after eight to nine months. The final (third instar) larvae which develop from February to May are voracious feeders and cause the most damage to the roots. The whole larval and pupal stage is spent in the soil and adults are stimulated to emerge by the first soaking summer rains.

Monitoring

The population of greyback cane beetle larvae can be determined by sampling soils from near banana plants to a depth of about 40 cm. Samples should be taken when the soil is moist because the cane grubs migrate closer to the surface.

Treatment will be necessary if monitoring reveals at least one cane grub per stool (over a minimum of ten stools) or if plant fallouts and poor growth is associated with the presence of grubs.

Before considering chemical control, sample areas of suspected infestation several times during the period February to May. A further sampling subsequent to chemical treatment will determine the effectiveness of the treatment.

Management guidelines

Chemical

Ethoprophos which is registered for banana weevil borer control should also control cane grubs in the soil. This treatment should be applied at the rate of 60 g per stool, in accordance with the label recommendations.

Treatments will be most effective if applied from January to March to coincide with egg-laying and the presence of young larvae close to the soil surface. Treatments should be made only when immediate rain is expected or prior to irrigation.

Chemical control of adult cane beetles in bananas is not warranted since this will destroy beneficial insects.

Cultural

The adults may be discouraged from laying if grasses are controlled within banana plantations during the period when adults are flying.

Banana-spotting bug
(Amblypelta lutescens lutescens)
Fruitspotting bug
(Amblypelta nitida)

Occurrence

These two bugs have a very wide host range. The banana-spotting bug is more common in North Queensland and the fruitspotting bug is the main species in Southern Queensland. These bugs feed primarily on native fruits in the rainforest or young tree shoots in open forest.

Bananas are not a preferred host and young nymphs fail to develop on a banana diet. Damage to young bunches is caused invariably by adults which may be deprived of their preferred food source.

No seasonal pattern has been observed. Natural events such as cyclones may trigger attacks to bananas because the preferred native food has been destroyed.

Figure 5.22: Mature bunch with fruitspotting bug damage

Damage

Characteristically, damage on young fruit is seen as numerous sunken circular black spots on the outer curves of the fingers. The sunken spots, which can be up to 5 mm in diameter, may have a small central hole where the bug has inserted its feeding mouthparts. As the fruit matures, the skin near these holes may split.

Severe damage can occur to isolated banana bunches in garden situations (from adult bugs

Figure 5.23: Close-up of fruitspotting bug damage. Note the dark sunken feeding spots and the development of cracks within the pits.

Figure 5.24: Adult fruitspotting bug: note that bananas are not a suitable host for successful development of nymphs.

which have built-up on more suitable hosts) but in commercial plantations, attack is usually restricted to isolated bunches in rows near standing scrub.

Description and life cycle

The oval green eggs are laid singly on host plants and have never been seen on bananas. The egg is followed by five nymphal instars. The young bugs are ant-like with prominent antennae. As the bugs grow, the two black scent glands on the abdomen become very prominent and are a distinguishing feature. The adults are yellowish-green and about 15 mm long. They are timid, and hide or drop out of sight or fly away when approached. Because they are difficult to detect, damage to the fruit is usually the first evidence of their activity.

Monitoring

No specific monitoring is required but if unusual levels of damage are detected, these can be recorded during routine monitoring for other pests.

Management guidelines

Chemical

If inspection of young bunches shows more than 5% under attack, spot-spray all new bunches with endosulfan.*

Cultural

No practical cultural methods are available.

Biological

Native egg parasites have been recorded but their impact is not known.

* Use 150 mL of 350 g/L endosulfan in 100 L of water.

Casemoths

A number of species of case-making caterpillars feed on banana leaves. These are commonly known as casemoths, or bagworms. The size, shape and nature of the material used for case-construction varies, depending on the species involved.

Casemoths damage leaves by chewing irregular holes in the leaf blade. Very occasionally they may feed on bunches. At times they may cause some concern to growers but no special control measures are needed. Natural predators and parasites will build-up when there are high casemoth populations and will eventually bring the pest under control.

Close examination of the outer surface of a case will often reveal the white eggs of parasitic flies.

Figure 5.25: Casemoth larva on banana leaf petiole: note the head protruding from the protective case.

Grasshoppers

A number of grasshoppers feed on the leaves and fruit of bananas but they rarely cause serious problems. No specific control methods are suggested for leaf-feeding grasshoppers because damage to the foliage can be compensated for by the plant. Bunch treatments with insecticides applied for other pests (such as

Figure 5.26: Nymph of *Valanga* sp. grasshopper feeding on a banana leaf

rust thrips and sugarcane bud moth), afford protection against grasshoppers.

Black swarming leaf beetle

Black swarming leaf beetles, or *Rhyparida* spp., occasionally feed on the very young furled upright leaf, or candela. The beetles can also cause damage on young fruit by feeding near the cushion area, resulting in deep, black irregular pits in the skin.

The beetles swarm in large numbers on a range of fruit crops and attack new growth. Damage on banana is uncommon and treatments are considered unnecessary.

Minor caterpillar pests

A wide variety of caterpillars, additional to those described in this manual, occasionally feed on banana fruit and leaves in various areas. None of these occur in numbers sufficient to warrant control measures being carried out.

Biological control agents and/or chemical controls used for other pests maintain these insects at very low levels and, in some instances, it is also likely that banana is not a preferred host.

Figure 5.27: Swarming leaf beetle damage to the upright candela

6 QUARANTINE PESTS

Spiralling whitefly (Aleurodicus dispersus)

Spiralling whitefly is a tiny sapsucking bug which occurs widely in Pacific countries and Papua New Guinea. Recently it has been found in Australia on the Torres Strait islands of Boigu and Saibai and on Thursday Island.

Feeding activity by nymphs and adults on banana leaves produces yellowing of leaf tissue adjacent to feeding sites. Spiralling whitefly has a wide host range besides banana, including cassava, chilli, citrus, guava, mango, papaw, taro and sweet potato.

Figure 6.1: Severe whitefly infestation on the lower surface of a banana leaf on Thursday Island showing white waxy deposits and growth of black sooty mould

Spiralling whitefly can be recognised by the characteristic spiral oviposition pattern.

White wax filaments are produced by the nymphs. The adults are 2 mm long and have white wings. During the day they can be observed resting among the filaments and fly away if disturbed. They also fly in the morning and evening, usually staying close to their host plant.

Another species of whitefly, the coconut whitefly (*Aleurodicus destructor*), is not considered a pest of banana. It also produces oviposition spirals and wax filaments and can easily be confused with spiralling whitefly. Suspected outbreaks of spiralling whitefly or coconut whitefly should be reported to the nearest Department of Primary Industries office.

Biological control of spiralling whitefly with the wasp parasite *Encarsia haitiensis* is being carried out on the Torres Strait islands by officers of the Queensland Department of Primary Industries.

Banana skipper butterfly (Erionota thrax)

Banana skipper butterfly is a pest of bananas in China, India, Indonesia, Mauritius, Hawaii and the Philippines. It has recently been found in Papua New Guinea.

The larvae feed on the leaf blade and roll strips of leaf lamina towards the midrib, glueing the roll together with silken threads. In heavy infestations, the leaf lamina is destroyed and most leaves are reduced to only the midrib.

The bright yellow eggs are laid in clusters on the leaf lamina.

The larvae are covered in a fine white powdery material and live within the leaf rolls.

Figure 6.2: Damage to banana leaves by the banana skipper butterfly in Java, Indonesia

Pupation also occurs within the leaf rolls. The adult moth is a large (7 cm wing span) brown butterfly with yellow markings on the forewings.

The impact of the banana skipper is reduced during wet weather because early instars are often drowned. Heavy winds which break the leaf lamina also help to reduce this pest. Effective egg and larval parasites have been identified and may be introduced if the skipper butterfly enters Australia.

Figure 6.3: Cluster of spherical yellow banana skipper butterfly eggs on a banana leaf

Figure 6.4: Close up of leaf roll; the banana skipper butterfly larvae feeds and pupates within the roll.

Banana stem boring weevil (Odoiporus longicollis)

Banana stem boring weevil is very similar in appearance to the banana weevil borer and is a pest of banana in South-east Asia. The damage is mainly found on old harvested stumps and, unlike weevil borer which feed in the corm below ground, the larvae of *Odoiporus* feed on the pseudostem above ground.

Unlike weevil borer which seldom fly, adults of *Odoiporus* are strong fliers and readily fly during hot days. Eggs are laid in the pseudostem, and the larvae create extensive tunnels which leads to the destruction of the pseudostem. When mature, the larvae pupate in the banana pseudostem within a cocoon made from pseudostem fibres.

The economic importance of this weevil is considered to be low because damage is primarily aimed at the old harvested 'stumps' and therefore does not affect plant growth and yield.

7 RECOMMENDED METHODS OF SPRAY APPLICATION

Bunch injection

Although bunch injection is used primarily for the control of scab moth and flower thrips, initial control of rust thrips can also be achieved.

The injection unit consists of a 3–4 m lightweight aluminium tube, injector needle, metered hand pump and a 5 L plastic solution container.

Bunch injection involves the application of a single dose of 20–40 mL of spray solution into each emerging bunch. (See also scab moth for further details.)

Injection is made into the top of the upright bunch so that the chemical can move throughout the bunch under gravity. The injection site is in the upper one-third portion of the upright bunch. Ideally, the injection should be made in the break between the male and female flowers. If the injection is made above this point, it will be difficult to inject the required volume because the dense bell will not allow the liquid to flow. Injection below this point will damage the lower hands because the needle will penetrate some fingers.

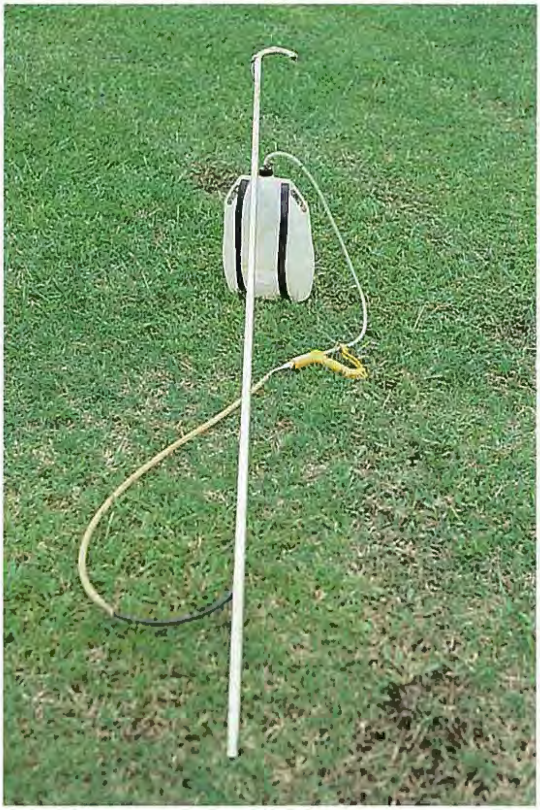


Figure 7.1: An inexpensive and lightweight unit used for injection

TABLE 7.1: Preferred pesticide application methods to be used against the major banana pests

Pest	Bunch injection	Dusting	Cover sprays	Bunch spray	Butt application	
					hand	boom
Scab moth	✔	✔				
Flower thrips	✔					
Rust thrips	✔	✔		✔	✔	✔
Mites			✔			
Banana weevil borer					✔	✔
Sugarcane bud moth		✔		✔		

TABLE 7.2: Recommended products for injection

Active ingredient	Product	Formulation	Withholding period (days)	Rate	Comments
chlorpyrifos	LORSBAN	250 WP	14	4 g/1L	Effective against both scab moth and flower thrips and may reduce rust thrips numbers.
"	LORSBAN	500 EC	14	2 ml/1L	
omethoate	FOLIMAT	800 EC	4	1.25 ml/1L	
bifenthrin	TALSTAR	80 SC	8	1.25 ml/1L	

Dusting

Dust application is recommended for the control of scab moth (late infestation), rust thrips and sugarcane bud moth. The main commercial dusters used are the Carpi and Volpi diaphragm dusters and the Swissmax applicator. One application of dust at the recommended rate should be applied to each bunch at the time of bagging. Bunches should be bagged, and then dusted. Dusting emerging bunches against scab moth has been replaced by injection.

On their minimum setting, the units apply 40–60 g of dust with each stroke. This has to be reduced to the desired quantity (5–10 g) by using a baffle inside the unit between the adjustable plate and the base plate (figure 7.2). The plastic insert can be made by cutting a 30 5 mm slot in an ice-cream lid or other flat round plastic material.

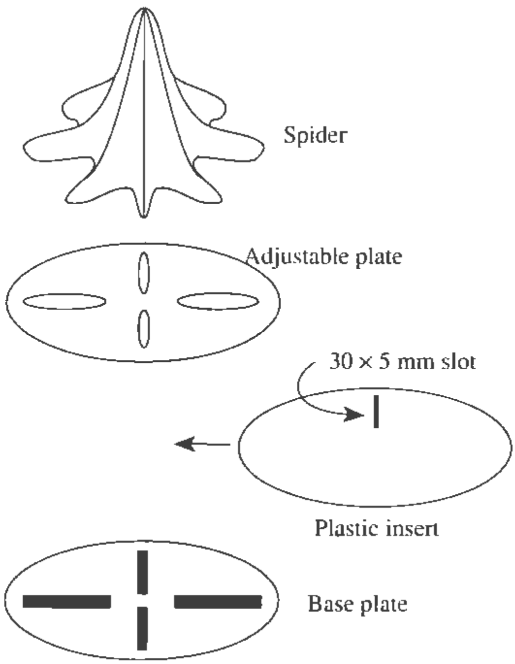


Figure 7.2: Modifications required to reduce the output of dust to prevent excessive dust deposits

Excess dust on the bunch may result in:

- difficulties in removing dust at packing time.
- Unsightly dust residues on fruit at the market.
- Levels of chemical remaining on the fruit in excess of the maximum residue limit.

Cover sprays

Cover sprays can be applied using air-blast sprayers or misting machines and are mainly used for the control of leaf diseases and mites.

Air-blast sprayers and misters (also referred to as air assisted sprayers) are suitable for use on bananas. The size of the spraying unit is an important consideration in choosing a suitable sprayer and the selection is based on:

- area to be sprayed
- type of terrain
- size of tractor.

The smaller three-point linkage sprayers are more suitable for smaller areas, especially where the terrain would make a larger trailed unit unsatisfactory or if tractor size is limited (<60 hp).

The disadvantage of the smaller unit is that it requires a slower speed of operation to provide the required air movement for good spray cover. The larger trailed units can be a disadvantage in wet boggy situations due to the weight (unit and 2000 L + of spray) and can be difficult to turn in tight headland situations. Because of the bigger fan and tank size of the larger units, the spray operations can be speeded up significantly.

TABLE 7.3: Recommended products for dusting

Active ingredient	Product	Formulation	Withholding period (days)	Rate	Comments
chlorpyrifos	LORSBAN 250W LORSBAN 500W	1 part in 24 parts talc 1 part in 49 parts talc	14	up to 5 g of dust per bunch	Apply once only at time of bunch covering. A light coating to the inside of the bunch cover and fruit is adequate for sugar-cane bud moth. It also controls rust thrips.
bendiocarb	FICAM BANANA DUST	1% dust	84	10 g per bunch	Apply every 3–4 days from bunch emergence to end of flowering.

Air-blast sprayers

Droplets are produced by hydraulic nozzles placed in the airstream. These are carried to the target by the air. Large volumes of air are displaced by an axial flow fan (800-900 mm diameter).

When operating at 540 PTO rpm, air velocity at the outlet is approximately 140 km/h. These sprayers are very versatile, being made suitable for both high- and low-volume spray application by changing nozzles and pressures to suit (see tables 7.4 and 7.5).

Misting machines

Droplets are produced by airshear nozzles placed in the path of a low-volume high-speed air current (250 + km/h) generated by a centrifugal fan. These sprayers are more suitable for low-volume spray applications (<300 L/ha) because, at high volumes, the efficiency of the airshear nozzles in greatly reduced and droplet formation becomes inefficient.

Note: Both types of sprayers are designed to operate most efficiently at 540 power take-off rpm.

Spraying pressure and nozzle matching in air-blast sprayers

Air-blast sprayers need careful matching of spraying pressure to the nozzle size (orifice opening) as both of these factors determine the droplet size produced and have a direct effect on the efficiency of the spray operation. To obtain good coverage of leaves with minimal drift, run-off and spray loss through evaporation, the

Figure 7.3: Large air-blast sprayer suitable for larger plantations

Figure 7.4: Three-point linkage Silvan mister

TABLE 7.4: Recommended spraying pressures for Albuz ceramic nozzles

Nozzle size (mm)	Pressure			VMD* (microns)	70–250 (micron class)
	Bar	Kpa	psi		
1.0 BROWN	10	1000	140	116	71%
1.2 YELLOW	10	1000	140	139	75%
1.5 ORANGE	10	1000	140	145	75%
2.0 RED	20	2000	280	150	72%
2.3 GREEN	20	2000	280	140	70%
3.0 BLUE	25	2500	350	144	68%

TABLE 7.5: Recommended spraying pressures for Silvan standard ceramic nozzles

Nozzle size (mm)	Pressure			VMD* (microns)	70–250 (micron class)
	Bar	Kpa	psi		
1.0	20	2000	280	141	70%
1.2	20	2000	280	149	70%
1.5	25	2500	350	144	65%
1.8	30	3000	420	142	65%
2.0	30	3000	420	149	65%
2.2	30	3000	420	155	64%

* Volume Median Diameter (VMD) is the droplet diameter in a spray which divides the spray volume so that 50% is derived from droplets larger than the VMD and 50% is derived from droplets smaller than the VMD.

Tables 7.4 and 7.5 reproduced with permission of G. Cunningham, Plant Protection, Gatton College, Lawes.

optimum droplet size should be in the range of 70-250 microns. Droplets with less than a 70 micron diameter will be susceptible to excessive drift and evaporation loss; those larger than 250 microns, will tend to bounce off leaves and will be lost on the ground or cause excessive run-off.

As a guide, use tables 7.4 and 7.5 to match pressures and nozzle size. Note the following points:

1. To maintain a high proportion of droplets in the desired size range, pressure needs to be increased as the nozzle size is increased.
2. For equivalent nozzle orifice size, the Silvan nozzles require higher operating pressures than the Albuz nozzles to produce the correct droplet size spectrum.

Guidelines for adequate cover spray volumes in bananas

Cover sprays for pest control in bananas are mainly miticide sprays, used against mites. Since miticides are not systemic, but rely on contact and residual activity only, good even cover on the underside of leaves where the mites live is essential.

Volumes of at least 400 L per hectare are required using a spraying speed of 4–6 km/h. As a guide, a comfortable walking pace has been shown to be a suitable spraying speed using either air-blast or misting sprayers on bananas. Nozzle spacing should be arranged to provide spray cover to the young suckers and leaves, including the new upper leaves.

Careful calibration of the sprayer to determine optimal performance (at 540 PTO rpm) is essential prior to spraying. Changes to nozzle size, spraying pressure and operating speed should be done before starting.

Figure 7.5: A simple spray unit for band application

Bunch sprays

Bunch sprays are mostly used for spot treatment to protect against fruit pests, such as banana-spotting bug, banana fruit caterpillar, fruit fly and other minor pests. Bunch sprays can also be used to protect fruit from sugarcane bud moth and rust thrips.

Volumes of 50-100 mL per bunch are adequate. Spraying is usually carried out with a hand-held wand and a hollow cone nozzle. Aim to obtain even cover on fruit without run-off. Excessive run-off can cause damaging fruit 'burn' under fingers where droplets coalesce.

Butt application

Butt application to the soil and lower parts of the pseudostem and suckers is the main method of treatment for banana weevil borer and rust thrips.

Hand application with high-volume low-pressure guns allows accurate targeting of the pesticide to the soil area around plants. This method is time-consuming but, because only an area of soil approximately 30 cm around the plants is treated, it is easy to achieve substantial savings of chemical.

Boom sprays treat approximately a 30–50 cm band on either side of the row centreline. The operation can be carried out swiftly by aiming 2–4 high-volume nozzles at the area to be treated. Approximately 50% more spray than by hand application is required since areas between plants (not treated by hand) are also sprayed.

8 SAFE HANDLING OF PESTICIDES

by R.H. Broadley

Care should be taken to ensure that the effects of pesticides on operators, and animals such as birds, bees, fish and natural enemies of pests, are as small as possible. This can be realistically achieved by adhering to correct handling, spraying and disposal techniques.

First and foremost, read the label carefully and follow the instructions given. The labels contain important information.

Note that pesticides can enter the human body in one or more of these three ways:

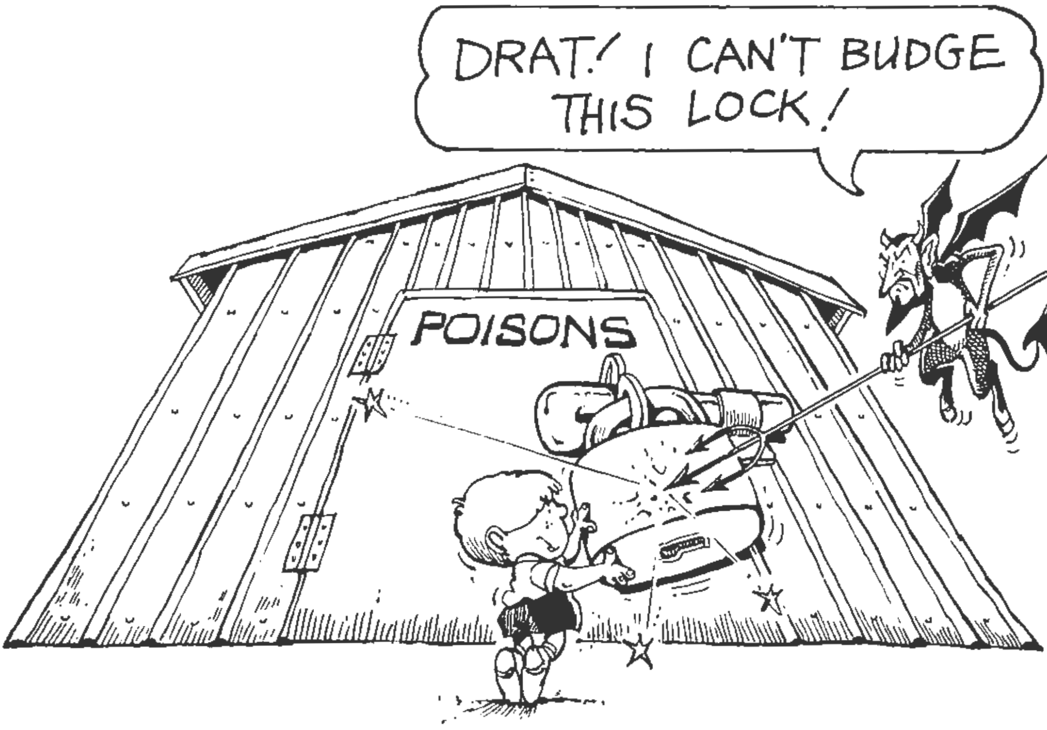
- oral (through the mouth)
- dermal (through the skin)
- by inhalation (mainly through the lungs).

Dermal absorption is the most common route for poisoning to occur.

In the case of a pesticide emergency, phone the Poisons Information Centre on 008 177 333 (24 hours) or 07 253 8233 and ask for the Shift Supervisor.

Storage of pesticides

- See the label for any specific requirements.
- Store pesticides in building that are secure, isolated, well ventilated, insulated, moisture-free, are resistant to fire, and have impervious floors which are bunded to contain spills. The Australian Standard AS 2507-1984 'The Storage and Handling of Pesticides' refers to design criteria.
- Do not store for prolonged periods in direct sunlight. Overheated containers of volatile solvents may explode.
- Never store pesticides in containers that are, or that look like, containers used for food, drink or non-toxic substances.
- Never store pesticides in an area prone to flooding.
- Keep pesticides out of reach of children.
- Never carry pesticides in the passenger area of a car.
- If you find leaking or broken containers, dispose of properly.



Measuring, mixing and spraying

Be safe — not sorry!

- Read the label; heed the label.
- Wear protective clothing as detailed on the label. If clothing becomes contaminated with spray-strength solution, remove immediately, rinse and launder in hot soapy water, separate from other washing. If clothing is contaminated with pesticide concentrate, dispose of the clothing.
- Be especially careful when measuring and handling concentrates. Ensure these do not overheat.
- Wear waterproof boots, overalls, washable hats, gloves, goggles and a respirator at all times when handling and spraying toxic concentrates, and applying chemicals.
- Remember to change respirator cartridges at recommended intervals. (Record the number of hours they have been in use.) Select the correct cartridge for the pesticide being used. This is especially important for fumigants.
- Change tractor cab filters regularly. Air-conditioned tractor cabs are not designed to filter pesticides. There is no Australian standard to cover pesticide filtration by air-conditioners. Servicing and maintenance are highly skilled operations and unless carried out properly, the risk to operator health is magnified. Inside such cabs we recommend the use of respirators and other protective clothing.
- Avoid contamination of skin, eyes and mouth. If the skin, eyes or mouth are contaminated by splashing or dust, wash immediately.
- Keep clean water, soap and an uncontaminated towel near the mixing and filling area.
- *Never* clean nozzles with your mouth.
- Measure and mix in a well-ventilated area.
- Clean up spills and damaged containers immediately.
- Use a sharp knife to open bags containing pesticide. Do not tear.
- Never pour pesticides into a spray tank while holding the container at eye level or above.
- Do not use matches or any other naked flame near pesticides, as the pesticide solvents could explode.

- *Never* eat, drink or smoke when handling or spraying pesticides. This precaution prevents oral poisoning and also, in the case of smoking, explosions. Do not smoke anywhere near pesticides.
- Move upwind while spraying, and keep out of the sprayed area for several hours, or the length of time specified on the label as the re-entry period.
- Immediately after spraying, wash all exposed skin with soap and water, and clean all equipment.

Pesticide poisoning

- Check the pesticide label for the recommended antidote, and have this readily available.
- Learn to recognise the symptoms of pesticide poisoning. Danger signs to look for are: headache, blurred vision, chest pains and nausea. The following are more serious symptoms: sweating, pinpoint pupils of the eyes, drooling and vomiting.
- If you are showing any symptoms of pesticide poisoning, see a doctor. Take the pesticide label with you. Have someone else take you or accompany you to the doctor; do not go to the doctor alone.
- Regular blood tests are advisable if you are spraying toxic pesticides at frequent intervals over an extended period.

Disposal of pesticides and containers

The DPI has produced a farm note covering disposal (*Disposal of unwanted chemicals and empty containers,* D.I. Hay, F71/Oct 89). Copies can be obtained from your local DPI office or from Agricultural Standards, telephone (07) 877 9526.

- Unwanted pesticides may be of use to somebody else. If not, dilute and dispose of it in a soakage pit, to which quicklime has been previously added, and cover with soil afterwards.
- When mixing spray, rinse pesticide containers into the spray tank three times. This can prevent significant wastage of pesticides.
- Do not use empty pesticide containers for any purpose.
- Crush and bury empty pesticide containers, preferably in a land-fill dump.
- Check labels before burning containers. Some herbicide containers should not be burnt.
- Do not dispose of containers in water, or areas likely to be flooded.

Fumigant handling

Special care is needed in the handling and storage of fumigants. Most are extremely poisonous and vapourise at room temperature, so are easily inhaled.

When transferring the fumigant to injection equipment, always do the following:

- use a respirator with the correct cartridge
- work in open air.

If any fumigant spills on clothing, shoes, belts, gloves or hats, follow these steps:

- immediately remove contaminated material
- thoroughly wash your skin with soap and water
- do not use the clothing again until it has been washed, dried and ventilated
- discard contaminated leather belts, shoes, gloves or hats.

Disposal of pesticide spills

Follow the procedures outlined in the farm note *Disposal of unwanted chemicals and empty containers,* (D.I.Hay, Agricultural Standards, F71/Oct 89). Contact your local DPI office or Agricultural Standards (tel. (07) 877 9526) for advice and copies of the farm note.

- Pesticide spills must be quickly confined with sand, sawdust or soil dykes. Slowly sweep towards the centre of the spill.
- After using absorbent material (for example sawdust) to soak up a spill, place it in a container and bury it.
- Never hose down a spill, as the pesticide will be spread over a larger area and is more likely to reach a stream.

- After disposing of a pesticide spill, clean the equipment you have used. Launder your clothes in hot, soapy water, separate from other washing.

Respirators

In general, respiratory equipment can be divided into three categories:

- air-purifying equipment such as mechanical filters, chemical cartridges and gas masks
- supplied-air equipment
- self-contained breathing apparatus.

Air-purifying equipment

Mechanical filters

These usually consist of a soft facepiece with the filter made of some fibrous material. They physically trap particles iu air during inhalation. They do not protect the user against gases or vapours.

Chemical filters (cartridges)

Chemical cartridges give protection against light concentrations of various gases and vapours by purifying inhaled air. Activated carbon is a common ingredient in these cartridges. Take note of the following limitations:

- Do not use chemical cartridges for protection against gases that are extremely toxic in low concentrations.
- Do not use chemical cartridges for gases that cannot be detected by smell.

Dispose of chemical cartridges after eight hours use, or when the odour of the chemical penetrates the filter. This may be less than eight hours.

Store respirators using chemical cartridges in a cool, dry place in a sealed plastic bag. Do not store them near pesticides. All parts, with the exception of a canister and cartridges, should be washed after each use.

Respirators must meet Australian Standards AS 1715 and AS 1716.

Respirators

Respirators come in many different shapes or forms, ranging from simple face-pieces, to those partially covering the face, to full-face helmets with a battery-powered, purified air supply (such as the Silvan Kasco helmet). Note that the comfort of different respirators varies considerably — select equipment on the basis of its ability to protect the user, and on the basis of wearer comfort.

Tractor cab filters

There are tractor cab air filtration systems available in Queensland, but currently there is no Australian design standard for these systems.

Gas masks with cartridges

These are designed to protect against gas at concentrations not exceeding 2%, or as indicated on the canister cartridge label. Note that specific canisters must be used for specific gases, i.e. methyl bromide filters must be used only against methyl bromide gas. It is also vital that the user is receiving enough oxygen.

Supplied-air equipment

Supplied-air equipment should be used in situations where air contaminants are not highly toxic, and in a situation from which the wearer can escape should the air supply fail. The air-line respirator is usually attached to a compressed system via a hose. Supplied-air equipment is not commonly used.

Self-contained breathing apparatus

Self-contained breathing apparatus provides complete respiratory protection in any concentration of toxic gases. The wearer is independent of the surrounding atmosphere. The apparatus usually consists of oxygen tanks or similar.

Brisbane suppliers of industrial equipment

Allen Protective Products
Telephone (07) 274 1400

Allsafe Safety Industries
Telephone (07) 274 1010

Commonwealth Industrial Gases
Telephone (07) 275 0111

Delways Industrial Clothing
Telephone (07) 391 4561

EGJ Enterprises
Telephone (07) 356 5310

Gardwell
Telephone (07) 267 6111

Hardi Sprayers (Sundstrom Respirators)
Telephone (07) 375 3544

Norton
Telephone (07) 343 8866

Protector Sureguard
Telephone (07) 344 1822

Queensland Safety
Telephone (07) 399 3555

Silvan Pumps and Sprayers
Telephone (07) 343 6122

Workware and Safety Warehouse
Telephone (07) 352 6606

Yakka Industrial Wear
Telephone (07) 844 8131

APPENDIX 1: INSECTICIDE AND MITICIDE SUMMARY

Summary of formulations, mammalian toxicity and application rates for insecticides and miticides registered or approved for use in bananas in Queensland

Active constituent	Trade name	Formulation	Withholding period (days)	LD_{50}*	Application rates
INSECTICIDES					
chlorpyrifos	Chlorfos	EC	14	135–163	1–2 L/ha or 0.2 L/100 L
	Lorsban 250 W	WP	14	135–163	2–4 kg/ha or 0.4 kg/100 L
	Lorsban 500 EC	EC	14	135–163	1–2 L/ha or 0.2 L/100 L
	Lorsban 500 W	WP	14	135–163	1–2 kg/ha or 0.2 kg/100L
	Pyrinex 500 EC	EC	14	135–163	1–2 L/ha or 0.2 L/100 L
omethoate	Folimat 800	EC	4	50	0.85 L/ha or 0.125 L/100 L
endosulfan	Endosan	EC	14	80–110	0.15 L/100 L
	Endosulfan 350 EC	EC	14	80–110	0.15 L/100 L
	Thiodan	EC	14	80–110	0.15 L/100 L
dimethoate	Dimethoate	EC	7	320–380	75 ml/100 L
	Perfekthion EC 400	EC	7	320–380	75 ml/100 L
	Roxion 400	EC	7	320–380	75 ml/100 L
	Saboteur	EC	7	320–380	75 ml/100 L
diazinon	Diazinon 800	EC	14	300–850	50 ml/100 L **
monocrotophos	Azodrin 400	EC	10	14–23	1–2 L/ha
	Cronofos 400	EC	10	14–23	1–2 L/ha
	Nuvacron 400	EC	10	14–23	1–2 L/ha
ethoprophos	Mocap	GR	Nil	62	40 g/stool or 2.5 kg/100 m
pirimiphos-ethyl	Solgard	EC	Nil	140–200	0.7 L/100 L

Active constituent	Trade name	Formulation	Withholding period (days)	LD_{50}*	Application rates
cadusafos	Rugby 100 G	GR	14	37	30 g/stool or 2 kg/100 m ÷ single row 4 kg/100 m ÷ double row
prothiofos	Tokuthion	SC	Nil	925–966	0.33–1 L/100 L
	Tokuthion	DP	Nil	925–966	30 g/stool
bendiocarb	Ficam Banana Dust	D	84	34–64	10 g/bunch
bifenthrin	Talstar 80	SC	8	54	125 mL/100 L
MITICIDES					
dicofol	Kelthane 240	EC	7	668–842	2.5–3 L/ha or 0.25 L/100 L
	Kelthane 179	EC	7	668–842	2.5–3 L/ha or 0.25 L/100 L
	Kelthane 480 MF	EC	7	668–842	1 L/ha or 0.1 L/100 L
fenbutatin oxide	Torque	SC	1	2630	0.37 L/ha
clofentezine	Apollo	SC	0	3200 +	250 ml/ha
propargite	Omite	WP & WG	7	<200 1.25 kg/ha	10.1 kg/100 L or
bifenthrin	Talstar 100	EC	8	54	40 mL/100 L

* LD_{50} = Acute Oral LD_{50} only (Ref. *The Pesticide Manual*, sixth edition 1979, C.R. Worthing, editor.)

LD_{50} Value — Oral	**Rating**
<5	Extremely toxic
5–50	Highly toxic
50–500	Moderately toxic
500–5000	Slightly toxic
>5000	Practically non-toxic

** Do not exceed this rate and do not treat bunches to run-off or significant fruit 'burn' will develop where drops coalesce at the bottom of the fruit.

EC = Emulsifiable concentrate
WP = Wettable powder
WG = Water-dispersible granules
GR = Granules
SC = Soluble concentrate
DP = Dispersible powder
D = Dust

APPENDIX 2: BANANA PLANT GROWTH STAGES

Figure 1: New bunch (bell) emerging from the 'throat' of the plant (GS5)

Figure 2: Young bunch with all bracts fallen and hands lifted (GS6)

Figure 3: Bunch half-filled (GS7)

APPENDIX 3: INSECT AND MITE PESTS OF BANANAS — A SUMMARY

The occurrence, importance and scope for biological control of insect and mite pests in bananas

MAJOR PESTS

Common name	Occurrence	Pest importance	Biocontrol potential	General Comments
Banana scab moth	N. Qld	severe/widespread	limited	Weather conditions play an important part in the severity of outbreaks.
Banana rust thrips	S.E. Qld & N. Q	minor–severe	limited	More severe on well drained red soils, some natural control from general predators appears likely at the pupal stage in the soil.
Strawberry (banana) spider mite	S.E. Qld & N. Qld	potentially severe/ widespread	high	A range of predators exerts considerable control. The small black mite-eating ladybird beetle, *Stethorus*, is the most common and effective. Severe mite damage follows the use of blanket chemical sprays which destroy the predators.
Two-spotted mite	S.E. Qld & N. Qld	potentially severe/ widespread	high	As above
Banana weevil borer	S.E. Qld & N. Qld	more severe in S.E.Q and widespread	limited	Some control is achieved by general predators such as cane toads, ants and beetles. Biological control with nematodes is being evaluated.
Sugarcane bud moth	N. Qld. S.E. Qld	minor–severe	unknown	Can cause significant fruit scarring from December to April.
Banana flower thrips	S.E. Qld & N. Qld	more severe in S.E.Q and widespread	unknown	More severe in dryer areas. Some evidence exists that overhead irrigation will reduce fruit damage.

continued over

MINOR PESTS

Common name	Occurrence	Pest importance	Biocontrol potential	General Comments
Banana aphid	N. Qld & S.E. Qld	minor — severe	unknown	Rarely an important direct pest. In S.E. Qld it transmits bunchy top virus.
Redshouldered leaf beetle	N. Qld & S.E. Qld	minor/sporadic	unknown	Redshouldered leaf beetle adults can swarm on bunches and feed on flowers. Damage to the fruit is rare.
Banana silvering thrips	N. Qld & S.E. Qld	minor/sporadic	unknown	Damage is rare and patchy within plantations.
Banana fruit fly	N. Qld & S.E. Qld	minor/sporadic	unknown	Damage is seldom severe. Removal of overripe bunches reduces the level of flies and damage.
Queensland fruit fly	N. Qld & S.E. Qld	minor/sporadic	unknown	Attacks only ripe fruit.
Banana fruit caterpillar	N.Qld & S.E.Qld	minor/sporadic	unknown	Seasonal and usually more troublesome near rainforest.
Cluster caterpillar	N. Qld & S.E. Qld	minor/sporadic	high	Heavy outbreaks cause scarifying of the leaf edidermis and older larvae can damage fruit. Parasites and disease epidemics give good natural control.
Transparent scale	N. Qld & S.E. Qld	minor/sporadic	high	Oil sprays for leafspot control suppress build up. Lacewings and ladybird beetles are also effective predators.
Greyback cane beetle	N. Qld & S.E. Qld	minor/sporadic	unknown	Severe defoliation to bananas can follow adult emergence in December/January. Larvae feeding on roots of bananas may cause plants to fall out.
Banana-spotting bug and fruitspotting bug	N. Qld & S.E. Qld	minor/sporadic	limited	These pests attack a wide range of cultivated crops but bananas are not a preferred host. Rows near rainforest are occasionally attacked especially if native food is not available.

APPENDIX 4: FIELD DATA SHEETS

HARVEST ASSESSMENT

Farm: ______________________________ Paddock: ____________________________

Total Bunches Assessed: ___________________ Date: ____________________________

Cause of damage	Weight of damaged fruit (kg)
Non-insect damage	
Mechanical — Pre-harvest	
Mechanical — Post-harvest	
Mechanical — Injection marks	
Sunburn	
Maturity bronzing	
Doubles	
Smalls	
Chemical burn	
Rat	
Other	
SUB-TOTAL (a)	
Insect damage	
Scab moth	
Sugarcane bud moth	
Mites (red spider)	
Banana fruit caterpillar	
Flower thrips	
Rust thrips	
Other	
SUB-TOTAL (b)	
Waste unsorted	
TOTAL WEIGHT ALL WASTE (c)	

Fruit weight/carton = ___________

Total cartons packed = _____________ (__________ XL, _________ L)

Total weight packed fruit = ________________ (d)

Total weight of harvested fruit = ______________ (c + d)

% Waste fruit (of total harvest) = $\frac{c}{c+d} \times 100 =$ ________________

% Insect damaged fruit (of total harvest) = $\frac{b}{c+d} \times 100 =$ ________________

% Insect damaged fruit (of total waste fruit) = $\frac{b}{c} \times 100 =$ ________________

MITE AND MITE PREDATOR ASSESSMENT SHEET

Farm: ______________________________ Date: ______________________

Block: ______________________________

			Plant no.				
			1	2	3	4	5
General rating*							
First leaf with damage							
First leaf +3**							
Total *Stethorus* Counts	Adults						
	Pupae						
	Larvae						
	Eggs						
Other coccinellids (ladybird beetles)							
Staphylinids (staphylinid beetles)							
Phytoseiids (predatory mites)							
Chrysopids (lacewings)							
Other predators							
No. of colonies (rating)***							
Total mite counts for:	Colony 1	Eggs					
		Motiles					
	Colony 2	Eggs					
		Motiles					
	Colony 3	Eggs					
		Motiles					
	Colony 4	Eggs					
		Motiles					
	Colony 5	Eggs					
		Motiles					

* Overall plant mite bronzing rating. L = Low M = Medium H = High
** All mite, *Stethorus* and other predator counts carried out on first leaf with mites +3
*** 0 = No colonies 1 = 1–10 2 = 11–50 3 = 51–100 4 = >100

RUST THRIPS, FLOWER THRIPS AND SUGARCANE BUD MOTH ASSESSMENT SHEET (GS7)

Farm: ______________________________ **Date:** ______________________________

Block: ______________________________

				Bunch number				
				1	2	3	4	5
			Bunch treatment					
RUST THRIPS	Top hand fingers	1	Thrips number					
			Damage rating					
		2	Thrips number					
			Damage rating					
		3	Thrips number					
			Damage rating					
		4	Thrips number					
			Damage rating					
		5	Thrips number					
			Damage rating					
FLOWER THRIPS	Second-lowest true hand fingers		1					
			2					
			3					
			4					
			5					

SUGARCANE BUD MOTH DAMAGE

Bunch number	**Bunch treatment**	**Hand number**												
		1	2	3	4	5	6	7	8	9	10	11	12	13
1														
2														
3														
4														
5														

Note: record presence (+) only

Note: Bunch treatments: I = injected B = bagged D = dusted S = sprayed

BANANA SCAB MOTH AND FLOWER THRIPS ASSESSMENT SHEET (GS6)

Farm: ______________________ **Date:** ______________________

Block: ______________________

	Treatment										
	Bunch no. / **Hand no.**	1	2	3	4	5	6	7	8	9	10
Scab moth damage	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	10										
	11										
	12										
	13										
	14										
Larvae on stalk											
Beneficials	Spiders										
	Ants										
	Bugs										
	Other										
Flower thrips	Males										
	Females										
	Oviposition marks										

Note: For scab moth record presence (+) on each banana hand, one (1) is the top hand.
For flower thrips record the rating number as shown in Table 4.8 (page 29)
Bunch treatment: I = injected B = bagged D = dusted S = sprayed.

BANANA WEEVIL BORER (BWB) ASSESSMENT SHEET

Farm: ______________________________ **Date set:** ________________

Block: ______________________________ **Date collected:** ________________

Trap	Number of BWB	*Tetramorium bicarinatum*	Other ant species	Earwigs	Spiders	Other
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						
Total						
Mean						

Treatments: Chemical used ....

Rate applied ....

Date applied ....

Method used ....

Note: For potential predators listed record presence (+) only.

Comments (rainfall, temperature, humidity, soil moisture during trapping period)

....

....

GLOSSARY OF TERMS

active ingredient (active constituent): the toxic component in a pesticide formulation. This quantity varies, depending on the formulation. Usually written as a.i.

candela (candle): the name given to the new upright banana leaf before if unfurls (resembles a candle)

cigar leaf: refer to **candela** (above)

crawler: the immature, mohile stage of scale insects

economic injury level (EIL): the level at which a pest population is capable of causing economic damage and which warrants the cost of pest control; i.e. when possible loss of production starts to exceed the cost of control

fallout: poor or damaged root system causes the whole plant to tip over, out of the soil

honeydew: sweet honey-like sticky substance excreted by sucking insects such as aphids and scales. Ants are attracted to this material, which also encourages the growth of sooty mould

hot spot: a location in a plantation where, from previous experience, pest problems are likely to be experienced first and where they are likely to be more severe

insecticide: natural or synthetic products used for destroying insects. These can be further divided into miticides (acaricides) if their efficacy is primarily against mites (e.g. red spider) and aphicides if primarily active against aphids.

instar(s): the stage(s) of insect development between each moult

knockdown: ability of a pesticide to kill actively moving stages of a pest

larva(e): the immature feeding stage of insects from hatching to becoming a pupa, e.g., moths, butterflies and heetles. This is usually the stage which causes most crop damage.

LD_{50}: LD_{50} stands for Lethal Dose 50% and is used as a standard description for chemical toxicity. The figure given represents the numher of milligrams of the substance which will result in 50% kill of the organisms. The lower the figure, the more toxic the product. The figure is standardised by referring to 1 kg bodyweight. LD_{50} values can be quoted for various forms of exposure, e.g. oral (by ingestion) and dermal (by absorption through the skin).

leaf bronzing: a descriptive term used in relation to mite damage. Leaf cells are destroyed when mites suck out the contents. The dead cells collapse and turn reddish brown and, when many neighbouring cells are damaged, the infected leaf area turns rusty red from which the term 'bronzing' is derived.

maximum residue limit (MRL): the maximum allowable limit of pesticide residue (in ppm — parts per million) on fruit (or other produce) at the time of harvest

moult: the periodic shedding of the outer cuticle (skin) of an insect. This process takes place a number of times during the larval or nymphal stages.

nematocide: synthetic products used against nematodes

nymph(s): the immature feeding stage of certain insects where the young resemble the adult but wings and reproductive parts are less-developed, e.g., bugs and grasshoppers.

ovicide: a pesticide with the ability to kill eggs

parasite(s): an organism (insect) whose immature stages develop on or within a host, e.g., parasitic wasps which develop inside host larvae and destroy them

predator(s): an organism which, as an immature or adult, feeds on other animals, e.g., *Stethorus* feeds on mites.

pseudostem: the correct botanical term for the banana stem which is made up of leaf bases or petioles

pupa(e): the resting non-feeding stage of insect development between the larva and the adult. Sometimes the term 'chrysalis' is used for this stage.

random sampling: selection of sample units by chance so that each sample has an equal chance of being selected. This is important to avoid biased results.

scale insect: a sap-sucking insect (true bug) covered by a hard or soft waxy covering. Scales are mobile in the immature stages (crawlers) and are usually immobile as late instars and as adults.

sooty mould: black mould which develops on honeydew. This mould is usually the first indication of the presence of aphids or scales. Its presence is superficial but can be difficult to remove from fruit.

transect: a line along which monitoring is undertaken in a crop.

volunteer plants: plants which establish and grow unattended in areas other than a specific paddock, e.g., creek banks, gullies and roadsides

withholding period: time interval (in days) between the last application of a pesticide and harvest. This is a requirement to ensure that the permitted maximum residue limit (MRL) in food for human consumption is not exceeded.

This book is a practical, illustrated guide to identifying, monitoring and managing insect and mite pests of bananas in Australia.

Detailed information is given on field monitoring , both for major pests and beneficials (parasites and predators of the pests). Control recommendations are included, with a strong emphasis towards non-chemical control where possible.

Bananas: insect and mite management is a valuable reference for commercial banana growers, consultants, agribusinesses, researchers, home growers, marketers, students and horticultural advisers.

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