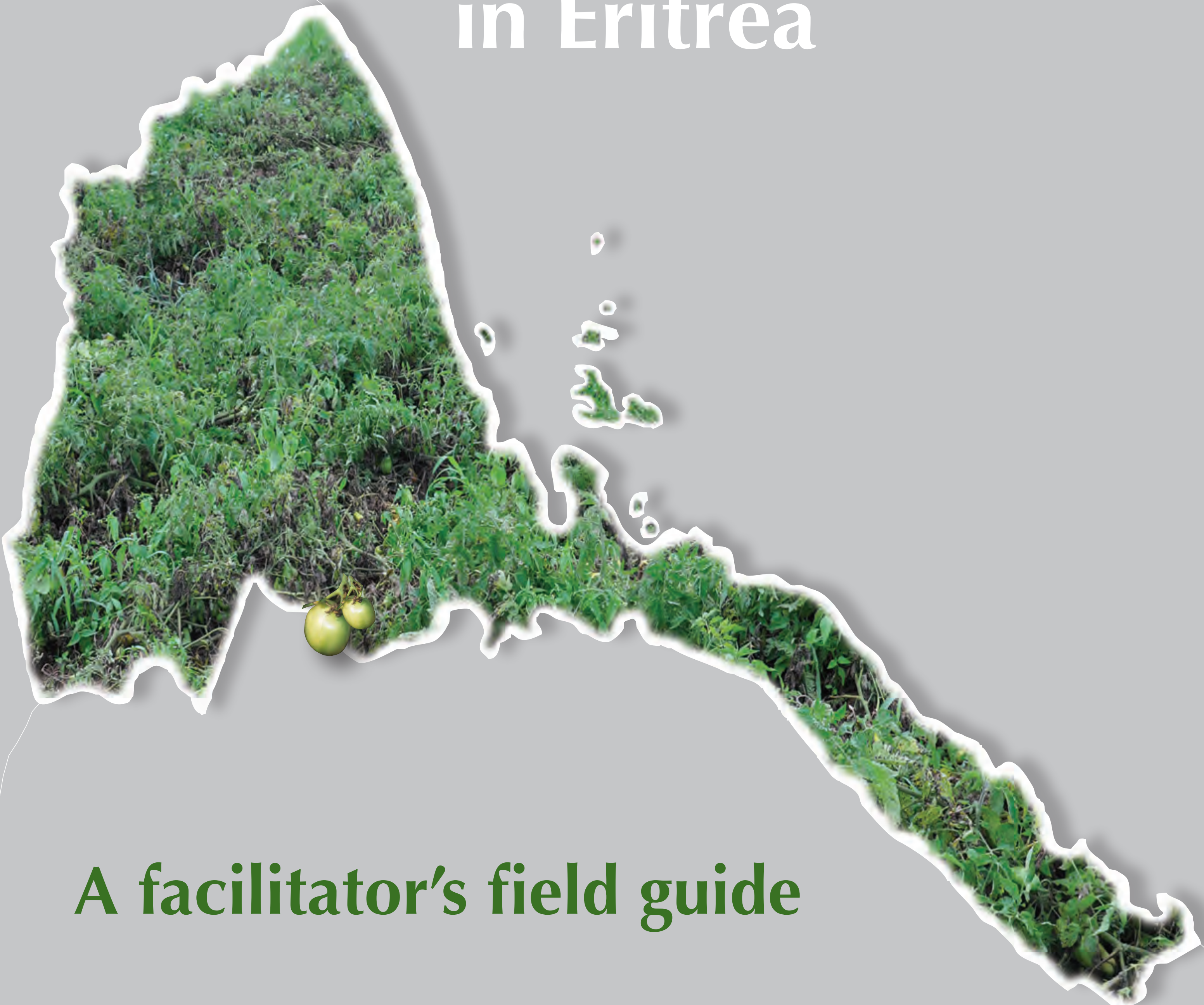
Food and Agriculture Organization
of the United Nations

Integrated Pest Management in tomato in Eritrea



A facilitator's field guide

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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Preface

The FAO/GEF Project "Prevention and Disposal of Persistent Organic Pollutants (POPs) and Obsolete Pesticides in Eritrea - Phase II" was designed to eliminate stockpiles of POPS and other obsolete pesticides in Eritrea, as well as to make sustainable improvements in pesticide management in order to reduce the threats that these chemicals pose to human health and the environment. Capacity building in Integrated Pest Management (IPM) was envisaged as an important component of it, with a view to rationalize pesticide use in the farming sector and lead to economic, environmental and health benefits. The Crop and Horticulture Development Plan for Eritrea (2005) states that the "production of fruits and vegetables in Eritrea is considered critical to supporting nutritional standards. Fruit and vegetables are very important because of the high levels of income and employment they create per hectare". On the other hand, the Agricultural Development Plan for Eritrea, 2008-2010, emphasized capacity building of farmers, advisory services and related academic institutions. The Project, of which the IPM/FFS (Farmers Field School) approach was part of, has put a major focus on capacity building in improved pests and pesticides management and on the strengthening of linkages from farmer level through to relevant advisory and research institutions and policy-makers. As a result, various IPM/FFS have been established in 5 regions in Eritrea.

This manual represents the attempt to condense the experience accumulated in those FFS, whose activities focused on tomato production. It is aimed at providing guidance for the Facilitators in the planning and implementation of future FFS activities, with a view to establishing a national FFS network implementing IPM approaches not only on tomato, but on a range of vegetables and other crops (e.g. citrus, cereals) prioritized in the different regions, in an effort to promote a safer use of chemical pesticides through promotion of IPM. The manual is a technical reference that gives background information and refers to practical exercises/activities that can be done in the field during the FFS, to help the trainees better understand the different topics. However, the exercises included in this manual should be seen only as suggestions and others may be proposed by the Facilitator, based on his/her appreciation of the farmers' needs.

This manual draws – sometimes heavily – on other existing guides, manuals and text books, which are detailed in the list of references and which the Facilitators can refer to in order to get additional ideas and to deepen their knowledge on specific subjects. It also makes practical references to existing pesticides and pesticide companies; please note that any such reference is only meant for educational purposes and does not constitute endorsement nor criticism.

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Last but not least, sincere appreciation is expressed to Nadia Pellicciotta for her professional editorial and graphic work during the final assembly of the manual.

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Acronyms and abbreviations

AESA	Agro ecosystem analysis
AI	Active ingredient
ETL	Economic threshold level
FFS	Farmers field school(s)
IPM	Integrated pest management
MoA	Mode of action
PPE	Personal protection equipment
RKN	Root knot nematode(s)

PART 1
Overview of farmer field schools

The Farmer Field School (FFS) approach was developed at the end of the 80's by FAO in South East Asia, as a way for small-scale rice farmers to investigate and learn for themselves the skills required for and the benefits to be obtained from adopting Integrated Pest Management (IPM) practices in their fields. Since that time, the FFS model has been adapted to various other crops, other countries and continents. There have been lots of variations to the model, but the process has maintained its basic features: learner-centered, participatory and relying on an experiential learning approach.

In a traditional research and extension system, researchers study specific topics and, at least in theory, deliver "answers" to the extension agencies which, in turn, have to pass on the information to the farmers. In this system, farmers are passive receivers of "packaged technology" which is not necessarily related – or does not cover in their entirety – their actual field problems. The FFS model links the expertise of various sources (farmers, researchers, extension agents, etc.) into one platform. In the FFS, all parties are equal partners in providing locally adapted crop management practices. Researchers and extensionists interact with farmers through the FFS and – compared to the traditional extension model – get a better understanding of their usually complex problems, which helps them to develop more integral solutions.

In a FFS, farmers are not just the passive receivers of technical knowledge, but they are provided with an opportunity to actively learn and achieve greater control over the conditions that they face every day in their fields. In other words, farmers are empowered by FFSs. In FFSs, farmers can master the ecological principles needed to implement IPM in their fields, become experts in IPM, and apply what they have learned to develop new initiatives and gain greater control over local conditions.

The basic educational concept of the FFS is drawn from adult non-formal education, which is a training method based on the assumptions of adult learning. Adults differ from children in the way they learn. Adults already have a lot of experience, knowledge and skills. They have their own beliefs, values, convictions, and their own perceptions, biases and feelings. This makes adult learners a very rich resource in the learning process, and that is why it is important that the learning is participatory, so that each learner can input his/her "resources" into the training. Farmers need opportunities to experiment with new (IPM) technologies, to learn how to evaluate different options systematically and to decide for themselves which ones are worthwhile. This realization can be found in the principles of adult education, which recognize that adults learn best from direct experience and when the topic they are studying is related to their everyday activities. Learning by doing adds to farmers' knowledge and experience, and improves their capacity as farm managers. Knowledge obtained this way is more easily internalized ("owned") and put into practice after the training is over. Passive exposure to more general extension messages is not as powerful as the discovery-based learning in FFS.

The basic elements of an FFS for IPM are the following:

- *It is participatory*. The activities of the FFS envisage the active involvement of a group of farmers (usually between 20 to 25), who interact with the facilitator and also with each other. In FFS everybody has the chance to participate and contribute to the activities being developed.

- *It is problem-oriented*. The topics to be discussed are selected by the farmers, based on local field problems. Not necessarily IPM is the only subject, as the FFS can often become the platform to discuss also other technical as well as non-technical subjects (e.g. issues related to the management of the community and communal resources).
- *It is practical*. The FFS is field-based and farmers participate in simple experiments, regular field observations and group analysis. The knowledge gained from these activities enables participants to make their own locally-specific decisions about crop management practices. This represents perhaps the most important difference with more formal training approaches, which expect farmers to adopt recommendations formulated by specialists from outside the community and therefore not necessarily responding to local problems. In the FFS, farmers conduct a study comparing good agricultural practice with common farmers' practice. In case of IPM, this means comparing a plot managed with an IPM strategy with another one managed with normal farmers' practice. Each meeting usually includes at least an agro-ecosystem analysis (AESA) activity conducted in the field, ending with a discussion of crop management decisions.
- *It is guided by a facilitator*, who offers experiential learning opportunities, rather than by a teacher/instructor delivering top-down instruction. There may be more than one facilitator, depending on the size of the group and the type of activities to be developed. The key non-formal education approaches used in the FFS learning include: sharing, case studies, role play (dramatized sessions), problem solving exercises, panel discussions, group dynamics, small group and large group discussion, brainstorming and simulation game. Non-formal education can already become apparent in details such as the setting of chairs for a meeting.
- *It is season long*. Farmers have regular group meetings, usually weekly, during the whole cropping season (from seeding to harvest and possibly post-harvest in annual crops, and from the first activities to harvest and possibly post-harvest in perennial crops). The frequency and timing of the meetings should be based on the critical periods of crop development, occurrence of pests and other problems, timing of cultural practices, etc. Meeting intervals may be longer in perennial crops. The FFS must be season-long for a number of reasons: i) Each stage of the crop has different pest problems; consequently, it is necessary to cover at least one entire season to observe all of them and their effects on the crop. ii) Each stage of the crop has different management requirements (irrigation, fertilization, mulching, weeding, thinning, pruning, etc.) and the results of management decisions made during one crop stage are observable only at a later crop stage, most often at harvest, in terms of yield and produce quality. As a matter of fact, in case of perennial crops the effects of management decisions may become apparent only in the following season. iii) Some processes that need to be observed (population dynamics of an insect, disease epidemics, possible plant compensation, etc.)

develop gradually over the course of the entire cropping season.

The FFS has several objectives:

1. It provides a means to develop IPM expertise among farmers in a farming community. This helps them to apply good crop management practices (informed seed selection, efficient fertilization, irrigation, reduction of pesticide use, etc.), possibly resulting in increased profit.
2. The FFS provides for development, validation and adaptation of IPM methods to local conditions, thereby leading to an evolution of farming practices that include IPM methods.
3. An FFS offers the opportunity to form farmer groups working together on many other farming related subjects, such as marketing.
4. An FFS can become a platform to initiate community action on a range of topics.
5. The FFS provides an opportunity to influence local and/or national policies. For IPM programs to be successful, policy support is essential. These include policies on pesticides (subsidies, bans on dangerous pesticides, etc.), support for research (ecological versus conventional/pesticide-based agriculture), support for advisory services to farmers, etc. When invited to an FFS, officials can see for themselves that farmer with IPM experience can reduce dependence on pesticides and maintain yields. This is as important as other objectives because it may lead to a change in local or national policies mistakenly supported by local officials convinced that pesticides are the only option to control pests.

Since many years, FFS have been the platform in many countries for educating farmers on IPM and an increasingly broader range of topics. When farmers have learned about basics, combined with their own experiences and needs, they make decisions that are more effective. When farmers have this basic knowledge they are better clients for extension and research systems because they have more specific questions and demands. They also are able to hold these systems accountable for their output and benefits.

PART 2

Overview of Integrated Pest Management (IPM)

What is IPM?

The concept of Integrated Pest Control was first articulated at the end of the 50s as an approach that applies ecological principles in utilizing biological and chemical control methods against insect pests. Subsequently, it was broadened to include all available control methods and all classes of pests (insects, plant pathogens, nematodes, weeds, vertebrate pests, etc.). The idea of "managing" insect pest populations was later advocated in preference to "control". The word "control" refers to solving pest problems after they occur, while managing the pest includes avoiding the problem. As a matter of fact, much of the emphasis of IPM is on preventing the development of pest problems. Besides, managing pests does not aim at their eradication but rather at maintaining pest populations at acceptable levels. A number of definitions for IPM have been coined over time. In the International Code of Conduct on pesticide management, which was adopted by the FAO and WHO in 2014 (FAO and WHO, 2014), the following definition of IPM is given: "Integrated Pest Management (IPM) means the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimize risks to human health and/or the environment. IPM emphasizes the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms". Therefore, as one can see, the focus is on trying and prevent the development of a pest problem and – only when necessary – use control measures that not only are the least dangerous for humans and the environment, but that are also cost-effective. IPM is not a centrally defined "packaged technology" that must be taught to farmers. IPM is an approach to pest management which is crop and location specific, based on local field ecology and socio-economic conditions.

Basic concepts of IPM

- The IPM philosophy recognizes that *there is no "cure-all" in pest control* and that – taken individually – any single method will have limited efficacy and/or some undesirable effects. For that reason, IPM utilizes all suitable pest management tools and tactics, including cultural, mechanical, biological, genetic (plant resistance), pesticides, etc.
- It also recognizes that *eradication of a pest is seldom necessary and generally not possible*. It accepts that some level of damage is unavoidable and generally acceptable; in other words, not necessarily pest presence = pest problem.
- The IPM approach *determines and corrects the cause of the problem*. Identifying the pest and understanding its biology becomes an essential component of the strategy, as it is the case with the manipulation of the environment in favor of the crop and to the detriment of the pest.
- IPM *uses control methods only when strictly necessary*. Therefore, when it comes to evaluating the need for a pesticide application, IPM uses a "wait-and-see" approach rather than "just-in-case".

An IPM strategy has five components. The first component, ***prevention***, means that all practices that can prevent a pest from infesting a crop, or limit its development, should be adopted. This includes an almost endless list of agronomical practices, such as adjusting the planting schedule, choosing fast-maturing varieties, adopting suitable crop rotations or intercropping, careful site selection, using resistant/tolerant cultivars, using healthy (possibly certified) seed, producing pest free transplants, practicing field and equipment sanitation, adopting suitable plant spacing/density, applying a balanced fertilization, preserving natural beneficial organisms, eliminating alternative wild hosts, etc.

The objective of ***monitoring*** is not only to observe the presence and identify the possible pests, but also to make a wider assessment of the conditions of the crop, e.g. stage of development, presence and type of beneficial organisms, possible nutritional deficiencies, etc. In case of insect pests, proper interpretation of the results from the monitoring requires an understanding of the pest and its life cycle. Where and when is it present? When is it most susceptible to control? When is too late to control? Monitoring can be done by direct visual assessment on the relevant plant parts, or – in the case of insects – with the aid of different types of traps (chromotropic, pheromone or light traps). In any case, record keeping must be an integral part of monitoring, as recording the type and number of pests over time represents the basis to decide whether any action is needed to control them. The frequency of monitoring will depend on the crop and on the vegetative stage of development.

Based on the information collected during the monitoring phase, the farmer will have to decide whether any control action is required. The Economic Threshold Level (ETL) used to be the main parameter used for ***decision-making*** in the past, but in a more recent interpretation of IPM it has often been replaced by the Agro-Ecological System Analysis (AESA), which is an analysis whereby farmers take decisions based on a larger range of observations. One of the limits of the ETL is that it is based on parameters that are changing all the time, and that are often not known to the farmer. An ETL is calculated from: i) the control cost (cost/area); ii) the price of the farm produce (cost/unit weight) and iii) the expected damage or yield loss (unit weight/area). However, the damage or loss caused by a certain density of insects is difficult to predict, if it can be predicted at all. It depends on many factors, such as crop variety, weather conditions, availability of water and nutrients, plant stage, etc. It also depends on the presence and performance of natural enemies. This is why ETLs that are often recommended in many manuals are difficult to apply in a small farmer's field. Farmers cannot base their decisions on just a simple count of pests. As mentioned, they will have to consider many other aspects, including their own economic and social situation, before they can make the right crop management decisions. Over time, IPM specialists have realized the limitations of ETLs and gradually developed the Agro-Ecosystem Analysis (AESA) as a more flexible tool to make crop management decisions.

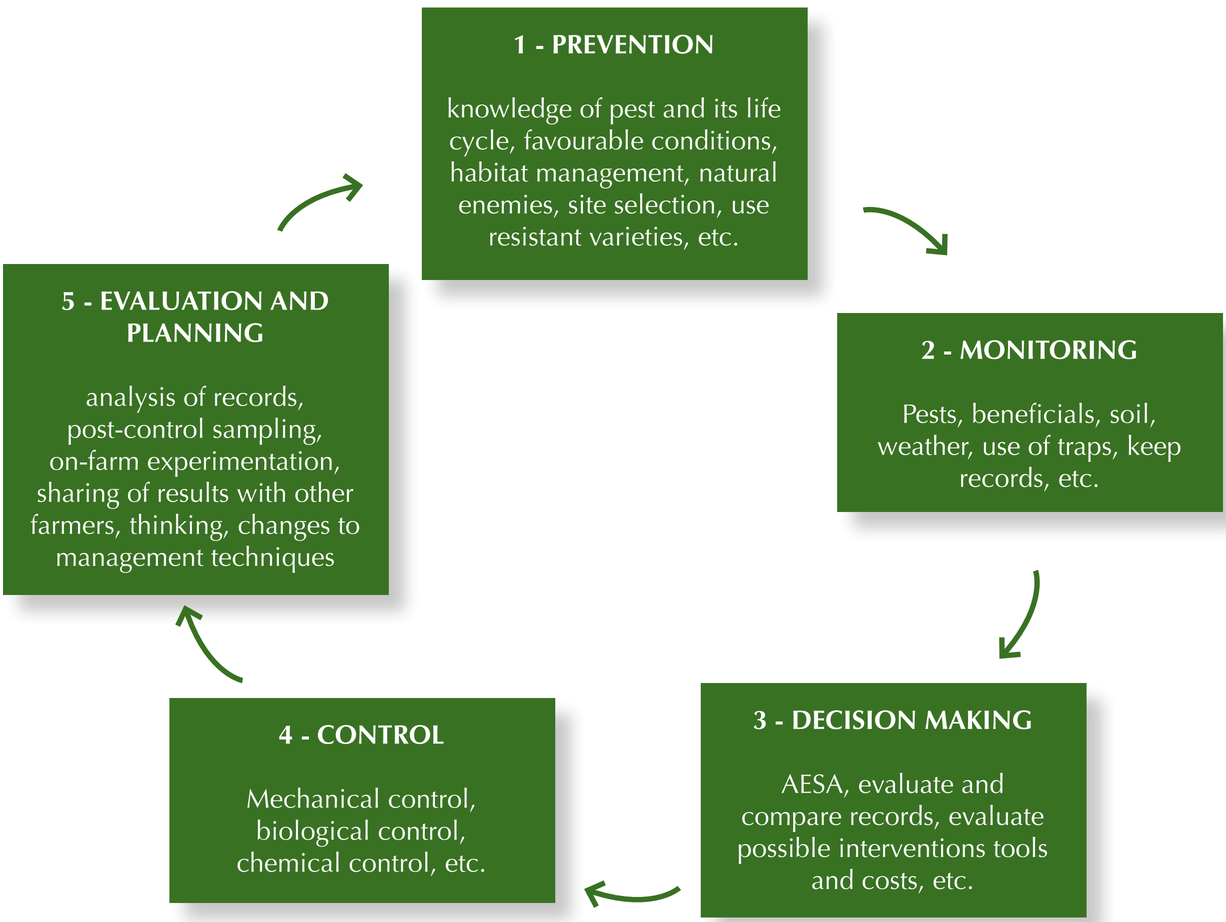
If ***control*** is required, any IPM strategy should always prioritize those methods that optimize cost and effect, while minimizing negative consequences. Again, a wide choice of methods is theoretically available and include cultural methods

2.1 - Combination of methods to control white grubs in the soil

(e.g. ploughing, rotovating, etc.), mechanical and physical methods (e.g. use of nets or other barriers), biological methods (e.g. use of predators, parasites or microbial pesticides), biochemical methods (e.g. use of pheromones), chemical methods (use of chemical pesticides), etc. However, as it will be explained more in detail in a later section of this manual, their feasibility will depend on a number of factors, including local availability and relative cost to the farmer. For example, the use of fleece net to preventatively protect leafy vegetables during the early development of the crop is now quite widespread and considered an economically viable solution by large growers; however, most of the small and subsistence vegetable farmers will find the cost of fleece net unaffordable and for that reason most of the local shops from which they buy agricultural inputs will not have it in store. It is a reality that very often farmers in developing countries lack affordable alternatives to the use of pesticides. However, IPM is also about using flexibility and creativity to develop locally effective solutions. Picture 2.1 shows a farmer successfully using a combination of an agronomical method (ploughing) and a biological method (chickens) to control white grubs in his field, instead of applying a highly toxic soil insecticide.

Evaluation and planning is the last, but not least, component of the IPM strategy. Evaluation is done through analysis of records, post-control sampling, on-farm experimentation and sharing of results with neighbour farmers and extension personnel. The evaluation process should help the farmer to answer questions like, "how much has the situation changed from the last control?" or "was the management decision correct and did the action have the desired effect?". Through the evaluation process, the farmer should be able to understand if the management strategy adopted was satisfactory or whether it should be improved to get better results in the following agricultural season.

A possible way to look at IPM is as a knowledge-intensive system that, through a continuous improvement cycle, allows to achieve better and better results. With each cycle (crop or season), more emphasis is placed on preventive strategies and gaining knowledge not only about the pest and its characteristics, but also about what conditions are favourable or unfavourable to its development. This is illustrated by picture 2.2 underneath.



2.2 - IPM improvement cycle

Why use IPM?

In the past, the over-reliance on chemical pesticides as sole method for pest control led to several problems, such as environmental contamination, health risks due to high exposure of humans directly to pesticides or their residues in food, development of resistance by the pests, secondary pest outbreaks and massive poisoning of honeybees and other pollinators.

IPM combines a variety of control methods, therefore presents a series of advantages compared to the use of only pesticides:

- *It reduces risks*. The impact of chemical pesticides on the environment and on human health has been greatly negative and continues to be of concern. Farmers and those who apply pesticides are more at risk, but everybody can be exposed to pesticide residues through contaminated food and water. With IPM, pest management is done with fewer pesticide applications, using the safest and most effective formulations. This minimizes the dangers associated with pesticide applications and the negative effects on non-target species and wildlife.
- *It provides a more reliable and longer-term solution*. The reliance on multiple complementary tactics increases the effectiveness of pest management and avoids – or significantly reduces – the development of resistance to pesticides. Using the same chemical control over and over again leads to a reduction of its effectiveness against the target pest. On the other hand, through the use of a pool of methods, resistance can be prevented or delayed. Preserving the effectiveness of existing pesticides also reduces costs for everyone that uses them. At the same time, regular scouting helps avoid unexpected pest outbreaks, which can cause heavy losses if not caught and treated.
- *It protects the environment*. IPM protects the environment through the elimination of unnecessary pesticide applications, which supports the integrity of all life forms. Additionally, through the adoption of good agricultural practices (e.g. soil mulching), it helps reducing problems such as soil erosion and therefore reducing sediment and polluted runoff from entering lakes, streams and rivers.
- *It may increase profit*. Inputs such as mechanical cultivation, pesticides and fertilizers represent a significant cost for the farmer. By using best management practices and applying these inputs when they are actually needed, farmers can reduce costs. Once perfected, IPM can also improve yields.

To conclude with, it should also be mentioned that IPM presents what may be seen as a disadvantage compared to the blanket use of pesticides. As already mentioned above, IPM is a knowledge-intensive system that requires a higher degree of knowledge and management skills. Consequently, it also requires a higher degree of commitment and ongoing training by the farmer and it is more labor-intensive than unreasoned chemical control.

PART 3

Preparations for tomato IPM farmers field schools

Selection of location

The choice of the location is extremely important to ensure that the FFS serves its scope and that its activities are sustainable. When deciding where to establish the FFS, one should consider the following elements for each of the areas potentially of interest:

- whether it is a centre for tomato production and whether tomatoes or other vegetables are the primary source of income for local farmers;
- whether farmers depend on tomato or other crops for their livelihoods. The more a farmer is dependent on farming, the more likely he or she will be interested in the FFS and the more he or she will participate in it;
- what the problems are with pests and diseases affecting tomato crops;
- whether pesticides and chemical fertilizers are being used, and to what extent;
- what the current practices for tomato production are. The larger the gap between current practices and IPM, the more likely farmers will be interested to join a FFS-IPM programme;
- the openness of the farmers and their interest in learning;
- the availability of an area / facility to conduct the FFS activities. The site must be suitable for the FFS activity in the selected season and must be representative of the problems in the area. It must be easily accessible and ideally the farmer owning the plot should be present for most of the time in the FFS sessions.

Another important criterion for selecting a FFS location is the travel distance for the facilitator (the closer the facilitator lives to the FFS location, the better), especially because many of the facilitators run an FFS in addition to other tasks and assignments. Other considerations might be economic, social and cultural conditions.

The person selecting the location (usually the facilitator) should visit all potential locations, going to villages and individual farmers' homes and plots, holding informal discussions with the farmers and keep a record of all information obtained.

Coordination with local authorities

Support from local government representatives and village authorities is essential in expediting IPM FFS preparation and smooth running. They can also assist in identifying potential participants or suggest suitable contact persons.

Local government authorities

1. Meet with the local administration and representatives of the Ministry of Agriculture and the relevant staff (e.g. specialists in plant protection and horticulture) and explain the aims of the tomato IPM FFS and the preparatory meetings with tomato farmers that will be held in their area.
2. Discuss with them also the following: strategic locations for tomato IPM FFS, major constraints for tomato production in the area, criteria for the selection of participants, timing for conducting the IPM FFS and activities to be carried out.
3. Request the officials' support for tomato IPM FFS activities in their district or sub-district.

Village-level coordination

1. Meet with the village administrator and other relevant village authorities and inform them about plans to initiate IPM FFS activities in their village, explaining about the objectives of the tomato IPM FFS and preparatory meetings with the farmers.
2. Discuss with them also the following: major constraints for tomato production in the area, strategic locations for tomato IPM FFS, criteria for the selection of participants, timing for conducting the IPM FFS and activities to be carried out.
3. Request the village officials' help in supporting the IPM FFS activities. If possible, request village data and maps for preparing meetings with the farmers.
4. In addition to meeting village officials, also consult prominent community figures, farmer group leaders, and other individuals who may be able to help with implementing the IPM FFS. Ask for their help with organizing the FFS preparatory meetings and inviting other farmers to take part in these meetings.
5. Make logistic arrangements for the preparation meetings and make sure you keep village authorities informed. Ask the village administration and relevant authorities to assist protecting the training site from any physical damage.

Meeting with farmers

Following the coordination meetings with local authorities and village officials, hold a series of meetings with farmers. Apart from being a means for identifying potential participants, these meetings are also useful for crosschecking data collected from the field and as fora for participatory identification of problems facing farmers. However, the most important objective of these meetings is that farmers understand what the program is about and they agree to participate.

1. To gain an understanding of conditions, constraints, needs and opportunities in the local area, involve participants in participatory rural appraisal activities to collect data, such as field mapping, seasonal activities, gender analysis, etc. Work together with the participants to analyze the collected data.
2. Having completed the above, provide explanations to participants regarding IPM, sustainable tomato production, the learning process through FFS, and the benefits of IPM FFS. A tomato IPM FFS graduate may be invited to talk about his or her experiences with field schools and how they have been of benefit.
3. After completing the above steps, agree on the IPM FFS implementation: who will take part, where meetings will take place, what is required of participants in terms of time and labor involved, the duration of the FFS and meeting frequency, explain about the participatory method and why it is different from the "traditional" extension method. Pay special attention to female participants, encouraging them to take part in IPM FFS studies if they also have a prominent role in tomato production.
4. At the end of each meeting, reiterate agreements made and make sure to meet with potential IPM FFS participants again.

Criteria for selection of participants

In order to become active FFS participants, obviously farmers should be interested in learning about IPM and other crop production topics. As mentioned above, the more a farmer is dependent on farming (full-time), the more likely he or she will be an active participant in a FFS. Full-timers probably also have more farming experience. It is advisable to form FFS groups with participants coming from a similar economic and crop production background, i.e. do not mix large farmers with small subsistence farmers, as they will likely have different problems and interests, and therefore also different training needs. One can use some basic indicators to get an idea of the economic level of a farmer; e.g., in Eritrea an acceptable indicator could be the number and power of water pumps and pipes. Subsistence farmers have only one small water pump (4-7 horse power), while better off farmers will likely have two or more water pumps. Another indicator is the size of land held: subsistence farmers will have a quarter to half hectare, while those better off will have large extensions.

A good number of participants for a FFS is 20 to 25. Selecting a slightly higher number of farmers initially may help as the group is likely to shrink after the first few sessions. A possibility is to select already-established groups like self-help groups, youth, and/or women's groups. The facilitator's familiarity with the history of the community, its cultural practices, gender relations, and potential areas of conflict are important elements in the selection process. Groups may consist of only men, only women, or mixed gender depending upon the culture and topic. Larger groups tend to become either difficult to handle or passive; on the other hand, communication and exchange of experiences may not be so effective in smaller groups. Women play a major role in a rural community life and are important decision makers at household level; therefore, it is important to ensure a gender balance in the group of trainees and it is also important to include women facilitators in the program.

PART 4

Tomato IPM FFS implementation

Developing a curriculum for tomato IPM FFS

As with any other learning process, a curriculum is an essential guide to both IPM FFS participants, as it shows them what they will study throughout the season, and to the facilitator, as it enables him or her to make the necessary preparations before facilitating the FFS meetings. When preparing a curriculum, the following should be considered:

- it should be based on critical factors affecting farmers' crops;
- it must involve an agreeable duration of meeting times;
- it should give farmers opportunities to gain relevant knowledge and skills, and don't merely transfer standard recommendations and technologies.

Before the FFS curriculum can be designed, baseline information must be collected to determine the main problems and issues facing the farmers. With this information, the facilitator can select – together with the farmer group – elements to study in the FFS.

By the end of the FFS, the participants should be able to carry out the following:

- describe the development of the crop;
- identify and prioritize, with other participants, questions/problems to be addressed in the FFS;
- identify the ecological function and the life-cycle of major insect pests and natural enemies seen in the field, and identify them by the local name;
- recognize symptoms and identify by the local name the major diseases and understand the influencing factors;
- describe the toxicity of commonly used pesticides (mostly fungicides and insecticides) and methods to avoid exposure to pesticides;
- describe the effect of pesticides on target pests, natural enemies, beneficials such as bumble bees, and the environment in general;
- describe the level of potential yield-loss given a particular field condition and compare with the cost of possible interventions (decision making);
- describe possible effects of management practices other than pesticides on pest population levels;
- describe why and how to set up a field study;
- describe the importance of record keeping;
- work as a group.

The steps to developing a FFS training curriculum include:

- determine field activities and learning topics (based on needs assessment and problem identification/prioritization);
- design field studies;
- plan number of meetings per season and their frequency;
- plan "routine" activities during FFS (AESA, meeting schedule);
- plan special topics;
- plan "less traditional IPM topics" e.g. marketing;
- plan farmer exchange visits/cross-monitoring visits;
- budget planning.

Routine activities during tomato IPM FFS

Like the other FFS, also for the tomato IPM FFS the approach must be 'learning by doing', meaning that farmers can learn from their own experiences. Tomato fields become the means for study, the classroom and the source of knowledge. Each tomato IPM FFS meeting should involve the activities indicated underneath.

Observation

Participants make observations in the learning plot throughout the season, so they can see for themselves what is happening with their crop. These observations cover all aspects relating to the tomato field ecosystem. The keys to successful observations are willingness, regularity, thoroughness and knowing what to look for. The final goal of IPM is to improve decision making for better production and profits. Sampling is one of the first steps in the management methods. Sampling for IPM is looking at some plants in the field and estimate what is happening in the whole field. Sampling can be done differently depending on the purpose for it. For a farmer, sampling should tell him/her if the pest population is above a damaging level, and if it is increasing or decreasing. It is not important for farmers to know the exact level of the pest population in the field, but they have to be able to make a reasonably accurate estimate. Together with other information such as presence of natural enemies, plant health, farm budget and weather, this estimation will be used to make an analysis of the field for decision making.

For observations and sampling, FFS participants should split into groups of about 5 people. Each group samples at least one location in the study field, checking at least 10 plants. Observations may consist of:

- date, type of study field assessed, no. of days/weeks after sowing/transplanting;
- soil and water conditions;
- weather conditions;
- plant development: plant height, number of branches/plant, size and number of leaves, growth stage, number of fruits, etc.;
- plant health status, based on leaf colour, etc.;
- pest and disease attack symptoms, number and types of pests and natural enemies present on each plant;
- presence of pest insects in the soil, or soil-borne diseases;
- weed incidence;
- unknown insects, leaves with an unfamiliar appearance (e.g. nutrient deficiency symptoms), with symptoms of unknown diseases, insect damage, or with other damage are collected in plastic bags or other containers and taken to the FFS meeting site for further observation, discussion and identification;
- other conditions worth noting, e.g. presence of beneficial insects, crop and pest situation in neighbouring fields, etc.

Agroecosystem analysis

The goal of Agro-Ecosystem Analysis (AESA) is to assess what type of action will be needed, based on the observed conditions of the crop. Each group pools the information gathered at their sampling sites and discusses the observations, differentiating between positive and negative elements for crop, field and environment. Finally, the group formulates a summary of their observations and draws conclusions (by drawing on a large sheet of paper what they have just observed) about the state of crop health, after taking into account the balance between positive and negative elements. In the beginning, the analysis will likely take a long time, but by the end of the season the process will be much shorter and it may be possible to do a complete analysis while standing in the field.

Presentation of discussion outcomes

Each group present their findings in order that all the participants can look at the agroecosystem in a more in-depth and systematic manner. The other groups ask questions and raise discussion points. After all the groups have finished, the facilitator guides the participants as they formulate an overall summary of field and plant conditions, draw conclusions and recommend actions (crop management practices) to be implemented during the upcoming week(s) until the next FFS meeting. One or more of the participants should be responsible for follow-up of the action points.

Special topics

Special topics support the agro-ecosystem analysis by dealing in more detail with specific issues relating to the agro-ecology, crop development, IPM principles, biology of insects, group dynamics, and provide training in basic experimentation methods. Often, special topics are identified during baseline surveys/needs assessment or during the participatory curriculum development. These special topics are intended to enrich participants' knowledge and to make it easier for them to reach decisions relating to their fields. Special topics can be done in the field, by setting up small experiments or establishing monitoring tools (e.g. traps). They can also take place in a discussion room, for example after having done AESA during the FFS meeting. However, it is advised to base special topics on actual field conditions. Special topics can be handled by the facilitator, when he/she is familiar with the subject. In special cases, a resource person can be invited to the training.

Group dynamics exercises

Working with groups means dealing with people with very different characters, educational backgrounds, age, experience, etc. Group dynamic exercises help the group become more active, effective and cohesive. No team can work well without contributions of individual team members, and the team succeeds more often when everyone works together while each improves individual skills and commitment. Facilitators should build up a repertoire of activities that can used for interesting opening that help participants to become comfortable with each other ("Ice Breakers"), activities that boost the energy level of the group after visiting the field or after a break ("Energizers"), activities that are just fun to do in groups and make getting together a better time ("Team Fun"), and activities that build team capacity through learning techniques for planning, organizing, and action ("Team Skills"). During the cycle of the FFS over one season, energizers and team fun might be used more at the beginning of the season, with more emphasis on Team Skills near the end of the season, especially in preparation for community organizing.

Preliminary and final tests

Preliminary tests are undertaken to get an idea of participants' knowledge and skills in relation to tomato cultivation, pests, diseases and natural enemies. With this information, a facilitator can see what participants need to master and choose appropriate topics accordingly. The baseline information usually required is about farmers' current practices, problems, and inputs/outputs in farming as well as general farm data. Often, needs assessment is done as part of baseline information gathering, because farming needs are an obvious next step after listing current practices. Baseline information is necessary to i) learn about problems and needs of farmers, in order to develop a training curriculum that meets farmer's needs; ii) to obtain information about farmers' current practices and major constraints for possible use in field experiments as control plot (the "farmers' practice"), iii) to collect information about farmers' current practices for later use to measure impact from the training, and iv) understand what the different pests, diseases and weeds of the area are and how they are managed. Baseline information can be collected using different methods, including informal and formal interviews. It should be collected before the start of the season, when selecting locations and participants. Early collection of this information allows sufficient time to plan the FFS curriculum, field study, special topics, etc. In addition to the objectives listed above, in a session with the farmers group, baseline information can be used to set priorities on the different needs identified, and to identify which topics can be addressed in the FFS. It also gives an idea on what the potential for IPM is for the farmers in the area, based on what their actual practices are.

Final tests are for gauging participants' progress in relation to the materials taught to them. Some examples of preliminary and final test models used are ballot boxes, group discussions and interviews about progress made.

IPM experiments in FFS experimental plots

Experiments are meant to provide farmers participating in FFS with the opportunity to find evidence of IPM practices, and to improve their skills in designing and conducting experiments to test new ideas. Examples of experiments conducted in tomato IPM FFS are included in the various sections of this manual.

Follow-up to tomato IPM FFS

Follow-up activities are important for sustainability of IPM implementation, as graduates from the FFS often require follow-up training to develop their newly acquired knowledge and skills according to the local circumstances. Follow-up plans should suit participants' wishes and local conditions. Possible follow-up activities are:

- adoption of IPM FFS field practice in the farmers' own fields;
- discuss with trainees the possible advantages and outcome of the training provided;
- disseminating learning outcomes to other farmers;
- facilitating other groups to learn about tomato IPM;
- routine group meetings for further collective learning and action;
- conducting further experiments.

The type of follow-up activities depends on the area and the requirements of the FFS group. In some cases, farmers have started activities in other subjects related to community development. In areas where water is an issue, water organizations have developed. IPM facilitators may promote the independent establishment of farmer associations and assist in writing proposals and requests for local funding.

Monitoring and evaluation

Evaluations are important to determine the strengths and weaknesses of the tomato IPM FFS. Things to look at when making evaluations are:

- Crop performance. The yield from IPM plots as compared to local methods and productivity levels, ease of implementation, results of economic analyses, etc.
- Learning process. Whether the tomato IPM FFS has been running according to plan. This will be apparent from the number of meetings, participant numbers and attendance throughout the season, suitability of special topic choices relating to specific issues in the field, etc.
- Percentage of trainees who adopted the techniques proposed by the IPM FFS.
- Impact. This is the most important aspect to evaluate. Farmers may improve their basic skills and knowledge, but this may not necessarily lead to a change in their crop management practices, in the reduction of pesticide use, to improved yields, or to improved economic returns. Impact evaluation must clarify how much the tomato IPM FFS learning process has succeeded in achieving its objectives.

Some of the manuals cited in the bibliography represent useful sources for the FFS facilitator to gather more information on possible ways to structure monitoring and evaluation activities.

Facilitation

The role of the facilitator is crucial for the successful implementation of a FFS. It includes the following:

- determine the site for the FFS and conduct a baseline assessment;
- conduct preparation meetings and select participants, in agreement with the broader community;
- prepare all necessary requirements for implementing the IPM FFS, i.e. outline the curriculum, tools and materials, experimental plots, plan meetings, invite resource persons when necessary, etc.;
- prepare him or herself to facilitate the IPM FFS, and to motivate participants;

- ensure that group discussions are lively and flowing;
- involve all participants in discussions so none are either too dominant or are left out;
- respect all participants, be friendly, warm and responsive so they are not reluctant to express their opinions;
- provide clear explanations when participants are unable to answer questions through their own observations or discussions;
- initiate experiments, make critical analyses of ideas, test them and draw conclusions;
- hold reviews or evaluations on completion of an activity;
- pay attention to timing so that everything goes according to schedule. Make sure that any changes are agreed by all participants;
- respect local traditions and habits (e.g. public holidays).

The facilitator should also have the ability to identify participants with leadership skills, who might take up some of the facilitation work in the future. Besides, he/she maintains constructive communications with local government officials, NGOs and other agencies/organizations in the area where the FFS is located. Simple steps to good communications with local leaders include inviting them to FFSs, visiting their offices and possibly taking them to see the FFS study fields. A field day, an activity late in the FFS schedule, is meant, in part, to let these leaders see the results of a FFS. Additionally, he/she must take care of a significant number of basic administrative issues which are important also to evaluate how well the FFS is doing (e.g. collect and report basic bio data of FFS participants, report results of pre- and post-test, save weekly results of agro-ecosystem analysis, prepare activity plans for each FFS meeting, etc.).

All the above clearly indicates that a facilitator should not only possess technical skills, but also have a good capacity for organization and inter-personal relations. To increase his or her knowledge, a facilitator must seek as much information as possible through reading, internet searches, discussions with subject specialists and innovative farmers, etc.

Section activities

4.1 - IPM versus conventional practice

In this study, the incidence of pests and diseases, the occurrence of natural enemies and eventually the yield of tomato under IPM (based on ecosystem analysis) and under farmers' practice will be monitored and compared.

Objective

to compare the technical and economic benefits of the different management methods.

Duration of exercise

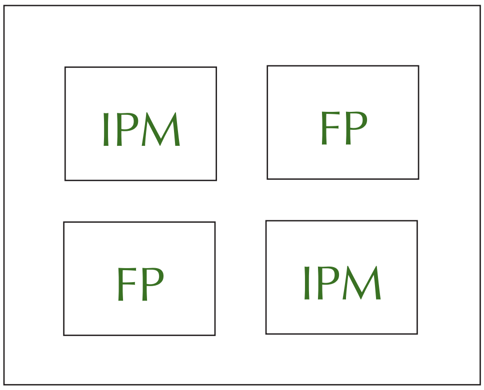
One full growing season.

Materials needed

- Seedlings of the most commonly used variety in the area
- All commonly used equipment and inputs such as fertilizers, pesticides, machinery, tools, etc.
- Scale for taking weights of harvested product
- Grading guidelines
- Any other input required for IPM (e.g. pheromone and/or yellow sticky traps, if available)

Procedure

The study is set up with 2 treatments: IPM based on ecosystem analysis, and conventional practice as in farmers' common practice (FP). The 2 treatments can be arranged as shown in fig. 4.1.



4.1 - Possible layout of plots to compare IPM and farmers' practice (FP).

Choose a field that is representative of the area and which has uniform fertility. Inside the field, create the plots for the different treatments (ideally 2 plots for each treatment).

All agronomical practices should be the traditional ones for FP plots, while they may vary for IPM plots, to include relevant changes (e.g. use of mulching to protect soil).

Keep a few border rows around each

treatment and around the entire study field, to avoid interferences (e.g. pesticide drift from FP plots into IPM plots).

Regularly carry out an AESA in each plot (weekly, or at every meeting).

Sample weekly 5 or 10 plants in each plot, to check for plant development, pests, diseases, natural enemies, weeds, etc. Measure yield at different harvesting times and collect all data for economic analysis during the season.

Observations

Compare all parameters (plant development, pests and diseases, yields, etc.), possibly by plotting data and making graphs. Make an economic analysis for each treatment.

Discussion

Compare plant growth and development in the different treatments.

What management practices are important in growing tomato (cultivation practices, fertilizer management, watering, etc.)?

What natural enemies occur? What is their significance? How can they be protected and also limit the damage of pests?

What pests occur in the tomato field? Which was the most important in each stage? How do you control them and also protect the natural enemies and beneficials (e.g. bumble bees)?

Did you see any compensation of the plants for injury by insects?

Compare disease incidence in each of the treatments. How did the weather and cultivation practices influence disease development? Why?

Compare yields in each of the treatments.

Which management method was most economic? Why?

Was there a difference in quality of tomatoes in the different treatments? What about the selling price?

How many times did you spray pesticide? Was it necessary? What was the effect of pesticide use on natural enemies?

What difficulties occurred during the experiment?

What further studies do you recommend to better understand and manage the ecosystem of tomato?

4.2 - Introduction to agro-ecosystem analysis

The core activity of an IPM field school is the so-called 'agro-ecosystem analysis' which is done weekly to monitor fields and to facilitate management decisions. The first few times an 'AESA' is done, participants are usually not familiar with the approach and take a long time to make their observations and do their drawing and analysis. After that, however, the AESA becomes a routine exercise and participants appreciate the value. When the AESA is done for the first time, it is recommended to spend some time discussing what observations are needed, how they should be recorded and what kind of information is needed to make good management decisions.

Objective

To build awareness of relationships that exist between organisms in the environment and improve decision making skills.

Duration of exercise

½ day or less.

Materials needed

- Vegetable field, divided into a conventional practice (CP) plot and an IPM plot
- Notebooks for each group
- Poster paper and crayons
- Jars/vials, plastic bags for collection of samples
- Paint brush to carefully collect insects for use in follow-up studies
- Hand lenses (one for each group)

Procedure

Step 1 - In the 'classroom'

In an interactive session, ask what kind of information is needed to make decisions regarding crop management. Discuss crop condition, weather, soil, pests (including diseases and weeds) and how these factors interact. Discuss how the crop should be observed to collect all the necessary information to make proper crop management decisions. Discuss how many plants should be observed and how these plants should be chosen (usually 10 to 20 plants are observed). One method to select sample plants is by using U or S or diagonal walking paths along which plants are chosen at random. Another method to select sample plants, is to count the 5th plant from the edge, then move 1-2 rows and then count the 5th plant from that position, etc., until sufficient plants are sampled. Each week, different plants should be sampled. This discussion should lead to the standard agro-ecosystem analysis as used in all IPM training courses.

Step 2 - In the field

Participants are divided into groups and each group observes the FP and the IPM plot (or, if time is short, for the first time each group observes either the CP or the IPM plot).

Record the weather condition.

Sample the number of plants as agreed in the classroom session.

Carefully observe each whole sample plant and record any pests and beneficials found on it (use a hand lens if possible). Start from the top of the plant and work downwards. Observe the flowers and fruits for any insects present or any injury symptoms. Also observe the soil surface for any ground-dwelling pests or beneficials.

Select three leaves from each sample plant, one taken from the top, one from the middle and one from the bottom of the plant. Pick or turn the leaf and – using a hand lens – count the number of thrips, leafhoppers, white flies, aphids, tiny spider mites and fast-moving predatory mites on both sides of leaves. Record different leaf spot disease symptoms and count the number of spots on the sampled leaves.

Per sample plant, count the egg masses, larvae and adults of leaf feeding insect pests (such as caterpillars). Assess the percentage of fruits affected by fruit feeding insect pests (such as boll worm, fruit fly) and count the insects present.

Per sample plant, count the branches that are affected by die-back or other shoot diseases. Assess the percentage of fruits affected by fruit affecting diseases (such as fruit rot).

Out of the x sample plants, assess the number of plants with virus symptoms. Do likewise for wilting symptoms. Pull wilting plants and observe symptoms on the roots (cut the roots to observe the colour of the vascular tissue), assess the number of plants with root deformations or vascular discoloration.

Out of the x sample plants, note the number of plants with flowers/fruits to assess the percentage of plants flowering/fruiting.

Do a walk-through: walk through the whole plot to assess whether any other beneficial, pest or disease, not observed on the 10 sample plants, is occurring. Note the general growth condition of the crop. Make records of the soil condition, water availability, cultural practices, and presence of weeds (observe the different kinds of weeds and their density).

Drawing

Find a place to sit as a group and make colour drawings on the large piece of paper. Draw the plants with injury symptoms (disease symptoms, holes due to insect feeding, etc.). On the left hand side of the plant, draw the pest insects and disease symptoms found (use hand lens if needed):

Sucking pests, mites and leaf spots

Indicate the total number found on all leaves, and the total number of leaves checked (e.g. 15 leafhoppers per 90 leaves). Calculate the average per leaf (e.g. 0.2 leafhoppers per leaf).

Other pests and diseases

Indicate the total or average number of pest insects found on the x sample plants.

Indicate the total number of branches infected with disease on the x sample plants and the percentage of plants with virus and wilting symptoms.

If a wilted plant that was uprooted shows root damage, draw the damaged root. Carefully indicate root deformations, colour differences, etc.

Indicate the percentage of fruits with injury symptoms.

On the right-hand side of the plant, draw the beneficials found. If you don't know whether an insect is a pest or a beneficial, draw it on the right-hand side with a question mark. Discuss during the presentation how you can find out. Again indicate the total numbers found (and calculate the average per plant). If weeds are occurring, draw the different weed species next to the plant.

Describe the general condition of the plant. Note weather, soil condition, etc., as well as last week's management practices. Note on the posters what, if any, measures should be taken (management decisions).

Presentation

When all groups have finalized their drawings and answered the questions, each group present their work in front of the others. They explain the sampling, explain the drawings and discuss the recommended decision on the measures that should be taken. Beware that in the FP plot, the conventional farmers' practice must be conducted.

Each week, a different person of each group should do the presentation. The agro-ecosystem analysis drawings of previous weeks should always be available for comparison and to discuss development of the crop and insect populations. It is easily forgotten what the field looked like earlier in the season, what insect populations were found, and what control measures were taken. Were the decisions made in the previous agro-ecosystem analysis effective? If not, why not?

After the group presentations, the facilitator should summarize the recommendations of each group. Together with all groups, a final decision is made on which management measures will be taken in the different plots. Also discuss which new problems were identified and how these will be investigated in the following days (e.g. do insect zoo studies to determine whether or not an insect is a pest).

PART 5
Tomato crop cultivation

The first objective of IPM is "grow a healthy crop". A healthy crop is obtained by good agricultural practices. A healthy crop will have less problems with pests and diseases and it will recover quickly from stressful factors. The management of pests and diseases starts even before buying the vegetable seed. It starts with selecting a suitable variety, with choosing the right field, with making a suitable soil preparation. It involves nutrient application of the right type, in the right quantity, at the right time. Nursery management is another very important factor, as many diseases may already start in the nursery. It also involves planning of crop rotation and several other factors. All these factors will be described below in general terms, providing – where appropriate – references to current practices in Eritrea.

Most of Eritrea's regions (or "zobas") have two distinct cropping seasons for tomato, as illustrated by the table underneath. Production levels are relatively low, in the range of 15-25 tons/ha, and the following factors have been identified as the main reasons for it:

- poor quality of seed;
- limited varietal choice, to suite soil and climate of the different agroecological zones;
- limited availability of fertilizers, both in quantity and type (DAP and urea are the only ones available);
- limited technical knowledge of farmers on good agricultural practices, including time of planting, watering, harvesting, etc.;
- deficiencies in the phytosanitary system.

Cropping calendar for tomato in different "zobas" of Eritrea

ZOBA	JAN				FEB				MAR				APR				MAY				
Gash Barka			S	S										H	H	H	H				
Anseba		S	S										H	H							
Maekel														H	H	H	H	H	H	H	
Debub														H	H	H	H	H	H	H	
NRS	H	H	H										H	H	H	H					

Key: S = Sowing; H = Harvesting

JUN				JUL				AUG				SEP				OCT				NOV				DEC			
	S	S													H	H	H	H									
	S	S	S	S	S														H	H	H	H	H	H	S	S	
	S	S																					H	H	S	S	
											S	S	S												S	S	H

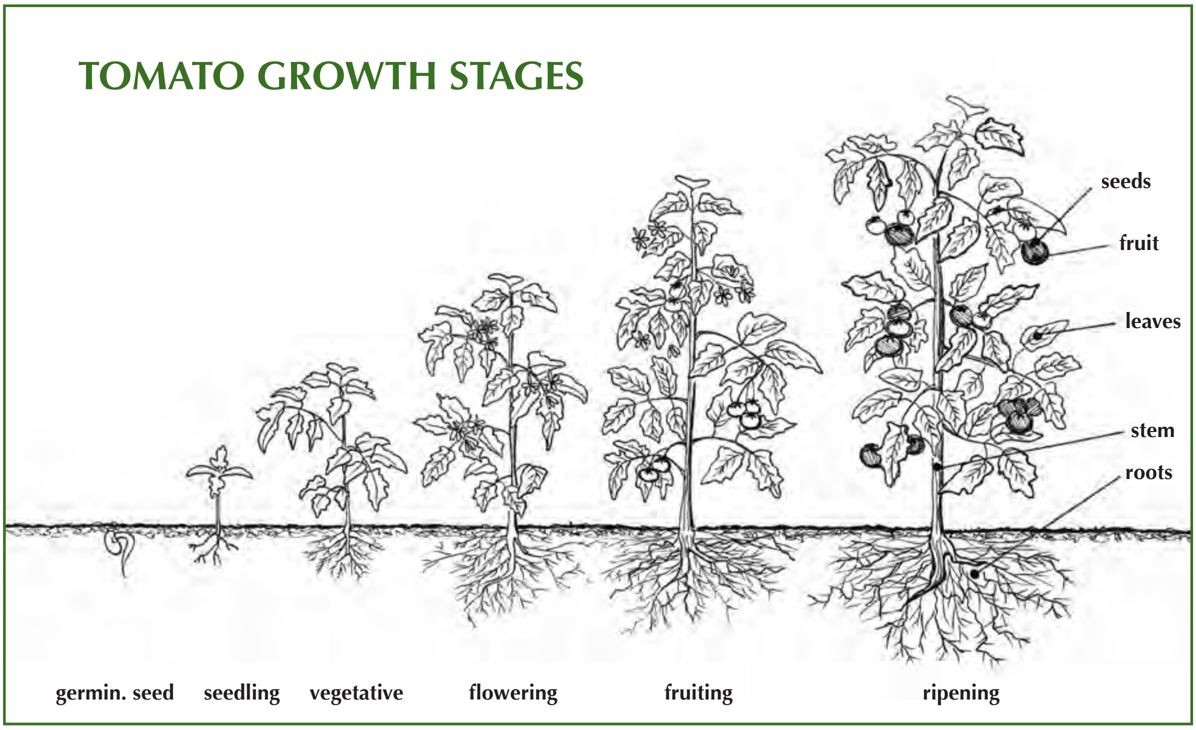
winter season summer season

The tomato plant

Tomato is an annual plant, which completes its life cycle in one season, although tomato plants can be cropped for 24 months or longer when growing conditions (water, fertilization, etc.) are optimal and plants are not exhausted by diseases or insect pests.

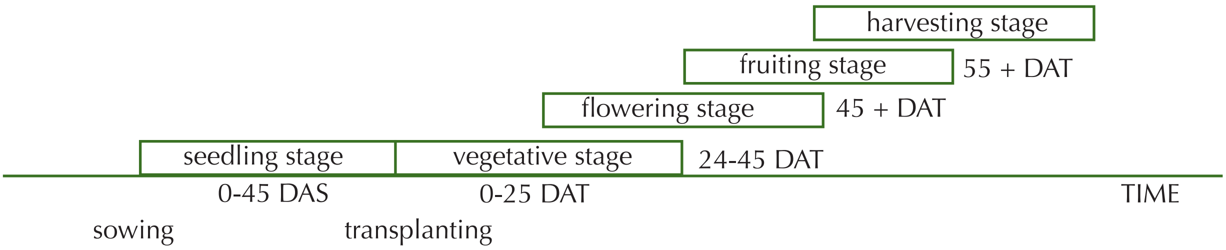
As illustrated by picture 5.1, the general growth stages for tomato are:

- seed;
- seedling, the period from emerging seed to transplanting the new plant to the field;
- vegetative, from transplanting until the first flower buds develop;
- flowering, plant with flower buds and open flowers;
- fruiting, plant with small to full-sized fruits;
- ripening, period when the plant yields mature fruits.



5.1 - Tomato growth stages (drawing by Gabriela Rovesti)

These growth stages are overlapping in time:



DAS = Days after sowing
DAT = Days after transplanting

Based on the plant habit (i.e. how the plant develops), tomatoes are usually characterized into two types.

- *Determinate tomatoes:* are those in which the side shoot above the first flower cluster produces a few leaves and a flower cluster on top, with no further vegetative shoots. This ends the upward growth of the plant. Many side shoots arise from the primary shoot, giving the plant a bushy appearance, but each eventually ends in a flower cluster. All the tomatoes from the plant ripen at approximately the same time (usually over a period of 1-2 weeks) and it requires a limited amount of staking for support.
- *Indeterminate tomatoes*: in this type the plant continues growing almost indefinitely (up to 2-3 m high) and flower clusters develop throughout the season, to the side of a main stem. This type of tomato needs staking and pruning of the side branches (called suckers) to obtain good quality fruits.

By sectioning tomato fruits transversally, it can be observed that they are divided into compartments (called locules). Cherry tomatoes and processing (plum or pear) tomatoes only have two locules, while most varieties for fresh market (e.g. the large 'beefsteak' types) have four, six or more locules.

Climate and site selection

Tomatoes can be grown in a wide altitude range, from the sub-tropical plains through to the high hills, depending on the variety and sowing dates. Despite this wide range, tomatoes are very sensitive to low light and adverse temperatures and they need at least 6 hours of direct sunlight per day to flower.

In Eritrea, it is grown from sea level to about 2 400 meters above sea level. In the western and eastern lowlands, the crop is produced from July to end of March, while in the highlands it is not produced from November to February due to low temperature and frost damage. Besides, farmers in the highlands do not produce tomato from June to September due to disease problems which are encouraged by rainfall or moisture. Production under plastic tunnels/greenhouses would allow year-round production, but it is not practiced in Eritrea.

Although tomatoes grow over a wide range of temperatures (18 to 35 °C), fruit set is very sensitive to high and low temperatures. A temperature range of 20-30 °C is considered optimum for the growth of tomato. At higher altitudes, when daytime temperatures are warm but nights drop below 12 °C, many varieties will not set fruit. In summer, when day temperature is above 35 °C and nights are above 25 °C, flowers may produce oddly-shaped fruits or flowers may fall off without setting fruit at all. During the cold months many Eritrean farmers grow their seedlings in small plastic tunnels, to protect them from frost.

Proper colouring of the fruit is also temperature-dependent. Lycopene and carotenes, components that determine colour, are not synthesized above 29 °C and lycopene is not synthesized below 10 °C, precluding normal colour development in ripening fruit.

Very windy areas should be avoided for tomato cultivation as pollination and fruit set may be impaired due to the strong winds. In addition, dry winds result in dropping of blossom. Maize plants, bamboo mats or trees can be used as windbreaks in windy areas.

Variety selection

In many countries, a large number of tomato varieties are available. Unfortunately, the choice in Eritrea is currently rather limited (refer to **annex I**). The choice of the variety will depend on factors such as climatic conditions (lowlands or highlands), time of planting (early or late maturing varieties), insect or disease resistance or tolerance, market requirements (demand, fresh consumption or processing) and – of course – also local availability and cost. Many tomato varieties sold nowadays by seed companies are hybrid varieties. Hybrids usually give higher yields and better quality fruits than open-pollinated varieties; however, they are more expensive and more demanding in terms of fertilizer and pesticide inputs. Seed from hybrids should not be saved, because it will produce inferior quality in the next crop. Therefore, hybrid seed needs to be bought for every sowing. Open pollinated varieties (i.e. produced from natural pollination) are usually less uniform and less productive than hybrids, but are much cheaper and their seed can be multiplied by farmers. However, also with these varieties some selection is required in order to get reasonable quality seed.

Seed selection, extraction and germination (refer also to activities 5.1, 5.2)

Many farmers use seed from a previous tomato crop. A good quality seed is the basis of a good crop. For the **selection** of good quality tomato seed, the following aspects should be considered:

- look for vigorous and early maturing plants. Selected plants should be marked, staked and inspected for diseases during the growing season;
- select fruits from the first harvest period. Often farmers extract seed from the last fruits harvested. By that time, plants may be already infected with diseases that can spread with the seed to the next crop. Seed-borne tomato diseases include early blight and fungal wilt;
- select fully mature fruits. The quality / viability of seed depends on the maturity of the fruit from which it is extracted;
- select only healthy, large sized fruits from healthy plants. Fruits must show no signs of disease or rotting;
- select only large seed;
- discard seed that is spotted or has discoloured areas, as those may be signs of fungal or bacterial infection;
- store seed cool and dry. Viable seed from mature fruits can lose its viability when stored improperly or when stored for a long time. Seed should be kept at cool temperature and low humidity conditions.

The **extraction** of the seed can be done in the following manner:

- cut each tomato into half at its equator and gently squeeze out the jelly-like substance that contains the seed;
- place the jelly and seeds into a small container for fermentation; add a little water (not chlorinated) if you are processing only a few tomatoes. Loosely cover the

container and place in a warm place (around 25-30 °C) for 2-3 days, stirring daily. Some molds will develop on the surface of the liquid, which is fine;

- fill the container with water and let most of the seed settle, then pour out the water together with all floating materials. Viable seeds are heavier and will quickly settle to the bottom of the container, while floating seed is likely empty and should be discarded during the washing;
- repeat the process until the water is almost clear and clean seeds line the bottom of the container (this normally takes 4-5 washings);
- after the last wash, seeds are recovered in a strainer or sieve, then spread out on paper (paper towel or newspaper is fine) to completely dry in the shade. Break up the clumps into individual seeds, label them and store for later use;
- for short-term storage, keep the seeds in a cool, shady and dry place. For long-term storage, place it in a refrigerator if available.

Farmer-extracted seed can be considered of good quality when around 70 percent of it germinates within 7-14 days. Commercial seed (hybrid seed in particular) should have a significantly higher germination rate. Irregular germination results in seedlings of different size. Actual germination rate depends on seed age and storage conditions.

Seed treatment (refer also to activity 5.3)

Commercial seed is often treated to control diseases which may be transmitted through it (seed-borne), or to protect the germinating seed and the seedling from infection by pathogens living in the soil (soil-borne diseases). Common seed-borne diseases of tomato are early blight (*Alternaria solani*), Tobacco Mosaic Virus (TMV) and fungal wilt (*Fusarium* and *Verticillium*), while a common soil-borne disease affecting seed and seedlings is damping-off, caused by a complex of fungi.

When seed is bought from reliable seed companies, it will usually be disease-free. On the other hand, when the farmer produces his own seed it is probably worth considering the possibility to treat it, particularly if a seed-borne disease is suspected or if the farm's soil has given problems with damping-off disease before. It is important to understand that seed treatment methods may reduce germination of the seed and should be done very carefully. The methods that can generally be used by farmers for seed treatment are: 1) hot water treatment and 2) chemical disinfection (with disinfectants or fungicides).

None of these treatments will completely prevent pathogen attack and for that reason it is important to adopt also other measures, e.g. to select a field that is free of soil-borne diseases. Management practices for soil-borne diseases include crop rotation (using land that has not been used for growing tomato or other solanaceous crops for at least 2 years) and the use of resistant or tolerant tomato varieties.

Hot water treatment. The seed must be soaked in hot water at 50 °C for 30 minutes. The right water temperature and the right duration are very important: if the water is too cold, the pathogens are not killed, while if the water is too hot, seed germination will be strongly reduced.

Chemical treatment. Many seed companies use chemical treatments, such as sodium hypochlorite or sodium phosphate, to sterilize the surface of the seed. Next to this, seed can be coated with a fungicide (e.g. thiram[1]). This fungicide can sometimes be seen on the seed as a colored coating. The fungicide used must be listed on the seed package. Also the fungicide can kill spores of diseases that are present on the seed and during germination it gives some protection of emerging roots to soil-borne diseases. Chemical fungicides for seed protection are relatively inexpensive and cause little environmental damage since they are used in small amounts. However, they are effective only for a short time (at most one month) and they do not spread through the soil with the root system.

As mentioned, chemical seed treatment cannot guarantee that the seed is completely disease free, because some pathogens may be present inside the seed and the chemicals only sterilize the surface of it. Hot water treatment may sometimes be more effective to control pathogens inside the seed.

Soil

Tomatoes grow on many soil types, although silt or clay loam soils are generally considered the most productive. In any case, tomato requires well-drained soils. During the rainy season Eritrean farmers try as much as possible to plant their crop on gentle slopes, to avoid water borne diseases. Another important factor is the acidity of the soil, which is expressed in the form of a pH value ranging from 1 to 14. Soil pH affects the ability of the soil to release nutrients. If the soil is strongly acidic or alkaline, nutrients can get immobilized in the soil and become unavailable to plants. Like most vegetables, tomato performs best in soil with a pH range of about 6.0 to 7.0, or in other words soil which is neutral or slightly acidic. There are methods to correct a soil which is too acidic or alkaline. However, correction of soil pH is a process that usually takes time, sometimes a very long time. Particularly in case of soil which is too acidic, incorporation of large amounts of organic matter is a good and more permanent solution to neutralize soil pH than the application of lime. However, strongly acid soils should still be corrected with lime. Most soils in Eritrea are moderately alkaline, and some also have salinity problems. The correction of an alkaline soil is possible, but they way to do it also depends on the reason for alkalinity. In a dry environment, usually alkalinity is primarily caused by a calcium carbonate-rich parent material from which the soil originates. Lowering the pH of alkaline soils, or acidifying the soil, can be done through the addition of elemental sulfur into the soil. Another option is the use of an acidifying fertilizer, such as ammonium sulfate, although it may not be easily available in Eritrea, where the most widely used commercial fertilizers appear to be DAP (Di-Ammonium Phosphate) and Urea (both of which have a physiologically acid reaction in the soil, although not as strong as ammonium sulphate). Addition of significant amounts of organic matter will help to acidify the soil, as microbes decompose it releasing CO_2 which then forms carbonic acid.

Soils naturally containing carbonates, or lime, are very difficult to acidify and it

1 Thiram is one of the most commonly used fungicides for seed treatment. However, and despite its low acute toxicity, it is dangerous if inhaled. Users should always wear suitable personal protective equipment (PPE), including a respirator.

may take years before a significant change in soil pH is seen. In those cases, choosing crops that grow well in mildly alkaline soils can be a better option than trying to lower the pH to a level suitable for tomato. Plants such as asparagus, beets, cabbage, cauliflower, celery, carrots, lettuce, parsley and spinach grow well in soils whose pH is between 7 and 8.

The few national facilities which could assist farmers for soil testing are the National Agricultural Research Institute (NARI) and the College of Agriculture.

Fertilizers and fertilization

Plants use nutrients from the soil in order to grow and produce a crop. Nutrients are also lost from the soil through erosion, leaching and immobilization. The farmer should aim at compensating these losses of nutrients. This can be done through the use of organic amendments, chemical fertilizers, or a combination of the two. Most chemical fertilizers bring only the macronutrients (nitrogen-N, phosphorous-P and potassium -K), while organic material usually contains both the macronutrients and micronutrients, although in lower proportions compared to chemical fertilizers. A well-balanced amount of available nutrients results in healthy plants, which can resist pests and diseases better. Excess of fertilizer is not only a waste of money, but can also make the plant more susceptible to adversities; e.g., it is known that too much nitrogen increases the susceptibility of plants to diseases and pests.

The use of compost, green manure or other organic materials, which release nutrients slowly, requires careful planning and consideration of long-term goals such as improving the structure and biological activity of the soil. This requires basic understanding of some of the processes that take place in the soil. Inorganic or chemical fertilizers are usually added for the short term needs of the plants. As already mentioned, the three main elements in chemical fertilizers are N, P and K. They can be bought as separate fertilizers or combined in a single fertilizer, in different proportions. A combination of the three elements is described on the fertilizer packaging by three numbers, referring to the content of each element. For example: 25-15-5 means that the fertilizer contains 25 percent N, 15 percent P and 5 percent K. Some micronutrients such as boron (B) can be bought separately; however, addition of micronutrients should be made only when a deficiency is indicated, preferably by a soil test analysis.

Nitrogen (N) promotes vegetative growth, but when it is applied in excess plants will be thick stemmed and dark green, with excessive vegetative growth but few flowers. Blossom end rot appears to be increasing with increasing levels of nitrogen (especially if in the ammonium form). On the other hand, shortage of N causes stunted plant growth. High level of phosphorus (P) throughout root zone is essential for rapid root development and for good utilization of water and other nutrients by the plants. Phosphorus has an effect on the number of flowers that develop. Poor root growth and poor fruit development are associated with low P levels. Potassium (K) affects fruit size and fruit quality: higher levels tend to increase fruit size. It also plays a role in the coloration of tomato fruits. Soft fruit and poor condition of skin are associated with low K. Both P and K are released slowly, and particularly P is needed for root development, therefore basal application of P and K is crucial for healthy crop development. Top dressing P and K is not efficient, therefore the whole amount of P and K can be applied during soil preparation, before transplanting or sowing, or split 50 percent before transplanting and 50 percent during crop growth. Low calcium availability increases blossom-end rot and may also cause fruit cracking. On the other hand, only a fraction of N (25 percent) should be applied before planting and the rest provided in 2-3 applications during the crop cycle.

Because of their rapid growth, long production season and large amount of biomass produced, tomatoes require a significant amount of nutrients. Production of one ton of tomato fruits removes from the soil 2-3 kg of nitrogen (N), 0.6-0.7 kg of phosphate (P_2O_5), 3.5-4 kg potassium (K_2O), 3.8 kg of calcium (CaO) and 0.7 kg of magnesium (MgO). Current practice in Eritrea is to apply DAP at 100 kg/ha at transplanting, and 50 kg/ha of urea at pre to flowering stage. Animal manure is also applied, at the almost insignificant rate of 1 500 kg/ha, incorporating it into the soil one to two months before transplanting. This fertilization plan may have to be adjusted in order to improve production levels, although – as previously mentioned – the availability of fertilizers is one of the factors currently limiting tomato production in Eritrea. Certainly, the amount of manure currently used is largely insufficient to maintain adequate levels of organic matter in the soil. In any case, any recommendation for a fertilization plan should be based on several factors, including the type and fertility level of the soils, the estimated production, the combined use of organic fertilizers, the type of rotation, etc. Again, the National Agricultural Research Institute (NARI) and the College of Agriculture are the national institutions which may assist farmers with recommendations on fertilizer use. Small trials can be set up during the FFS to test different types and doses of fertilizers, to check the ideal combination for each crop and field situation.

Nursery preparation (also refer to activities 5.4, 5.5, 5.6)

Tomatoes can be sown directly in the field, but more frequently are sown in a nursery and later transplanted. The nursery should be located at a sunny site with good drainage, to reduce risks of damping-off. If possible, the nursery should be sited on land which has not grown tomato or other solanaceous crops for 3 years or more. If the soil is contaminated with pathogens or nematodes, it may be "cleaned" using different methods, including burning organic material on the soil surface and soil solarization. To reduce soil-borne diseases like damping-off, a good option is to prepare raised seedbeds which will dry up more quickly than flat-field plantings. Compost can be mixed in the seedbeds to get a fine soil structure with sufficient nutrients. Seedbeds should be properly levelled and trenches dug between them to facilitate drainage.

Seed is sown in rows, 1-1.5 cm deep and with a spacing of about 3 cm between the plants and 20 cm between the rows. Seed can either be sown in the rows and thinned out later or placed individually every 3 cm. If the seed is planted deeper, it will take more time to germinate and may be more susceptible to the attack by pathogens. Sowing seed very superficially (less than 1 cm deep) will make it more susceptible to drought and will produce weaker seedlings. Broadcasting the whole seedbed usually requires a lot of seed and results in irregular patches of seedlings which need to be thinned out later to obtain strong seedlings. In Eritrea, 250 g of seed are normally used/ ha of crop. Nurseries are usually prepared in the months of January and September.

The optimum soil temperature for germination is 25-30 °C. On average, 7 to14 days are required for germination. The seed bed may be covered with a layer of mulch, e.g. barley or wheat straw, to protect the soil from becoming very hot and from drying out (during a warm and dry period), as well as to prevent weed germination. Usually, the mulch has to be removed once the seedlings have germinated or it can be moved aside to give enough space to seedlings but still covering the area next to the seedlings. After germination, it is recommended to thin the plants to 2-3 cm apart to ensure that each plant will have sufficient space and nutrients.

In order to protect seedlings from insect pests (e.g. *Tuta absoluta*, whiteflies), it is advisable the use of a screen cage (picture 5.2). This will also provide shade for the seedlings. When necessary, shade and shelter for heavy rainfall can also be provided by placing polythene or a roof of straw or leaves over the nursery beds. Do not shadow the nursery beds for too long a period as this results in weaker and stretched seedlings.

Field preparation (see also activity 5.7)

Tillage or ploughing is normally carried out to prepare good plant beds. Ploughing also helps to bury residues from a previous crop, to get rid of weeds and to kill insects that live or pupate in the soil. Repeated ploughing, however, also disturbs the micro-organisms in the soil and accelerates the degradation of the organic matter in the soil. This may reduce soil fertility and, to maintain it, it is important to apply organic materials such as compost every year. Sustainable soil practices are focused on using less tillage and more organic materials, such as green manure or mulch, to increase biological activity in the soil.

When drainage of the field is problematic, or when crops are grown during the rainy season, it is advisable to prepare raised beds for growing the crop (picture 5.3). This is also a good practice when problems with soil-borne diseases can be expected. Excess water in the soil, or even water-logging, results in weak plants which are more susceptible to diseases and pests and give a lower yield.

Transplanting and planting density

Tomato seedlings can be transplanted when they are about 15 cm high and have 4 or 5 true leaves. This normally happens 4 to 8 weeks after sowing. Seedlings should be thoroughly watered several hours before transplanting to the field. Plants should be dug from the soil and transplanted as quickly as possible, ensuring that the roots are not damaged and exposed to sun or drying wind. Transplanting should preferably be done in the late afternoon or evening. Set transplants deep, the first true leaves just above the soil level. In some parts of Eritrea long roots of tomato seedlings (and also pepper) are cut during transplanting, to avoid bending of the root. Ideally, cutting of roots should be avoided and transplanting of seedlings with a soil plug should be promoted. Irrigate frequently after transplanting during dry periods. Suddenly

5.2 - Screen cages used to protect seedlings

5.3 - Raised beds for tomato growing during the rainy season

moving plants from a favourable, stable environment to a field with wide variations in temperature, light and wind can seriously damage plants. If the seedlings have been produced in a shaded, protected environment, it's important to take steps to acclimatize them to the field environment (e.g. gradually exposing them to direct sunlight). This process is known as "hardening" and should take at least a week to avoid abrupt changes.

Planting density depends on the type and variety used, soil fertility, soil moisture and also on farmer's objectives. In Eritrea, usual planting distances are 75 cm between rows and 50 cm between plants; at lower altitudes (along the Red Sea coast), density is usually less, with 1m×1m spacing. The planting density has an effect on crop production and susceptibility to diseases. Wider crop densities result in more space and nutrients to each plant, which will usually result in more and larger fruits per plant. The number and the weight of tomato fruit per plant increases more with wider plant spacing than with wider row spacing. However, high yields can also be a result of high plant population and high fruit numbers. Planting density has an effect also on the micro-climate within the crop. In a close planting, wind and sunshine cannot reach to the soil level and as a result, the lower leaves of the crop stay wet longer and this can stimulate disease infection. If plant diseases are usually a problem, then the adoption of a wider spacing is advisable. This will keep the plant dryer and prevent fungal spores from germinating and infecting the plant.

Pruning system and local tradition also have an influence on planting density. Within-row spacing will depend on the vigour of the variety and on how severely it will be pruned. Some farmers space plants widely (65-90cm) in the row and prune very lightly or not at all. Pruning of suckers is usually done for staking type tomatoes. Bush type tomatoes will only need pruning to remove large numbers of small fruits and some leaves. Pruning of excessive leaves ensures proper fruit colour as it allows the sun to reach the fruits. Care should be taken to leave enough of foliage to shade the fruit and protect it against sunscald. Pruning should be done regularly, starting at an early stage. The method used for pruning depends on the variety used, on market requirements and also on local traditions.

If possible, mulching should be used to reduce weed germination, to keep the soil cool and moist and to protect it from erosion. Organic mulch can also provide shelter for predators such as ground beetles and spiders. Mulch can be a layer of organic material, for example rice straw or a layer of green leaves or pulled out weeds. Mulching can also be done with non-transparent plastic sheets; however, this method is quite expensive for small farmers and in hot weather has the disadvantage to increase soil temperature.

Pollination and fruit setting

Tomato is mainly a self-pollinating crop and its flowers have both male and female parts in it. Field tomatoes are pollinated by wind rather than by bees, one reason being that tomato flowers do not produce nectar (only pollen) so they are not so attractive to honey bees. Nevertheless, some beneficial insects (e.g. bumblebees) feed on pollen from tomato flowers and help with the pollination; that's another reason to try and reduce as much as possible the use of broad spectrum insecticides.

Poor pollination results in deformed fruits (because seeds do not develop uniformly throughout the fruit), smaller fruits and fruits that are rough (ridged) along the tops. Pollination can be prevented by various stresses such as cold or hot temperatures, drought, high humidity, nutrient deficiencies as well as lack of pollen transfer.

Water management

Tomatoes have a high water requirement but also have an extensive root system. With good growing conditions, plants should be given as much water as possible during vegetative growth. Probably the most important consideration in watering tomatoes is consistency. When water availability fluctuates or when it is too high or too low at critical stages, fruit disorders such as blossom-end rot develop. Watering extensively after a dry period may cause a sudden growth burst resulting in cracking of the fruits. For maximum yield, adequate water levels need to be maintained throughout fruit development. Soil type does not affect the amount of total water needed, but does influence frequency of water application. Lighter soils need more frequent water applications, but less water applied per application. Sandy soils may require water at more frequent intervals as water drains off quicker. Soils with adequate organic matter usually have a higher water holding capacity and need less frequent irrigation.

The irrigation method may also have an effect on pests and diseases. Overhead irrigation can increase diseases. The spores of early and late blight in tomato for example, can easily germinate when the leaves are wet. The use of ditch or furrow irrigation is usually preferred to overhead irrigation. Furrows also ensure rapid drainage of excess soil moisture during the rainy season.

Some management practices are useful to keep foliage dry and to prevent spread of water-borne pathogens:

- planting in wide rows arranged to increase air flow between rows;
- orienting rows towards prevailing wind;
- irrigate early enough to give plants a chance to dry before night;
- work with plants only when leaves are dry.

If irrigation is important, equally important is drainage, as tomato does not stand waterlogging. Seed and seedlings are likely to rot in wet soil. As already mentioned, when the soil tends to stay too wet, growing the plants on raised beds may help.

Rotation

As for other crops, also in case of tomato a proper rotation is necessary to avoid build-up of pests and pathogens and, to less an extent, to avoid nutrient deficiency and degradation of soil fertility. Tomato shares most of the pests and diseases with the other common solanaceous crops (i.e. tomato, potato, pepper, chili, eggplant), so these must be avoided in the rotation; however, it also shares several with cucurbits (cucumber, gourds, melons, pumpkins, zucchini), so the choice of crops to rotate with may be limited. The usual crop rotation adopted by Eritrean farmers includes cereals/pulses/tomato and will be effective against some of the common pathogens (e.g. early blight and mosaic virus), but not against others which have a very broad range or can survive for a very long time in the soil even in the absence of a susceptible host (e.g., *Sclerotinia sclerotiorum* can survive for up to 7 years, while *Fusarium* and *Verticillium* can survive even longer).

Section activities

5.1 - Test for seed germination

A seed can only germinate when the embryo is viable, when the food reserves are sufficient, and when water and oxygen are available. Immature fruits usually contain undeveloped embryo's that are not viable. Viable seed from mature fruits can lose its viability when it is stored improperly. Generally speaking, seeds should be kept under low temperature and low humidity conditions. When conducting the experiment described below, it must be kept in mind that the method using tissue paper is faster than sowing seeds in soil and monitoring emergence of seedlings, but also could give an overestimation of the percentage germination and seedling emergence in soil.

Objective

To estimate the germination capacity of seeds.

Duration of exercise *(indication)*

½ day to set up, and about 1 week monitoring.

Materials needed

- Tissue paper (chemical-free)
- Seed lots of tomato (or other vegetable crops; one seed lot per group of participants)
- Plastic bags
- Clean water

Procedure (refer also to picture 5.4)

Count 100 seeds of the seed lot assigned. Prepare two layers of tissue paper and carefully sprinkle clean water on the tissue. The tissue should be moist but not soaking wet. Position the 100 seeds on the tissue paper in 10 rows of 10 seeds each (distance between seeds about 2 cm). The seeds will stick on the moist tissue. Cover the seeds with another layer of tissue and also moisten the top tissue layer. Loosely roll up the tissue with the seeds into a 'sausage'. Insert the roll into a clear or black plastic bag, to contain humidity (most vegetable seeds germinate best in a dark environment and usually a black plastic bag is preferred). Carefully label the bag, to avoid confusion, with name of group, seed lot and date of "sowing". Close the bag, but leave some air inside. Keep the bag in a shady place.

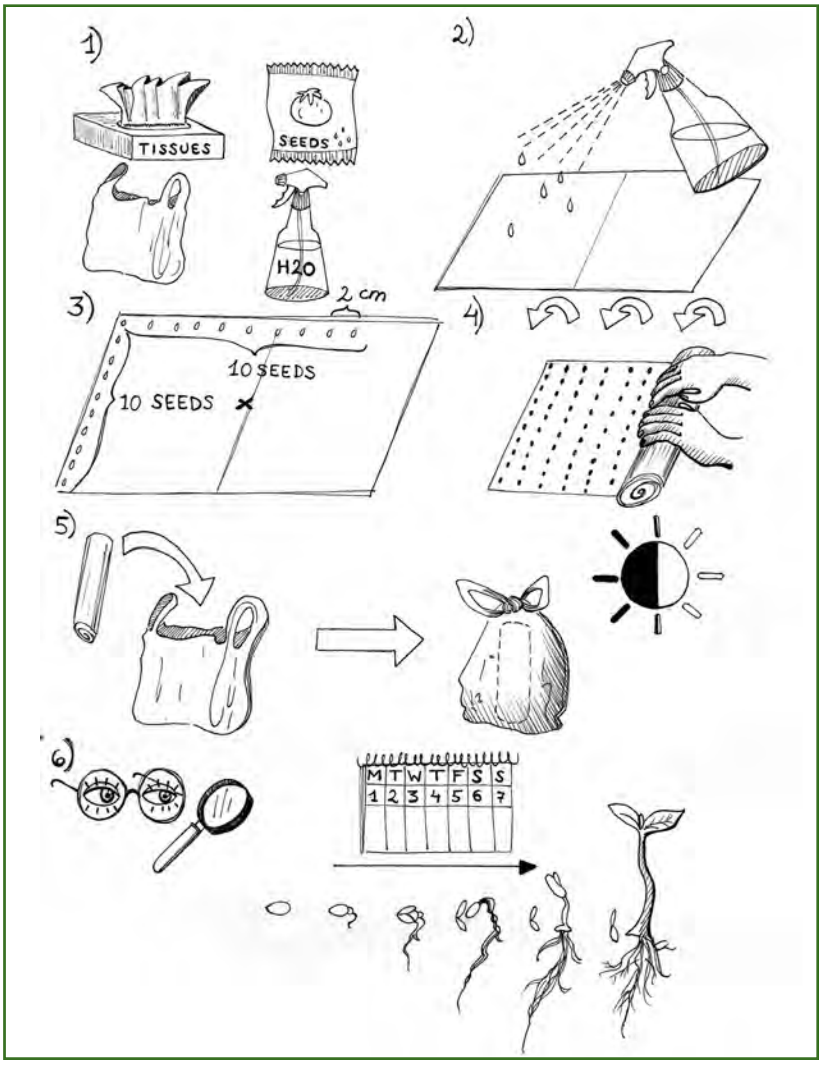
Observations

Depending on the vegetable crop, germination can be observed after 1, 2, or more days. Note the number of germinated seeds. After observation (remove the germinated seeds), roll up the tissue and reinsert into the plastic bag for further (daily) observations. After one week, or longer if desirable, results can be summarized in a bar graph (horizontal: days after 'sowing'; vertical: cumulative percent germination) on poster paper and presented per group.

Discussion

How long did the seed take to germinate?
How many of the seeds germinated? Is this low or high?
Why would farmers want to know the germination capacity of seeds?

Note: The seed lot could be inserted into a jar or bucket of water to see whether or not some seeds sink and others float. If so, it is expected that floating seeds are not filled well and may not germinate as readily as the sinking seeds. In that case, the exercise could be used to compare the seed germination of floating seeds and the germination of sinking seeds: separate the sinking from the floating seeds and prepare separate sausages for each sub-lot.



5.4 - Procedure for testing seed germination (drawing by Gabriela Rovesti)

5.2 - Use of healthy seed

Vegetable farmers often multiply seeds of fruit vegetables, such as hot pepper, okra, eggplant and beans, by themselves. There are various methods observed: some farmers select healthy plants and only use fruits for seed processing from those plants, some farmers select healthy fruits only after harvesting, some farmers buy ripe fruits at the market and process seeds from those fruits, some farmers use waste of restaurants (e.g. after preparation of chilli sauce) as their source of seeds. This exercise shows that the fruit health has an effect on seed germination and health and therefore indicates that there is a need for careful selection of fruits for seed multiplication.

Objective

To study the effect of use of seed-borne disease infected fruits on the vigor and health of seedlings.

Duration of exercise *(indication)*

1 day to set up, and 4 to 8 weeks monitoring.

Materials needed

- Ripe, infected fruits (e.g. Tomato fruits heavily infected with early blight, or hot pepper fruits with anthracnose or TMV)
- Ripe, healthy fruits of the same crop
- Two trays or wide pots filled with clean (if possible sterilized) sub-soil/compost/sand mixture

Procedure

Take the seed from the heavily infected fruits. Observe the seeds. Sow 200 seeds in one tray or pot and label "Infected seed". Take the seed from the healthy fruits. Observe the seeds. Sow 200 seeds in the other tray or pot and label "Healthy seed". Irrigate the trays or pots regularly and apply additional nutrients when needed.

Observations

Weekly observe the number of seedlings growing in each tray or pot and assess the percentage germination per treatment. After 4 to 6 weeks, observe any leaf spots, damping-off or other abnormalities on the seedlings in both treatments. Carefully remove 25 seedlings from each treatment and measure root and shoot length.

Discussion

Was there a difference between the shape or color of healthy seeds and the infected seeds?
Was there a difference in germination between the treatments?
Were there any abnormalities during growth of seedlings in the different treatments?
What would happen with the seedlings after transplanting in the field?
Why should the use of diseased seeds be avoided?

This exercise can be modified in the case of fruit spots/rots using healthy, slightly infected, moderately infected and heavily infected fruits. Sow each seed lot in a different pot and monitor emergence and health of seedlings.

5.3 - Effect of hot water seed treatment

This exercise is applicable only to vegetable crops that are susceptible to seed-borne diseases, such as tomato early blight, bacterial leaf spot on hot pepper or black rot on white cabbage. Do not use pre-treated (coated) seeds. The treatment may reduce germination of the seed and should be done very carefully. The temperature and timing indicated refer to tomato seed and may have to be adapted for other vegetables.

Objective

To demonstrate the effect of hot water treatment on seed-borne diseases.

Duration of exercise *(indication)*

1 day to set up, and 4 to 8 weeks monitoring.

Materials needed

- Seeds extracted from infected fruits (e.g. Tomato fruits heavily infected with early blight, or hot pepper fruits with anthracnose or TMV)
- Thermos flask with warm/hot water (50 °C)
- Thermometer
- Two trays or wide pots filled with clean (if possible sterilized) sub-soil/compost/sand mixture

Procedure

Count two groups of 200 seeds each. Heat the water and pour it into the thermos flask. Allow the water to cool to 50-52 °C (measure with the thermometer), then dip 200 seeds in the thermos flask and leave them in the hot water for 25 minutes. Remove the seeds and let them air-dry. Sow the 200 hot-water-treated seeds in one portion of the seed bed. Label the plot "hot water treated seed". Sow the 200 untreated seeds in the other portion of the seed bed. Label "untreated seed". Apply irrigation and other nursery practices following farmers' practices. Do not apply any pesticides. If needed, construct a cage with a screen net to keep insects out.

Observations

After 4-5 weeks, observe the number of seedlings growing in each treatment. Calculate the percentage germination per treatment. Observe any leaf spots or other abnormalities in both treatments.

Discussion

Was there a difference in germination between the treatments?
Were there any abnormalities during growth of seedlings in the different treatments? Were there any leaf spots in the nursery? If so, where did it come from?
What other seed treatments do you know and could be tested in a similar way?

5.4 - Solarization of the seed bed

Solarization is a method that uses the heat released by sunlight to pasteurize the superficial layer of the soil. It can kill nematodes, soil borne diseases, and insects, reducing their negative effect on the plants. To be effective, it must be done during periods of high solar radiation.

Objective

To study the effect of solarization of the seed bed in relation to seedling growth and vigor.

Duration of exercise *(indication)*

1 day to set up, 6 weeks waiting time and 4 to 5 weeks monitoring.

Materials needed

- Seed bed in a vegetable field (untreated soil)
- Polyethylene film (possibly black, 50-100 μm thick. Make sure it has no holes in it)
- Tomato seeds

Procedure (see also picture 5.5)

Prepare a seed bed of about 2 x 5 m^2 according to farmers' practices, including harrowing and fertilizing. Remove plant material and other wastes from it. Make sure that the seed bed is level, in order to avoid water flow from one

part to another of the bed. Divide it in two plots of 2 x 2.5 m^2 each. Irrigate one plot and apply the plastic film, securing it along the borders by burying all four edges of the plastic well into the soil so that no heat can escape from underneath the plastic. Leave the other half of the seedbed fallow (control). Record the weather during the following weeks (sunny/cloudy/rain).
After 4 weeks, remove the plastic and work the soil again. Cover with the plastic film as described above and leave covered for 2 more weeks. Sow 200 seeds in each plot. Apply normal irrigation and other nursery practices (not spraying!) during the seedling raising period. If needed, construct a cage with screen net to keep insects out.

Observations

At removal of the plastic, check the plastic in the solarization plot for holes. Record in case there are holes (these will negatively influence the effect of the solarization). After 4 to 5 weeks, record total number of seedlings, seedlings with signs of diseases and number of weeds.
Calculate the overall percentage of healthy seedlings. Randomly uproot 25 seedlings per treatment. Assess the average number of leaves per seedling, measure root length and possible presence of problems (e.g. nematode galling).
Prepare presentations in the form of an agro-ecosystem analysis poster with, per treatment, a drawing of a seedling and all the data grouped around the seedling.

Discussion

What are the differences between the two treatments?
Was there difference in seedling growth and health? Why?
What is the cost and labor needed for the solarization?
What will happen to the beneficials (incl. natural enemies) in the topsoil?
What are other advantages and disadvantages of the treatment?

5.5 - Solarization of test plots

5.5 - Topsoil burning

Topsoil burning is widely practiced in several countries to kill nematodes and weed seeds in the upper soil. It should be noted however that a substantial amount of slow-burning but high-temperature output material is required on the soil surface to have sufficient penetration of heat into the soil. Therefore, wood chips would be preferred above grass and a 5 cm thick layer of rice husks above a 15 cm layer of rice straw.

Objective

To study the effect of topsoil burning in the seed bed in relation to seedling growth and vigor.

Duration of exercise *(indication)*

1 day to set up, and 4 to 8 weeks monitoring.

Materials needed

- Seed bed in a vegetable field (untreated soil)
- Dry rice husk or wood chips
- Tomato seeds

Procedure

Prepare a seed bed of about 2 x 5 m^2 according to farmers' practices, including harrowing and fertilizing. Divide it into two plots of 2 x 2.5 m^2 each. Make sure that the seed bed is level, in order to avoid that water flows from one plot to the other. In one plot, apply an even layer (about 5 cm thick) of dry rice husks or wood chips. Burn the layer (this will take an hour or more). Leave the bed to cool down. Sow 200 seeds in each plot. Apply normal irrigation and other nursery practices (not spraying!) during the seedling raising period.

Observations

After 4 to 5 weeks, record total number of seedlings, seedlings with signs of diseases and number of weeds.

Calculate the overall percentage of healthy seedlings. Randomly uproot 25 seedlings per treatment. Assess the average number of leaves per seedling and measure root length and possible presence of problems (e.g. nematode galling). Prepare presentations in the form of an agro-ecosystem analysis poster with, per treatment, a drawing of a seedling and all the data grouped around the seedling.

Discussion

What are the differences between the different treatments?
Was there difference in seedling growth and health? Why?
What is the cost and labor needed for the topsoil burning?
What will happen to the beneficials (incl. natural enemies) in the topsoil?
What are advantages and disadvantages of the treatment?

5.6 - Raise seedlings in a screen cage (picture 5.2)

In order to protect seedlings from insect pests, it is advisable to cover them with a screen cage. This will also provide shade (avoid too much shade) for the seedlings. The cage can also be provided with a roof to protect the seedlings from excessive rainfall. However, care should be taken not to shade the seedlings too much as elongated and etiolated seedlings may not survive the transplanting shock in the field.

Objective

To avoid infestation from insects and infection with insect-vectored viruses during the nursery phase.

Duration of exercise *(indication)*

1 day to set up, and 4 to 8 weeks monitoring.

Materials needed

- Wood sticks or bamboo to construct the cage frame
- Muslin or cheesecloth (fine mesh, aphid-proof); the mesh known as "shash" in Eritrea is a good option)
- Healthy tomato seeds
- Soil medium, preferably a mixture of subsoil, sand and compost or manure

Procedure

Choose a location for the nursery with good access to irrigation. Till a small plot of land (1.5 x 2.5 m) very finely, removing stones and plant material. Apply alluvial soil, sand and compost, then thoroughly mix with the top soil. Prepare a raised seed bed measuring 1 x 2 m and divide it into two identical parts. Using a watering can, water very gently to avoid erosion of the seed bed. In each part, sow the tomato seeds in rows about 10 cm apart and cover with 1 cm of light, sieved soil. Slightly water again. Using the sticks and the "shash" cloth, make a cage above one of the two parts of the seedbed, about 1 m high. Make sure that there are no holes in the screen and bury the edges of the screen into the soil so that insects cannot enter the cage. Label one plot "uncovered seed bed" and the other plot "screen covered seed bed". The seed beds may be mulched with fine straw or rice husks to maintain humidity; after germination, the mulching should can be removed. Irrigate regularly (from above the cage) and apply nutrients according to local farmers' practices. Do not apply any pesticides. Towards the end of the nursery phase, about 4 days before planting, the screen cage should be removed in order to harden the young plants.

Observations

Observations can be conducted after 4 to 5 weeks by counting seedlings ready for planting. Randomly choose 25 seedlings and count leaves per seedling and measure seedling height. Count seedlings with damage on their leaves, presence of whiteflies, aphids or other symptoms. Record symptoms. Calculate the percentage of successfully raised seedlings, average number of leaves per seedling, average seedling height, percentage of seedlings infested by leafminers, whiteflies or and other pests/diseases.

Discussion

What were the differences between the nurseries? Are any insects or diseases present?
What will happen with the plants after transplanting in the field (survival rates)?
What is the difference in labor intensity between the two treatments (try to quantify)?
Would the screen-covered nursery be cost-effective?

5.7 - Raised plant beds to reduce disease incidence

Many diseases have a higher incidence in fields with a bad soil structure and poor drainage. Improvement in drainage can help reduce the problem. In this trial, the use of raised plant beds is tested in relation to the incidence of diseases.

Objective

To test the effect of changes in soil structure/drainage on diseases.

Duration of exercise *(indication)*

1 day to set up, and 4 to 8 weeks monitoring.

Materials needed

- Vegetable field with a history of diseases
- Hoes, spades and other tools to work the soil
- Tomato seedlings

Procedure

In an area of the field with poor drainage or where diseases have been frequently observed, prepare two plots of 2 x 4 m: one plot level and the other plot with raised, small windrows 15-30 cm high. Plant the seedlings and raise the crops in each plot using common farmers' practices, including regular watering during dry periods.

Observations

Weekly observe both plots and record numbers of wilted or diseased plants. Pull out the wilted plants and study the root system. Record any abnormalities on the roots. After 1 or 2 months, pull out all the remaining plants and study the roots. Measure and compare the root length in both plots. Also measure and compare the plant length in both plots.

Discussion

Was there a difference in disease incidence between both plots?
Was there a difference in root length in both plots? Why?
Was there a difference in plant length in both plots? Why?
What other measures could improve drainage and/or reduce disease incidence?

PART 6
Adversities of tomato

A number of pests and diseases, as well as some physiological disorders, affect the tomato plant. Some pests occur all over the world, while others are found only in specific geographical areas. Likewise, some are present throughout the growing season and can affect any growth stage of the tomato plant, while others cause damage only – or mainly – during certain stages of development of the crop. The level of damage they cause will also depend on the tomato variety grown and other elements of the ecosystem like natural enemies, weather conditions, fertilizer, water availability and so on. The following table 6.1 summarizes the pests and diseases that – based on the information provided by local specialists – are of main concern for Eritrean tomato growers, with an indication of the vegetative stage when they are more likely to occur. Please note that this is just a broad indication and the importance of these pests may vary in different regions within the country.

These pests and diseases are described in the rest of this section. For each pest, a list of recommended pesticides is provided in Annex II. To this regard, three important aspects should be noted:

1. the central column of the annex lists the recommended pesticides – amongst those which are currently authorized for use in Eritrea – which in the author's opinion represent the most suitable options for use by small farmers. These recommendations take into account not only the efficacy of a given pesticide, but also its acute toxicity for humans and the environment and their suitability to be included in an IPM programme;
2. the last column (on the right hand side of the annex II table) includes a list of pesticides which, in the author's knowledge, are successfully used in other countries for the control of a given pest or disease. Their inclusion in the table is NOT a recommendation to their use at present, but is simply meant as an additional information to be taken into account if and when these pesticides become registered by the Ministry of Agriculture of Eritrea. NO UNREGISTERED PESTICIDE SHOULD BE USED;

3. the chart in Annex V lists all pesticides authorized for use in Eritrea at the time of writing of this manual. The number which appears in the square next to each pesticide (active ingredient) indicates the mode of action (MoA) group to which that pesticide belongs. To prevent or at least slow down development of resistance by pests and pathogens, it is important that farmers alternate pesticides with different MoA or, in other words, they must avoid applying repeatedly the same pesticide or pesticides characterized by the same number.

Table 6.1 - Susceptibility of tomato growth stages to pests and diseases

Pest \ Growth stage	*seedling*	*vegetative*	*flowering*	*fruiting*	*harvesting*
Damping-off	●				
Anthracnose				○	●
Powdery mildew			●	●	●
Late blight	○	●	●	●	●
Early blight	●	●	●	●	●
Virus		●	●	●	●
Root knot nematodes	○	○	○	○	○
Cutworms	●	○			
Aphids	○	●	●	○	○
Whiteflies	○	●	●	○	○
Vegetable leafminer	○	●	●	●	●
African bollworm		○	●	●	●
Tomato leafminer	○	○	●	●	●
Spider mites			●	●	●
Blossom end rot				○	○

● main pest occurrence

○ pest occurs to lesser an extent

Aphids

Common and (*scientific name*)

Cotton aphid (*Aphis gossypii*), potato aphid (*Macrosiphum euphorbiae*), foxglove aphid (*Aulacorthum solani*), green peach aphid (*Myzus persicae*).

Importance

Aphids are considered a major pest of tomato in Eritrea. *A. gossypii* is usually the species mentioned, but the other species are presumably also present.

Other host crops

Capsicum, chilli, eggplant, potatoes, etc.

Description

- **Egg:** In most cases aphids reproduce by giving birth to live young. When they produce eggs, these are elliptical in shape but too small to be seen in the field.
- **Immature:** Immature aphids resemble the adults, but have no wings.
- **Adult** (pictures 6.1 and 6.2): Aphids are soft-bodied insects with six legs. They are small in size (ranging from 1-2 or 2-3 mm, depending on the species). They can have wings or not, depending on the stage of their life cycle. The body colour varies (shades of yellow, green pink or black) between species and also within each species, depending on development stage and environmental conditions.

Damage

The direct damage caused by the aphids sucking the plant sap, is not a major concern unless the infestation is very heavy. Indirect damage is caused by the production of a sticky liquid (known as honeydew) on which sooty moulds may develop (picture 6.3), causing a reduction in plant vigour and also cosmetic damage to the fruits. Aphids can also transmit plant viruses when they feed (e.g. tomato yellow top viruses), although specifically in tomato this is not as big a problem as with the tobacco whitefly, *Bemisia tabaci*.

Detection: Aphids preferentially feed on the underside of leaves and on the soft growing tips. Infested plants may show signs of curling, wrinkling or cupping of leaves. Aphids are often attended by ants, therefore ants walking on the foliage may be an indication of the presence of aphids (or of other sap-sucking insects).

Beneficials

Aphids are attacked by many predators and parasitoids, including ladybirds, lacewings, hoverflies and parasitic wasps.

Management

- Monitor incoming winged aphids using yellow traps (sticky or water-pan). Monitor the crop from bloom to fruit set by checking especially the underside of leaves. A treatment may be warranted if aphid population is increasing and beneficial population is not.
- Tomato plants can usually withstand a small population of aphids without any yield loss and beneficial insects may keep populations under control if they are not sprayed with broad-spectrum insecticides.
- Remove weeds hosting aphids.
- Intercropping tomato with strong-smelling plants such as garlic, onion and parsley is said to reduce aphid infestation.
- Avoid planting near an aphid-infested crop.
- Spraying with soapy water or a detergent solution can control aphids. Avoid the use of highly concentrated solutions (>1:20), as they may cause phytotoxicity.
- Overhead irrigation may hinder the development of the aphid population (but is likely to cause plant pathogen problems). Under moist conditions, insect-pathogenic fungi can cause a significant reduction of the aphid population.
- Apply insecticides if aphids are causing significant damage or if incidence of aphid-transmitted virus is usually a problem. Prefer selective insecticides, to minimise harmful effects to beneficial organisms. Refer to annex II for recommended active ingredients.

6.1 - Juveniles and adults of A. gossypii

6.2 - Juveniles and adults of M. euphorbiae

6.3 - Sooty mold on tomato fruits

African bollworm

Common and (*scientific name*)

African bollworm, cotton bollworm, tomato fruitworm (*Helicoverpa armigera*)

Importance

It is a key pest of tomato in Eritrea.

Other host crops

Peppers, eggplant, beans, lettuce, sweet corn, etc.

Description

- **Egg:** Rounded, 0.5-1 mm in diameter, are laid individually on the plant. Eggs change colour as the embryo develops, turning from a white or off-white colour to yellow then orange and brown just before hatching.
- **Larva:** Newly emerged larvae are 1.5 mm long, hairy, and cream to reddish-brown in colour with a dark-brown head. Fully grown larvae are ca 30-40 mm long and their colour is extremely variable (pictures 6.4 and 6.5) with shades of green, straw-yellow, and pinkish- to reddish-brown. Larvae have distinct lateral stripes and visible hairs.
- **Adult:** Stout-bodied moth of typical noctuid appearance, 14-18 mm long and with 3.5-4 cm wing span. The colour is variable, but males are usually greenish-grey while females are orange-brown (pictures 6.6 and 6.7).

Damage

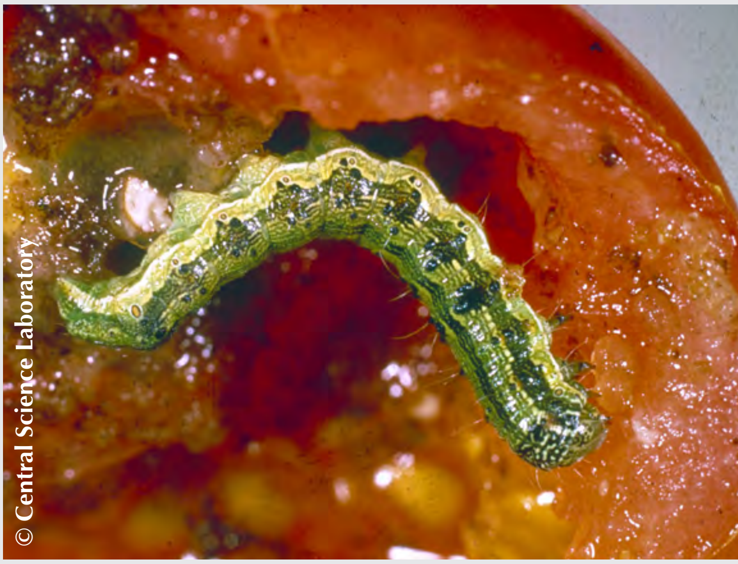
The larvae feed on leaves, flowers and fruits. The damage on leaves is usually not important on well-developed plants, while the attack on the fruits may cause them to drop or in any case causes blemishes and creates entry holes for disease and rots (picture 6.8). Once inside the fruits, the larvae cannot be reached and killed by the treatments.

Detection

All instars can be found over the plant canopy. When feeding, larvae like to be protected and are found mostly in hidden areas of the foliage or burrowed into the fruits.

Beneficials

Both eggs and larvae are parasitised by various parasitic wasps (e.g. *Trichogramma* in case of eggs, *Cotesia* in case of larvae). Both eggs and larvae



6.4 - H. armigera larva

6.5 - H. armigera larva

6.6 - H. armigera female

6.7 - H. armigera male

are also fed upon by a range of generalist predators including predatory bugs, wasps, beetles and spiders.

Management

- Monitor moth activity using pheromone traps if available, if not light traps can be used. When moths are being caught in the traps, begin sampling leaves for eggs and small larvae.
- In small plots, remove eggs and larvae by hand.
- Apply sanitation, by destroying infested fruits and plants (e.g. by composting). Sanitation must also be applied to the plots of other susceptible crops. Note that crop rotation would only be effective if applied on very large areas, as the adults of this pest are very mobile.
- If required, apply insecticide sprays targeting the very young larvae, before they bore into the fruits. When possible, use selective insecticides such as *Bacillus thuringiensis* (Bt). Note that *H. armigera* has developed resistance to pyrethroid and carbamate insecticides. Refer to annex II for recommended active ingredients.
- Cultivate soil to a depth of 10 cm after harvest, to expose and kill the pupae and help reduce carryover between crops.

6.8 - Damaged fruits

Tomato leafminer

Common and (*scientific name*)

Tomato leafminer (*Tuta absoluta*)

Importance

It is a key pest of tomato in Eritrea.

Other host crops

Peppers, eggplant, potato, and a number of other cultivated and wild solanaceous plants (however, tomato is by far the preferred host).

Description

- **Egg:** The eggs are cylindrical and very small (approx. 0.3 mm long), difficult to see with the naked eye. They are found mainly on the underside of young leaves, but also on new stems and on the calix of young fruits. Their colour is initially creamy-yellow, darkening as the embryo develops and becoming almost black near eclosion.
- **Larva:** Newly hatched larvae are very small in size (0.5 mm) and yellowish in colour. As they grow, they turn yellow-green, with a black band behind their head (picture 6.9). Fully-grown caterpillars measure 8-9 mm and have a pinkish colour on their back.
- **Adult:** *T. absoluta* adults are small (5-7 mm long), grey-brown moths with black spots on the forewings (pictures 6.10 and 6.11). Males are somewhat darker than females. They are nocturnal and during the day usually hide within the leaves, mostly on their underside, moving away very fast if disturbed.

Damage: The larvae can infest any part of the plant above the ground. They prefer leaves and stems, but may also attack the fruits (pictures 6.12 and 6.13), where they may be found underneath the crown and even inside the fruit. Larvae can also form extensive galleries in the stems, which affect the development of the plants. The newly hatched larvae attack only green fruits, usually penetrating in the calix area (picture 6.14), while the larger larvae that exit from leaf mines can attack also maturing fruits. Their entry-ways

6.9 - Larva of T. absoluta

6.10 - T. absoluta adult on a tomato branch. Note the small size

6.11 - Close-up view of a T. absoluta moth usually facilitate the infection by secondary pathogens, leading to fruit rot. The continuous development of this pest results in its presence in the crop throughout the growing season.

6.12 - Typical mines on leaf

6.13 - Damage on fruit

6.14 - Penetration hole under the fruit calix

Detection

The most distinctive symptom of the presence of the pest are the blotch-shaped mines in the leaves. Inside these mines, both the larvae and their dark frass can be seen (observe against a source of light; picture 6.15). In case of heavy infestation, leaves may die off completely. On fruits, small heaps of excrement are often found near the entrance hole. Pheromone traps are a reliable tool for timely detection of the male moths (pictures 6.16, 6.17). Light and blue light traps are also effective, but their use is limited by the need of a power supply.

Beneficials

T. absoluta has several natural enemies, including parasitoids (*Trichogramma spp., Apanteles* spp., *Cremastus sp.)* and predators (*Chilocorus sp., Nesidiocoris spp.)*. However, under commercial conditions their action is usually not sufficient to keep the damage by the pest within acceptable limits.

Management

- Monitoring and mass trapping: use chromotropic, pheromone or light traps. Chromotropic traps can be of the sticky type or the water-pan type. The latter should be filled with soapy water or water with a thin layer of oil on top. While the yellow colour is often used, various experiences in Latin America seem to indicate that black traps are more effective and that their horizontal placement is more effective than hanging them vertically (OIRSA, 2015). Chromotropic traps are more effective during the initial development of the crop, when the vegetation is still reduced. Place the traps (10 every 1000 m^2) 30 cm above the plants and raise them as they grow. Light traps are effective, but have the disadvantage that they attract many types of insects, including beneficial ones. There are two peak times for capturing the adult moths: i.e. the first 3 hours after dusk and the last 3 hours before dawn. Pheromone traps can attract the male moths only by the use of the pheromone attractant, or by complementing it with an attractive colour (see chromotropic traps). For mass-trapping, use 4-5 traps/1 000 m^2 of crop.

- Remove all wild Solanaceous and other host plants.
- Use exclusion screening in seedling nurseries and make sure to use clean transplants.
- Avoid planting next to an already infested plot.
- During cultivation, if the pest occurs in hot spots, remove infested leaves and fruits and destroy them.
- According to some studies, dustable sulphur applied weekly appears to have a repellent effect on oviposition.
- Immediately after the last harvest, apply sanitation by destroying the rests of the crop (e.g. by composting or ploughing them in). Sanitation must also be applied to the plots of other susceptible crops, if infested. Note that the adults of this pest are very mobile and crop rotation would only be effective if applied on very large areas.
- Cultivate the soil to a depth of 10 cm after harvest to expose and kill the pupae and help reduce carryover between crops.
- If required, apply insecticides. Effective chemical control is difficult because *T. absoluta* larvae feed inside the plant tissues. Besides, this pest has high reproduction capacity and short generation cycle, thus a higher ability to develop resistance to insecticides. This risk increases significantly when management relies exclusively on chemical control with a limited number of effective insecticides available, therefore rotation of suitable active ingredients is of paramount importance. Resistance of *T. absoluta* has been reported for organophosphates, pyrethroids, abamectin, cartap, chlorantraniliprole, flubendiamide, permethrin and spinosad. Refer to annex II for recommended active ingredients.

6.15 - Young larvae feeding inside leaf mines

6.16 - Pheromone sticky trap

6.17 - Tuta adults caught in water trap

Whiteflies

Common and (*scientific name*)

Tobacco whitefly, cotton whitefly (*Bemisia tabaci*).

Importance

It is an important pest of tomato in Eritrea.

Other host crops

Peppers, eggplant, sweet potato, beans, cucurbits, and a range of weeds.

Description

- **Egg:** The eggs are elliptical, very small (0.2 mm long) and are mostly laid on the underside of leaves. They are initially yellow-green in colour, to then gradually turn light brown.
- **Larva:** The larva that emerges from the egg is initially mobile, but soon loses its ability to move and feeds sedentarily by sucking sap on the underside of the leaf. The larvae of the different instars are glassy and yellowish, with a flattened scale-like body. Eventually, it originates a pupa which is rather flat and transparent and in whose interior it is possible to observe the forming adult (yellow in colour, with red eyes and white wing buds) (picture 6.18). The pupa is the instar which more easily permits to distinguish between this species and *Trialeurodes vaporariorum*, which presumably is also a pest of tomato in Eritrea, although not as important.
- **Adult:** Approximately 1 mm long, has a moth-like appearance with white wings (picture 6.19).

Damage

Whiteflies suck sap from the plant and heavy infestations can result in poor growth, leaf yellowing and loss of plant vigour. Honeydew is also produced, that encourages sooty mould growth, which further reduces plant vigour. However, this pest is mostly feared because it is a vector of several important plant viruses, e.g. the yellow leaf curl virus.

Detection

Adults and nymphs are normally found feeding on the underside of leaves (picture 6.20). Yellow sticky traps can be used for early detection of the adults.

Beneficials

Parasitoid wasps (e.g. *Encarsia spp.*, *Eretmocerus spp.*), predatory mites, predatory thrips and lacewings.

Management

- Monitor by routinely checking field margins for whiteflies, as these areas are usually infested first. Be especially

6.18 - Larvae and pupae of B. tabaci

6.19 - Close-up view of
***B. tabaci* adults**

6.20 - Leaves infested by
B. tabaci

alert for the rapid migration of whiteflies when nearby host crops are in decline. Yellow sticky traps may be useful in detecting initial whitefly infestation.

- Use whitefly exclusion screening in seedling nurseries and make sure to use clean transplants.
- Do not plant a new crop next to one which is infested.
- Remove plants that show virus signs and destroy crops after harvest to reduce virus transmission within the crop or to neighbouring crops.
- Immediately after the last harvest, apply sanitation by destroying the rests of the crop (e.g. by composting or ploughing them in). Sanitation must also be applied to the plots of other susceptible crops, if infested. Note that the adults of this pest are very mobile and crop rotation would only be effective if applied on very large areas.
- Spraying with soapy water or a detergent solution can control whiteflies. Avoid the use of highly concentrated solutions (>1:20), as they may cause phytotoxicity.
- If required, apply an insecticide but try and avoid broad-spectrum ones, especially early in the season. Systemic insecticides will work best. Note that *B. tabaci* has developed resistance to several insecticides and rotation of active ingredients is very important. Refer to annex II for recommended active ingredients.

Cutworms

Common and (*scientific name*)
Cutworms (*Agrotis spp.*).

Importance
Their importance is mainly for the damage they can cause in nurseries, not so much in the field.

Other host crops
Peppers, eggplant, brassicas, cucurbits, carrots, lettuce, maize, etc.

Description
- **Egg:** Eggs are laid in clusters close to the soil on crop leaves or weeds. They are rounded (approximately 0.5 mm in diameter) and initially whitish in colour, but turns brown with age.
- **Larva:** Depending on the species, fully grown larvae can range from 25 mm to 50 mm in length. Their colour can vary, but are usually a dark greyish brown and with a smooth cuticle (picture 6.21). Larvae curl into a distinct 'C' shape when disturbed. Older larvae are not easily seen, as they hide in the soil during the day and only emerge at night to feed.
- **Adult:** Moths are stout bodied with dark-coloured forewings and pale hindwings (picture 6.22); their wingspan is 40 to 50 mm. They are active at night and select preferentially low-growing broadleaf plants for oviposition.

Damage
Young larvae may feed on leaves and cause small holes, but after some days they drop to the ground, from where they emerge only at night for feeding. Older larvae cut seedlings off at ground level, causing the plant to fall over and die (picture 6.23). They may drag the end of the cut seedling into the soil, to feed on it during the day. Sometimes it is possible to see wilting seedling that have been incompletely cut. Often the same larva cuts various seedling next to each other. The damage usually appears in a sudden way and is often associated with the presence of weeds or large amounts of plant residues in the field, or in field with poor drainage. Later in the season these pests can also injure tomato fruits touching or close to the ground.

6.21 - *A. ipsilon* larva

6.22 - *A. ipsilon* adult

6.23 - Cutworm larva and damage

6.24 - A. ipsilon pupa

Detection

Cutworms can be seen feeding in the evening or at night. During the day, larvae may be found in the soil at the base of cut plants. If the species present in a given area is known, pheromone traps can be used to monitor the presence of male moths. Pupae are often seen when removing the soil (picture 6.24).

Beneficials

Eggs can be parasitised by *Trichogramma* spp. and *Telenomus* spp. Predatory beetles feed on larvae when in soil.

Management

- Prepare the soil and eliminate weeds a few weeks before planting.
- Long fallow periods before planting reduce infestation.
- If cutworms are a recurrent problem, use bigger transplants as they are more resistant to the attack.
- After planting/seeding, visually monitor the new seedling for egg masses and feeding damage.
- In small plots, infestations can be controlled by digging around the cut plants and killing the larvae present, or removing egg masses from the plants.
- Because cutworm damage is often localized within a field, replanting damaged seedlings in the affected areas might be more economical than treating the whole field.
- If insecticides are required, spray at night when the larvae are more active. Persistent insecticides are commonly applied to plants and soil surface for cutworm suppression. Larvae readily accept baits made with insecticide-treated bran (e.g. using carbaryl). Systemic insecticides applied to the seeds also provide some protection to the seedlings. Refer to annex II for recommended active ingredients.

Vegetable leafminer

Common and (*scientific name*)
Leafminer (*Liriomyza trifolii;* other species may be present).

Importance
It is a common pest in Eritrea, although usually does not represent a major problem on tomato.

Other host crops
Peppers, eggplant, beans, peas, and several other vegetables and weeds.

6.25 - Larvae feeding inside its mine

6.26 - Adult of Liriomyza fly

Description
- **Egg:** Eggs are very small and are laid within the leaf tissue. Several eggs can be deposited in a single leaf.
- **Larva:** It is legless, almost cylindrical in shape although slightly pointed at the head end (the head is not clearly distinguishable). Initially the larva is colourless, but becomes yellowish as it matures. The larva feeds within the leaf tissue, making an irregular tunnel known as a “mine” (picture 6.25). When fully grown, the larva usually exits its tunnel and drops to the soil where it pupates. Only occasionally they may pupate within the leaf mine.
- **Adult:** Small (about 2 mm long), shiny, black-and-yellow flies with reddish eyes (picture 6.26).

Damage
The feeding and laying activity of the adults cause the appearance of whitish spots, or stippling, on the leaves (picture 6.27). This may damage seedlings if the infestation is heavy. On developed plants, the only significant damage is that caused by the tunnelling of the larvae in the leaves, which reduces the functional leaf area and in case of heavy infestations can cause leaves to dry out and drop (pictures 6.28 and 6.29).

Detection
Early detection of infestation may be achieved by checking leaves for adult activity (“stippling”), or through the use of yellow sticky traps. Counting mines in leaves is a good indicator of past activity, but many mines may be vacant; on the other hand, counting live larvae in mines is accurate but time consuming.

Beneficials
Several different species of parasitic wasps parasitize larvae of *Liriomyza*.

Management

- Monitor the presence of adult flies with the use of yellow sticky traps. Mass trapping could be an option under greenhouse, but not in the field.
- The most important aspect of leafminer management is conserving their natural enemies, which are often killed by broad-spectrum insecticides applied for other tomato pests. Apply insecticides only when really needed and choosing those that are least likely to harm natural enemies.
- Where leafminer damage is expected, use tolerant varieties if available (tomato varieties with curled leaves are less susceptible to leafminer damage).
- Grow seedlings under protective netting and ensure that transplants are free from the pest.
- Remove alternative host weeds in and around the crop.
- Remove or destroy infested crops immediately after harvest. Note that this pest has a wide host range and its adults are very mobile, thus crop rotation would only be effective if applied on very large areas.
- If a treatment is warranted, apply either translaminar or systemic products. Refer to annex II for recommended active ingredients.

6.27 - Adult feeding signs (round spots) and larval mines

6.28 - Multiple mines on a tomato leaflet

6.29 - Damage on tomato leaves

Spider mites

Common and (*scientific name*)

Two-spotted mite (*Tetranychus urticae*; other *Tetranychus* species may be present).

Importance

Spider mites can represent serious pests in areas or periods with hot and dry weather.

Other host crops

Peppers, eggplant, beans, cucurbits, tobacco, etc.

Description

- **Egg:** Eggs are round, minute (0.1 mm) and translucent. They are usually found on the underside of leaves.
- **Larva/nymph:** The nymphs are pale green with darker markings. They are similar to the adult in shape and colour, but smaller (picture 6.30).
- **Adult:** The adult female is 0.6 mm long, pale green or greenish-yellow with two darker patches on the body, which is oval with quite long hairs on the dorsal side. Overwintering females are orange-red in colour. The male has a smaller, narrower, more pointed body than the female.

Damage

The initial symptom of infestation is silvering of the lower leaves, which may become bronze coloured and drop off in the most severe infestations. A close examination of the leaves reveals white spots where the mites have been feeding (pictures 6.31, 6.32). The damage moves up the plant. The stems lose their surface hairs and become shiny, smooth and brown. With high populations, *T. urticae* covers the plant with a fine webbing (pictures 6.33, 6.34). Heavy infestations cause a weakening of the plant. As an indirect damage, fruits may be more susceptible to sunscald due to loss of the leave cover. The development of the mite is greatly favoured by warm and dry weather conditions.

6.30 - Juveniles and adults of T. urticae seen under the microscope

6.31 - Feeding damage on leaflet

Detection

Look for bronzing on the lower leaves, then check them and the leaves immediately above for presence of mites on the underside. Often the infestation starts on the edges of the field, on in patches within the field. When the pest population is high fruits can also be damaged, with white speckling and loss of market value.

Beneficials

Spider mites are fed upon by a range of other predatory mites, including the well-known *Phytoseiulus persimilis and Neoseiulus cucumeris*.

Management

- Spider mites are favoured by dry and dusty conditions. Try to reduce dust (e.g. next to a dirt road) by watering or through a grass cover.
- The use of overhead irrigation will limit the development of the mite population (though, it is likely to favour the development of diseases).
- Staking materials from infested fields must be treated before using them for a new crop.
- Avoid or limit to a minimum the use of broad-spectrum pesticides (e.g. pyrethroids), which kill the natural enemies of the mites.
- Visually monitor seedlings and crops at least weekly for signs of damage.
- When moving between plots, always start from those which are free from the pest and possibly wash hands before moving to a new plot.
- If infestations occur regularly in the same field, make sure to remove alternate hosts such as nightshades and morning glory.
- Do not plant next to an infested plot, particulary if it is downwind of the old crop.
- Use acaricides if pest pressure becomes too high. Note that mites develop resistance quickly and rotation of active ingredients is very important. Refer to annex II for recommended active ingredients.

6.32 - Heavy damage on leaves

6.33 - Feeding damage and webbing

6.34 - Detail of webbing and mites

Root Knot Nematodes (RKN)

Common and (*scientific name*)

Root Knot Nematodes (*Meloidogyne spp.;* the species *M. incognita* is usually mentioned, but other species are presumably also present).

Importance

RKN can cause significant damage locally, but are not considered a major pest for tomato in Eritrea.

Other host crops

Peppers, eggplant, cucurbits, and a wide array of vegetable crops and weeds.

Description

Nematodes are tiny thread-like worms that live in the soil. They are too small to be seen with the eye. They feed on the roots of many plants, on which they cause small lumps known as knots or galls (picture 6.35). These nematodes spend most of their life inside the galls. After infesting the root, the body of the female changes considerably and – if the gall is sectioned open - they can be seen with the aid of a hand lens as tiny, white pearl embedded in the root tissue.

6.35 - Heavy galling on tomato roots

Damage

The galling caused in the plant roots reduces their functionality and interferes with the absorption of water and nutrients by the plant, whose development is stunted. Infested plants may appear yellow and are prone to wilt in hot weather. Heavily affected plants may eventually die (pictures 6.36 and 6.37). Nematode development is usually favoured by lighter-textured soils and humid conditions. Nematodes can also cause an indirect damage, as their penetration in the roots may facilitate penetration by pathogens such as bacterial wilt and fusarium wilt.

Detection

The most obvious sign of nematode infestation is the presence of the galling on the roots (in leguminous crops, it should not be confused with the nodules caused by the symbiotic *Rhyzobium* bacteria). However, often farmers are more likely to notice the stunted aspect and the wilting of the affected plants. These usually appear in irregular patches in the field.

Beneficials

Like any other living organism, nematodes have natural enemies which can limit their development. However, under commercial conditions their action alone is not sufficient. Some of those natural enemies (e.g. the fungus, *Purpureocillium lilacinum* (syn. *Paecilomyces lilacinus*) have been developed in some countries as biological pesticides.

Management

- Avoid using infested land for susceptible crops. Checking for root galls in the roots

6.36 - Stunted tomato plant, with totally compromised root system

6.37 - Experimental plot showing different degrees of damage by nematodes

of the current crop or even weeds is a simple – though not accurate - way to check for nematodes. If galls are found on any host plant, one can assume that susceptible varieties of tomatoes in the same soil would be infected. On the other hand, absence of root galls on other plants does not necessarily mean the soil is free of nematodes that could injure tomatoes.

- Do not locate seedbeds where susceptible crops have been previously grown, or disinfect the soil with soil solarisation or by burning a fire on it.
- Avoid moving contaminated soil to non-infested plots, by cleaning cultivation implements, boots, etc.).
- Alternate tomato with tolerant (e.g. brassicas, turnip, sweet potato) or resistant (e.g. garlic, onion, maize, millet, wheat) crops.
- Plants with nematicidal properties can be intercropped with tomato, or grown as cover crop, to reduce nematode populations. The incorporation of neem seed cake – if available locally – is also effective.
- Because root knot nematodes feed and multiply on many weed species, weed control is an important aspect of their management.
- Use nematode-resistant varieties, if available (no resistant variety is currently available in Eritrea).
- Use 3-6 months' fallow to reduce nematode populations.
- After harvest, uproot plants and destroy the roots by burning (the aerial part can be composted).
- Incorporate as much organic matter (manure or compost), as that will help reducing the nematode population.
- Nematicides currently available in Eritrea are too toxic to recommend them for use by smallholder farmers.

Damping off

Common and (*scientific name*)

Damping off (*Pythium spp.; Rhizoctonia solani; Fusarium spp. Thielaviopsis basicola; Phytophthora spp.)*.

Importance

It is of primary importance (at nursery level).

Other host crops

Peppers, eggplant, cucurbits, and a wide array of vegetable crops.

Description and damage

"Damping-off" is a general term for the death of seedlings, either before or after emergence, under damp conditions. Seedlings affected by damping-off fail to emerge or fall over and die soon after emergence. Stems usually have a dark, shrivelled portion at the soil level (pictures 6.38, 6.39, 6.40). Damping-off is generally limited to areas where drainage is poor or where soil is compacted, but whole fields can be affected, especially in early plantings exposed to rain. It is mainly an early season problem, causing the greatest losses in cool, wet soils.

Fungi that cause damping-off occur in all soils where tomatoes are grown and they infect tomatoes when the soil is wet. Infection is most common under cool conditions, although both *Phytophthora* and *Rhizoctonia* can also infect seedlings in warmer soils. Once tomato seedlings reach the 2- or 3-leaf stage, they are no longer susceptible to infection by *Pythium* or *Rhizoctonia;* however, *Phytophthora* can infect tomato plants at any stage. Damping-off does not necessarily carry over from one season to another in the same places but appears only when and where conditions favour infection.

Transmission

The fungi causing this disease are transmitted through contaminated seed and soil (on tools, boots and through cultivation practices). Infection of the plants can be via the roots or via leaves that touch the soil or have been splashed by water.

6.38 - Cotton seedling with symptoms of damping off

Management

- Proper field and seedbed preparation and good water management (i.e. avoid stress from excess water or poor drainage) significantly reduce losses from damping-off.

- Sterilise seedbed soil (with heat treatment or solarisation) and use clean water to water the seedlings.
- If possible, use certified, disease-free seeds. If doubts exist about the quality of the seed (e.g. farmer-saved seed), consider treating it with a fungicide or with hot water (50°C for 25'; for details, refer to http://vegetablemdonline.ppath.cornell.edu/NewsArticles/HotWaterSeedTreatment.html).
- Sow seedlings thinly to avoid overcrowding.
- Keep seedlings well ventilated to reduce humidity.
- If possible, avoid planting when the soil is cool; in warm soil, seeds germinate faster and seedlings are more vigorous, so they are less likely to be infected.
- If damping off occurs in the seedbed, apply a suitable fungicide. Refer to annex II for recommended active ingredients.

6.39 - Bean seedlings with damping off caused by Rhizoctonia

6.40 - Typical patch of dead seedlings caused by damping off

Anthracnose

Common and (*scientific name*)

Anthracnose (*Colletotrichum spp. teleomorph: Glomerella cingulata*).

Importance

It may cause significant damage under specific conditions, but it is not usually regarded as a major problem in Eritrea.

Other host crops

Peppers, potato and many other vegetable and fruit crops.

Description and damage

Anthracnose primarily affects ripe fruits, on which depressed, circular lesions of 1-1.5 cm in diameter appear (picture 6.41). With time the lesions expand and become sunken, with concentric ring markings, and may crack open (picture 6.42). The center of the lesion becomes tan and dotted with small black specks. With time, the fungus may be observed sporulating on the infected area (6.43). Green fruits are readily infected, but the symptoms do not appear until they ripen. Infection may also occur on stems, leaves, and roots, but it is not normally a problem. In dry areas anthracnose on fruit occurs infrequently. Root rot caused by this fungus, however, is not uncommon, especially where tomatoes are grown year after year in the same soils.

Transmission

This fungus is a weak pathogen and generally infects ripe or overripe fruit and roots of mature plants. It can be seed-borne or can infect the plants from infected plant debris in the soil, on which it can survive for years. In this latter case, the fungus can infect the plant tissues directly in contact with the soil, or reach them through water splashing caused by rain or overhead irrigation.

Management

- Rotate with non-solanaceous crops at least every other year.
- Use certified seed or – if this disease is often a problem – treat seed with hot water.
- Avoid sprinkler irrigation when fruit begin to ripen.
- Stake plants to keep them off the soil.
- Remove and destroy severely infected plants.
- Harvesting fruits before they fully ripen may help in reducing the problem.
- Fungicides are generally not required. However, if conditions favour the development of the disease, a preventative spray program initiated at the first green fruit stage may be required. Refer to annex II for recommended active ingredients.

6.41 - Initial symptoms

6.42 - Advanced anthracnose symptoms

6.43 - The fungus C. coccodes growing on the infected area (source - Nancy Gregory, University of Delaware, Bugwood.org)

Powdery mildew

Common and (*scientific name*)

Powdery mildew (*Leveillula taurica*; presence of *Oidium* sp. is likely).

Importance

Powdery mildew is an important disease of tomato in Eritrea.

Other host crops

Cotton, peppers, cucumber eggplant, beans, several other vegetables and weeds.

Description and damage

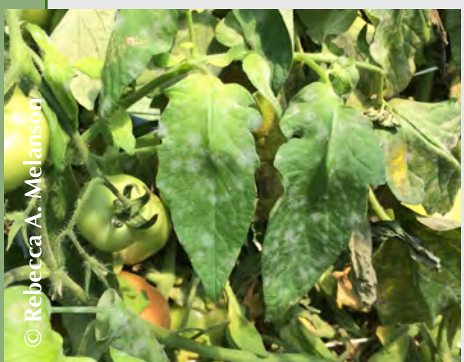
The first symptom is the development of light green to bright yellow blotches on the upper surface of the affected leaves. A light powdery fungal sporulation then appears on the lower leaf surface. Under conditions favourable to the disease, white powdery growth will develop on both surfaces of the leaf (pictures 6.44, 6.45). As the disease progresses, the affected areas merge and become necrotic. In severe attacks whole leaves die and the affected plants may be defoliated (picture 6.46). This may result in reduced yield, smaller fruits and sunburned fruits. Older plants are more susceptible than young plants, so powdery mildew often appears late in the crop cycle.

Transmission

The spores of the fungus are carried by wind to tomato plants. They can germinate and infect the tomato leaves under low (50-75 percent) relative humidity. The development of the disease is favoured by warm conditions. Plants stressed by other factors appear to be more susceptible to powdery mildew.

Management

- Keep tomato fields free of weeds.
- Avoid water stress to the crop.
- Avoid overhead irrigation (free water on the leaves may reduce the levels of powdery mildew, but will cause other problems).
- Remove and destroy crop residues (e.g. by composting) after the last harvest.
- When conditions are conducive to the disease and sporulation is abundant, application of fungicides may be warranted. Refer to annex II for recommended active ingredients.



6.44 - Initial symptoms

6.45 - Details of powdery growth on leaves

6.46 - Heavily affected plant

Late blight

Common and (*scientific name*)

Late blight, Phytophthora blight (*Phytophthora infestans*).

Importance

It is a key disease for tomato production during the wet season.

Other host crops

Potato, peppers and several other solanaceous crops and weeds.

Description and damage

Leaf symptoms of late blight first appear as small, water-soaked areas that rapidly enlarge to form purple-brown, oily-appearing blotches. Under humid conditions, on the lower side of leaves a delicate, grayish-white fungal growth appears around the blotches (pictures 6.47, 6.48). Entire leaves may blacken and shrivel, or, if the weather stays humid, may rot away; the infection quickly spreads to petioles and young stems, with the development of blackened, elongated areas (picture 6.49). Developing tomato fruit may also be affected (pictures 6.50, 6.51). Dark-green, water-soaked areas appear on the surface of the fruit and a short fungal growth may develop on affected tissue. Symptoms usually begin on the shoulders of the fruit as large, irregular, brownish-green and greasy blotches, which turn brown but remain firm unless infected by secondary decay organisms. Sometimes the damage is not apparent until the fruit reaches market. Late blight is a problem when humid conditions coincide with mild temperatures for prolonged periods of time. When humidity is above 90 percent and the average temperature is in the range of 15° to 20 °C, the infection occurs in a few hours. If conditions remain favourable (cool nights around 10-15 °C and mild days around 20-25 °C, with high humidity), the disease develops very rapidly and the whole crop can be lost in a few days (pictures 6.52, 6.53).

6.47 - Symprom on upper leaf surface

6.48 - Fungal sporulation on lower leaf surface

Transmission

The fungus survives in crop residues, volunteer plants, solanaceous weeds and also in the soil. Spores of the fungus

6.49 - Infection on young stem

are easily spread to other plants by the wind and by splashes of water.

Management

- Use tolerant varieties, if they become available (currently there are none in Eritrea).
- Apply field sanitation (collect and destroy cull tomatoes, volunteer solanaceous plants and weeds).
- Use only disease-free transplants.
- Avoid adjacent plantings with older, infected crops. Rotations with non-susceptible crops will only be effective if applied on a large area.
- If possible, stake plants to keep them off the soil and mulch to reduce water splashing.
- Constantly scout during the wet season and in the wetter parts of the field.
- Avoid overhead irrigation.
- Remove and destroy crop residues (e.g. by composting) after the last harvest.
- Apply fungicides as soon as the disease appears during a wet period (or if overhead irrigation is practiced) or when local experience suggests that the weather conditions are favourable to the disease. Refer to annex II for recommended active ingredients.

6.50 - Affected leaves and fruits

6.51 - Heavily infected fruits

6.52 - Heavily infected tomato field

6.53 - Area almost defoliated by late blight

Early blight

Common and (*scientific name*)

Early blight (*Alternaria solani*).

Importance

It is an important disease for tomato production in Eritrea.

Other host crops

Potato, peppers, eggplant and other solanaceous crops and weeds.

Description and damage

All parts of the plant may be infected, including leaves, stems and fruit. Small (5-10 mm), irregular brown spots, often surrounded by a yellow halo, develop on the leaves. Leaf spots are leathery and often have a concentric ring pattern. They usually appear on older leaves first (pictures 6.54. 6.55, 6.56). The spots enlarge and may fuse to form large, irregularly shaped dead areas. The oldest leaves show the largest lesions and die rapidly, though sometimes they fail to drop. They give the lower portion of the plant a dead, drooping appearance, which extends upwards as the disease progresses (picture 6.57). Lesions may appear as dark brown, elongated, sunken areas on the stem and petiole (picture 6.58). Lesion development at the soil line can result in a collar rot that often girdles the stem. Spots on fruit are sunken, dry, and may also have a concentric pattern (picture 6.59); frequently they occur near the calyx end of the fruit. The fungus develops into the fruit as a spherical black mass. The affected area later breaks down and the fruit rots. The incidence of the disease increases under warm and moist conditions (particularly if the plants are stressed (e.g. by poor nutrition or nematode attack) and may cause defoliation of the crop. Disease development usually stops in dry, hot weather, unless there are frequent dew periods or overhead irrigation is used.

6.54 - Initial leaf spots

6.55 - Typical spots with concentric rings

Transmission

The early blight fungus is transmitted on infected seed, and also survives in the soil on crop residue and on susceptible weeds (e.g. nightshade). The spores of the fungus are spread by the wind or water splashing. Germination of spores and infection require free water.

Management

- Use certified pathogen-free seed and transplants. If farmer-saved seed is used, treat it with hot water or dress it with a suitable fungicide.

6.56 - *A. solani* infection typically begins from lower leaves

6.57 - Plant heavily infected

6.58 - Sypmtoms of infection on stem

6.59 - Fungal sporulation on infected fruit

- Use long rotations away from tomato and other solanaceous crops.
- avoid planting tomato near related crops (e.g. potato, peppers) that are more mature.
- Maintain plant vigour through adequate irrigation and fertilization, to increase plant resistance.
- Destroy host weeds (e.g. nightshades).
- Remove and destroy crop residues (e.g. by composting) after the last harvest.
- If early blight is a recurrent problem and environmental conditions are favourable to the disease, apply a fungicide when the first sign of disease becomes apparent. Refer to annex II for recommended active ingredients.

Yellow Leaf Curl Virus (TYLCV)

Common and (*scientific name*)

TYLCV (*Tomato Yellow Leaf Curl Virus*).

Importance

It is one of the most damaging diseases of tomato in Eritrea.

Other host crops

Crops (e.g. tobacco) and weeds (e.g Datura) in the family Solanaceae, common beans. Note that some of these alternative hosts (e.g. tobacco) do not show symptoms of the infection.

Description and damage

Infected tomato plants initially show stunted and erect or upright plant growth; plants infected at an early stage of growth will show severe stunting. However, the most diagnostic symptoms are those in leaves, which in infected plants are small, curl upward and show strong crumpling and interveinal and marginal yellowing. The internodes of infected plants become shortened and, together with the stunted growth, plants often take on a bushy appearance (picture 6.60). Flowers formed on infected plants commonly do not develop and fall off. Fruit production is dramatically reduced, particularly when plants are infected at an early age. Fruit that has set before the plants become infected often ripens normally.

Transmission

The primary way the virus is spread is through the adults of the whitefly, *Bemisia tabaci*, which acquire the virus from infected tomato or other plants. It is also spread through the distribution of infected seedlings, on which the symptoms of the disease take up to 3 weeks to develop. This virus is neither seed-borne nor mechanically transmitted during agronomical operations.

6.60 - Plant affected by TYLCV

Management

- The use of resistant varieties is the best option. However, no resistant variety is currently available in Eritrea (Cvs. Roma and Marglobe are known to be highly susceptible).
- Use whitefly exclusion screening in seedling production and use virus- and whitefly-free transplants.
- Avoid planting new fields near older fields (especially those having TYLCV-infected plants).
- Uproot and destroy virus-diseased plants, when the incidence is still low.
- Practice good weed management in and around fields.
- Manage whiteflies (in areas where the virus is a problem, control of whiteflies must be initiated as soon as they appear, as small numbers of them can quickly spread the virus).
- Remove and destroy old crop residues.

Mosaic virus

Common and (*scientific name*)
ToMV (*Tomato mosaic virus*).

Importance
It is an important disease in Eritrea.

Other host crops
Crops and weeds in the family Solanaceae.

Description and damage
Symptoms vary with the cultivar and the specific strain of the virus. A mild mosaic (mottled leaves with irregular, light-green and dark-green areas) develops on the youngest leaves (picture 6.61), which may be stunted or elongated (this condition is called "fernleaf"). Leaves formed before the infection remain normal. In cool weather and low light intensity, stunting and leaf distorsion may be severe. Under high temperature and high light intensity, the mottling can be severe. In older plants, stunting and poor blossom set can reduce yield, sometimes considerably. Fruit that does set may ripen unevenly, becoming blotchy and unsaleable.

6.61 - Symptoms of mosaic virus

Transmission
ToMV host range includes solanaceous crops and weeds, all of which are sources of inoculum. It is also transmitted through the seed and seedlings produced from infected seed are infected at germination. In seedbeds, the disease can spread from a few infected seedlings during transplanting. The virus is easily transmitted mechanically by contact between plants or through human activities, e.g. during pruning and other cultural operations (it is not transmitted by insects). As a result, usually this virus is not a problem in direct-seeded tomato crops. ToMV is very resistant and can remain infective in dead plant material for several years.

Management
- The use of resistant varieties is the best option. However, no resistant variety is currently available in Eritrea.
- Use certified, disease-free seed.
- Before handling seedlings, all personnel should wash their hands with soap and sterilize all tools. Milk powder (20% wt/vol) is effective at inactivating the virus and may be used to wash hands and hand tools, and dip hands in milk every 5 minutes when handling plants.
- Remove solanaceous weeds from around and within the tomato field.
- When working in the field or nursery, workers should not smoke as ToMV can be transmitted from the tobacco.
- In the field, snap off suckers without touching the plant, instead of knife pruning.
- Remove and destroy crop residues (e.g. by composting) after the last harvest.

Broomrape

Common and (*scientific name*)

Broomrape (*Orobanche spp.*). The Common broomrape (*O. minor*) is indicated as the most frequent species occurring on tomato in Eritrea.

Importance

This parasitic weed can represent a significant problem at local level, in areas with poor drainage.

Other host crops

Beans, peas, brassicas, groundnut, peppers, potato, sunflower, tobacco.

Description and damage

Broomrapes are obligate parasites on the roots of various host plants. The first noticeable sign of their presence is the appearance of whitish-yellow shoots at the base of the parasitized plant. Upon removing the soil, the broomrape roots are found attached to the roots of the tomato plant. The broomrape plant is small, 10-60 cm tall depending on the species. It is best recognized by its yellow-to-straw coloured stems bearing yellow, white or blue flowers (picture 6.62). These plants generally flower when weather conditions are cool to moderately warm. The seeds are minute, tan-to-brown, and blacken with age. When they are not flowering, no part of these plants is visible above the surface of the soil. The symptoms exhibited by parasitized plants are leaf yellowing, water stress, stunting and wilting. The tomato host plant may eventually die (picture 6.63). In any case, much of the damage is inflicted before the broomrape emerges above ground.

Transmission

The very small seeds may very easily be moved from one field to another by water, wind, animals and man. Agricultural seeds of various crops may carry *Orobanche* seeds if harvested in an infested field. Broomrape seeds remain viable even after passing through the alimentary system of animals, so manure may be contaminated with viable seeds. Once in the soil, these seeds may lie dormant for up to 20 years and be stimulated to germinate by the exudates from the roots of the tomato or another host plant.

6.62 - Orobanche parasitizing tomato

Management

- Phytosanitation: adopt any measure to prevent the spread of viable seeds (i.e. minimize the movement of infested soil by farm machinery, prevent grazing on infested areas, properly compost manure, avoid the use of hay made of *Orobanche*-infested plants, avoid the use of *Orobanche*-infested crop seeds, etc.).

- Use of soil solarization, which kills seeds in the upper soil layers. This is effective only if applied for several weeks at a time of high solar radiation.
- Hand-weeding. The flowering stems should be weeded as early as possible (before flowering) and destroyed as they can continue developing flowers and spreading seeds even without being connected to the host.
- Remove and destroy parasitized tomato plants and their roots, together with the weed.
- Rotation with non-host crops has a limited effect, given the extended survival of the seeds of the parasite in the soil. Besides, it is necessary to know the host preferences of the particular *Orobanche* population in the field.
- In case of heavy infestations, use of herbicides may be warranted. However, these weeds are not easily controlled even with chemical herbicides. Recent studies seem to indicate that sulfonylurea herbicides (e.g. rimsulfuron) are the best option. Fumigants for soil disinfection are too toxic to recommend for use by smallholder farmers and in any case even their use does not guarantee a complete control.

6.63 - Tomato plant killed by orobanche

Blossom end rot

Common and (*scientific name*)

Blossom end rot (BER).

Importance

It is a common problem, particularly in plum or pear shaped cultivars and in acidic soils.

Other susceptible crops

Peppers, aubergine.

Description and damage

Blossom end rot is characterized by large brown to black, dry, leathery areas on the blossom end of tomato fruit. Initial symptoms appear as small, water-soaked areas that resemble bruises on the blossom end of immature or green fruit. These spots can enlarge and coalesce until the affected areas involve a large portion of the surface of the fruit. In severe cases, it may completely cover the lower half of the fruit, which becomes flat or concave. Development of BER can also cause distortion of the fruit. Affected tissues eventually dry, shrink, and become leathery (pictures 6.64, 6.65). During this process, the colour of the affected area gradually changes from a bleached yellow to a characteristic dark brown or black. Fruit affected by BER often ripen more rapidly than normal, healthy fruit (picture 6.66).

This condition is caused by a deficiency or insufficient uptake and translocation of calcium to the fruits. It can occur when the plant is rapidly growing and calcium requirements cannot be met. Plum or pear-shaped tomato cultivars have been found to be most susceptible. Although various factors trigger the BER, water stress (particularly very low moisture) appears to have a key role. The other factors include early planting in cold soil, high temperature, water logging of the soil, high levels of ammonium nitrogen and low soil pH (<5.5).

Management

- If BER is a known problem on the farm, if possible avoid growing susceptible varieties (both San Marzano and Roma are susceptible).
- If possible, before planting get the soil analysed for calcium levels and pH. Amend calcium deficiency with gypsum, high calcium limestone or dolomite. Correct acid soil by applying

6.64 - Initial stage of blossom end rot

6.65 - Terminal stage of blossom end rot; note the dry, leathery tissue

lime and alkaline soil by applying acidifying or sulfate forms of fertilisers (e.g. sulfate of ammonia, sulfate of potash).

- Avoid excessive N fertilizer, particularly in the ammonium form, just before or during fruiting.
- During vegetative growth, monitor for early detection of fruits with signs of blossom end rot.
- Maintain adequate soil moisture levels throughout the growing season, but particularly during flowering and fruiting, through consistent irrigation and mulching.
- When cultivating, avoid destroying or damaging the feeder roots that are responsible for uptake of water and nutrients.
- The foliar application of calcium nitrate (or other Ca fertilizer) from early flowering through fruiting to harvest may help reducing the incidence of BER, but its efficacy is limited because Ca is poorly absorbed by the plant. It is more effective when it is applied with irrigation around the base of the tomato plant, so the roots can take it up.

6.66 - Early maturing tomatoes affected by blossom end rot

Section activities

6.1 - Description of disease symptoms

A training session on disease management could start with this group dynamic which will make participants aware of the importance of careful observation and proper descriptions of symptoms. This exercise resembles the situation when a farmer visits an extension office (or a pesticide shop) and describes the problem he has with his crop. It shows how difficult it is to make recommendations or decisions on what crop health management actions need to be taken without visiting a field and actually observing the crop.

Objective

To become aware of the need for field observations.

Duration of exercise *(indication)*

½ day or less.

Materials needed

- Diseased plant material; different crops or different diseases per group
- Poster paper
- Color crayons

Procedure

Divide the class into the usual subgroups of 4 to 6 persons. Per group, isolate one person. The isolated person is not allowed to see his/her fellow group members. The fellow group members are not allowed to see the person or the diseased plant. So, ask the group to line up, faces all in one direction and ask the isolated person to stand behind the line, facing the opposite direction. Hand a diseased plant or diseased plant part out to the isolated person. Ask the isolated person to describe the disease symptoms of the plant without mentioning the name of the disease or mentioning any technical term. The isolated person may mention the common name of the plant. The others in the group are asked to make drawings of the diseased plant without looking at the isolated person or the plant sample. They are allowed to ask questions!

Observations

After about 15 minutes, the drawings should be finalized. Ask each group to present the drawings and explain about the disease they thought the sample was infected with. Compare the drawings with the diseased specimen.

Discussion

Was it difficult to make the drawings?
Are the drawings accurate? Do they resemble the symptoms?
What does the drawing tell about the severity of the disease?
Could one tell from the drawing whether or not this disease is a problem in the field?
What does the drawing tell about the stage of the disease (spreading or not)?
Can one give advice on the management of this disease based on the drawings?
If no, why not?

6.2 - Identification of disease symptoms

Once the importance of field inspections in relation to disease identification and management has become evident, a following exercise could be conducted to learn about different types of disease symptoms and about stages of severity of diseases in the field. The exercise shows that, without knowing names of diseases, one can group types of diseases and learn about the developmental stages of a disease in the field.

Objective

To distinguish between different groups of disease symptoms and learn about the developmental stages.

Duration of exercise (indication)

½ day or less.

Materials needed

- Vegetable field with different diseases in different progressive stages
- Hand lenses (at least 1 per group)
- Poster paper
- Color crayons
- Plastic bags

Procedure

Visit the field and ask each group to collect as many different disease symptoms in different progressive stages as can be found (so not only leaf spots, but also other disease symptoms such as deformed roots, discolored leaves, etc.).
In the "classroom", the disease symptoms should be grouped into leaf spot diseases (including molds/mildews), wilts, fruit spots and rots, root disorders, shoot disorders and mosaics (including mottling). Assign each disease group to a group of trainees. Request the trainees per group to rank the disease

symptoms in order of severity. Use the hand lens to check whether any spore structures can be found.
Ask each group to make drawings of progressive stages of the disease. Have a presentation on the disease symptoms and disease development per group. Avoid the use of scientific terms such as Latin names of diseases.

Discussion
Which diseases were present? What are the local names of the diseases?
How do the symptoms look like? How do they start?
Which plant parts are affected by the different diseases?
How do the diseases reproduce and spread? How can one find out?
Are the described diseases problematic? If yes, why?
During which season are the diseases most severe?

6.3 - Effect of the use of infected planting material

This exercise applies to transplanted vegetable crops, such as tomato, or other planted crops, such as potato or onion (not from true seeds). When the exercise is done with relatively dangerous diseases, such as late blight, care must be taken to do the exercise during a less conducive season/time of the year. Otherwise the disease could spread beyond the trial and cause problems also in the surrounding fields.

Objective
Discover the importance of starting with healthy planting material.

Duration of exercise (indication)
season-long.

Materials needed
- Site for the experiment in the field
- Plastic foil + bamboo sticks
- 10 Healthy seedlings
- 10 Seedlings with a "leaf spots" disease (early blight, late blight)

Procedure
Choose a location for the trial with two plots (if needed with access to irrigation). Prepare the soil following farmers' practices. Plant the 10 healthy plants/plant parts and label that first plot "healthy planting material". Fence the first plot with plastic foil, supported by 4 bamboo sticks. Plant the 10 infected seedlings in the second plot and label it "infected plant material". Fence the second

plot with plastic foil, supported by 4 bamboo sticks. Apply crop management practices following farmers' practices, but do not apply any pesticides.

Observations

One week after planting, the observations can start. Weekly monitor the number of plants with lesions and estimate the percentage of diseased leaves per plant. When the plants mature, harvest the crop. Count and weigh the harvested product. In the case of potato/onion, cut the tubers/bulbs alongside and observe any discoloration.

Discussion

What are the differences between the treatments in terms of crop health?
What are the differences in terms of yield?
Is it possible to grow a healthy crop from infected plant material?

6.4 - Restricted fungicide use to manage leaf spots

This field study is especially suitable for late blight as management of this leaf spot disease almost always needs application of chemicals at certain stages of the development of the disease epidemic.

Objective

Minimize fungicide use in the management of leaf spot diseases.

Duration of exercise

season-long.

Materials needed

- Susceptible crop in the field (young crop)
- Preventative and curative fungicides (e.g. in the case of late blight on tomato, mancozeb or maneb and metalaxyl)
- Plastic foil and 12 bamboo sticks

Procedure

Discuss with the participants about threshold treatments and assess the most practical and, according to the participants, most appropriate threshold treatments. In this example, 10 and 5 percent threshold treatments are used.
In the vegetable field, allocate three, distant plots of 5 x 5 m^2 each. Fence the plots with plastic sheet, supported with bamboo sticks. Label one plot as "farmers practice", another plot as "threshold treatment 10 percent" and the third plot as "threshold treatment 5 percent". In the "farmers practice" plot, apply the usual farmers spray regime to control late blight (most probably

frequent sprays using fungicide cocktails). In the other plots, monitor the disease development and apply a fungicide (one chemical only) at the recommended rate only when the threshold is reached.
E.g. in the "threshold treatment 10 percent", apply a fungicide when 1 lesion is found per 10 plants, but not more often than every 5 days. In the "threshold treatment 5 percent" monitor the disease development. Apply a fungicide when 1 lesion is found per 20 plants, but not more often than every 5 days. In the threshold treatments, if possible, alternate the fungicides used.

Observations

In addition to the disease development, record the fungicides used, the number of applications per plot and, at harvesting, the total yield per plot. If possible also include observations on other diseases, plant development, natural enemies, arthropod pests, etc. During the season, after 2 or 3 months, prepare presentations with the disease development over time and the total fungicide usage.

Discussion

What are the differences between the treatments? Why?
What were the differences in input + labor costs?
What were the differences in yield and market grade?
Which treatment could be adopted in a next season?

6.5 - Identification of late blight

This exercise is applicable only to late blight susceptible crops, such as tomato, potato, hot pepper, eggplant.

Objective

To identify late blight disease and study the symptoms.

Duration of exercise *(indication)*

½ day to set up, and about 1-week monitoring.

Materials needed

- Tomato (or potato, eggplant or pepper) field with a leaf spot disease
- Clean water
- Tissue paper
- Clear plastic bags or jars
- Hand lenses

Procedure

Pick leaves with different lesions in the field. Place leaves or leaf portions with lesions in separate plastic bags. Also insert some moist tissue in each bag. Close the bags tightly but leave some air inside. Keep the bags in a cool, shady place. Leave the bags overnight.

Observations

After one day, open the bags and observe the leaf portions. If you see mould at the underside of the lesions, then the lesion is caused by late blight. If not, another leaf spot disease may have caused the lesion.

Discussion

Can this test be used as an identification tool by farmers?
What may have been the reason for the lesion if late blight was not observed?

If the mould was observed, a follow-up exercise can be conducted on the same day: see 6.6 - Study of spread of a fungal leaf spot.

Notes on Symptoms

After 12 hours in dark in 'wet tissue' disease culture the following characters should be observed for early and late blights:

LATE BLIGHT	EARLY BLIGHT
Clear pale, white zone of mycelia growth along the edges of the leaf spot	No clear pale, white zone along the edges of the leaf spot. If there is some mycelia, it will be all across the spot

6.6 - Study of spread of a fungal leaf spot

This exercise is a nice follow-up on the previous exercise 6.5 - Identification of late blight.

Objective

To observe spread of a fungal disease from an infected to a healthy plant.

Duration of exercise

1 day to set up, and 4 to 8 weeks monitoring.

Materials needed

- 4 Potted plants (healthy!)
- Leaf spot infected leaves
- Clean water
- Small hand sprayer
- Clear plastic bags
- Tissue
- Labels

Procedure

First day preparations (as in exercise 6.5 - Identification of late blight): insert the leaf spot infected leaves in a plastic bag with moist (not soaking wet) tissue paper. Close the bag tightly, but leave some air inside to avoid rotting. Leave the bag overnight.

The second day: bring the potted plants into the classroom. Insert clean (tap) water into the container of the small hand sprayer. Spray two potted plants with the clean water. Label one plant "healthy control, uncovered". Cover the other plant with a plastic bag and label the plant "healthy control, covered".

Prepare the disease inoculum by stirring the leaf portions with leaf spots in a glass with clean water. Transfer the inoculum to the small hand sprayer. Spray the inoculum on the other two potted plants. Label one plant "leaf spot infected, uncovered". Cover the other plant with a plastic bag so that high humidity is maintained and label that plant "leaf spot infected, covered". Clean the hand sprayer carefully after use. The plastic bags should not be removed, except for observations or watering of the plants.

Observations

Observe the development of symptoms in both pots over time. Once the symptoms have been observed sufficiently, destroy the infected plants to avoid infection of other plants.

Discussion

Why did we inoculate the plants inside the classroom and not in the field?
How many days did it take before symptoms were visible?
How does a fungal leaf spot spread in a field?
What can be recommended to a farmer with a leaf spot in his field?

6.7 - Insect zoo

Some arthropods are pests, feeding on plant parts, others feed on insect prey, others live inside other arthropods and again others come from weeds or neighbouring crops, and are simply resting in the vegetable crop. To learn about the biology of arthropods, the 'insect zoo' and some variations of it can be conducted.

Objective

To study arthropods, their feeding and life cycles.

Duration of exercise *(indication)*

½ day to set up, and about 1 week monitoring.

Materials needed

- Small plastic jars (or vials) and bags
- Tissue paper
- Camel or fine hair brush
- Labels
- Hand lenses
- Insect collection box
- Pins

Procedure

To find out whether an arthropod is a pest, collect it in a jar, give it some food (leaves, stems and/or fruits of the studied crop). Close the jar and place a piece of tissue paper between the jar and the lid to avoid condensation inside. Keep the jars out of direct sunlight. Observe whether the insect feeds and on what it feeds; check again after some time.

To find out whether an arthropod is a predator, collect it in a jar, give it some prey (aphids, eggs or small larvae). Close the jar and place a piece of tissue paper between the jar and the lid, to avoid condensation inside. Keep the jars out of direct sunlight. Observe whether the insect feeds and on what it feeds; check again after some time.

To find out about the developmental stages of arthropods, collect eggs, larvae/nymphs or pupae encountered in the field and rear them in jars through the next stages until the adult stage. Feed the larval stage on appropriate food (leaves, fruits, insect prey in case of predators) every day, and observe the arthropods during development. It is important to always place a piece of tissue paper between the jar and the lid, to avoid condensation inside the jar.

Another way to build 'insect zoos' is to transfer plants to pots, remove all arthropods on the plants and cover the plants with large transparent plastic covers (make a few windows with fine screen to avoid condensation). Insert the arthropods that you want to study and daily observe the zoo. It is a good idea to build up a reference collection of pests and natural enemies during a field school season. To make a reference collection, pierce the dead insects on insect pins or fine tailor pins (pierce the pin through the thorax, the middle part of the body) and add a small paper label to the pin with details of the collection date, place and crop.

Observations

Record the local name of the arthropod that was collected and the location where it was collected and describe your observations on poster paper. Explain in presentation sessions which arthropod(s) you collected, where you collected them, what they were feeding on, whether they changed development stages and how long they remained in certain development stages. Illustrate the observations with drawings of each developmental stage of the studied arthropod.

Discussion

Did you learn more about the arthropod you studied in the insect zoo?
Was the studied arthropod a "friend of the farmer" or an "enemy of the farmer"?
How could the information about duration of development stages help you in the management of arthropod pests?

6.8 - Sampling for arthropods with light trap

As much information as possible on the abundance of pests and their natural enemies in the field is desirable for making a well-informed and good decision in pest management. Different trapping methods have different specific advantages, but each giving only a partial picture. For example, light trap will generally catch only flying adults. Together with other methods, the catches can provide a fuller picture of the agro-ecosystem.

Objective

To learn how to use a light trap and discover which arthropods are trapped using a light trap.

Duration of exercise

½ day to set up, and about 1 week monitoring.

Materials needed

- Light trap (to be constructed as described below)
- Plastic bags (to collect the catches)
- Light-colored (preferably white) plastic trays (for separating and sorting the catches)
- Camel or fine hair brushes
- Forceps
- Pin mounted on a pencil-like wood (as handle) for separating the specimens
- Vials, containers (for keeping specimens, if needed for future reference)
- 1 pencil and paper for labels
- Detergent

Procedure

The light trap can be cheaply constructed using locally available materials: using a simple kerosene lamp above a water basin supported by a tripod made with bamboo sticks or branches collected in the field. A battery-operated lamp would be ideal. Prepare and set up the light trap during the day in the selected site (or a site in the vicinity). The lamp should be at a height above the crop level. Ensure that some detergent is added to the water in the basin.

Light the (kerosene) lamp only in the evening (at dusk) when the sun sets. On the next morning, pour the catches from the basin into plastic bag(s) together with some water. All excess water should be discarded. Back in the classroom, pour the catches into the trays. Separate and sort the catches into the various arthropod/insect groups (e.g., wasps, moths, leafhoppers, flies, etc.). Count the numbers caught for each group and tabulate the results for discussion.

Note

For purposes of comparison or to complement the catch information by other means (sampling methods), the light trap may also be set up at about the same time as other trapping devices, such as sticky board, water pan trap, pitfall trap.

Discussion

What does the catch consist of mostly (larva/nymph or adult)? Which are the main groups of insects/arthropod caught?
Which group is most and which is least prevalent? And what is the ranking (in abundance) of the others?
Since all these are caught using the light trap, what can you conclude?
Can you relate any of these with the crops in the area where the trap is set up?
What particular groups (stage and types) are not caught? And what can you conclude from this? In what way is the light trap useful and what are its limitation?
If other traps are also set up (or other assessment methods done), how do the catches of the light trap compare with them? What can you conclude?

6.9 - Sampling for arthropods with sticky traps

As much information as possible on the abundance of pests and their natural enemies in the field is desirable for making a well-informed and good decision in pest management. Different trapping methods have different specific advantages, but each giving only a partial picture. For example, sticky traps will generally catch only flying adults. Together with other methods, the catches can provide a fuller picture of the agro-ecosystem.

Objective

To learn how to use sticky traps and discover which arthropods are trapped by them.

Duration of exercise ***(indication)***

½ day to set up, and about 1 week monitoring.

Materials needed

- Sticky board (yellow or white). Ready-made commercial ones may be used, otherwise they can be prepared using appropriate glue and board / tin plate of yellow or white color.
- Plastic bags (to collect the catches)
- Camel or fine hair brushes
- Forceps
- Pin mounted on a pencil-like wooden handle (for separating the specimens)
- Vials (or other containers) to keep specimen if needed for future reference
- 1 pencil and paper for labels, 1 marker pen
- Pieces of bamboo or wooden sticks (to hold up traps in the field)

Procedure

The sticky board can be hung from or tied onto a wooden stick(s) or bamboo which is firmly poked into the ground where the trap is being set up (either in the field or in the vicinity). Keep the board in the vertical position and a little above the crop. It is best to set up the sticky trap in the morning and to collect it later in the day before dark. During collection, each board can be slipped into a clear plastic bag and labelled before taking it to the lab / classroom for checking / counting of the catch.

To facilitate counting, grid lines may be drawn with marker pen over the plastic bag (without removing the sticky board). Counts from each square are taken and subsequently pooled together for each group of arthropod (leafhoppers, flies, wasps, etc.) caught. They are then tabulated and the results analyzed and discussed.

Note

For purposes of comparison or to complement the catch information by other means (sampling methods), the sticky board may also be set up at about the same time as the others, such as water pan trap, pitfall trap, light trap.

Discussion

What does the catch consist of mostly (larva / nymph or adult)? What are the main groups of insects / arthropod caught?

Which group is most and which is least prevalent? And what is the ranking (in abundance) of the others?

Since all these are caught using the sticky board, what can you conclude?

Can you relate any of these with the crops in the area where the trap is set up?

What particular groups (stage and types) are not caught? And what can you conclude from this? In what way is the sticky board useful and what are its limitations?

If other traps are also set up (or other assessment methods done), how do the catches of the sticky board compare with them? What can you conclude?

6.10 - Sampling for arthropods with water pan trap

As much information as possible on the abundance of pests and their natural enemies in the field is desirable for making a well-informed and good decision in pest management. Different trapping methods have different specific advantages, but each giving only a partial picture. For example, the water pan trap will generally catch only flying adults. Together with other methods, the catches can provide a fuller picture of the agro-ecosystem.

Objective

To learn how to use a water pan trap and discover which arthropods are trapped using the water pan trap.

Duration of exercise *(indication)*

½ day to set up, and about 1 week monitoring.

Materials needed

- Light colour (yellow or white) shallow dish (e.g. those used for serving food)
- Detergent
- Light-coloured (preferably white) plastic trays (for separating and sorting the catch)
- Plastic bags (to collect the catches)
- Camel or fine hair brushes
- Forceps
- Pin mounted on a pencil-like wooden handle (for separating the specimens)
- Vials (or other containers) to keep specimen if needed for future reference
- 1 pencil and paper for labels
- Short bamboo or wooden sticks (for making a simple tripod to support the dish)

Procedure

Cross 3 pieces of short sticks or bamboo in such a way that they form a tripod on the ground to support the water pan trap. Then place a dish on the tripod. Fill the dish halfway with water and add some detergent. The water pan trap should be set up in the open area with no vegetation hanging over. It may be located between crop rows or in the vicinity just outside the field, depending on the study objective.

The trap may be set up in the morning and collected later in the day before dark. During collection, pour the catch (including the water) into a plastic bag. Label the plastic bag before taking it to the lab/classroom for checking/counting of the catch. For sorting the catch, pour the catch into the tray. Remove excess water. Separate the catch into the various arthropod/insect groups (e.g., wasps, moths, leafhoppers, flies, etc.). Count the numbers caught for each group and tabulate the results for discussion.

Note

For purposes of comparison or to complement the catch information by other means (sampling methods), the water pan trap may also be set up at about the same time as the others such as, sticky board, pitfall trap, light trap.

Discussion

What does the catch consist of mostly (larva/nymph or adult)? What are the main groups of insects/arthropod caught?
Which group is most and which is least prevalent? And what is the ranking (in abundance) of the others?
Since all these are caught using the water pan trap, what can you conclude?
Can you relate any of these with the crops in the area where the trap is set up?
What particular groups (stage and types) are not caught? And what can you conclude from this? In what way is the water pan trap useful and what are its limitation?
If other traps are also set up (or other assessment methods done), how do the catches of the water pan trap compare with them? What can you conclude?

6.11 - Studying predators in the field

Predators ("friends of the farmer" who are feeding on pests) are not so easy to observe in vegetables. However, they are present and often play a very important role in keeping pest species under control.

Objective

To learn methods to collect and observe predators.

Duration of exercise ***(indication)***

½ day to set up, and about 1 week monitoring.

Materials needed

- Clear plastic containers (e.g. plastic bottles) and bags
- One 10x magnifying glass or hand lenses
- One camel or fine hair brush
- Labels
- Tissue paper

Procedure

Go to the field and search for predators. Collect them in the clear plastic containers without touching the insects (use the brush). Any unfamiliar arthropod on the vegetable plants should be collected and brought back to the classroom for study. For each insect to be studied, place it inside a plastic

bottle together with parts of the plant and some known insect pests. Observe for 3 days and record whether the test insect feeds on plant or other insects. Experience will enable trainers and farmers to help other farmers understand which insect is a pest and which is a predator.
Besides using plastic bottles and hair brush to collect predators, trainers and farmers may use the pitfall traps to determine what predators are active at the soil level and to provide an indication of the number of ground dwelling predators present. A pitfall trap is a cup with straight sides, of about 12 cm high and 6 cm wide (diameter). It is buried up to the brim in the soil, usually between plants in a plant row. Live predators can be collected if no water is placed inside the cup. However, if numbers of predators are to be assessed, place water mixed with some liquid detergent to collect all insects that fall into the cup. Check the cups in the morning after leaving them overnight. Predators caught in pitfall traps will help complement the visual counts of predators during field sampling.

Discussion
What kind of predators are present in vegetable fields?
Which predator is most common? Which insects are eaten by the predator?
What is caught in pitfall traps? Are there more predators in pitfall traps than in visual counts?
Are all insects found in pitfall traps predators? If not, what are their functions?
Did you find new predators? Which stages of insect pests did it feed on?

6.12 - Life cycle of caterpillar pests

Objective
To understand the life cycle and development stages of an insect with complete metamorphosis.

Duration of exercise
½ day to set up, and about 1 week monitoring.

Materials needed
- Clear plastic bottles, vials or bags
- Cages (covered with screen) and potted cabbages
- Unsprayed vegetable field
- Sweep net to collect moths
- One Magnifying glass (10x)
- One camel or fine hair brush
- Tissue paper

Procedure

To study egg laying, collect moths from the field using the sweep net and place them inside a potted, screen-caged vegetable plant. Leave the moths inside the cage for 24 hours. After 24 hours, remove the moths and observe for eggs laid on the plant. Observe the eggs and make drawings. Don't touch the eggs! Continue to monitor.

Also take a few leaves or leaf parts with eggs from the potted plant and place them into clear plastic bottles that are lined with slightly moist tissue paper. Label the bottles (name, date, crop). Keep them in the classroom or in the shade. Monitor the eggs and observe time of hatching.

After hatching observe the larvae in the bottles as well as on the caged plants. In the bottles, regularly provide new cabbage leaves for food. Regularly make drawings. Note dates of pupation. Monitor the progress closely, as the experiment can fail due to diseases, predation or escape.

Discussion

Egg stage:
Where are the eggs laid – on the plant or on the soil?
If on the plant – which part of the plant? If on the leaf – which part of the leaf?
If on the stem, which part of the stem?
How many eggs were laid?
What is the shape and color of the eggs? Are there differences in color? How many days does it take for the eggs to hatch?

Larval stage:
What is the size of the caterpillar at hatching? Where do the larvae feed? Which part of the plant? Do the larvae change skin? Why?
What are the sizes of the larval stages?
What happens when the caterpillar is full grown? How many days lasts the larval stage?

Pupal stage:
Where does the caterpillar pupate?
Does it make a cocoon? What is the color, shape and size of pupa and cocoon?
What is the function of the cocoon?
How many days lasts the pupal stage?

PART 7
Pesticides and their use

Why to use pesticides?

Despite all the preventive measures taken by the farmer, some pests or diseases may develop to a level that may warrant some direct action to limit the damage they cause. As it was previously mentioned in part 2 above, direct action may involve the use of a number of control methods, including pesticides. These substances should always be regarded as the last resort, but it is undeniable that there are situations when farmers need to use them to safeguard their productions and their livelihood. Therefore, pesticides should be regarded as useful tools that can make an important component of an IPM programme. However, one should not forget that their use also has disadvantages and poses some challenges (mainly because of their toxicity to human beings as well as to the environment) and it is very important that farmers are aware about them and understand how best to use pesticides in order to minimize possible risks. It is important to remember that pesticides are designed to kill or otherwise adversely affect living organisms; therefore, by their very nature, pesticides are potentially dangerous to humans, animals and the environment.

What is a pesticide?

According to the above-mentioned FAO/WHO Code of Conduct, a pesticide is any substance, or mixture of substances of chemical or biological ingredients intended for repelling, destroying or controlling any pest, or regulating plant growth. On the other hand, a pest is any species, strain or biotype of plant, animal or pathogenic agent injurious to plants and plant products, materials or environments, including vectors of parasites or pathogens of human and animal disease and animals causing public health nuisance. Therefore, pests include insects, mites, fungi, bacteria, viruses, nematodes, weeds and vertebrates.

Pesticides are named in three different ways: by active ingredient, by trade name, and by chemical name (see box below).

- The *active ingredient* is the common name of the chemical that controls the pest.
- The *trade name* is the brand name that the manufacturer gives to its commercial pesticide. It is the name which is shown prominently on a pesticide label. Pesticides with different trade names can contain the same active ingredient, while at the same time some pesticides contain more than one active ingredient.
- The *chemical name* is the scientific name of the active ingredient and is normally used by scientists.

Pesticides may be classified in a number of ways. These classifications can provide useful information about their chemical characteristics, how they work, what pests they are active on, etc. The classifications most useful to farmers and extension officers are briefly outlined underneath.

Example

- glyphosate is the common name of an herbicide active ingredient
- Roundup is one of the many trade names for herbicide products containing glyphosate
- N-(phosphonomethyl) glycine is the chemical name of the active ingredient in Roundup

Classification by target pest

It is one of the most commonly used and is based on the type of organism the pesticides are active on. The following types of pesticides are used to kill specific types of pests:

Pesticide	Pest controlled	Pesticide	Pest controlled
algicide	algae	Miticide/acaricide	mites
avicide	birds	Molluscicide	Snails and slugs
bactericide	bacteria	nematicide	nematodes
fungicide	fungi	piscicide	fish
herbicide	weeds	rodenticides	Mice and rats
Insecticides	insects		

Some pesticides have multiple activities and fall in more than one of these categories (e.g., sulfur is both a fungicide and an acaricide, i.e. it is active against fungi but also against mites, while various pyrethroids are active against both insects and mites, therefore are insecticides/acaricides). The word ending (or suffix) –cide means to kill. However, some substances are not really meant to kill the target organism; for example, they may be designed to repel it (e.g. methyl anthranilate, is a bird-repellant) or on the contrary to attract it (e.g. the pheromones used to attract the males of certain insects).

Classification by source/origin of the pesticide

- Synthetic pesticides are chemicals manufactured by humans, that do not occur in nature.
- Biological pesticides (or organic pesticides) are obtained from animal or plant parts. They include microbial pesticides (based on microorganisms, e.g. the bacteria *Bacillus thuringiensis*) and biochemical pesticides (pheromones, enzymes, bio repellents, etc.).

Classification by Mode of Action (MoA)

Pesticides can be grouped according to their mode of action, or in other words the mechanism by which they control the target pest. For example, one insecticide may affect an insect's nerves while another may affect its ability to grow. Likewise, one herbicide may interfere with the hormones regulating the plants' growth and another may affect its ability to convert light into food. The MoA of a pesticide is often indicated on the label as a group number; products with the same group number will have the same (or very similar) MoA.

Classification by how or when they work

This type of classification includes a heterogeneous collection of definitions which give the user information about how, where and when the pesticide acts on its target. For example:

- *Contact pesticides* control a pest as a result of direct contact; i.e. insects or other pests are killed when sprayed directly or when they crawl across surfaces treated with the pesticide.

- *Systemic pesticides* are absorbed by plants or animals and move to untreated parts of the same plant or animal. Some pesticides only move in one direction (up or down) within the plant, others can move in both directions.
- *Selective* pesticides will only control certain pests (e.g., *B. thuringiensis* var. *kurstaki* is only effective against larvae of Lepidoptera). Selective pesticides will not kill the majority of beneficial insects.
- *Non-selective* (or *broad-spectrum*) pesticides will control a wide range of pests (e.g., synthetic pyrethroids will kill all insects present on the crop, whether bad or good).
- *Protectant fungicides* prevent fungal infections. They prevent the pathogen from entering treated plants.
- *Eradicant* fungicides control fungi that have already infected the plant.
- *Residual pesticides* do not break down quickly after they are applied and control pests for a long time.
- *Non-residual pesticides* are quickly inactivated after application and their effect is short-lived.
- *Pre-plant* herbicides are applied to the soil before seeding or transplanting.
- *Pre-emergence* herbicides are applied to the soil after planting but before emergence of the crop or weed.
- *Post-emergence* herbicides are applied after the crop or weed has emerged.
- *Foliar pesticides* are applied to plant leaves, stems and branches.
- *Soil pesticides* are applied to the soil. Some are taken up by roots and translocated inside the plant.
- *Fumigants* are chemicals that are applied as toxic gas or as a solid or liquid which release a toxic gas. The gas will penetrate cracks and crevices and kill the pest.

Pesticide formulations

When a pesticide active ingredient is manufactured, it is not in a usable form (it may be too toxic, may not mix well with water or may be unstable). Therefore, it must be mixed with other substances to improve its effectiveness, safety, handling and storage. This mixture of the active ingredient and other inert (= inactive) substances is called a pesticide formulation. Pesticide formulations may be solids (e.g. bait, dust, granules), liquids (e.g. emulsifiable concentrate, flowable, solution) or gases (e.g. fumigants). Some formulations come ready to use, but the majority must be mixed by the farmer with water before use.

Understanding pesticide labels

It is a fact that many users do not read the label before using a pesticide. It is equally true that in many countries pesticide labels are not always available in a language that the user can easily understand. A pesticide label is a very important document and there are several good reasons why the user should carefully read it:

- it explains how to use the product safely and effectively;
- it describes risks and benefits of the product;

- it is the primary source of information to the user;
- it is the primary tool of pesticide regulation, which must be approved by the relevant national authority;
- THE LABEL IS THE LAW, therefore a given pesticide must be used only according to the instruction which appears on it.

A good label will provide the user with all the important information on how to store, use and dispose safely of that pesticide, as well as with the possible risks associated with the use of that pesticide and the measures to minimize them. The main information usually provided by the label is illustrated in picture 7.1 and in the rest of this section.

7.1 - Some of the important information contained in a pesticide label

1

Use classification statement. This statement may be found on the label of pesticides from the USA, where the Environmental Protection Agency (EPA) classifies pesticides in two categories: restricted use pesticides (RUPs) and general use pesticides (GUPs). RUPs have the potential to cause unreasonable adverse effects to the environment or the users. Therefore, the "Restricted Use" classification restricts a product to be used only by a certified applicator, or under his direct supervision. The RUP status of a product is not necessarily linked to its acute toxicity to man (in this example, the "unreasonable adverse effect" concerns the very high toxicity of the product for fish and other aquatic organisms).

2

Mode of Action (MoA) group. It indicates the mode of action of the pesticide (refer to "Classification by Mode of Action" above). When alternating pesticides to avoid the development of resistance by the target pest, it is important to ensure that the pesticides used do not belong to the same MoA group, or – in other words – that they have a different MoA number.

3

Brand or product name. This is the name used by the company to identify and market the product. Different companies will use different brand names to market their products, even when they contain the same active ingredient. This is always the information which shows more prominently on the label, but it is not the most important to the farmer.

4

Type of pesticide. It indicates against what group of pests the product is active (in this case it is an insecticide, so it kills insects)

5

Ingredient statement. It indicates the name of the active ingredient and the quantity (as a percentage by weight) which is contained in the product.

6

Signal word. This word identifies the acute toxicity of a specific product. The signal words, in order of increasing toxicity (i.e. of increasing danger), are Caution, Warning and Danger, as indicated in the following table:

Category	Signal Word	Approximate amount required to kill an average person
Class I — highly toxic	Danger or Danger-Poison	A few drops to 1 teaspoon
Class II — moderately toxic	Warning	1 teaspoon to 28 grams (1 ounce)
Class III — slightly toxic	Caution	More than 28 grams (1 ounce)
Class IV — very slight hazard	Caution or none	

While this system of signal words is used mainly in USA and Europe, many countries around the world adopt the WHO colour-code system, in which the toxicity of a given pesticide is indicated also by a colour band around the sales panel at the bottom of the label, as illustrated below.

Pesticide Class	Warning statements on container	Colour of band on container
Class IA	Very toxic	RED
Class IB	Toxic	RED
Class II	Harmful	YELLOW
Class III	Caution	BLUE
Class IV	No warning statement required	GREEN

The meaning of the different colors is as follows:

- **Very toxic:** Most toxic pesticides. Protected equipment and clothing MUST be used.
- **Harmful:** Second most toxic pesticide group. Use all precautions stated on label.
- **Caution**: Use carefully and use protection stated on label.
- **Relatively safe:** Use carefully and follow instructions on the label.

A summary of this type of hazard classification is provided in annex III a. Farmers and other users who have not been specifically trained for pesticide application and have no access to or do not use personal protective equipment (PPE) should use only "green" or "blue" products.

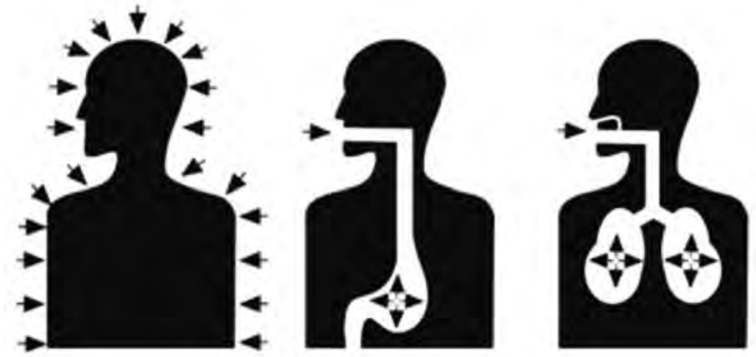
Colour bands include also a range of warning and advice pictograms (i.e. illustrated instructions) which explain the dangers associated with the use of that product and what kind of protection should be used by the farmer, both during the preparation and the application of the pesticide (picture 7.2). The meaning of such pictograms is illustrated in annex III b.

7.2 - Some of the pictograms and other information usually found on pesticide labels

Good labels also provide additional important information, in various sections (usually not in the front panel of the label), such as:

7

Precautionary statement. This section explains the risks associated with that specific pesticide and guides the user to take proper precautions to protect humans or animals that could be exposed. This includes the indication of the protective clothing required. As illustrated by picture 7.3, the main routes of contamination of the human body are contact (eye and skin), inhalation and ingestion. The dermal and inhalation routes of pesticide entry are likely to be the most important routes of pesticide applicator exposure. Farmers might breathe pesticide, splash them on their skin, or expose themselves to pesticide drift. Absorption through the skin can be reduced by 99 percent simply by wearing chemical resistant gloves, a long-sleeve shirt and long trousers.



7.3 - Main routes of pesticide entry in the human organism (from Damalas C.C. and Koutroubas S.D., 2016)

8

Directions for use. This section tells the farmer on what crops, against which pests and in what amount the pesticide should be applied. These directions should be followed for effective, safe, and legal use of pesticides. Usually this section also indicates how much time must elapse after the application of the pesticide before workers are allowed back in to the treated area (this is known as *Re-Entry Interval* or REI). For use on food crops, this section will also indicate how much time must pass between the pesticide application and the harvest (this is called *Pre-Harvest Interval* or PHI). The consequences of not following the PHI is that people eating the harvested produce will be exposed to potentially harmful amounts of the pesticide.

9

Storage and disposal. Proper storage of any pesticide is important to ensure that the pesticide keeps its efficacy and to avoid human health and environmental contamination problems. Some basic rules for the storage of pesticides include:

- store pesticides in their original container, with the label clearly visible (never store them in bottles or food containers);
- store pesticides in tightly sealed containers and check containers periodically for leakage, tears, etc.;
- keep pesticides in a store which can be locked; only trained personnel should have access to the keys;
- stored pesticides must be protected from freezing or excessive heat;

- make sure that the pesticide store is well-ventilated, to prevent the accumulation of toxic fumes;
- always store different types of pesticides in different areas, to prevent cross contamination and the possibility of applying a product inadvertently;
- never store pesticides near food, feed, or seed.

Pesticide stores for small farmers do not need to be fancy and expensive structures and with some creativity it is possible to ensure the required safety by developing low-cost solutions; pictures 7.4 and 7.5 show two deposits (one for liquid pesticides and one for solids) cleverly developed by a farmer in Paraguay.

7.4 and 7.5 - Two pesticide stores ingeniously made by a farmer in Paraguay

With regard to disposal of empty pesticide containers, perhaps the most important measure is to triple-rinse and puncture the containers to avoid re-use, before disposing them in a sound way that complies with national and regional regulations. In any case, they should not be treated as ordinary rubbish and abandoned in the environment (picture 7.6); they should at least be temporarily kept in a safe manner while waiting for proper disposal (pictures 7.7 and 7.8).

More detailed information on appropriate measures and behaviour for the responsible use of pesticide (including purchase, transportation, storage, application, disposal of empty containers), as well as emergency measures in case of pesticide poisoning, is provided in annex III c-h.

Deciding whether to apply pesticides

In the field, each situation is different and there are no general rules to decide if and when to spray. Through regular monitoring of the crop, the farmer must become familiar with the biological processes developing in the field in order to take informed decision on whether or not to apply a pesticide. In many cases, the reduced presence of a pest can be tolerated and only when it appears that its population increases significantly and there is no parallel development of natural enemies should the farmer apply pesticides. However, there are cases when it is not possible to wait and a pesticide application may be warranted at a very early stage of the appearance of the pest, or even before (i.e. preventatively) if local experience indicates that the environmental conditions are conducive for the development of that pest or disease. This is the case with late blight, which under favorable conditions can develop very fast and destroy the whole crop in a few days. Likewise, treatments against the whitefly, *Bemisia tabaci*, should not be delayed if vector-transmitted viral diseases are a recurrent problem in the area.

Scouting should be done at least once a week, but possibly more often, by walking through the crop and checking the different parts of the plants for pests, diseases and natural enemies. Ten to 20 plants in a plot of about 1 000 m^2 should normally be enough. It is important to record the number and type of the organisms encountered, as record keeping is the only way to know if the problem is increasing or not. If the number of an insect pest has not increased from the previous scouting, it means that its natural enemies or some other causes are preventing its massive development and therefore there is no need – for the time being – to use pesticides. If an insect is present but it is not clear whether it is a pest or not, the farmer can place it into a small jar together with some leaves and observe if it feeds on them. If it does, then it is a potential pest. The jar or other container used for this simple test should be closed with a gauze or in any case not in an air-tight manner, to avoid that water condensation kills the insect (refer to exercise 6.7).

Once the farmer comes to the conclusion that a given pest or disease is getting out of control and that a pesticide treatment is warranted, there are several steps that must be taken to ensure that the treatment is both effective and safe. These are described in the following paragraphs.

7.6 - Incorrect management of empty pesticide containers

7.7 - Though not ideal, this method to temporarily keep empty containers is already a step ahead

7.8 - Correct temporary storage of empty containers implemented by a small farmer

Choosing the right pesticide

If a treatment is required, the choice of the pesticide is very important. Smallholder farmers normally are concerned with the use of insecticides or fungicides, as they usually manage weeds by manual weeding. The first step when choosing a pesticide, is to ensure that it is effective against the pest that has to be controlled, but also the most affordable and safest option. Very often the only support the farmer gets is from the local pesticide shops, whose interests usually differ from those of the farmer. Often local vendors recommend the pesticides which they have in store or those on which they have the highest margins, not necessarily the most effective or the safest ones. It is also very common for local vendors to recommend some extra treatments "just in case", which not only is against the principles of IPM, but is also against the farmer's economy. In many cases, the farmer is let on his own to make important decisions and it is not so uncommon to see farmers using a very toxic pesticide while an equally effective – but less toxic – pesticide is available, or even applying an insecticide to control a fungus, or vice versa.

Another important parameter to consider when choosing a pesticide is its pre-harvest interval (PHI), i.e. the time that the farmer should wait after spraying before he harvests the crops. Clearly, a pesticide with a long PHI should not be used if the harvest of the tomato has already started, because otherwise the fruits that are collected in the days following the treatment would have very high residues and would threat the consumer's health. A third aspect that must be considered is the toxicity of the pesticide. It is always advisable to try and use the pesticides with the lowest acute toxicity, to protect the farmer's health, but also those that have the least impact on the environment. For example, the acute toxicity to man of synthetic pyrethroids is not high, but they have a very high environmental toxicity and their application will kill virtually all natural enemies and many other non-target organisms (particularly fish and other aquatic organism). The use of low-toxicity pesticides is very important particularly when farmers do not have access, or in any case do not use, personal protective equipment.

Finally, the choice of the pesticide should also depend on the habit of the target pest and on the timing of the application; e.g. systemic insecticides should be the chosen when targeting an insect feeding on the underside of leaves or anyhow sheltered within plant tissues; likewise, a fungicide with eradicative properties should be used against a plant pathogen which has already infected the plant, as under such circumstance a contact fungicide would be ineffective. Said the above, it is clear that very often the farmer's choice is limited to what's available locally and what's affordable in terms of cost.

Choosing the right equipment for pesticide application

The piece of equipment which is most widely used by small farmers for the application of pesticides is a lever-operated knapsack sprayer. Many farmers still use rather rudimentary methods such as a brush or broom, which is dipped into a container with the pesticide solution and then used to sprinkle it onto the crop.

However, this is an inefficient and unsafe method that should not be recommended. Although knapsack sprayers can be expensive for the majority of small farmers, it is advisable that they buy the best quality they can afford, because the efficacy and the safety of a pesticide application depend largely on the efficient functioning of the sprayer. Cheap sprayers break down often and usually leak, not only wasting pesticide but also posing a health challenge to the user. In any case, independent of the quality of the sprayer, it is important that the farmer provides suitable maintenance of the spraying equipment, replacing when needed nozzles, joints, seals, etc.

Nozzles are a key component of any sprayer and their function is to break up the pesticide solution into small droplets. From their quality and proper maintenance depends the quality of the application. There are many types of nozzles, but those usually used on knapsack sprayers are the so-called *flat-fan* and *hollow-cone*. Flat-fan nozzles are widely used for broadcast spraying of herbicides and produce relatively large droplets. These nozzles operate with an ideal range of between 30 and 40 psi. On the other hand, hollow-cone nozzles are generally used to apply insecticides or fungicides to field crops, when foliage penetration and complete coverage of the leaf surface is required. These nozzles operate at a higher pressure (from 40 to 100 psi) and produce smaller droplets than flat fan nozzles.

To prevent continuous clogging of the nozzles, there should be filters on the mouth of the sprayer's tank, in the lance trigger and also at the nozzles themselves. If nozzles get clogged, they should be cleaned using a wooden toothpick or toothbrush; do not use wires or other metal tools that may abrade or somehow damage the nozzle. Above all, do not put nozzles into your mouth to blow them clean.

Independent of the type of application equipment, proper maintenance is very important as using an efficient sprayer is the only way to:

- ensure an effective application of the pesticide
- reduce the risk of skin exposure of the operator
- reduce the risk of environmental pollution
- prevent waste of product and money.

More details about maintenance of knapsack sprayers are provided in annex IV.

When applying pesticides, most farmers direct the spray from above the crop downwards. This gives a good coverage of the upper leaf surface, but very little of the pesticide reaches the underside of the leaves, which is where many arthropod pests such as mites, aphids and whiteflies (but also several pathogenic fungi) are usually found. This is not a major problem when using systemic or locally systemic pesticides, but any contact pesticide applied this way will have rather limited effect. If using a contact pesticide against the above-mentioned pests, the farmers should make an effort to spray from underneath the vegetation upwards, targeting the underside of leaves. Certain companies sell accessories (e.g. the so-called "V-lance") that can be applied to the sprayer to make this easier.

Applying the correct amount of pesticide (refer also to activity 7.1)

When using a pesticide, it is important to apply the correct dose, which is the one recommended on the pesticide label. Overdosing a pesticide means an unnecessarily high impact on the environment, and also a waste of money for the farmer. On the other hand, under dosing it might not result in an effective treatment and may contribute to the development of resistant populations of the pest. Overdosing may be done deliberately by farmers, many of whom seem to believe that "if 100 grams is good, 200 is better". However, often the application of the wrong dose is the involuntary consequence of the farmer putting too much (or too little) of the concentrated pesticide into the sprayer tank each time he refills it, or the application of too high (or too low) a volume on the crop (e.g. because farmers tend to spray the plants until they drip, or because the nozzle of the sprayer wears off thus delivering too high a volume). This happens because pesticide labels often give application instructions which are not easily understood by the farmer, or because the farmer may have no accurate way of measuring the correct amount of the pesticide to put into the sprayer tank, or because sometimes it is necessary to make calculations which some farmers may find difficult.

Dosage instructions on pesticide labels are usually given as 1) the amount of commercial pesticide/ha (e.g., 1 L or 1 kg/ha, depending on whether the product is a liquid or solid) or 2) as the amount of pesticide/volume water (e.g. 50 ml or 50 g/100 L water). Only for those products targeting specifically small farmers the label may give the application rate as a tank-dose, or in other words as the amount of pesticides to add to each sprayer tank of a standard size (e.g. 20 g in a 10 L tank). The tank-dose is the simplest method for the farmer, particularly if the label also states the area which must be covered with each knapsack tank. Whatever the method used to indicate the recommended application rate, almost invariably some calculations are necessary to work out how much pesticide and how much water should be mixed together to spray a certain area. Even with the tank dose, large errors in the dose applied are still possible: e.g., the manufacturer may assume that the product will be applied using 50 liters/1 000 m^2 of plots, but if the farmer applies 100 liters then the amount of product applied is actually double than that recommended. In practice, in order to make a safe and efficient use of the pesticide, the farmer must ensure that not only the right amount of pesticide is added to each sprayer tank, but also that the volume applied on the crop is suitable for the vegetative stage of the crop (in general terms it should range between 200 and 500 L/ha, but can be much less if the plants are still small). This can be achieved by calibrating the sprayer before application of the pesticide, as explained in activity 7.1.

Finally, it should be mentioned that not always it is necessary to spray the whole field. In the cases when the pest infestation is localized in "hot-spots" (which happens quite frequently with spider mites), the farmer should consider the possibility to spray only those hot spots, rather than the whole crop. This will reduce the amount of pesticide needed, and also preserve the natural enemies that may be present in the unsprayed areas.

A checklist for pesticide application (refer also to activities 7.2, 7.3 and 7.4)

The following is a summary of the most important aspects to take into account when deciding to use and applying a pesticide, to ensure that its application is both safe and effective, while the box at the end of this section contains the three fundamental steps for pesticide risk reduction according to FAO Guidance on Pest and Pesticide Management-Policy Development (2010).

◆ Choose the safest pesticide available. Avoid as much as possible pesticides which belong to toxicological class I (red label) or class II (yellow label).

◆ Choose a product which is appropriate for the pest or disease to be controlled, and possibly selective for beneficial insects. As a rule of thumb, the shortest the persistence of a pesticide, the smaller its impact on natural enemies.

◆ Read carefully the safety and application instructions on the label.

◆ Calibrate the sprayer.

◆ When preparing the pesticide solution or spraying, wear adequate personal protective equipment (PPE) and clothing. If it is not available, or if you cannot afford it, at least wear rubber boots, long trousers, long-sleeved shirt, a face mask and rubber gloves. Wash clothing after pesticide application.

◆ Rubber gloves (preferably nitrile rubber or other chemical-resistant type) must be worn when handling concentrated pesticides. Protect your eyes from accidental splashes of the pesticide. Even ordinary glasses or sunglasses are better than no protection.

◆ Half fill the sprayer with water before pouring the concentrated pesticide into it. Then add the rest of the water, close the lid and shake well the tank to ensure that the pesticide is properly mixed with water.

◆ Wash off any splash of pesticide which fall on your body with soap and water.

◆ Start spraying at the downwind hedge of the crop and move across the wind direction, spraying on the downwind side of your body so that you are not walking through vegetation wetted with pesticide spray.

◆ Spray when it is not windy. Early in the morning or late in the evening are usually the best times of the day.

◆ Do not use worn nozzles. Choose a nozzle which is suitable for the type of application.

◆ Do not spray until run-off, as all pesticide which falls on to the soil is wasted.

◆ Always comply with the pre-harvest interval recommended for a given pesticide.

◆ Do not eat, drink or smoke during pesticide preparation or spraying, or before washing at the end of it.

◆ Do not let pesticide get into streams and ponds, including when washing the sprayer and pesticide containers after use.

◆ Do not use drink bottles to store or measure pesticides, as other people (particularly children) may drink from them.

◆ Keep pesticides locked, away from foodstuff and children.

◆ Do not use empty pesticide containers to store food or water. Rinse them out three times, puncture them and bury them away from the house or water bodies.

Alternatively, after rinsing and puncturing offer them for recycling if that kind of service is available locally.

- Only apply pesticides when really necessary, and on the basis of scouting.
- Target the pest, by applying the pesticide where the pest is feeding (e.g. on the underside of leaves) or using a systemic product. If the pest appears in hotspots, treat only the hotspots and not the whole field.
- Time the application to hit the most susceptible stages of the pest (the younger the insect, the most susceptible it is) or the "weak link" during its life cycle (e.g. stem or fruit borers must be controlled before they penetrate into the plant tissues, after which they will be protected from any chemical spray).

Fundamental steps for pesticide risk reduction

1. Reduce reliance on pesticides. Determine to what extent current levels of pesticide use are actually needed. Make optimum use of non-chemical pest management approaches and eliminate unjustified pesticide use.

2. Select pesticides with the lowest risk. If use of pesticides is deemed necessary, select products with the lowest risk to human health and the environment from the available registered products that are effective against the pest or disease.

3. Ensure proper use of the selected products for approved applications and in compliance with international standards.

Section activities

7.1 - Sprayer calibration

As mentioned in this section, sprayer calibration is essential to ensure that the correct amount of pesticide is applied. This relatively simple procedure explains how to calculate the correct amount of water as well as of pesticide when a spray is required.

Objective

To illustrate to the farmers how to apply the correct amount of pesticide.

Duration of exercise *(indication)*

½ day or less.

Materials needed

- Knap-sack sprayer
- Water
- Graduated plastic carafe (2 to 5 L volume)
- Wooden sticks
- Pen, paper, calculator

Procedure (also refer to picture 7.9)

Step 1. Measure the volume required to spray the crop

- In the crop to be sprayed, measure out an area of 10 x 10 m = 100 m^2 = 1/100 Ha. Mark the area with sticks in the corners.
- Carefully measure a volume of 5 L of water (e.g. using a graduated carafe) and pour it into the tank. Do not add any pesticide.
- Spray the marked area with the water, as if it was a pesticide spray.
- Pour the remaining water back into the carafe and calculate the volume of water used to spray the 100 m^2 plot. If the volume used was 4 L, this corresponds to a volume of 4 x 100 = 400 L/Ha; if it was 3.2 L, this corresponds to 3.2 x 100 = 320 L/ha; if it was 4.8 L, this corresponds to 4.8 x 100 = 480 L/ha and so on.

Step 2. Adjust the spray volume

- If the volume sprayed is much higher than 4 L, under most situations that is too much and part of the pesticide would be wasted (e.g. because of running off). In this case there is a need to modify the spraying technique to reduce the volume applied. This can be done by using a smaller nozzle (i.e. a nozzle that delivers a smaller volume of liquid/minute), or the person spraying should walk faster. With some practice, the conditions to apply the right amount of water can be found.

Step 3. Calculate the right tank dose

Supposing that 4 L of water were used to spray the 100 m², that means that each litre is sufficient to spray 25 m² (100 : 4 = 25 m²). If the tank of our sprayer holds 15 L, then one full tank can spray 15 x 25 = 375 m². If the total area to be sprayed is one hectare (10 000 m²), it can be covered with: 10 000 m² : 375 m² = 26,6 (= No. of sprayer tanks needed for 1 ha). If it was a smaller plot of only 1 000 square meters, then: 1 000 m² : 375 m² = 2.6 (= No. of sprayer tanks needed for 1 000 m²).

If the recommended application rate for the pesticide is 2 L/ha (= 2 000 ml/ha), we can now calculate how much product should be added into each tank: 2 000 ml : 26.6 = 75 ml (= amount of pesticide to be added into each sprayer tank). This amount is independent of the area to be sprayed.

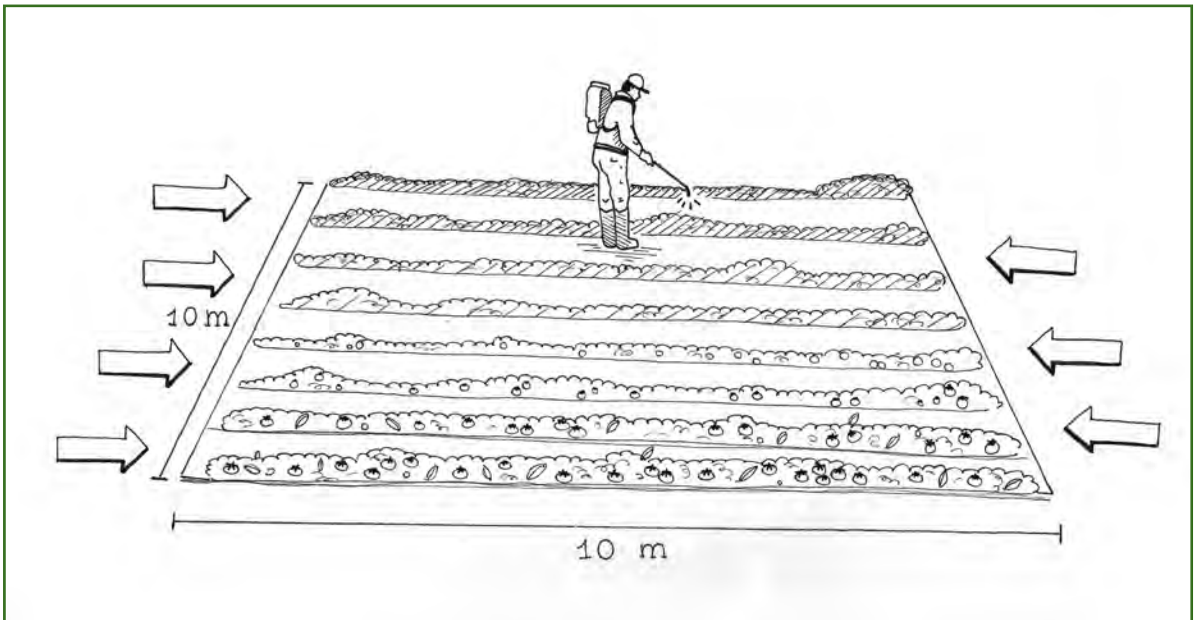
At this point, the farmer will need a graduated measuring cup to make sure that the amount added to the tank is correct. The cost of a measuring cup is certainly less than that of a wrong pesticide application in terms of wasted pesticide, health risks, ineffective treatment, etc. A correct measurement is more difficult with solid pesticides (wettable powders, granules, etc.). However, cups can also be used to estimate the weight of a solid; a 30 ml cup will usually hold 15-20 g of a pesticide in powder form.

Discussion

How do you decide how much pesticide to put in each sprayer tank?

How much water do you apply when you spray your crop? (e.g. on 1 000 m²). Why that amount?

Do you know any other method/any simpler method to calculate the amount of pesticide required?



7.9 - Sprayer calibration (drawing by Gabriela Rovesti)

7.2 – Do's and don'ts in pesticide application

It is important that farmers understand the importance of using personal protective equipment when preparing and applying pesticides. Through this very simple exercise, and based on what was discussed in this session, farmers can identify what one of their peers is doing correctly and what he's doing wrong.

Objective

To make the farmers understand the do's and don'ts in pesticide application.

Duration of exercise *(indication)*

½ an hour.

Materials needed

- Printouts of pictures 7.10 and 7.11
- Flip board
- Markers

Procedure

Give farmers a printout of pictures 7.10 and 7.11, which show a farmer preparing and then applying a pesticide. Ask them to identify in each picture what the farmer is doing well and what he's doing wrong, with regard to the use of PPE.

Discussion

Is the farmer using suitable protections? What is he missing?
Is there any difference in the protections to be used during the preparation and during the application of the pesticide? Why?
Look at the farmer's cloths; is there any indication that he regularly washes his clothes after pesticide application?
What good agricultural practice can you observe in picture 7.11?

7.10

7.11

7.3 - Spray dye exercise

One of the disadvantages of using chemical pesticides is the risk for farmers themselves of becoming exposed to poisonous chemicals during their application. Many farmers – particularly in developing countries – suffer from pesticide intoxication at least once in their working life. Even though farmers spray in the direction of the crop, some parts of their body become contaminated with the spray. It is important for farmers to know about the exposure of their body to pesticides during application.

Objective

To make the farmers aware of the direct exposure of their body to pesticides.

Duration of exercise *(indication)*

½ day or less.

Materials needed

- Knap-sack sprayer
- Water
- Color dye (preferably red, use non-toxic dye such as food coloring; leaves of Roselle (*Hibiscus sabdariffa*) are a good option as they are easily available in Eritrea)
- White cotton overall
- Field with a well-developed tomato crop
- One volunteer

Procedure

Prepare a color solution with the dye (if using Roselle leaves, crush 40-50 g of them into a fine powder and dissolve it in water to obtain a uniform red color). Use the solution to half-fill the knap-sack sprayer. Ask the volunteer to wear the white overall and subsequently to spray the test plot (10 x 10 m) in the tomato field as he would normally do with a pesticide. If the weather is windy, ask the sprayer to spray off-wind and later repeat the test against the wind.

Observations

Remove the knapsack sprayer and record the spots of dye on the different body parts: head, torso, back, arms, hands, legs, feet.

Discussion

On which part of the body was the dye found?

Would protection with mask, hat, gloves and boots reduce contamination

with pesticides while spraying?
What symptoms can be caused by pesticides? Have you ever felt headache, dizziness or otherwise after spraying?
Do you think that the person spraying also breaths in some of the pesticide mist?
Would you expect more or less contamination when crops of different sizes are sprayed? What was the effect of the wind?
What can we learn from these results? Is 'safe application' of pesticides really possible?

7.4 - Effect of pesticides on natural enemies

When pesticides are applied in the field, they affect the general environment and – if no precautions are taken – they may have serious negative effects on beneficial insects, fish and many other forms of life.

Objective
To evaluate the effect of pesticides on the survival of natural enemies.

Duration of exercise *(indication)*
½ to 1 day to set up, and 1 or 2 days monitoring.

Materials needed
- Vegetable field, unsprayed
- 4 Jars with lids
- 4 Pieces of muslin cloth with rubber bands, to close the jars Labels
- Note paper, pen
- 4 Small hand-sprayers (0.5 L), shared between groups
- Small amounts of different broad-spectrum insecticides and one bio-insecticide (e.g. *Bacillus thuringiensis*)

Procedure
1. Prepare 4 hand sprayers before the practical. If a sprayer has been used before, wash it thoroughly with detergent. Prepare and fill 3 hand sprayers with commonly used insecticides, at field rate concentrations, for example: methomyl (carbamate), cypermethrin (pyrethroid), *Bacillus thuringiensis* (biological insecticide). Fill the fourth hand sprayer with pure water (control). Label the hand sprayers to avoid confusion.
2. Select 4 plants, at a reasonable distance from each other, in the field: one plant per spray treatment. Label each plant with the name of the treatment.

Spray the labelled plants with the corresponding spray solution and let the leaves dry on the plant.

3. Pick some leaves from each treatment and transfer these to the corresponding glass jars (use gloves). Label the jars. Each group should have one jar of each spray treatment (4 jars in total). Try to get the leaves to lie flat on the inside surface of the jar.
4. Collect predators, e.g. spiders or lady beetles, from the field. Try not to touch the predators but use a brush to collect them in jars. Carefully transfer them to the treatments (one of each species per jar). Use the same predator species in all treatments and make sure they are of similar size. Close the jar with the lid, placing a piece of tissue paper between them to avoid condensation inside the jar.

Observations

Check and record the condition of the predators after 8 hours and again after 24 and 48 hours. Count the number of dead insects. It may be necessary to touch the insect with a pen or pencil to determine if it is dead. If it does not walk off in a normal manner, then record it as dead.

Discussion

What happened to the predators in the different jars? Why?
What happens in the field when a farmer sprays against a certain pest? What will happen in a field 1, 2, 3 weeks after spraying?

An alternative way to do the same, would be to set up two plots of 5 x 5 = 25 m^2. Using a knapsack sprayer, one of the plots is sprayed with a broad-spectrum insecticide (e.g. a pyrethroid) and the other one with a biological pesticide (e.g. *B. thuringiensis*). The following day compare the presence of beneficial insects in the two plots, recording the number of beneficials found alive and dead. The assessment can be done by using an insect net or by direct observation of the plants (use gloves to handle the treated foliage).

PART 8
Harvest, post-harvest and marketing

Harvest

The time required to reach maturity depends both on the tomato variety and the climatic conditions. As a general indication, early varieties will need 50-65 days, mid varieties 65-80 days and late varieties 80-100 days from transplanting to harvest. For most of the varieties grown in Eritrea, harvest starts after 70-80 days and the expected production ranges between 15 and 25 tons/ha.

In tomatoes, the following ripening stages are usually identified:

IMMATURE: the fruit is fully green. When sectioning a fruit, seeds are cut by a sharp knife. There is no jelly-like material in any of the locules. If harvested in this stage, fruits will not mature.

MATURE GREEN: fruits are still green, but seeds are fully developed and not cut when slicing the fruit. Jelly-like material fills – although partially – the locules or at least some of them. Commercially, this is the minimum harvest maturity. In practice, fruit are picked by size and location on the plant.

BREAKERS: There is a definite break of colour from green to tannish-yellow, pink or red of 10 percent or less of the tomato surface (usually on the flower end). "Breakers" ripen naturally without gassing with ethylene.

TURNING: Tannish-yellow, pink or red colour shows on over 10 percent but not more than 30 percent of the tomato surface.

PINK: Pink or red colour shows on over 30 percent but not more than 90 percent of the tomato surface.

LIGHT RED: Pinkish-red or red colour shows on over 60 percent, but red colour covers not more than 90 percent of the tomato surface.

RED: more than 90 percent of the tomato surface is red.

Market requirements usually dictate the ripening stage at harvest. A common recommendation for fresh market tomatoes (round type) is to harvest when about 10 percent of the fruit on the first hand is at the breaker stage of maturity. Tomatoes harvested at the mature green stage make up the bulk of the commercial fresh market tomato crop because they tolerate rough handling better than the riper stages and hold the longest in storage, transport, and on the store or supermarket shelf. Round tomatoes for field production can be harvested at mature-green stage and be ripened into good quality tomatoes. In industrialized countries, tomatoes picked at the mature green stage are ripened artificially with ethylene gas in special rooms. For local market or home consumption, fruits can be left on the plant until fully ripe, if disease/pest pressure allow. Plum tomatoes (i.e. San Marzano type), which are usually canned or used in processing, are harvested red-ripe.

Tomato is harvested in subsequent pickings. The interval between the pickings depends on the weather, from 2-3 days in warm weather up to one week if the weather is cool. To avoid damage, they should be picked from the plants by twisting them rather than pulling them. Vines and fruits should be completely dry when mature green fruit are harvested. Otherwise, fruit may develop sunken, blackened areas during ripening.

Post-harvest

In many countries, tomatoes are packed after harvest and sent to the market. In the more demanding markets, fresh market tomatoes are dropped into a water tank after harvest to clean the fruit. Improper tank procedures can also spread disease, however, thus increasing storage losses. Disease spread can be minimized by slightly chlorinating the water and warming the water to a few degrees centigrade above fruit temperature, to avoid that cool water constricts the fruit, pulling in pathogens.

In general, the length of storage depends on the harvest stage. Mature green fruits can be stored up to 30 days at cool temperatures. Ripe fruits will keep for about a week. Tomatoes are chilling sensitive and should not be stored below 10 °C. Symptoms of chilling injury on tomatoes may include decreased flavour, lack of uniform ripening, and softness and mealiness when transferred to warmer temperatures for ripening. If tomatoes are stored long enough at low temperature, there will be increased decay. Extended exposure of green tomatoes to temperatures of 5 °C or lower causes rotting of fruit before they ripen. In a refrigerator at 5 °C, the enzymes necessary for ripening are deactivated and the tomato won't ripen even after it is taken out of the refrigerator. Thus, tomatoes should not be kept in the refrigerator unless they are already fully ripe.

Marketing and farm economic analysis

A farm economic analysis should be done in order to calculate whether farming efforts have been, or will be, economically viable. By doing such an analysis, farmers can compare their profits with their costs and estimate their income. Unfortunately, farmers rarely make these calculations, and sometimes their incomes are not enough to cover their production costs. The two important points to consider when conducting a farm economic analysis are expenditure and income. When looking at expenditure, determining factors are all goods and services costs, outgoing payments for land rental, labour, inputs (seed, fertilizer, treatments etc.), transport, tax, harvesting, etc. When calculating income, the determining factors are the amount of produce harvested and the market price. All produce is calculated in monetary terms even though some may be consumed by the family or given to neighbours (opportunity cost). All outgoing and incoming amounts are calculated and added up to reach total figures for expenditure and income. The figure for total expenditure is subtracted from the total income to determine actual earnings (net return or profit).

With a look at the future, cleaner products resulting from implementation of IPM technology should allow better access to domestic and international markets. Increased requirements for high quality products are needed to comply with the strict guidelines on Maximum Residue Levels of pesticides (MRLs) from potential importers, such as the European Union. Domestic markets will also likely increasingly require better quality and low pesticide residues in the products. A national IPM certification system may be needed in the future. That will be a long process requiring the involvement of the national authorities, as well as traders and retailers. The certification of IPM products would require precise guidelines/ regulations and the control of a number of parameters, e.g. on the kind of crop management practices (including brands, types, dosages, application methods of pesticides) allowed at what time in the cropping cycle. In addition, an inspection system that includes sampling for residues would have to be established to ensure that IPM claims are justified and to correct farm procedures if necessary.

Here are some activities that can be taken up by a FFS, which may help farmers to prepare themselves to accessing markets to obtain a better price.

1. *Record keeping* is an important element in everyday activity, as well as for future certification schemes. Farmers will need to keep a record for example of fertilizer and pesticide use, in order to prove their compliance to IPM guidelines.
2. *Grading* of products after harvest is something to discuss in the FFS group, where applicable. Basic grading done at farm level may increase unit price for best quality versus selling in "bulk".
3. *Packaging* of products can get special attention in the FFS.
4. The facilitator or FFS members may contact trade companies, retail organizations, hotels, local supermarkets, etc., to discuss options for sale of clean IPM products from the FFS members. In many countries, large supermarkets are already taking food safety seriously and will only buy products from farmers they can trust to produce healthy food.
5. The FFS can be a platform for sharing the findings of marketing studies and discuss the marketing opportunities of crops produced through IPM methods.

Section activities

8.1 - Farm economic analysis

The two important points to consider when conducting a farm economic analysis are expenditure and income. In this activity we discover what factors influence profit and loss, and how best to develop strategies to increase efficiency and profits.

Objective

To develop farmers' ability to do a tomato production economic analysis and to understand the principles of a farm economic analysis.

Duration of exercise

1 hour

Materials needed

- Large sheets of paper, markers, adhesive tape
- Coloured cards
- Record keeping and analysis forms

Procedure

1. Explain the objectives of this session.
2. Ask participants what the term "farm economic analysis" means to them and what its use is.
3. Write down their answers on a large sheet of paper, and provide a more detailed explanation of a farm economic analysis.
4. Ask participants what they should calculate when analysing their farming enterprises (e.g. income, expenditure, etc.). Invite them to list what things come under expenditure and income. Using coloured cards, give every participant the opportunity to offer his or her opinion. When participants have finished listing all forms of expenditure and income, invite them to analyse their tomato production enterprise so they can know how much net profit they actually make.
5. Help participants to do a tomato farm economic analysis either of their own fields, or of the experimental plot. Show them an example of how to keep records of expenditures, labour investments and income throughout the season, and how to do the economic analysis using the record data.

Discussion

1. What is a farm economic analysis?
2. What are the benefits of doing farming economic analyses?
3. How can you do a good farm economic analysis?

ANNEXES

Annex I – Tomato varieties currently available in Eritrea

Name of the variety	Type (determined/ indetermined)	Life cycle (days)	Fruit size (small/ medium/large)	Resistance to pests or diseases	Remarks
Cherry toma-to (local)	indetermined	60-90	small	-	used locally by some farmers
Chicco	indetermined	90-120	medium	-	current use
Marglobe	determined	90	large	-	very limited use at present; short shelf life
Money Ma-ker	indetermined	90-120	medium	-	very limited use at present
Rio Grande	determined	90	medium	-	current use
Roma VF	determined	90	medium	Verticillium, Fusarium	very limited use at present
San Marzano lungo	indetermined	90-120	medium	-	current use
San Marzano nano	indetermined	90-120	medium	-	current use

Annex II – List of recommended active ingredients

Pest/disease	Currently authorized in Eritrea	Currently NOT authorized in Eritrea[#]
Aphids	dimethoate, imidacloprid, pyrethrins	flonicamid, pirimicarb, pymetrozine, spirotetramat, thiamethoxam
African bollworm	emamectin benzoate*, fenpropathrin*, indoxacarb	*Bacillus thuringiensis*, chlorantraniliprole, methoxyfenozide, novaluron, spinetoram, spinosad
Tomato leafminer	abamectin*, azadirachtin[1], deltamethrin[2]*, emamectin benzoate*, imidacloprid, indoxacarb,	*Bacillus thuringiensis*[1], chlorantraniliprole, chlorfenapyr, flubendiamide, lufenuron, methoxyfenozide, spinosad, tebufenozide
Tobacco whitefly	azadirachtin, dimethoate, imidacloprid, pyrethrins	buprofezin, flonicamid, pymetrozine, pyriproxyfen, spiromesifen, spirotetramat, thiamethoxam
Cutworms	carbaryl, cypermethrin	spinosad
Vegetable leafminer	abamectin*, azadirachtin, dimethoate	chlorantraniliprole, spinetoram, spinosad,
Mites	abamectin*, neem oil, sulfur	bifenazate, clofentezine, etoxazole, exitiazox, fenpiroximate, spiromesifen
Nematode	-	fluopyram, *Paecilomyces lilacinus*
Damping off	thiram (only seed treatment)	Propamocarb[3]
Anthracnose	chlorothalonil, mancozeb	azoxystrobin, pyraclostrobin
Powdery mildew	bupirimate, pyrazophos, sulfur	azoxystrobin, quinoxyfen, tebuconazolo, trifloxystrobin
Late blight	chlorothalonil, copper oxychloride, mancozeb, metalaxyl	azoxystrobin, cyazofamide, cymoxanil, dimethomorph, mandipropamide, metiram, propamocarb, pyraclostrobin
Early blight	chlorothalonil, copper oxychloride, mancozeb	azoxystrobin, difenoconazole, metiram, propamocarb, pyraclostrobin

[1]: Suitable in case of low-level infestations

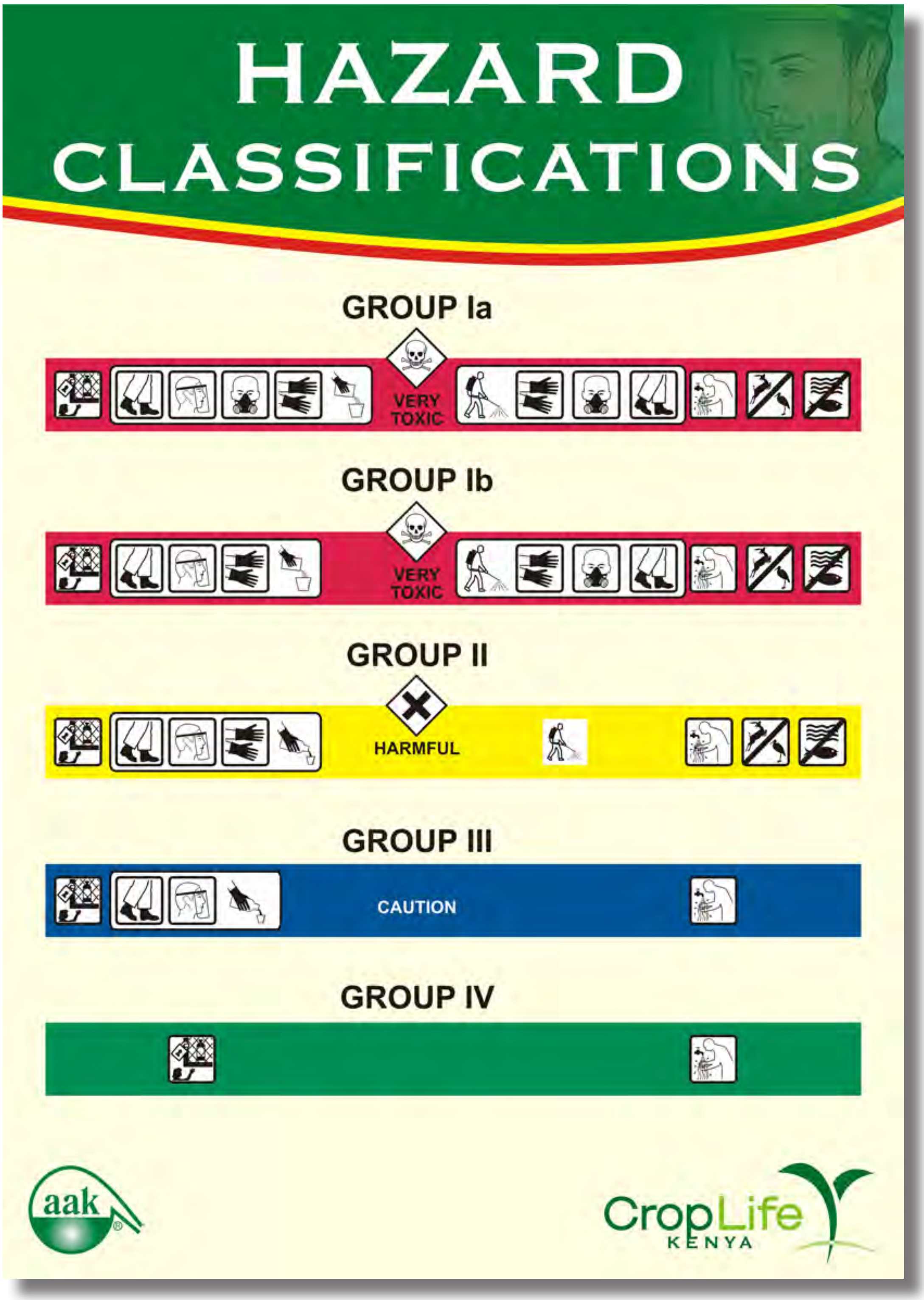
[2]: For adult control

[3]: for nursery application

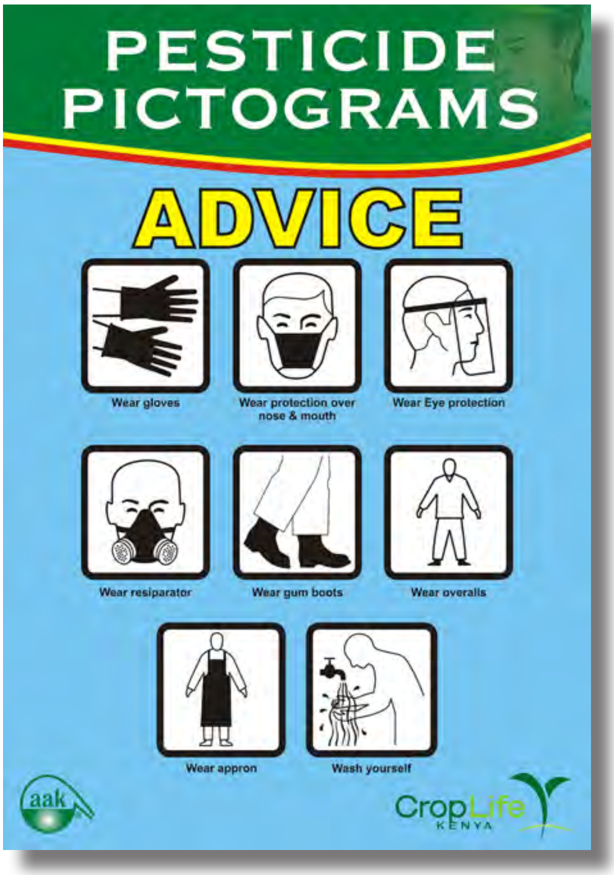
[*]: Pesticide with higher toxicity, prefer other options if available

[#]: As mentioned at the beginning of Part 6, in the author's knowledge these pesticides are effectively used in other countries for the control of a given pest or disease. However, they are currently not authorized for use in Eritrea and their inclusion in the table is NOT a recommendation to their use at present, but is simply meant as an additional information to be taken into account if and when these pesticides become registered by the Ministry of Agriculture of Eritrea. NO UNREGISTERED PESTICIDE SHOULD BE USED.

ANNEX III a – WHO hazard classification for pesticides

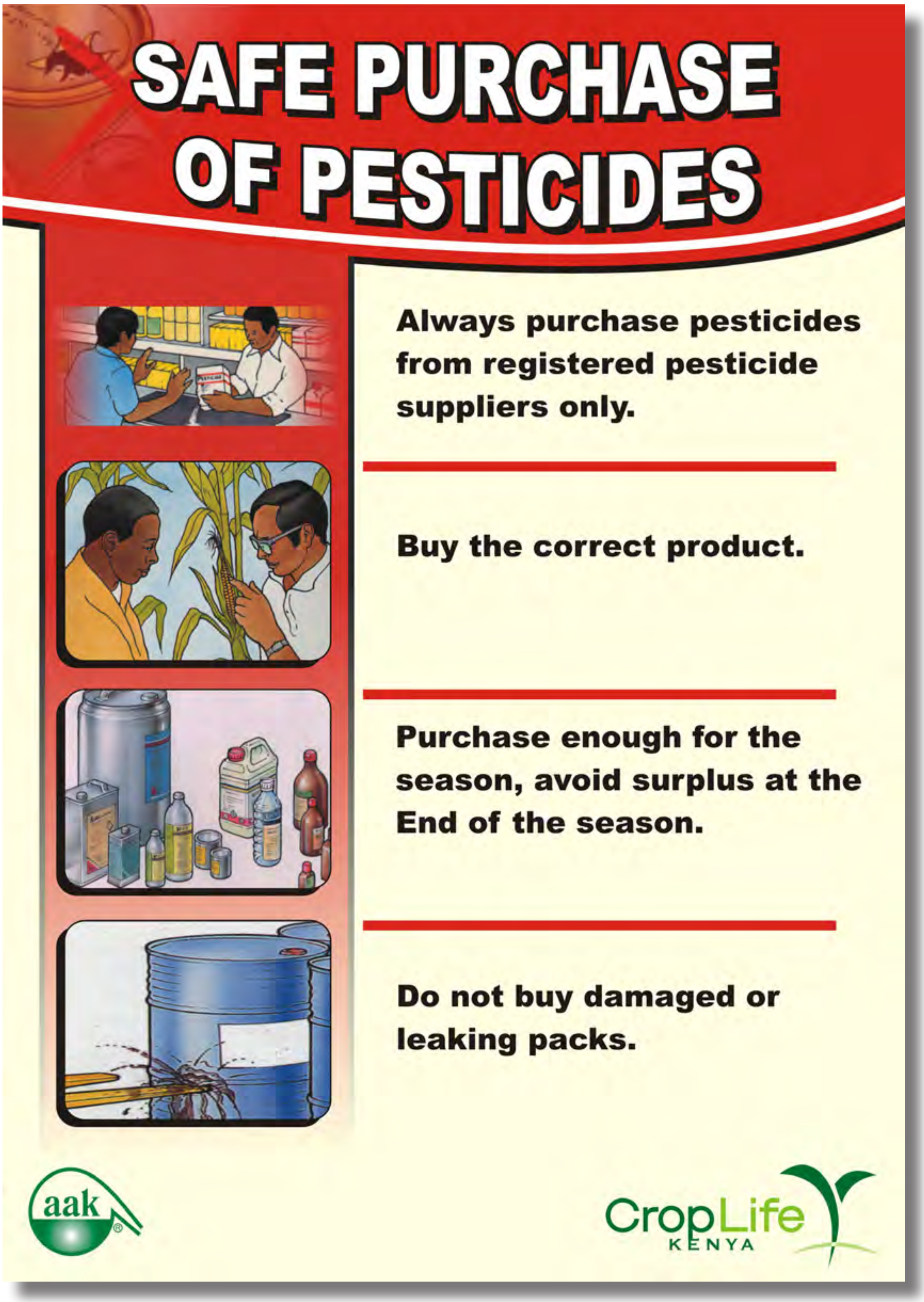


ANNEX III b – Pictograms found on pesticide labels and their meaning

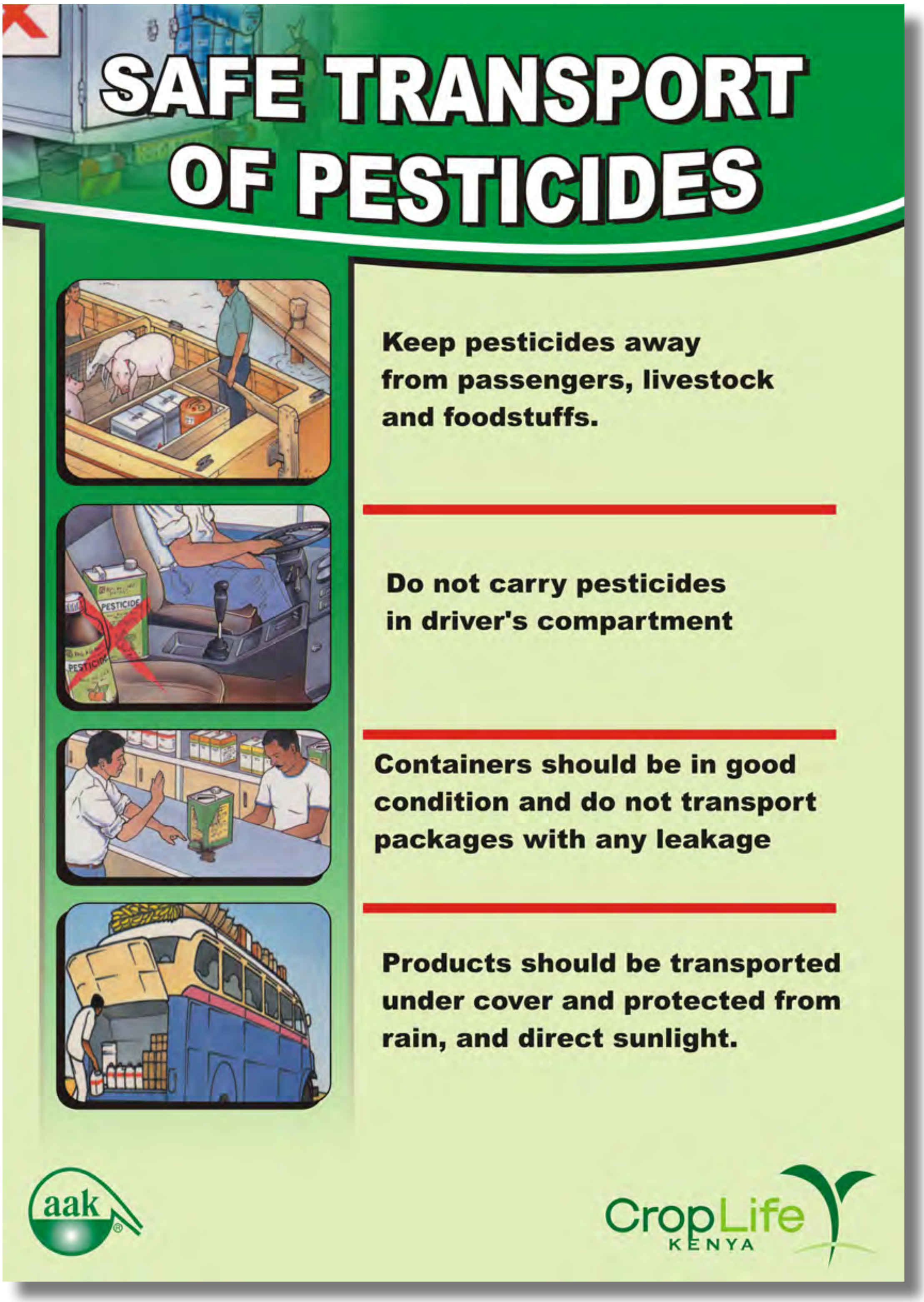


ANNEXES

ANNEX III c – Safe purchase of pesticides



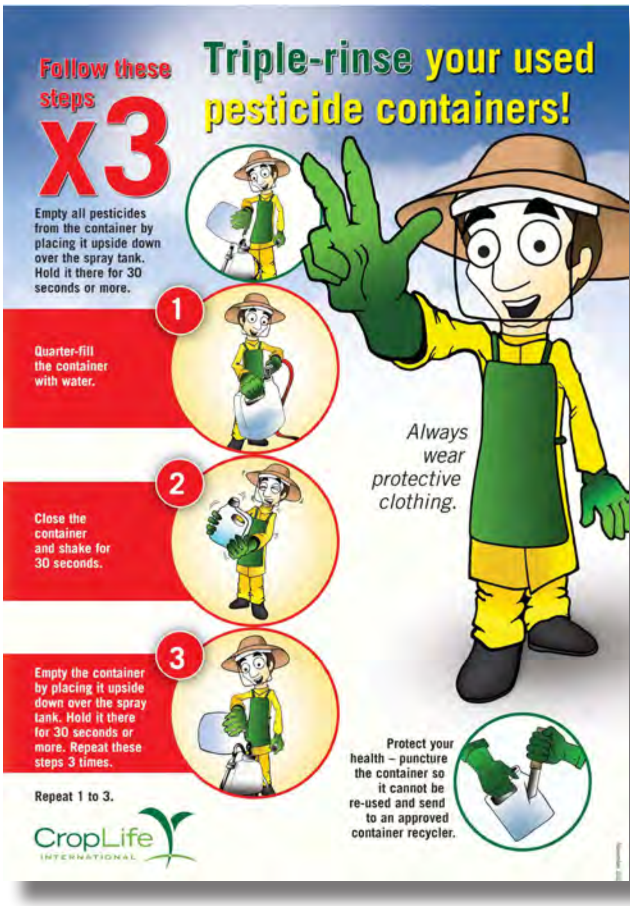
ANNEX III d – Safe transportation of pesticides

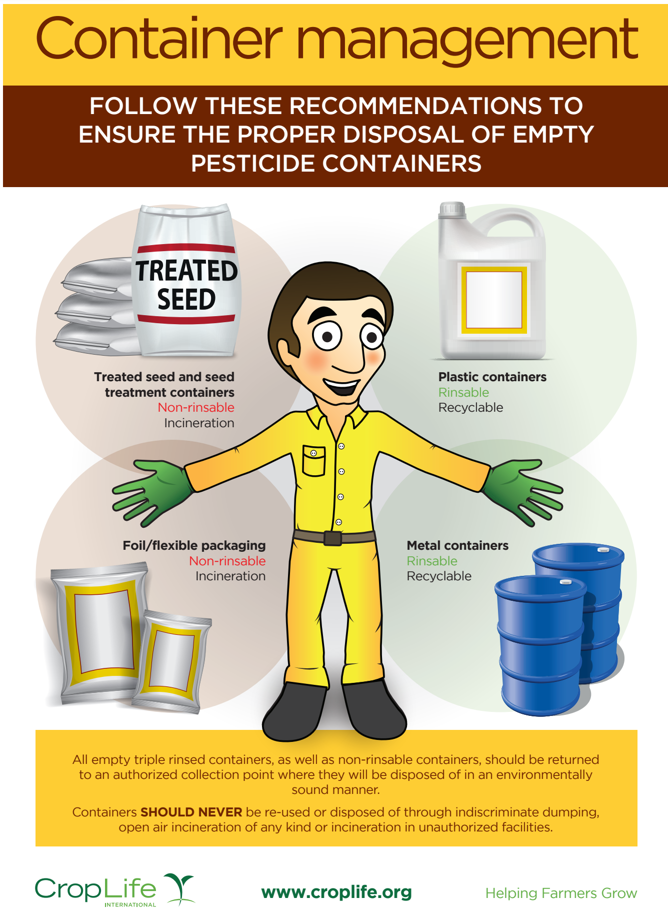


ANNEX III e – Safe storage of pesticides

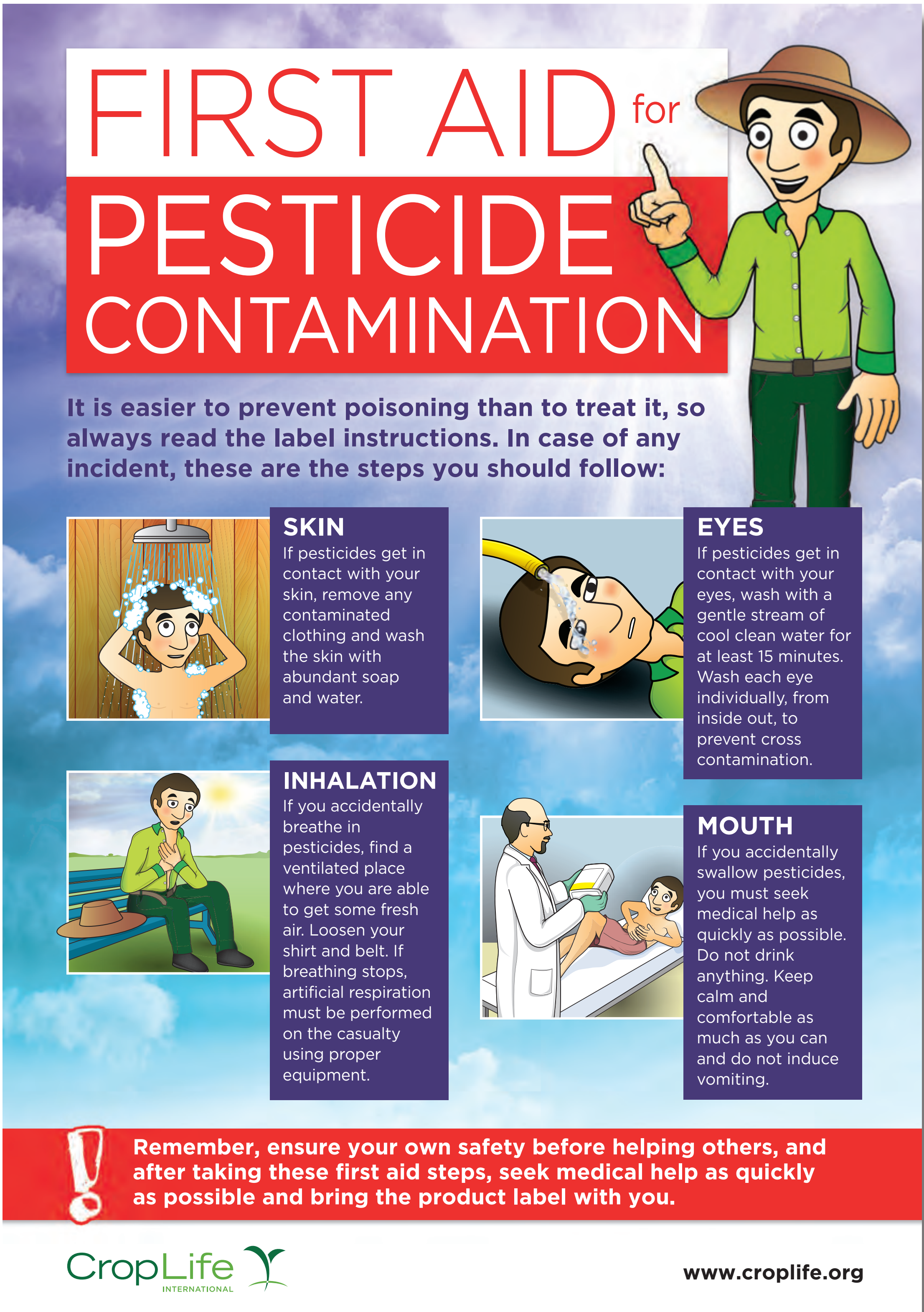
ANNEX III f – Responsible use of pesticides

ANNEX III g – Correct management of empty containers

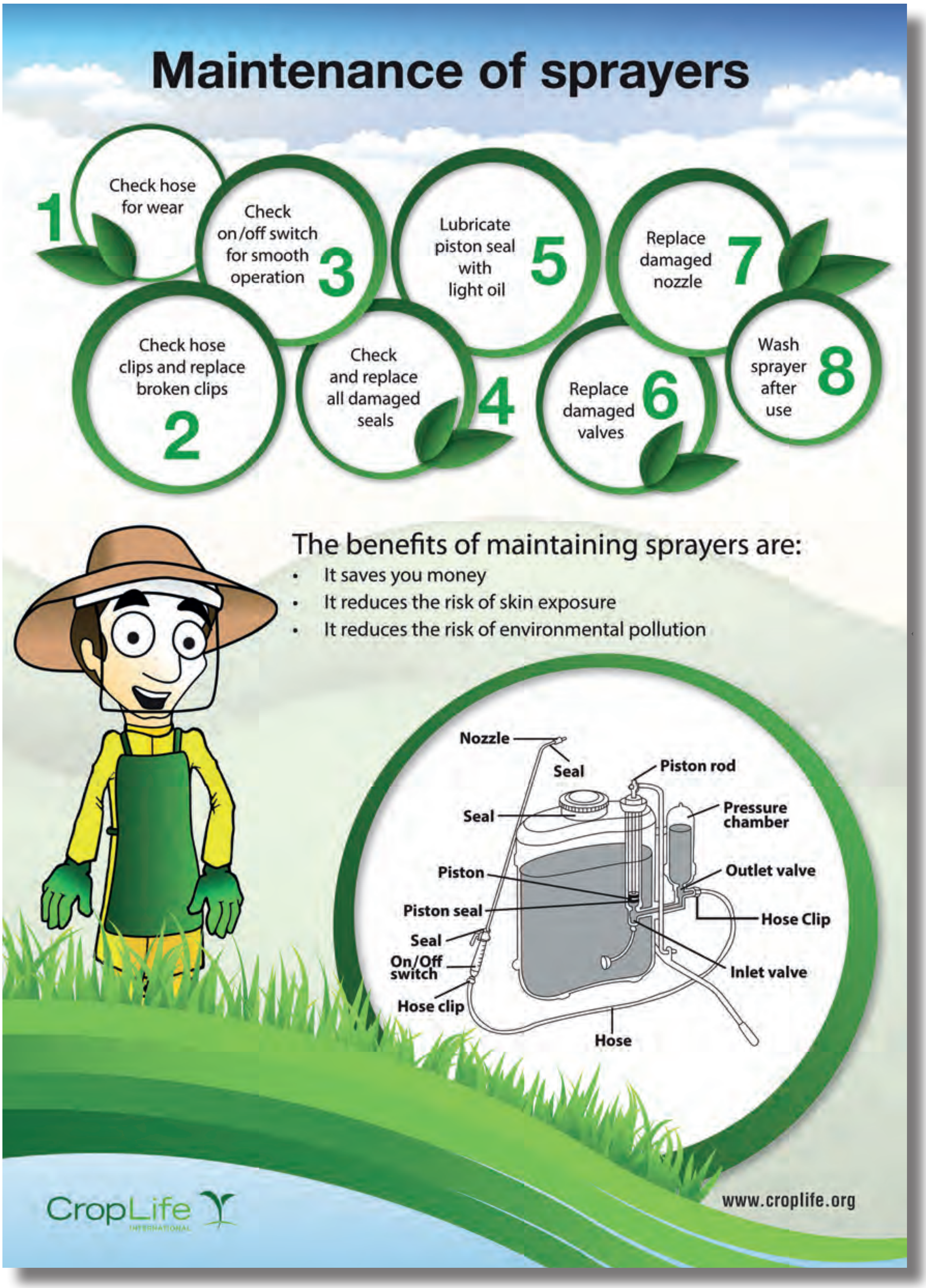




ANNEX III h – First aid for pesticide contamination



ANNEX IV – Maintenance of sprayers



ANNEX V – Pesticides currently authorized in Eritrea

The following table summarizes the pesticides (as active ingredients, AI) officially approved for use in Eritrea at the time of writing this manual, together with an evaluation of their suitability for use by smallholder farmers (refer to the colour-key below). Please note that such an evaluation is subjective and based mostly on the acute and environmental toxicity of each AI, having in mind the general context in which smallholders usually apply pesticides (i.e. with no specific training, with no availability or no use of PPE, etc.). A more objective evaluation would require the knowledge of the actual commercial products which – over the time – are made available to the farmers, as the danger associated with a specific pesticide depends on the amount of AI it contains, on the type of formulation, on its intended use, etc.

As mentioned in Part 6 above, the number which appears in the square next to each AI indicates the mode of action (MoA) group to which that AI belongs. To prevent or at least slow down the development of resistance by pests and diseases, it is important that users alternate pesticides with different MoA or, in other words, that they avoid applying repeatedly the same pesticide or pesticides which bear the same MoA number.

INSECTICIDES

6	abamectin
1B	acephate
19	amitraz
	azadirachtin
1A	bendiocarb
1A	carbaryl
1A	carbofuran
1A	carbusulfan
1B	chlorfenvinphos
1B	chlorpyrifos
1B	chlorpyrifos-methyl
1B	coumaphos
3A	cypermethrin
	cythioate
3A	deltamethrin
1B	diazinon
1B	dimethoate
6	Emamectin benzoate
3A	fenpropathrin
1B	fenitrothion
1B	fenthion
3A	fenvalerate
2B	Fipronil
3A	Flumethrin
4A	imidacloprid
22A	Indoxacarb
3A	lambda cyhalothrin
1B	malathion
	Metarhizium acridum
1A	methomyl
	naphthalene
3A	permethrin
1B	phosmet
24A	phosphine (Al, Mg and Zn phosphide)
1B	pirimiphos-methyl
1B	profenofos
1A	propoxur
3A	pyrethrins
1B	temephos
1B	trichlrofon

FUNGICIDES

1	benomyl
8	bupirimate
M04	captan
1	carbendazim
M05	chlorothalonil
M01	copper oxychloride
5	dodemorph
3	imazalil
2	iprodione
M03	mancozeb
4	metalaxyl
7	oxycarboxin
3	propiconazole
6	pyrazophos
M02	sulfur
3	tebuconazole
1	thiabendazole
M03	thiram
3	triadimefon

HERBICIDES

5	atrazine
4	2,4 D
1	clodinafop-propargyl
1	fenoxaprop-P-ethyl
1	fluazifop-p-butyl
9	glyphosate
	mefenpyr-diethyl
22	paraquat dichloride
3	pendimethalin

RODENTICIDES

	bromethalin
	chloralose
	chlorophacinone
	difenacoum
	flocoumafen

NEMATICIDES

1B	ethoprophos
1B	fenamiphos
1B	phorate

ACARICIDES

6	abamectin
3A	acrinathrin
12B	fenbutatin oxide
12D	tetradifon

ADJUVANTS

	nonylph. polyethoxy ethanol
	white oil

PRESERVATIVES

	aluminum sulphate
	calcium hypochlorite

HORMONES

	Indolylacetic acid

RESTRICTED USE PRODUCTS

3B	DDT
2A	Endosulfan
8A	Methyl bromide

KEY: Suitable — Use only if no alternatives are available — Not recommended

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