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TECHNICAL BROCHURE

SIERRA LEONE

FALSE CODLING MOTH, *THAUMATOTIBIA LEUCOTRETA*

FOR THE COACHING SESSIONS FOR PEPPER GROWERS

COLEACP

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Thaumatotibia leucotreta (sometimes *Cryptophlebia leucotreta*) is commonly called False Codling Moth (FCM). Its caterpillars (larvae) attack more than 70 host plants, mainly in Africa. FCM primarily affects horticultural crops with fruit, pods and berries, such as beans, grapes, citrus, pepper, avocado, guava, pomegranate and ornamental plants. It also attacks macadamia, cotton, tea and a wide range of wild plants. However, it is particularly problematic on *Capsicum*, as female moths find the fruit attractive for egg-laying, leading to larvae being found inside the developing fruit.

In recent years, consignments of peppers from African, Caribbean and Pacific (ACP) countries to Europe have been intercepted due to the presence of FCM. The detection within a consignment of a single living individual of FCM at any stage of development leads to rejection of the whole consignment. This is because the European Commission (EC) includes FCM on its list of harmful organisms recommended for regulation as quarantine pests,[1] to prevent its introduction into Europe, where it could attack outdoor or glasshouse crops.

The European Union (EU) is also overhauling its plant health (phytosanitary) regulations. On 14th December 2019, a new plant health regulation (EU 2016/2031) came into operation, bringing rigorous new rules to prevent the introduction and spread of pests and diseases in the EU. This regulation takes a much more proactive approach, affecting both the European fruit and vegetable sector, and imports from third countries outside the EU.

Under the new regime, special measures have already been introduced for crops that are a known pathway into the EU for serious pests that could damage Europe's agriculture or environment. These measures include stringent new requirements covering the export of *Capsicum* to prevent the introduction of FCM and other pests.

The new rules stipulate certain conditions that exporting countries must meet before exports of *Capsicum* are allowed.[2] Meeting these new rules requires immediate and concerted action from producers, exporters and National Plant Protection Organisations. There is no room for complacency by any *Capsicum* exporting country. If there are any interceptions of these pests in exported *Capsicum*, the EU is expected to react and impose more stringent measures. The US authorities also consider that introduction of FCM could cause serious economic losses. This leaflet aims to help growers address the problem so that they can maintain access to European, US and other export markets.

1 See https://gd.eppo.int/taxon/ARGPLE for more information.
2 See the "COLEACP guidelines on the export of *Capsicum* from Africa, Madagascar, Cape Verde, and Mauritius" for more detailed information.

DESCRIPTION OF FALSE CODLING MOTH AND ITS LIFE CYCLE

 An adult moth, resting (7–10 mm long)	 Actual size	 The adult moth pinned (15–20 mm wingspan)	 Actual size
 The larva (caterpillar) can be up to 15 mm long and is pinkish with a brown head	 Actual size	 The pupa (5–7 mm long) can be found in the soil or in plant debris	 Actual size

Eggs are less than 1 mm long (difficult to see), oval and flattened, and laid singly or in small groups on the developing fruit. They are white at first, then turn reddish with a black spot before hatching after 4–8 days to small, whitish caterpillars (larvae) with dark brown heads. They move on the fruit for a short period before burrowing into it. A larva will eat other eggs it encounters, so there is usually only one larva in a fruit. The entry hole is small and difficult to see, but an infested fruit may have a small hole where the larva entered and frass (larval faeces) around the hole.

After 3–4 weeks, when the FCM larva has fed and grown, causing damage inside the fruit, the larva (now pinkish) leaves the fruit and drops on a fine thread to the soil, where it burrows in and pupates. Pupae or cocoons are 5–7 mm long, and may have soil and leaf debris on the outside to camouflage and protect them from predators. After 2–3 weeks in the soil, the adult moths emerge.

Adult moths are grey/brown, and tend to be active late in the day and during the night. They fly well, and females lay around 100 eggs in their lifetime. There can be six generations in one year. Each generation cycle takes 6–15 weeks, depending on temperature and food availability. Damage can increase in severity as the season progresses if there are plenty of host plants available.[3]

3 See the COLEACP technical document "Support to inspection and phytosanitary certification" for additional information.

AVOID CONFUSION WITH OTHER COMMON PESTS

Fruit fly

Fruit fly larvae (maggots) do not have a separate head

Adult fruit fly

Bollworm (*Helicoverpa armigera*)

Bollworm larvae are much larger; this one is feeding on a tomato fruit

Larvae vary in colour; this one is feeding on a flower

Adult bollworm moths are 12–20 mm long

MONITORING OF FALSE CODLING MOTH POPULATIONS

Surveillance is a major component of the integrated management of FCM.

- All production sites growing *Capsicum* for export should undertake monitoring on a daily basis using traps with pheromones specific to FCM. The national authorities should be able to specify the type of trap and attractant to use under local conditions (according to availability and effectiveness), as well as the frequency of collection. For example, adult numbers can be assessed using traps (Figures 1 and 2) baited with a pheromone mixture of (Z)-8-dodecen-ol acetate and (E)-8-dodecen-ol acetate at a ratio of 50:50 (Stibick, 2007). Products composed of a rubber lure containing these pheromones in combination with a sticky paper incorporated in a delta-trap will attract specifically male adult FCM moths.
- The authorities should agree with industry the thresholds of intervention. For example, the number of trapped FCM that will trigger a decision to spray or stop harvesting for export. As the level of tolerance to FCM in export *Capsicum* is zero, the sector should agree to take action as soon as the first male moth is caught.

Assessing the infestation level in growing fruit is difficult without opening and thus destroying the fruit. Frass (larval faeces) can sometimes be seen on the outside of fruit, indicating that there is a larva inside. Note that this could also be caused by bollworm or fruit fly rather than FCM (see above).

Infestation levels vary greatly from season to season, and it is important to know if adult moths are in the area so that preventive measures can be carried out and control can be prepared. Fallen fruit are particularly important in assessing populations of FCM within the crop. After opening fruit to check for larvae, they must be destroyed to prevent any larvae from pupating and emerging as adult moths. This can be done by burning or burying to a depth of 60–90 cm.

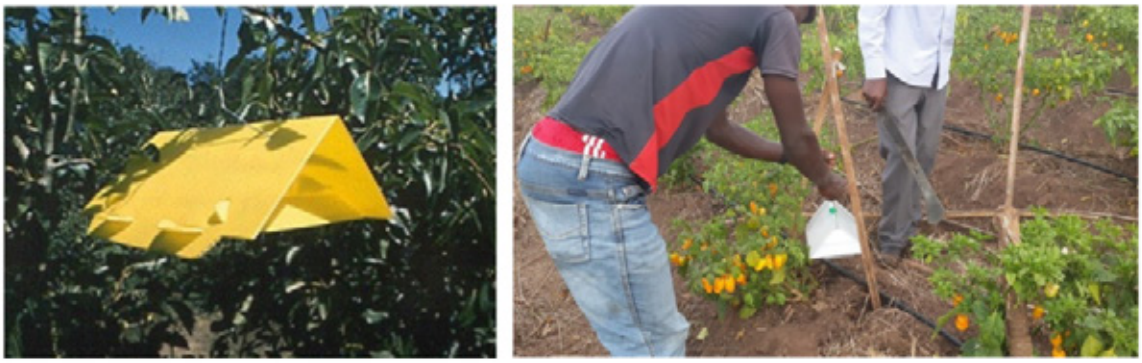

Figure 1: Examples of traps used to monitor FCM populations

Procedures to be followed by companies when there is an FCM Alert should be discussed and validated with the competent authorities.

Strict procedures should be maintained until the pest is under control and *Capsicum* crops are certified FCM free by the National Plant Protection Organisation (NPPO). For example:

- Quarantine all harvest from the infested site and initiate a product recall of fruit recently harvested in the vicinity;
- Implement an eradication programme;
- Apply cultural and chemical control;
- Adhere to bio-safety measures on the farm to eliminate pest transfer.

CONTROL MEASURES AGAINST FALSE CODLING MOTH ON PEPPER

Ensure all people involved are trained so that they are aware of and apply good practices to reduce the risk of FCM attack; this includes good practices for prevention, control, crop hygiene and traceability

Cultural control – Sanitation aims to destroy the pest to reduce the introduction and build-up of FCM over the season. If the life cycle can be broken by destroying fruit that are infested, particularly rejects or fruit that have fallen to the ground, there will be fewer adults laying eggs and fewer larvae affecting the current crop or later crops. Sanitation should be carried out at weekly intervals in nurseries, farms, gardens and other establishments

where hosts are present within the core and buffer areas. Depending on the circumstances and equipment available, use the following techniques before fruit are the size of marbles (Stibick, 2007).

- Remove infested fruit from cultivated and wild hosts.
- Remove all fallen fruit from the area, including fruit from nearby wild hosts.
- Remove all out-of-season fruit.

Exposing larvae to the air and sunlight will kill most of them, or allow them to be found and killed by predators. Infested fruit can be destroyed by putting them in plastic bags and exposing them to the sun, or by burning or burying them to a depth of 60–90 cm.

In addition to sanitation measures, other cultural control methods should be implemented to reduce FCM incidence, for example:

- Rotate FCM-susceptible crops with non-susceptible or low-risk crops (e.g. baby corn and green beans);
- Allow land to remain fallow in the dry season so that FCM is less likely to reach pest proportions;
- Plough before transplanting during the dry season;
- Keep land free of *Capsicum* plants and other susceptible crops for at least 4 months every year to break the FCM cycle and remove egg-laying sites for new generations;
- Produce *Capsicum* away from other host crops.

Physical control – Pests can be kept out of the crop (preventing moths from reaching plants) by use of a mesh or net barrier to protect the growing peppers, for example using a greenhouse or screenhouse such as those used by flower growers. This may only be economic for larger producers, due to the investment cost of such structures.

Biological control – Although there are living organisms that kill FCM (e.g. the egg parasitoid *Trichogrammatoidea cryptophlebiae*), there are currently very limited options for utilising them to control the pest. However, there are some biological pesticides that show good efficacy (see Table 1).

Chemical control – Currently the main option to control FCM is the use of pesticide sprays (when adult moths are present during fruit development), which means that care must be taken to avoid the presence of excessive residues at harvest time, that is, levels that exceed the maximum residue level (MRL). Like the presence of FCM in a consignment, MRL violations can also cause rejection of a consignment by the importing country.

False Codling Moth is one of the more demanding pests to control with insecticides for the following reasons.

- FCM attacks a wide range of crops and wild plants so there are many sources of infestation other than peppers.
- Eggs are difficult to detect as they are very small.
- Larvae are difficult to reach with sprays after they enter the pepper fruit, which they do soon after hatching.
- The crop is harvested regularly, so any pesticide must have a short pre-harvest interval to avoid residue issues.
- The import market in Europe is sensitive to the presence of even a single individual, which can cause a whole consignment to be rejected.

For FCM, chemical control is directed at the larvae. The principle is to apply an insecticide to the surface of the fruit so that larvae are killed by contact with the insecticide when they hatch, or by eating the dosed tissue as they burrow in.

Spraying is unlikely to have a significant impact on the adult moth population.

WHICH INSECTICIDES REGISTERED IN SIERRA LEONE CAN BE USED AGAINST FALSE CODLING MOTH?

The national authorities should provide guidance on which products to use, and how to use them (including application method, dose rate, pre-harvest interval). These must be in accordance with the registration status in the country of origin, and the maximum residue level (MRL) of the active ingredient in the EU.

Plant protection products currently registered for use in Sierra Leone and commercially available in the country for the control of FCM are presented in Table 1. The active ingredients of these products are also listed in Annex I to Regulation (EC) No 1107/2009.

Pesticide approvals are regularly changed, so their current status should be checked before any application. The conditions on pesticide product labels and Extension of Authorisation for Minor Use (EAMU) must be read and followed and their impact on any biological control agents should be considered.

Table 1: Plant protection products known to be effective against False Codling Moth and currently registered in Sierra Leone (2020)

Recommended active ingredients to control FCM[1]	**Category**	**Status under Reg. (EC) No 1107/2009**	**EU MRL for Capsicum [mg/kg]**
Maltodextrin	Biopesticides	Approved	No MRL required
Bacillus thuringiensis var. *Kurstaki*	Biopesticides	Approved[2]	0.01[2]
Beauveria bassiana strain GHA	Biopesticides	Approved[2]	No MRL required[2]
Spinosad	Biopesticides	Approved	2
Azadirachtin	Biopesticides	Approved	1

1 - Source: Sierra Leone approved list of pesticides (2019 version).

2 - Default MRL of 0.01 mg/kg according to Art 18(1)(b) Reg 396 / 2005. However to the best of our knowledge and considering that *Bacillus thuringiensis* is a microorganism, this value was set by default and no analytical method exist for residue quantification. Note that status and MRL requirements may vary depending on the strain of the organism. For this plant protection product please consult the EU Pesticides Database prior use (https://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/public/?event=homepage&language=EN).

To comply with EU MRLs for fresh peppers (Regulation (EC) No 396/2005), users should follow the Good Agricultural Practices (GAPs) provided by the manufacturer or based on relevant residue trials (e.g. data on dose rate, applications and pre-harvest interval). In general, this information can be found on the product label.[4]

COLEACP's E-GAP database is an online service for members and beneficiaries, which compiles GAPs for a variety of crop–active substance combinations using data available from manufacturers, the scientific literature, and COLEACP's trials.[5] The database contains information on GAPs that ensure compliance with current EU and Codex Alimentarius MRLs. Additional information includes the type of pesticide, the status of an active substance in the EU, the World Health Organization (WHO) recommended classification by hazard, and the resistance group. The E-GAP database can be accessed at https://eservices.coleacp.org/en/vue-substance-active-culture.

The larvae of FCM bore into the fruit after a short period of time. This means that in order for an insecticide to be effective against these larvae, the timing of application must be accurate, or the period of residual efficacy must be satisfactorily prolonged.

Maltodextrin is a compound made from decomposed potato starch. It blocks the insect's respiratory orifices causing asphyxiation. The effect observed 2 to 4 hours after application is improved by repeated applications. Although maltodextrin is a naturally formed polysaccharide, a high risk to non-target arthropods which come into direct contact with the product cannot be excluded. It was argued that due to drying and likely degradation between applications, only a short-term (physical) effect is expected and recovery might occur within an ecologically relevant period (EFSA, 2013).

Bacillus thuringiensis (Bt) can be used in integrated crop management to avoid side-effects of insecticide treatments on natural enemies. It has been shown to be effective against FCM (Li Bouwer, 2012) and is widely used in Africa against most lepidopteran pests. It is applied as a full-coverage spray when larvae are present and can be repeated at 10-14 day intervals while larvae are active.

Beauveria bassiana strain GHA is used as a pesticide for controlling many kinds of insects. This fungus controls insects by growing on them, secreting enzymes that weaken their outer coat, and then getting inside the insect and continuing to grow, eventually killing the infected pest. The product is sprayed on growing plants using hand, ground or aerial equipment; it can also be applied through irrigation systems on large agricultural fields. The fungus is not toxic to mammals, birds or plants. There is a potential for the pesticide to harm bees, so the products must not be applied near beehives or where bees are actively hunting for food. If the pesticide products are used as labelled, no harmful environmental effects are expected.

Spinosad is an active ingredient obtained from a bacterium naturally present in the soil. It is active by both contact and ingestion in numerous insect species, killing them by hyperexcitation of their nervous system. Spinosad is generally avoided because it might disrupt biological control.

4 COLEACP highlights the importance of following the label but accepts no responsibility for any efficacy or residue problems that may result.

5 Before application of any plant protection product, it is advisable to check the latest regulatory changes in the EU Pesticides Database (https://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/public/?event=homepage&language=EN).

Azadirachtin is a secondary metabolite present in neem seeds. It is now known to affect over 200 species of insects, by acting mainly as an antifeedant and growth disruptor. Azadirachtin must be ingested to be effective. Insects that feed on plant tissue are primarily affected, while those that feed on nectar or other insects rarely contact significant concentrations of neem products. For this reason, azadirachtin is relatively harmless to spiders, butterflies, bees, ladybugs, and wasps

FUTURE POSSIBILITIES: PRODUCTS THAT COULD BE EFFECTIVE BUT ARE NOT YET AVAILABLE IN SIERRA LEONE

While the active ingredients currently recommended and used for the control of FCM on *Capsicum* in Sierra Leone are known to be effective, other substances with alternative modes of action such as chlorantraniliprole, spinetoram, and methoxyfenozide are registered for use to control FCM in other countries.

Chlorantraniliprole, a novel anthranilic diamide insecticide, is said to be effective against FCM as an insecticidal spray. It is a ryanodine receptor activator, which means that it prevents muscle contractions and causes death by paralysis (Moore, 2017). It was approved in the EU in March 2013 (in accordance with Article 6(2) of Council Directive 91/414/EEC Ireland). Trials conducted by COLEACP with a product containing this active substance successfully controlled FCM on avocado in Kenya.

Spinetoram (an insecticide derived from microorganisms) and methoxyfenozide (an insect hormone mimic) were both found to be effective in COLEACP/PIP trials against FCM on avocado.

An alternative product containing a granulovirus was effective to control the FCM in COLEACP/PIP trials on avocado. Similar products are already registered in South Africa on peppers, grapes, avocadoes, citrus and other crops (Moore, 2017; Moore & Hattingh, 2012)

A product based on the entomopathogenic nematode *Heterorhabditis bacteriophora* is currently registered in South Africa (Moore, 2017) to control FCM larvae and pupae in the soil.

In South Africa, a 'lure, disperse and kill' (LDK) technique has been used experimentally, in which pheromone traps are laced with a fungal pathogen called *Metarhizium*. Moths are attracted to the trap by the odour. In the trap they pick up spores of the fungus, which kills the moths after they leave the trap. If an infected moth mates before dying, the lethal fungus is spread to the other moth which also dies (Moore, 2017; Potting & Straten, 2010).

Mating disruption products like Isomate have also been developed against FCM. Isomate is a biocontrol product, a Straight Chain Lepidopteran Pheromone (SCLP). Diffusers are placed in the trees at the beginning of the season and release a pheromone mixture which saturates the atmosphere of the field on a regular basis. The pheromone trace emitted by the female can no longer be identified and followed by the male. Mating and reproduction cannot occur, and the pest cycle is thus broken before its harmful stage.

The sterile insect technique (SIT), based on the mass production and release of sterilised moths that compete with the wild target population, has been tested in South Africa. Over 3 years, the status of FCM as a pest threat was systematically reduced in the sterile insect release area compared to the non-release area. This method offers area-wide but expensive control of insect pests (Hofmeyr *et al.*, 2015).

WORKING TOGETHER: STAKEHOLDER ENGAGEMENT AND NATIONAL ACTION PLANS

The risk for exporters is that continued presence of FCM larvae in exported peppers could threaten access to the European market. If further shipments are found to contain the pest, it is possible that imports of peppers might be disallowed. This means that growers, exporters and Ministry officials, such as inspectors and phytosanitary experts, must act together to protect the industry. Companies and growers must also work together, in particular by informing each other about FCM numbers. If adult moths are discovered in the field/traps, or larvae are found in fruit, this information must be shared with other growers. It is important to remember that if only one exporter sends infested consignments to the EU, it could bring down the entire export sector.

Along the supply chain, a series of protective measures and checks should be put in place to ensure FCM is not present in exported produce. These cover six stages.

1. Farmers growing peppers for export should be registered by their NPPO.
2. Growers should monitor their fields for FCM and, when necessary, treatments should be applied. Growers must keep records of all monitoring and control operations, including: date, reason for applying pesticides, product applied, rate used, and preharvest interval. These records can be inspected by their NPPO.
3. Peppers should be inspected before they leave the farm. If even a single fruit with a larva is found, sale to an exporter should be stopped.
4. During transport to the pack house, batches from individual farms/plots must be labelled and kept separate.
5. In the pack house, each individual batch of peppers must be examined. Batches must be kept separate until they have been inspected and found to be clean, and only then can they be packed for shipment. The presence of even a single larva in a batch means that the batch must not be exported.
6. At the airport, phytosanitary inspectors must carry out official inspections. They should issue a phytosanitary certificate only if there is zero presence of larvae, insect frass, or signs of infestation on the peppers. Each inspection involves a thorough visual examination of the consignment, and destructive dissection of approximately one fruit in every 100. Small samples should have at least five peppers cut open for assessment.

Experience has shown that meeting the new EU rules requires effective dialogue and engagement between public and private sectors. All stakeholders must agree on the actions needed to ensure that exported *Capsicum* is free of the designated pests. This means identifying and agreeing on actions to be taken by private sector operators at all stages, from production to export. It also means agreeing to the responsibilities of the public sector authorities, in particular the National Plant Protection Organisation (NPPO).

COLEACP recommends the establishment of committees or task forces that bring all major stakeholders around the table to develop (and oversee the implementation of) a national *Capsicum* action plan. To be effective, this national action plan must be appropriate to the local context, and usable by the range of different producers and exporters concerned (large and small). It is essential that all stakeholders (growers, export companies and airport inspectors) agree to and implement the national action plan. Evidence of this good practice will need to be demonstrated to the European Food and Veterinary Office (FVO) if an inspection visit is conducted in an exporting country.

COLEACP RESOURCES ON FALSE CODLING MOTH

- COLEACP guidelines on the export of "*Capsicum* from Africa, Madagascar, Cape Verde, and Mauritius"
- Managing False Codling Moth for packhouse staff and managers
- Support to inspection and phytosanitary certification

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