

## **FALSE CODLING MOTH**

*Thaumatotibia leucotreta* Meyr.

### **1 PEST PROFILE**

#### **1.1 Distribution and status**

False codling moth (FCM) occurs in all citrus production areas of southern Africa. However, pest pressure varies dramatically in these regions and is generally less abundant in the far northern regions. Navel oranges are the most susceptible citrus type, but there is considerable variation in susceptibility between Navel cultivars. Satsumas and Turkey Valencias are also highly susceptible. Midseasons, mandarin types other than Satsumas and Star Ruby grapefruit are less susceptible. Most Valencias and white grapefruit are seldom subject to serious attack. However, Valencias can serve as a bridge to carry FCM over from one season to the next. Lemons at the commercially harvested stage of ripeness are not a host for FCM.

#### **1.2 Description**

The FCM adult is an inconspicuous nocturnal moth that is seldom noticed in citrus orchards. It has a variable grey colour with a noticeable plume of grey scales on the dorsal surface of the body. FCM eggs resemble an inverted saucer-shaped dome and are about 1 mm in diameter. The eggs are initially translucent but darken internally through a red stage to black shortly before hatching. The black part is the head capsule of the developing larva. Parasitised eggs also appear black in colour but in this case the whole egg is black, therefore easily differentiated. Newly hatched and young larvae are creamy white with a dark brown to black head. As they age, larvae darken through off-white and finally have a pink body colour. The pupae are dark brown and about 10 mm long.

#### **1.3 Infestation sites on tree**

Only fruit are infested by FCM and they are susceptible to damage from pea-size to harvest. Female moths lay their eggs directly on fruit and often near the stylar end. The newly hatched larva moves around for a while on the fruit surface until it finds a suitable spot at which to penetrate the fruit. The mature larva leaves the fruit about a month later and pupates just under the soil surface.

#### **1.4 Damage**

##### **1.4.1 Symptoms**

Fresh larval penetration holes in fruit can only be found with the aid of thorough inspection. In the case

of green fruit, the peel around the penetration hole eventually assumes a yellow colour. On ripe fruit this area is initially orange-coloured, but can eventually become sunken and brown as the damaged tissue decays. The mature larva enlarges the original hole sufficiently to leave the fruit and pupate. Granular excreta (frass) can be found in the larval work area in the fruit. An infested fruit usually falls from the tree three to five weeks after penetration by a larva. In the packhouse it is difficult to identify fruit that become infested shortly before harvest and they are a source of post-harvest decay.

##### **1.4.2 Seasonal occurrence**

The major fruit drop resulting from FCM infestation usually takes place during the period December to April.

However, more importantly, FCM is a phytosanitary pest for some of South Africa's export markets, as it is endemic to sub-Saharan Africa. Interception of even one individual in a consignment could mean rejection of the entire consignment.

### **2 MANAGEMENT ASPECTS**

It is critical to understand that FCM control is dependent on a multidisciplinary approach to be (i) effective and (ii) least disruptive to natural enemies. In situations of high pest pressure, there is no single control measure currently available that will independently suppress FCM satisfactorily to the required degree. This means that available measures that can be integrated into an FCM control programme must be used wherever possible.

#### **2.1 Monitoring**

##### **2.1.1 Trap monitoring**

Pheromone-based trapping systems have been developed to provide a means to monitor population levels. Dispensers are loaded with the female pheromone, which attracts male moths to the trap. The first of the trapping systems, the Lorelei, was developed to aid in deciding whether or not chemical intervention was required for the control of FCM. However, due to the phytosanitary status of FCM for some export markets, this has changed. No longer should economic thresholds be applied for export citrus, but FCM should be controlled to as close to zero levels as possible. The purpose of trapping is now therefore:

- To compare FCM activity levels between seasons, which will enable one to gauge probable post-harvest risk;
- To compare FCM activity levels between orchards, which will enable prioritisation of

treatment application;

- To assist in the accurate timing of treatment application – particularly relevant to virus products.

There are three pheromone monitoring systems registered for FCM. These are the Lorelei, FCM PheroLure and Chempac FCM Lure. The Lorelei trap system has been preferentially recommended, as it is the only system for which a threshold has been developed i.e. an association between moth catches and fruit infestation, and its pheromone release rate has been shown to be the most consistent of the three, despite moth catches being higher with the other two dispensers. However, production of the Lorelei dispenser has been suspended and it is thus currently unavailable.

#### 2.1.1.1 The pheromone dispenser

- Dispensers should be stored in the refrigerator until use.
- When replacing a dispenser, do not dispose of it or leave it lying in the orchard. This will result in the old dispenser competing with the new dispenser in the trap and will thus compromise moth catches in the trap.

##### 2.1.1.1.1 The FCM Pherolure

- The FCM Pherolure dispenser is a sealed small vial. The vial should not be opened.
- The vial should be stored in the refrigerator until used.
- The galvanised wire, provided with the delta trap, must be pushed through the two open holes on top of the trap. The lure should be suspended from the wire on the inside of the trap.
- Lures should be replaced every 10 weeks.

##### 2.1.1.1.2 The Chempac FCM Lure

- The Chempac FCM Lure dispenser is a round pill-like capsule.
- The lure must be placed in the centre of the sticky floor on the base of the trap.
- Lures should be replaced every 3 months.

#### 2.1.1.2 The trap

Two trap types are available. These are the beige PVC pipe trap and the yellow delta trap. Only the delta trap is recommended for use with the FCM

PheroLure and Chempac FCM Lure dispensers. If there is prior history of using the PVC pipe trap, the relationship between the two traps must be understood. It has been shown that if the same type of lure is used, the yellow delta trap catches on average 2.75 times the number of moths that the pipe trap catches.

#### 2.1.1.2.1 Yellow delta trap

- The trap is acquired in unassembled format and should be assembled by folding the two longer outside flaps of the trap inwards towards the centre. Slide the two horizontal tabs through the diagonal openings.
- Sticky floors are provided for these traps, making them more user-friendly than the pipe trap. Open the sticky floor and slide it onto the bottom of the trap, before closing the horizontal flap on the entrance floor in a vertical position.
- Moths and debris should be removed from the sticky floor when the trap is inspected. Sticky floors can be reactivated by folding the two sides together, down the centrefold, and reopening the floor. The floor can be replaced at any stage as needed i.e. if the debris load in the glue is so much that it compromises the stickiness of the floor or the ability to clearly identify moths stuck to the floor.

#### 2.1.1.3 Trap placement

##### a) In the orchard

- The trap should be placed in the fourth or fifth row from the perimeter of the orchard.
- Position the trap on the upwind side of the orchard. Avoid placing the trap in a windless part of the orchard, i.e. near tall windbreak trees, as trap efficiency can be impaired due to insufficient air movement.
- Do not use more than one trap per four hectares of FCM-susceptible citrus. One trap can represent more than one orchard, if the total area of the orchards is not more than four hectares and the orchards are adjacent to one another. Individual orchards in excess of 4 ha require no more than one trap.

##### b) In the tree

**It is essential to hang the traps as prescribed. Incorrect placement will jeopardise the accuracy of the monitoring system.**

- The trap should be placed on the southern side of the tree. If the space between tree canopies is less than two metres, the trap must be relocated to the south-western or western side.
- The trap must be suspended as high as possible (small tree) or as high as an outstretched arm can reach (big tree). Place the trap in partial shade in the outer foliage canopy. The trap must be suspended in such a way that it is easily visible from the front and sides. Do not bury the trap inside the tree. The trap should rather receive too much sun than too much shade.
- Remove all twigs and leaves around the trap so that it can swing freely, even when the wind blows. Ensure that moths have unhindered sight of and access to the trap. Remember that the branch to which the trap is attached, will probably sag appreciably with the increase in fruit mass as the season progresses. Choose a branch which will not be significantly affected, or when necessary, relocate the trap to a higher branch on the same or an adjoining tree. Alternatively, all fruit can be removed from the branch.
- If a mating disruption product is being used, trap catches will be negatively influenced (see 2.2.3.2 for more details). In order to obtain trapping data that can be useful in decision-making, traps can be hung outside of treated orchards or can be hung on poles positioned higher than the treetops. If the latter practice is employed, it should be used consistently throughout the farm in order that trap catches are comparable, as it may lead to elevated trap catches.

#### 2.1.1.4 Interpretation and usage of trap data

Trapping for FCM is not an exact science. Ultimately what one wants to determine is the risk or likelihood of fruit being infested and the estimated level of that infestation. By monitoring male moths in a trap, one is assuming that this will provide an accurate indication of female moth activity, which in turn will reflect egg laying and ultimately larval infestation of fruit. It is impossible for trap catches to always provide an accurate indication of the potential for fruit infestation. Having said this, trapping remains the most accurate and most practical way of predicting the risk of fruit infestation.

As experience with and confidence in the trapping system is accumulated, one can place greater reliance on it for assisting with decision making within a control programme.

Trap catches must be counted weekly, on the same day every week. This will provide the best opportunity

for establishing a relationship between trap catches and fruit infestation. Trap surveys must be initiated in spring and continued until harvest time. The first post-winter peak in moth activity, which reflects a generational peak, usually occurs early in October. This is followed by what is usually a much larger peak in activity, by the subsequent generation, in late November or early December, depending on the region. The most reliable way to accurately identify these trends is by using data from as many traps as possible on the farm or in the area, rather than relying on individual traps, as generational peaks will be fairly synchronous throughout a climatically homogenous region.

A peak in moth activity should be followed by a peak in FCM-induced fruit drop 3 to 5 weeks later. This is likely to be particularly evident if trap catches are high. Research indicates that when 10 or more moths are caught per trap per week, subsequent FCM infestation is likely to exceed one FCM infested fruit dropping per tree per week. This used to be regarded as the economic threshold for intervention. However, due to the increased phytosanitary status of FCM, this no longer applies. Trapping is a valuable management practice but should not be used for deciding whether a registered control measure should be applied or not.

A peak in trap catches can be used for accurate timing of a virus application. One would expect that a peak in FCM egg hatching would occur within 1-2 weeks after a peak in trap catches. As this is the only window of opportunity for a virus to work against FCM, a spray should be applied at or shortly before this point. Augmentative releases of egg parasitoids may also be best timed approximately one week after a peak in trap catches. Mating disruption should be initiated before a peak in moth activity occurs. This is something one can obviously only apply with historical data.

On average, there are 6 generations of FCM per year. One might expect all of these generational peaks to be detected by traps. However, this is often not the case. Although, moth activity is fairly well synchronised after winter, as the season progresses, generations begin to overlap with one another to an increasing extent. Moth peaks may become more blurred and can often be difficult to detect late in the season.

Trap catches near harvest will not necessarily reflect the real potential for post-harvest problems due to FCM infestation. Increased crop damage at this time of the season is often not due to larger moth numbers in the orchard but the result of reduced natural larval mortality. However, a sudden increase in moth catches just before or during harvest is useful as a warning that the crop may be exposed to increased

fruit infestation.

### 2.1.2 Fruit drop surveys

#### **Fruit drop surveying is the most important means of monitoring FCM**

- This is the only way in which one can truly gauge the extent of the FCM situation in a particular orchard and hence the risk for post-harvest infestation and fruit decay.
- There are many other possible causes of fruit drop – particularly in Navel oranges – and it cannot be assumed that all or most fruit drop can be attributed to any one cause, such as FCM, without substantiating this through fruit drop surveys. Without doing this, incorrect conclusions can often be drawn. Also bear in mind that the major causes of fruit drop can change throughout the season. Therefore, one or two weeks' data is nothing more than a small window on the season and may not accurately reflect the whole season.
- The effectiveness of the chosen control programme can be measured. One can then determine whether any further control measures are required.
- Such surveys will also corroborate the accuracy of trap data and enable producers to gain confidence in their trap counts or indicate possible problems with the trapping procedure, in particular poor trap placement.

It is recommended that at least five trees be used as a data station and that these data stations be replicated throughout FCM susceptible orchards, at a density of one data station per orchard or per 3-6 ha, where orchards are larger. More severe crop damage often occurs in parts of orchards where traps do not function properly, i.e. in sheltered spots, such as near windbreaks. If that is the case, the data stations must be positioned where, from experience, crop damage is usually most severe and not necessarily where the traps function best.

Fruit drop surveys must be conducted on a set day once a week. All dropped fruit must be collected under the five data trees per data station, cut open and the probable reason for the fruit drop recorded. The surveys need not be initiated earlier than January, but should be conducted for at least 12-16 weeks preceding harvest, unless the orchard is harvested earlier than that. Although signs of tunnelling, frass and head capsules in fruit can be indicative of FCM infestation, fruit need only be recorded as FCM-infested, if an FCM larva is found in the fruit. The person conducting the survey should

familiarise him/herself with the appearance of all stages of the FCM larva. As fruit can also be infested by other pests, such as fruit fly and carob moth larvae, and by secondary scavengers, such as vinegar fly and beetle larvae, it is quite possible for one of these to be confused with an FCM larva.

### 2.1.3 Egg surveys

It is difficult to monitor FCM by inspecting fruit for the presence of eggs. This is due to the eggs' size and their transparent appearance. Egg surveys can be useful to monitor FCM population fluctuations. However, there is a relatively poor and variable relationship between egg numbers and the resultant fruit drop and there are no thresholds available to relate these two factors to each other. This is because the eventual fruit drop due to FCM infestation is influenced by egg parasitism and the normally high natural mortality of newly hatched larvae due to factors such as cannibalism, predation, and accidental removal of larvae by brushing leaves and strong winds.

The only way in which egg surveys could be useful would probably be to reveal an increase in egg laying activity and the impact of naturally occurring and/or artificially released egg parasitoids.

## 2.2 Control options

There are three fundamental requirements for a successful control programme: firstly, it must be underscored by season-long regular orchard sanitation; natural enemies, particularly egg parasitoids, must be preserved, through judicious selection of pesticides for control of other pests; and lastly, control of FCM must be initiated early in the season while FCM levels are still low.

Various options are available to control FCM. None of these are effective enough to be used as stand-alone treatments under extreme situations. It is therefore essential that FCM control is based on a multidisciplinary approach, aimed at the suppression of FCM from early in the season to prevent the build-up of subsequent potentially harmful population numbers. This will support any further control procedures that are applied later on in the season such as spray treatments.

Due to the phytosanitary status of FCM for most markets, control measures should be applied preventatively, rather than only in response to elevated trap catches or fruit infestation. However, if fruit drop surveys do indicate that infestation is elevated, additional control measures should be applied.

**2.2.1 Cultural**

**Orchard sanitation is the cornerstone of FCM control**

Research has shown that it is possible to remove an average of up to 75% of FCM larvae from an orchard by conducting weekly orchard sanitation. However, this level of efficacy would be influenced by temperature and would thus oscillate between the cooler and warmer months of the season.

It is important to remove all injured or fallen fruit from orchards. The purpose of this sanitation procedure is threefold. Firstly, it eliminates FCM and fruit fly larvae which may be present in such fruit. Secondly, it removes injured fruit which can be more attractive and susceptible to FCM attack. Thirdly, it will reduce the contribution made by rotting fruit to post-harvest decay.

- Orchard sanitation begins immediately after harvesting in an orchard is completed. All fruit on the ground and all fruit left hanging in the trees must be removed. This will eliminate any possible means of FCM completing its life cycle in the orchard over winter.
- In the following season, it is strongly advisable that orchard sanitation commence before fruit are marble-sized. This will help to restrict the overall size of the FCM population during the season.
- Notwithstanding the previous advice, it is essential that orchard sanitation commence no later than late November to mid-December, immediately after the end of natural physiological November fruit drop.
- Larvae leave fruit soon after they have fallen. Therefore, sanitation must be conducted at least at weekly intervals. However, the more frequently sanitation is conducted, the more effective it will be.
- Mature larvae sometimes leave the fruit while they are still on the tree. It is therefore strongly recommended that obviously infested fruit on the tree must be removed during sanitation. Additionally, any other damaged fruit must also be removed, as these could be attractive and susceptible to FCM attack.
- As the rate of development of FCM larvae, and hence the rate at which larvae exit the fruit, is temperature dependent, sanitation should be conducted more frequently than once a week in the hotter months of the year, if feasible.

- It is strongly advised that out-of-season fruit be removed from the trees as they are also a source of FCM infestation.
- Orchard sanitation must continue during the Valencia picking season. This procedure can help to reduce FCM infestation the following season.

After collection, fallen fruit can be destroyed in one of the following ways:

- Small hard fruit should be buried at least 30 cm deep and covered with compacted soil. Alternatively, they can be submerged in water for a week.
- Juicy fruit can be pulped with a hammermill. Ensure that the fruit is properly pulped to destroy the larvae. Merely slashing the fruit into large pieces with an ineffective hammermill will not be sufficient and another means of fruit disposal, such as burial, must then be considered. Pulping should be done as far outside of orchards as is practically feasible, but not less than 50 m from the nearest orchard. The pulp must be spread out thinly on the ground to facilitate rapid drying in the sun. This will (i) reduce the prospect of fungal growth which plays a role in post-harvest decay, and (ii) reduce the possibility that fruit flies may be attracted into an orchard by the smell of the decaying pulp. When conditions are not conducive to rapid sun drying, the pulp must be buried.

With the exception of orchard sanitation there are no other cultural options that contribute to FCM control.

**2.2.2 Natural enemies**

The most effective biological suppression of FCM is provided by the egg parasitoid *Trichogrammatoidea cryptophlebiae* Nagaraja. It occurs naturally in all citrus-producing regions and if undisrupted, can parasitise more than 80% of FCM eggs from shortly after mid-summer. This level of parasitism has been shown to significantly reduce FCM levels in an orchard. Spray programmes for other pests should therefore be structured to minimise non-target effects on these parasitoids.

There are also several species of naturally occurring larval parasitoids that play a role in suppressing the pest. Most of these are wasps but a few are flies. Probably the most effective of these parasitoids is the wasp *Agathis bishopi*, which has been shown to parasitise up to 40% of FCM larvae in the Eastern Cape. Although very limited surveys conducted in the Western Cape and Mpumalanga have not shown the same levels of parasitism, it is still possible that larval

parasitism could play a similarly influential role in regions other than the Eastern Cape.

*Orius* bugs have been noted to prey on FCM eggs and assassin bugs can attack FCM larvae. However, probably the most effective predators are ants, which have been shown to dramatically reduce planted FCM pupae in research trials. This is a strong justification for not poisoning ants in an orchard. Trees should rather be banded with an ant barrier, to prevent ants from entering the trees and disrupting natural enemies of sucking pests, particularly mealybugs.

Two species of entomopathogenic fungus and two virus species have also been recovered from FCM larvae. Additionally, several species of entomopathogenic nematodes (EPN) and numerous isolates of entomopathogenic fungi (EPF) have been isolated from citrus orchard soil. However, the only pathogens for which there is evidence of a natural suppressant effect on FCM in the field are the *Cryptophlebia leucotreta* granulovirus (CrleGV) and an entomopathogenic nematode, *Heterorhabditis zealandica*.

### 2.2.3 Plant protection products

#### 2.2.3.1 Biological Control

##### 2.2.3.1.1 Egg parasitoids

Good results can be obtained with the mass-release of the egg parasitoid, *T. cryptophlebiae*. The parasitoid should be released repeatedly while the fruit is susceptible. Releases should be initiated as early as October. Research has shown that a total of 100 000 parasitoids per hectare (in four monthly releases of 25 000 each) is usually adequate in all areas except the Western Cape. In the Western Cape five releases, each of 25 000 parasitoids per hectare (a total of 125 000 parasitoids per hectare) should be made. Initiation of a release programme later than December has been shown to be minimally effective.

##### 2.2.3.1.2 Virus

There are three virus-based products on the market: Cryptogran, Cryptex and Gratham. All of the products are based on the naturally occurring indigenous pathogen of FCM, called the *Cryptophlebia leucotreta* granulovirus (CrleGV), therefore a biological control agent. The main difference between Cryptogran and the other two products is the registered application rate, which is higher for Cryptogran. These virus products are fully compatible with an IPM programme as they have absolutely no effect on beneficial insects. However, unlike other biocontrol agents, virus can be used within a chemical control

programme without any detrimental effects.

When virus is sprayed onto a crop, FCM larvae will ingest the virus particles, potentially even before they begin to actively feed. The virus will eventually infect the entire body of the larva, killing it and causing it to rupture. Millions of virus particles are spontaneously released back into the environment, ready for ingestion by other larvae.

Timing of application of virus is very important. The only FCM life-stage which can be targeted with virus is the neonate larva. Therefore, there is a very small window of opportunity for a virus application to be effective. In order to achieve this, pheromone traps must be used. Virus should be sprayed within a few days after the start of a peak in moth catches. The spray will then coincide with a peak in egg hatching. Commercial experience indicates that virus applied in November/December has been notably more effective than applications at other times of the year. This is almost certainly due to the greater synchrony of life-stages at this time than later in the season. Although a spray as early as October is a possibility, the November/December spray will usually be the first virus application of the season.

Note that not only virus, but all sprays applied for FCM control, should be applied as high volume medium cover film sprays. Neonate larvae sometimes don't spend more than a few minutes on the surface of the fruit and do not move more than a few centimetres before penetrating into the fruit. During this brief period, a larva will need to encounter and ingest sufficient virus to induce mortality. Hence, spray coverage must be absolutely thorough.

Virus can also be applied 4 weeks before harvest in order to reduce post-harvest problems. However, FCM must already be under commercial control at this stage. A virus spray is also recommended as a follow-up treatment where mating disruption or attract and kill have been used earlier in the season.

Due to the ultra-violet sensitivity of insect viruses, they should be applied during the late afternoon or evening. Viruses should be used in the north-western region of the Western Cape and the Northern Cape with caution due to UV irradiation, which is higher in these regions from November to March than anywhere else in the country.

Viruses have traditionally been registered to be sprayed with molasses. However, some registrations have subsequently changed. Therefore, although there may be a temptation to exclude the molasses component, due to its messiness and cumbersomeness, numerous field trials with two of the commercial viruses demonstrated that efficacy is superior when mixed with molasses compared to

without. However, application in a tank-mix with mancozeb (applied for citrus blackspot control) has also been shown to improve virus efficacy.

### 2.2.3.1.3 Sterile Insect Technique

The principle of the sterile insect technique (SIT) is to flood citrus orchards with large numbers of partially sterile moths. A ratio of 10 sterile to 1 wild male moth is used as a ratio guideline. The result will be that the probability of a wild female moth mating with a sterile male moth will be significantly greater than the probability of it mating with a wild male moth.

Moths are mass reared and partially sterilised using gamma irradiation. Partial sterility is used, as it produces a more competitive moth than full sterility. However, very few, if any, viable eggs will be produced from a liaison between a sterile male moth and a wild female moth, most of this second generation are male and all individuals are completely sterile.

SIT is an area-wide approach and can only be employed on a large scale area-wide basis. Where it is employed on such a scale, particularly over several years, it can be extremely effective in suppressing the FCM population down to negligible levels. SIT is the most effective area-wide population suppression technique available.

### 2.2.3.1.4 Cryptonem

Cryptonem is currently the only product registered to be applied against the soil-dwelling life-stages of FCM. Its active ingredient is the entomopathogenic nematode, *Heterorhabditis bacteriophora*. The infective juveniles (IJs) are alive and need to be applied as soon after receipt as possible. If there is any delay in application, Cryptonem must be kept refrigerated. After application, the IJs actively seek out FCM pupae and pre-pupating larvae in the soil, penetrating them through any available orifice. After penetration, the EPNs release synergistic bacteria which kill the insect, facilitating multiplication of the EPNs and re-entry back into the soil environment.

Cryptonem is registered to be applied at 500 million IJs/ha (which is 10 IJs/cm<sup>2</sup>) and can be applied through a microsprinkler irrigation system. The ideal timings for application are when the largest proportion of the FCM population is in the soil dwelling stage. This would be spring, 3-4 weeks after the traditional December flight peak, and autumn.

### 2.2.3.1.5 Entomopathogenic fungi (EPF)

Two EPFs are registered for control of FCM. These are Broadband and Eco-Bb, both of the species, *Beauveria bassiana*. When the spores of the fungus

come into contact with the FCM larva, they germinate secreting enzymes which weaken the larva's cuticle. The fungus then invades the larva through its weakened cuticle. Once inside the body of its host, the fungus continues to grow, feeding on the internal organs and consequently killing the larva.

Broadband is registered to be sprayed three times in a season at 3-7 day intervals. Eco-Bb is registered to be applied every 10-14 days. Like the virus products, these EPFs are UV-sensitive and are therefore recommended to be applied during the afternoon or evening.

### 2.2.3.2 Mating disruptants

The mating disruption (MD) approach for the control of FCM (and other insects) relies on the prevention of mating, thereby reducing the number of viable eggs deposited on fruit. In practice this is achieved by applying synthetic female sex pheromone (which usually attracts the males of the species) in such a way that the males are confused, repelled or habituated to such an extent that they are unable to find the females for mating. This effect is temporary and males can recover to try again later.

MD should be initiated early in the season i.e. while FCM levels are still low, in order to achieve the best results possible. MD is a negatively density dependent technology and will therefore not be optimally effective once FCM levels have begun to escalate. Initiation of MD only later in the season is therefore strongly discouraged. MD should also be employed over a large area in order to minimise the edge effect of mated female moths moving into the MD area from the outside and laying viable eggs on fruit. MD should be applied to the top third of the tree i.e. at the level at which moths would normally fly. The volatilised pheromone is heavier than air and if applied lower than this will not be detectable by flying moths and will not be effective. The rate of release of pheromone is influenced by temperature. If temperatures are too cool, inadequate pheromone might be released to induce control of FCM. In autumn, as harvest approaches, it is often necessary to follow up the use of MD with another product, which is not influenced by temperature.

There are currently four MD products registered and available for FCM control. These are Isomate FCM, Checkmate FCM-F, Splat-FCM and X-Mate FCM. Isomate consists of thin polyethylene tube dispensers containing liquid sex pheromone which is released through the tube walls into the atmosphere. Dispensers are distributed by hand with a special applicator twice per season: 500 in October and a further 300 in January.

Checkmate is a pheromone containing capsule

suspension formulation. It is applied as a very low volume foliar spray to the top third of the tree. It is most conveniently applied using a fruit fly baiting machine. It should be reapplied every 21-28 days.

Splat FCM is an amorphous polymer matrix, containing pheromone. It is applied as 1000 g per ha, with a minimum of 400 point sources per ha, spaced evenly throughout. It should be applied using either a calibrated caulking gun or the Splat mechanical applicator. It should be reapplied every 10-12 weeks.

X-Mate consists of cellulose disc dispensers containing liquid sex pheromone. These are hung at a rate of 40-42 dispensers per ha and last up to 5 months.

It is important to note that where MD is employed, pheromone traps become virtually redundant. The pheromone emitted by the MD product causes shutdown of the trap, resulting in dramatically reduced catches. Unfortunately, this does not necessarily mean that there is no FCM activity and therefore no FCM infestation of fruit taking place. It appears that the ability of male moths to find the synthetic pheromone in the trap may be disrupted more easily than their ability to find and mate with female moths. Despite this, pheromone traps should still be used in MD orchards. If moths are caught, then this should be taken as a sign that moths are not being adequately disrupted.

As pheromone is dependent on warm temperatures to be released at an adequate rate to be effective, these MD products tend to become less effective during the cooler months of the year. Consequently, their use is not recommended after the end of the warm summer months.

#### 2.2.3.3 Attract and Kill

The attract and kill (A&K) technique approaches the control of certain insects along the same lines as MD. The major difference is that, instead of disrupting mating temporarily, the males are killed and thus permanently removed from the orchard environment.

The A&K product Last Call FCM, is registered for FCM control. The product consists of synthetic pheromone and a pyrethroid incorporated into a transparent gel like base material. Three to four applications of up to 3000 droplets of the product per hectare per application are applied by hand with a special applicator.

As with MD, A&K should be used against low levels of FCM activity. Use of Last Call FCM should therefore be initiated early in season while FCM activity is still low or as a follow up to the application of another product, which has successfully

suppressed FCM levels. Reapplication is necessary every 4 weeks. Similarly to MD, the efficacy of A&K is likely to decline during the cooler autumn months.

#### 2.2.3.4 Chitin synthesis inhibitors

Two chitin synthesis inhibitors (benzoyl urea group), Alsystin and Nomolt, are registered for FCM control. Both are ovicides that disrupt the embryonic development of larvae in the eggs. However, this occurs only when eggs are laid on the treatment residue. Thorough coverage of fruit with the products is therefore of the greatest importance.

Three different spray programmes involving Alsystin and Nomolt are possible. They are based on the length of time before harvest during which protection is required.

- *Eight weeks protection:* Apply either Alsystin at 10 ml/100 l water or Nomolt at 20 ml/100 l water, eight weeks before the expected harvest date.
- *Twelve weeks protection:* Apply either Alsystin at 20 ml/100 l water or Nomolt at 40 ml/100 l water, 12 weeks before the expected harvest date.
- *Sixteen weeks protection:* Apply double treatments of either Alsystin at 10 ml/100 l water or Nomolt at 20 ml/100 l water, 16 weeks and eight weeks before the expected harvest date.

A number of markets will not tolerate residues of one or both of these products on fruit. One should therefore familiarize one's self with these restrictions before use. Also note that FCM has developed tolerance to Alsystin and Nomolt where these products were used frequently in the past.

#### 2.2.3.5 Pyrethroids

Two pyrethroids are currently registered for FCM control, i.e. cypermethrin and Meothrin. Growers need to check for specific market tolerance to each of these. They are larvicides that kill FCM larvae by contact on the fruit surface. They are intended to be used to protect fruit against FCM infestation shortly before harvest. Pyrethroids are potentially toxic to a wide range of natural enemies and the necessity for their usage must first be very carefully considered.

A pyrethroid must be applied once only, four to five weeks before harvest. It must be applied thoroughly to ensure complete fruit coverage. To minimize the risk of pest repercussions the crop must be free from pests like red scale, mealybug and soft brown scale, at the time of application. To prevent pest repercussions on the following crop, pyrethroid usage against FCM in the late summer or autumn, must be followed by a comprehensive chemical control

programme during spring. Pyrethroids should be avoided if previously used for thrips control in the same season. This is for the purpose of thrips resistance management.

**2.2.3.6 Delegate**

The active ingredient of Delegate is spinetoram, a member of the group of spinosyns, thus related to spinosad. Delegate targets a nicotinic acetylcholine receptor, leading to a series of events which cause insect death. It is registered as a two-spray programme, 8 and 4 weeks before the projected start of harvesting.

**2.2.3.7 Coragen**

Coragen is a novel anthranilic diamide insecticide. It has a novel mode of action, in that it is a ryanodine receptor activator, which means that it prevents muscle contractions and causes death by paralysis. Although it does have some contact action, most of its activity is by ingestion. It is harmless against most beneficial insects and relatively safe to humans.

A single or double spray of Coragen can be applied any time from 16 weeks before harvest. Each spray should not exceed 8500 L per hectare.

**2.2.3.8 Methoxyfenozide**

There are now two products available with methoxyfenozide as the active ingredient, namely Runner and Walker. Methoxyfenozide is an ecdysone agonist, resulting in moulting acceleration, which means that like Alsystin and Nomolt, it is an insect growth regulator (IGR). It is effective against both eggs and larvae of FCM. However, like the other IGRs it is more effective when applied preventatively i.e. when eggs are laid on its freshly applied residue. After ingestion, larvae cease feeding within 4-8 hours, as they undergo an incomplete and developmentally lethal premature moult.

Runner is registered to be sprayed 8 and 4 weeks prior to harvest, and not more than twice per season, in order to manage against the development of resistance.

A summary of registered spray options for trees is tabulated below.

Product	Dosage/100 ℓ water
Cryptogran + molasses + wetter OR Cryptogran + mancozeb + spray oil	10 ml + 250 ml (or 225 g powdered) + registered volume 10 ml + 150/200 g + registered volume
Cryptex	3.3 ml
Gratham	3.3 ml
Delegate	20 g
Coragen	17.5 ml
Alsystin	10-20 ml
Nomolt	20-40 ml
Meothrin	30 ml
Cypermethrin	25 ml
Runner	60 ml
Walker	60 ml
Broadband	50 ml
Eco-Bb	600-1000 g/ha*

\*Dose rate given per ha. Would translate to approximately 10 g/100 L as a full cover spray.