

An IPM guide for Enset root mealybug (*Cataenococcus ensete*) in Enset production

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Preface

Enset, *Ensete ventricosum* cultivation has existed for several hundred years as a sustainable form of agriculture in Ethiopia (Brandt *et al.* 1997) (Figure 1). More than 20% of Ethiopia's population depends upon Enset (a close relative of the banana) for human food, fibre, animal forage, construction materials and medicines. It was initially domesticated not for its fruit but for the leaf stalks and underground corm. However, the sustainability of Enset-based agriculture is threatened by a number of factors. The main biotic stresses are bacterial wilt, the Enset root mealybug, nematodes, fungi and other vertebrate pests like mole-rats (Addis *et al.* 2006).

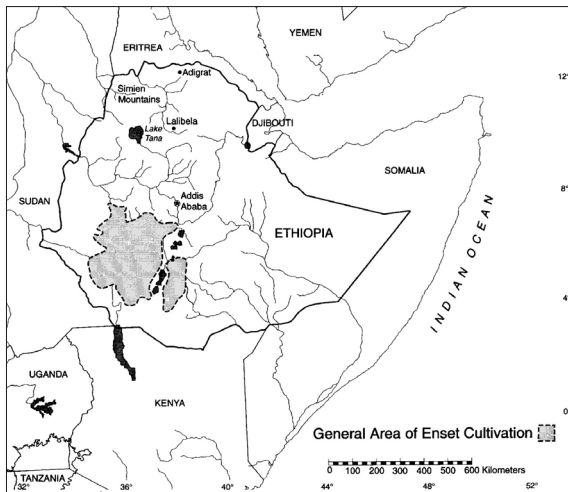


Figure 1. The distribution of domesticated Enset.

Enset root mealybug, *Cataenococcus ensete* is a major pest of Enset in Enset growing areas of southern Ethiopia. It has been reported from Wonago as a new record for Ethiopia (Tsedeke 1988). The insect is known to attack Enset in Gedeo, Sidama, Gurage, Kembata Tembaro, Hadyia, Keffa and Bench zones and Amaro and Yem districts (Addis *et al.* 2008a).

This guide has been produced as an overview of a body of work that aims to help mitigate the threat of Enset mealybug. Part one covers the biology and description of Enset mealybug; part two describes its behaviour; part three articulates its geographical distribution; part four describes pest symptoms; part five lists mealybug dispersal methods, and finally part six covers the means of mealybug management, including *prevention* (clean planting material, extension, affordable management, quarantine, hygiene and ant control), *cultural control* (farmyard manure, hot water treatment,

cultivation), *biological control*, *use of insecticidal plant extracts* (botanicals), and *agrochemical control*.

The pest attacks Enset plants at any age, with infestations being most serious on 2 to 4 year-old plants (Anonymous 2001). Mealybug-infested Enset plants exhibit retarded growth, loss of vigour, dried lateral leaves but green central shoot and eventually plant death (Addis 2005). Empirical data on Enset yield loss as a result of mealybug attack are scanty. According to Addis (2005), more than 30% of the sampled Enset farms were infested with Enset root mealybugs.

Generally, mealybugs are difficult to control with insecticides due to their cryptic nature, waxy-coat and life-style of forming dense colonies of multiple and overlapping generations (Blumberg and Van Driesche 2001). Also chemical insecticides are often too costly for farmers, particularly in developing countries. These reasons, together with the demand for contaminant-free food had fostered the search for alternative methods of control (Ekesi *et al.* 1998).

Enset root mealybugs are mainly distributed to new regions and farms through infested planting materials. Production of mealybug-free planting materials is the key control measure used to manage Enset root mealybugs. Enset growers usually produce Enset suckers for planting for their own use, exchange with others, or sale of suckers in the markets (Bizuyeyu 2002). Enset corms used for production of new suckers may be invariably infested with soil pests particularly with Enset root mealybugs. Transplanting the contaminated planting materials facilitates their spread.

A number of techniques have been developed to decontaminate infested planting materials from pests and pathogens (Speijer 1999), with hot water treatment seeming amongst the most successful (Tenkouano *et al.* 2006).

1. Biology and description

Root mealybug is a generic term for a number of *Pseudococcidae* feeding on underground plant parts. Enset root mealybugs have an elongate-oval body covered with wax secretions on the dorsal and lateral sides. The wax secretions give the appearance of cottony, spine-like projections. While these waxy secretions are not part of the mealybugs' body, they are lost with each moult.

Different development stages of Enset root mealybugs are recognized:

1. Bright-orange to yellow-orange coloured “crawlers” or rapidly moving first instars, that are creamy white but barely visible, being 0.5 to 2.7 mm long. They greatly resemble the adults but are significantly smaller. Average duration of the first, second and third instars nymphs are 16.2 ± 0.5 , 18.2 ± 0.7 and 19.8 ± 0.4 days, respectively.



Plate 1. Adult enset root mealybugs.

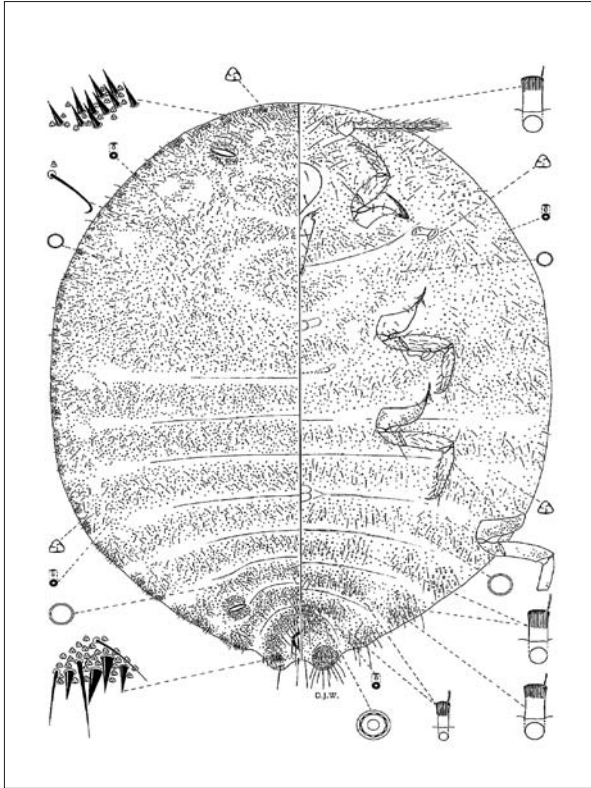


Figure 2. Adult enset root mealybug (adapted from Williams and Matile-Ferrero, 1999)

2. Second and third instars mealybugs begin to develop distinct lateral and caudal spines, increase in body size, and start to produce large amount of honeydew excretion (Addis 2005; Addis *et al.* 2008a).

3. Adult female mealybugs have an elongate-oval body covered with wax secretions on the dorsal and lateral sides (Figure 2 and Plate 1). Adult females show pronounced cross wise grooves running down their body and give birth to live young ones on a shallow pile of waxy secretions. Each female mealybug produces 156 to 383 nymphs in its life time. The adult life of a mealybug is 50.0 ± 0.5 days. The total life span of mealybugs is 94-113 days. The body size of adult mealybugs ranges from 2.8 to 4.0 mm in length and 2.85 to 3.70 mm in width.

2. Density and distribution on roots and corm

The majority of the mealybugs inhabited the roots (79%), while 21% was found on the corms (Addis *et al.* 2008b). The root density of Enset, as well as mealybug populations decreased with increasing soil depth. About 99% of the mealybugs were found in the upper 40 cm soil layer (Figure 3A). Similarly, about 90% of the mealybugs were collected within a 60 cm radius from the plants and about 63% from the corm and on the roots within a 20 cm radius from the corm (Figure 3B). Hence, sampling a 20 x 20 x 20 cm³ of soil and roots adjacent to the corm will capture a large proportion of the total root mealybug population on a plant. In addition, several plants should be uprooted to assess population densities on the corm surface especially during the dry season when mealybugs move to the corm surface due to root drying and a reduction in new root growth.

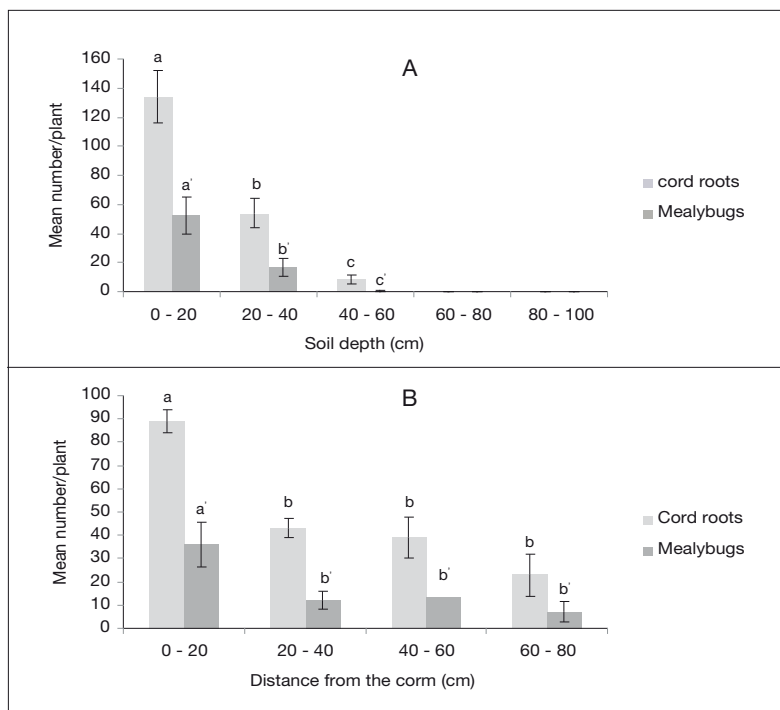


Figure 3. (A) vertical and (B) horizontal distribution of enset cord roots and enset root mealybugs.

3. Geographical distribution

Field surveys conducted on peasant farms (Figure 4) showed that more than 30% of the sampled farms were infested with Enset root mealybugs. Mealybugs were recorded in Sidama, Gedeo, Gurage, Bench, Kembata Tembaro, Keffa, and Hadyia zones and Amaro and Yem districts (Figure 4). In Sidama, Gedeo, Amaro and Bench respectively 62, 67, 100 and 57% of sites visited were infested by the root mealybugs. The Enset root mealybug infestation was found to be most serious at an elevation between 1400 to 2200 masl. The highest level of Enset root mealybug infestation was recorded at an elevation between 1600-1800 masl. Enset root mealybugs were not recorded at altitudes greater than 2600 masl and below 1400 masl (Addis 2005).

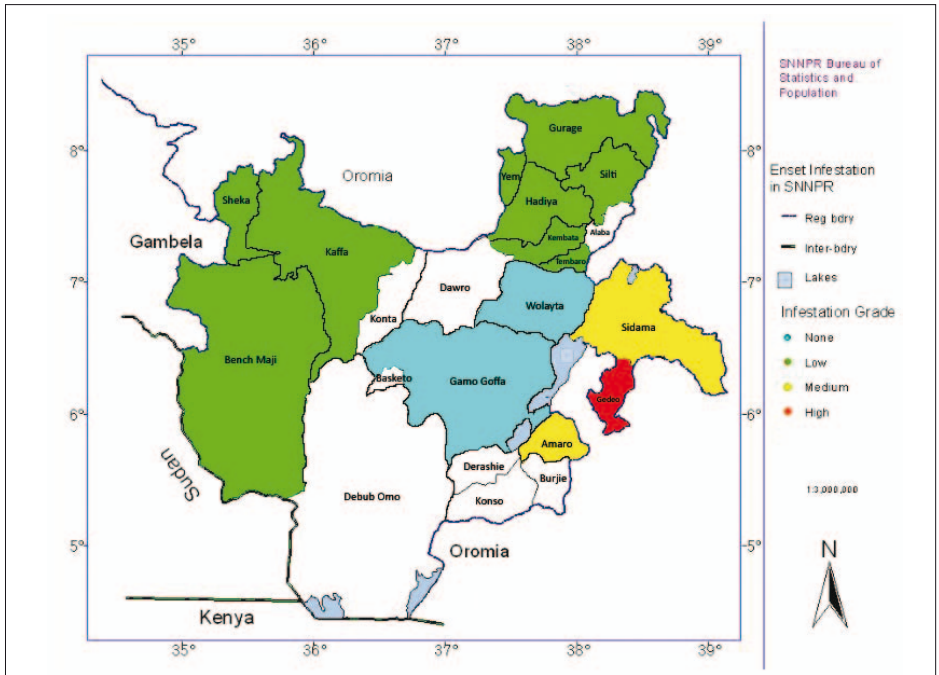


Figure 4. Surveyed areas, Enset root mealybug distribution and degree of infestation in southern Ethiopia.

4. Damage symptoms

Enset root mealybugs were found exclusively on the roots and corm of Enset (Plates 2 and 3). Damage by Enset root mealybugs was non specific, including common symptoms of slow plant growth, lack of vigour and subsequent death, especially under moisture-stress. Infested plants displayed retarded growth where most lateral leaves were desiccated, but with a green central shoot. All roots were found to be vulnerable to mealybugs attack. It was observed that Enset plants attacked by root mealybugs have a significantly lower number of roots as compared to healthy plants. In addition, mealybug-damaged Enset plants were more easily uprooted.



Plate 2. Enset corm severely infested with root mealybugs.



Plate 3. Enset roots severely infested with root mealybugs.



Plate 4. Young Enset plants are very susceptible to root mealybugs.

5. Means of dispersal

Enset mealybugs are dispersed by a number of different biological and physical means.

5.1 Nymph 'crawlers'

Crawling first instar nymphs can play a key role in dispersal over the host plant, and can be responsible for spreading the mealybug population to new host plants. Occasionally, these crawlers are observed on the lower part of the pseudostem just above the soil.

5.2 Water

Mealybugs can also be dispersed by water, when flooding occurs.

5.3 Infested corms

The main dispersal route is via the distribution of Enset suckers from infested corms, especially in nursery sites established below 2000 masl where there is an environment conducive to mealybug reproduction (see section 3 on geographical distribution). Planting material is commonly exchanged between farmers without discrimination of infested suckers, and subsequent transplanting of infested plants leads to further dispersal (Plates 2, 3 and 5).

Out of the 163 farms surveyed in southern Ethiopia, more than 30% were found infested with root mealybugs (Addis 2005). According to Addis (2005) most of the Enset farmers (79%) produce their own suckers for planting. It



Plate 5. Enset plants of different ages - plants are regularly replanted and this enhances the spread of mealybugs.

was observed that it is not uncommon to purchase Enset seedlings from local markets. About 20% of the farmers purchased suckers from local suppliers because they believe that suckers raised on their own farms would not perform well. Few farmers (1.2%) got suckers freely from government nursery sites. In areas where there was frequent exchange of planting materials among farmers like in Amaro, Gedeo, Sidama and Bench, there was a high level of infestation by *C. ensete* (100%, 67%, 62% and 57%, respectively). In contrast, in Hadyia, Gurage, Kembata Tembaro, Keffa and Yem where there was limited exchange of planting materials and farmers depend on self raised seedlings, the infestation was relatively low (17%, 8%, 25%, 29% and 17% respectively). This study thus showed that exchange of planting materials -in the absence of proper local quarantine services- is an important means for spreading mealybugs to new farms and villages

It was observed that some of the Enset nurseries found in southern Ethiopia (Yirgachefe and Wonago districts) were highly infested by mealybugs. It has been reported that some development organizations have been procuring suckers from these nursery sites and maintenance fields in order to distribute them to different areas of the country where farmers are trying to adopt Enset production. Thus, the use of infested suckers from such centres has facilitated the distribution and spread of the insect to non-infested and new Enset production areas.

The establishment of a quarantine/planting-material certification scheme could help address this problem (see section 6.1 below on prevention).

5.4 Ants

Ants' activities have also been implicated in mealybug dispersal. The literature documents many examples of the symbiotic relationship between ants and mealybugs, in which the ants protect the mealybugs to harvest their honeydew. Even though the species of ants that are closely associated with Enset root mealybugs are not yet identified, they were observed in association with the mealybug infestation in all places. It is known that ants play a role in the protection and dispersal of root mealybugs. Malsch *et al.* (2001) mentioned that when the mealybugs are disturbed at the time of cultivation, weeding, transplanting and harvesting, their attendant ants carry and take them to new plants or root parts. Even though dispersal of mealybugs by ants is a short distance, ants help

them to find hidden places in the roots and corm, which are very difficult to reach even with insecticides. Before this was commonly known, farmers and others would sometimes attribute crop wilt to the presence of ants, rather than the protection they afforded to the much less obvious mealybugs. In this case, controlling the ants can also reduce levels of mealybug infestation and consequent wilt (Jahn *et al.* 2003).

5.5 Cultivation and transplanting

Finally, mealybugs can also be transported by machinery, tools, equipment and soil movement during cultivation and repeated transplanting operations conducted at different times. Thus, appropriate hygiene measures applied to these items may also be an effective way of reducing dispersal.

An Enset plant may be transplanted two to five times before it is finally harvested. During transplanting, farmers pull out and replant all transplants including infested ones. It appears that little or no advisory services are provided by the extension agents to mitigate the distribution of the mealybugs.

6. Management of Enset root mealybugs

6.1 Prevention

Clean planting material

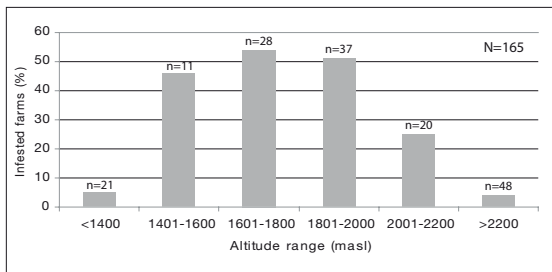


Figure 5. Effect of altitude on Enset mealybug infestation.

The first resort for mealybug control is the use/production of clean planting material. In a study by Addis *et al.* (2008b) *C. ensete* infestation was severe only between 1400 and 2200 masl (Figure 5). So material from altitudes outside this range may offer potential for a mealybug-free source of planting

material, especially if the production in these areas deploys an integrated approach to further minimise infestation risk.

Extension

Farmers’ awareness of the Enset root mealybug damage symptoms, and of management and control options is the key to a successful eradication of this important pest. Farmers also need training in clean Enset seedling/planting material production. Therefore, extension programmes on Enset management and control strategies should be strengthened so that large numbers of farmers can control the insects in established plantations, establish new Enset fields with clean planting materials and stop the distribution of this pest to new Enset production areas.

Quarantine

Quarantine measures could be designed to prevent further spread of the insect to different parts of the region. If practical, a clean sucker certification scheme could be developed, in which farmers who produce planting materials would be monitored. Areas and localities with a high incidence and severity of the insect should be delineated and a concerted effort should be made to stop the distri-

bution of infested seedlings/planting materials to neighbouring areas. Farmers should get support to eradicate infested Enset plants/plots and to start new plantations using clean seedlings/transplants.

Hygiene

Preparatory hygiene measures might also include exploiting the fact that adult female mealybugs are unable to survive for more than three weeks in the soil without any plant material/food supply. Therefore, crop rotation (during one or two cropping seasons) and/or removal of grasses and weeds in Enset fields will also help to control this pest. Infested Enset plants need to be properly disposed of so that all the plant debris decays and no re-growth occurs.

Ant control

Removal of ant vectors has also proven successful in reducing mealybug infestation levels in some other crops (see section 5).

6.2. Cultural control

Use of farmyard manure

Farm yard manure contributes to better plant performance through improved crop nutrition (mostly nitrogen (N), but also possibly potassium (K), and even sulphur (S)). More robust plants are better able to ward off pests and diseases. Hence, the application of farm yard manure could enhance Enset plant growth and make the plant more resistant to Enset root mealybug attack. In addition, the manure could directly inhibit mealybug development. Farm yard manure can also improve the soil and root health conditions.

A preliminary study carried out by the Awassa Agricultural Research Centre assessed the effect of different rates (0, 5, 10, 15 and 20 kg/plant per year) of farmyard manure on the performance of Enset in Enset root mealybug infested fields. Plants which had received 20 kg/plant per year had visibly lower Enset root mealybug numbers. In addition, these plants grew better and had less damage signs (Anonymous 2002). Farm yard manure should be applied when available in Enset cultivation, to enhance

plant growth but also as an IPM method in the control of the Enset root mealybug.

Hot water treatment

Hot water treatments completely eliminated banana aphids, cotton aphids, mealybugs' nymphs and ants (Hara *et al.* 2001). Enset plants can be disinfested from Enset root mealybugs by using hot water. However, immersion of the seedlings in boiling water for 10 to 30 seconds prior to planting will most easily be adopted by farmers (Lemawork 2008).

Cultivation

Adult mealybugs are unable to survive for more than three weeks in the absence of any plant material (Addis 2005; Addis *et al.* 2008b) (Figure 6). While transplanting, planting pits should be left open for about a month so that any mealybug present in or in the vicinity of the planting hole will die of starvation. Repeated ploughing and removal of weeds and grasses in Enset field is believed to eradicate the Enset root mealybug (Tadesse *et al.* 2003).

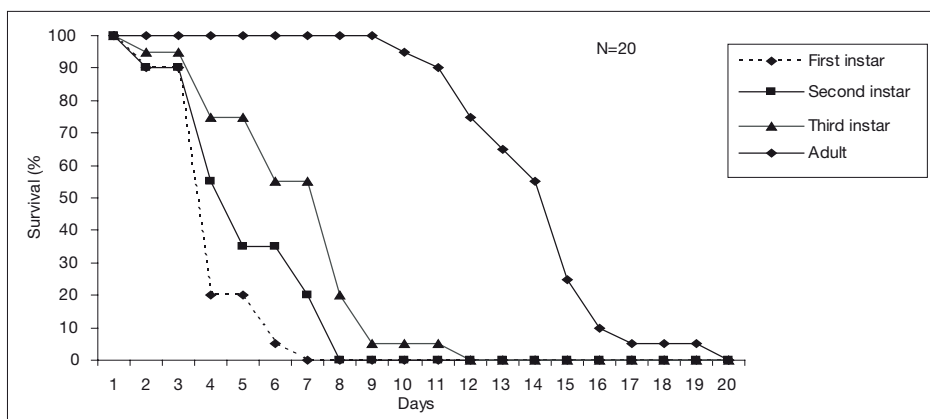


Figure 6. Effect of food deprivation on the survival of the different stages of *Cataenococcus ensete* in the soil.

6.3. Biological control

Some species of hyphomycete fungi have demonstrated insecticidal activity against a broad range of insect pests and are the main contenders for commercial production and use against homopterous pest insects (Lacey *et al.* 2001). Lemawork (2008) examined the efficacy of two *Beauveria bassiana* and two *Metarhizium anisopliae* isolates in controlling Enset root mealybugs. Under field conditions, the entomopathogenic fungi, White Muscardine (*B. bassiana* PPRC-56) caused the highest levels of mortality. However, the maximum mortality rate was only 54%. The isolate Green Muscardine (*M. anisopliae* Mm) was found to be least effective in controlling mealybugs (Lemawork 2008). The study showed that entomopathogens have the potential to be used in the integrated pest management of Enset root mealybugs. However, there is a need to screen a larger number of isolates to identify potent entomopathogens.

6.4. Use of insecticidal plant extracts (Botanicals)

Different insecticidal seed/plant-extract treatments (*Millettia ferruginea*, *Azadirachta indica*, *Melia azedarach*, *Phytolaca dodecandra* and *Schinus molle*) have been assessed for their effectiveness in controlling Enset root mealybugs in the laboratory, in pot experiments and in farmers' fields. A seed-water suspension of 10% *M. ferruginea* was toxic to Enset root mealybugs. The dose-response bioassay of *M. ferruginea* was calculated to be $LD_{50} = 40.39 \text{ mg}/5\text{cm}^3$ of soil. With the pot experiment, drenching the soil (on which the infested young Enset plants were planted) with seed-water suspensions of 10% *M. ferruginea* caused higher levels of mortality (66%) compared to the other botanicals and the untreated plants ($P < 0.05$). On the other hand, double applications of *M. ferruginea* improved its efficacy to 79%. However, *M. ferruginea* was inferior to the synthetic organophosphorous insecticide Diazinon 60% EC in both pot and dipping experiments (99% mortality rate). Drenching a seed-water suspension of 10% *M. ferruginea* into the root-zone of infested Enset plants in the field was found to be effective against the Enset root mealybugs. *M. ferruginea* seed water suspension was found to be superior than the other botanicals in terms of causing mortality to Enset root mealybugs (Tadesse 2006). *Millettia* trees are abundant in the area and seeds can be collected and stored for long periods. The preparation is simple and requires few technical skills. Thus, combinations of dipping young Enset plants in *Millettia* solutions and drenching root-zones of infested Enset plants can be used for the management of the Enset root mealybugs.

6.5. Chemical control

Commercial, synthetic insecticides have proven too costly for many smallscale Enset growers. However, the application of Chlorpyrifos¹ 48% EC and Diazinon² 60% EC at a rate of 1.7 L of solution (after dilution of the insecticide in 1:5 L of water) per field-grown Enset plant and poured on the root collar area, resulted in high levels of root mealybug mortality (Tadesse 2006). More than 90% of the adult mealybugs were killed within 2 weeks of application. For both chemicals the mortality rate reached about 98% at 45 days after application of the chemicals. On the other hand, the application of Malathion, Dimethoate, Endosulfan and Fenitrothion caused mortality rates which were lower than Chlorpyrifos and Diazinon but were still significantly higher than the control treatment (Bekele 2001). Other insecticides used to control mealybugs include: bendiocarb (also a fungicide), bifenthrin, cyfluthrin, fenpropathrin, insecticidal soap and kinoprene (Lindquist 1987). It is suggested that insecticide application is done at the beginning of the dry season when mealybugs can really devastate the drought-stressed Enset plants.

6.6. Integration of management and control options and methods

The above mentioned management and control measures could be integrated for use by resource-poor smallscale Enset farmers in Ethiopia. Prevention is almost always more (cost-) effective than cure. Therefore incorporating the preventive measures of extension, hygiene and quarantine are essential in any integrated programme. Informed by findings such as those described in this guide, Enset nurseries should be established, perhaps at appropriate altitudes, for the production of clean seedlings/planting materials. Better hygiene measures, particularly at the nursery level, could be adopted, perhaps in conjunction with some form of quarantine and monitoring system. Boiling-water treatment should especially be included as a major disinfestation technique. Appropriate nutrition, perhaps using manure will also help in producing healthier, more robust plants.

For already infested Enset plants, insecticidal plant/seed extracts could be used instead of synthetic insecticides. In the future, the use of entomopathogenic fungi may also become a realistic option. However, such an integrated approach can only be effective where management techniques are designed to be locally accessible, appropriate and affordable.

¹ Both Chlorpyrifos and Diazinon have potential to bioaccumulate. They are toxic to freshwater and marine organisms, birds and honeybees, and considered hazardous to pollinators. (see: <http://www.abcbirds.org/abcbprograms/policy/pesticides/Profiles.html>)

² Ibid.

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