Integrated Pest Management for Selected Crops

Manual

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Principles and Concepts of IPM

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Integrated Pest Management has been defined in many different ways; the definition agreed by the UN's Food and Agriculture Organization (FAO), NGOs, such as the Pesticide Action Network (PAN), and the pesticide industry, is: An approach which "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 the environment. IPM emphasizes the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms."This definition incorporates the underlying concepts that IPM:

- is farmer based,
- is not a "package" but is location specific (even down to the field level or crop growth stage),
- is a combination of all suitable techniques,
- • must be considered as an integral part of crop production together with all agronomic techniques (i.e. integrated crop management – ICM),
- considers the economics of pest management, and
- minimizes pesticide use for the protection of health and the environment – "as little as possible, as much as necessary."

There is no single "recipe" for IPM. Even within one crop there will be differences between locations, crop growth, yield potential, the attacks of the different pests, and the farmer's resources. It is impossible to give one package of recommendations that will adequately cope with all the combinations of these possibilities. The implementation of IPM, therefore, must be flexible, and adapt to local agronomic, pest, and farmer circumstances.

IPM is a combination of all suitable techniques which minimize pest numbers and damage. The actual techniques included in an IPM program will vary, not only between crops, but also within the same crop grown in different locations, depending on the suitability of the different techniques for that situation and availability of tools and resources.IPM must be considered as an integral part of crop production together with all agronomic techniques (i.e. integrated crop management – ICM). Pest management cannot be considered on its own, it is a part of the overall production practice of a crop, which includes seed/variety selection, land preparation, fertility and water management etc. Changes to production practices will affect pest management practices.

IPM considers the economics of pest management as the crop has to pay for all the input costs. If unnecessary inputs are used, such as unnecessary pesticide applications, profits and the farmer's income are reduced.IPM minimizes pesticide use for the protection of health and the environment. This may not be of immediate concern to the farmer, but is important for the long term preservation of the health of everyone, and of the environment.

IPM practices are not new. Farmers used many of the practices that we now incorporate into IPM strategies for hundreds of years before synthetic pesticides were available, using their own knowledge of the crops and pests to minimize pest damage. These practices were largely abandoned when synthetic pesticides, which provided an easy answer to pest problems, were developed in the 1940s and then widely used in the 1950s. However, in the 1960s the above problems of pesticide use started to become acute. In consequence, pesticide use began to be rationalized in certain crops, particularly cotton. IPM has gradually developed since then, and modern IPM combines aspects of the old farmer knowledge with more recent technical advances.

Integrated Pest management Farmers Field Schools (IPM-FFS) was initially developed by FAO to address problems of pesticide dependency and to develop location specific management expertise that did not depend only on the formal research system. Later the initial generic FFS for integrated pest management of rice have been adapted for other crops and many agricultural topics. Reports reveal that the first Field Schools were established in 1989 in Central Java during a pilot season by 50 plant protection officers to test and develop field training methods as part of their IPM training.

IPM Farmers Field Schools: Concepts and Practices

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Introduction

A farmer field school (FFS) is a season-long training activity that takes place in the field. It is season-long so that it covers all the different developmental stages of the crop and their related management practices. The training process is always learner-centered, participatory and relying on an experiential learning approach.

To run an IPM Farmers Field School (FFS), experienced facilitators are needed, who have sufficient background knowledge of IPM, a good understanding of the crop, and who above all have the skills and the right attitude to make it a practical and participatory learning experience for the farmers.

To organize farmer field schools it is necessary to first develop the people who are acting as "teachers/trainers" to make them become "facilitators". Long experiences in many countries have shown that this can only be achieved through season-long "training of trainers" (TOT) courses.

The season-long training (from land preparation to harvest) provides the opportunity to get a deeper understanding of IPM during all stages of the crop and it also allows sufficient time to develop the appropriate approach and to practice the required skills. The TOT participants have to practice these new skills several times with real farmers while being guided by experienced master trainers.

As general remark Farmer field schools (FFS) are platforms supporting integrated decision-making and innovation for sustainable agriculture in smallholder agriculture dominated system. It is oriented towards providing agro-ecological education through participatory learning based on group extension method and adult non-formal education principle. On many adult learning books and training books the following colloquia is widely used: "Education for children is often like filling a cup with tea, milk and sugar, while adult education is more like stirring an already full cup of tea to blend the ingredients in a new way . “

Basics and Principles of FFS

Doubtless there are many other programmes besides IPM Field Schools which have succeeded to provide good educational results. Much of the Field School ideas grew out of the traditions of literacy education and village-level basic health care. Similar programmes have been developed for soils, and livestock in other regions. The Field Schools are not a new idea, just an effective idea that has been ignored by those caught in the system of top-down research message delivery and who too often turn a deaf ear to the conventional wisdom of farmers. Some farmer participants say that the IPM Field Schools succeed because they provide basic scientific conceptual frameworks and knowledge in very democratically run field groups and of course because farmers make more money with less inputs.

FFS is based on adult education principle. It assumes that farmers already have a wealth of experience, and knowledge. It also assumes that there may be misconceptions and bad habits learned during intensification programmes (e.g. little knowledge of natural enemies, basic fear of any insect that is seen in the field, etc.). Therefore the Field Schools are oriented to providing basic agro-ecological knowledge and skills, but in a participatory manner so that farmer experience is integrated into the programme.

Key elements of Typical FFS

FFS Curriculum:

FFS curriculum follows the natural cycle of its subject, be it crop, animal, soil or process. That means the cycle could be from seed to seed or from egg to egg. This allows all aspects to happen and covered in parallel with what is happening in FFS participating farmers’ fields. Curriculum is developed showing the duration, dates and activities in the natural cycle. So farmers will be informed their stay duration and timing for a day sessions. Unlike its name there are no lectures in FFS because the field is used as their lab and exercise book. Farmers may contribute their labor on the study filed operations as the process is based on learning by doing. In the curriculum specific time will be allocated for each specific topics/activities which lasts not more than two hours. In each session group dynamic exercises like energizers (joks) and icebreakers will be used to motivate interaction.

FFS is based on crop phonology and time limited. The Field Schools and season long training for trainers are based on the crop phenology; seedling issues are studied during the seedling stage, fertiliser issues are discussed during high nutrient demand stages, and so on. This method allows to use the crop as a teacher, and to ensure that farmers can immediately use and practice what is being learned. Meeting on a weekly basis means that farmers are participating in a course for a whole season, but from an administrative/financial point of view, the same 40 hours as in an intensive one week programme. The educational benefits of meetings when problems are present (learner readiness), on a recurrent basis have been studied and shown to be far more effective that intensive courses. Also the courses are delimited by the crop cycle. Therefore, there is a definite beginning and end. The present system of many extension programmes of unending two week cycles removes focus, and excitement. Field schools may extend beyond one season if groups agree, but rarely can be effective when less than the phenological cycle of the crop.

Agroecosystem Analysis

Agroecosystem analysis (AESA) is the core activity of any typical FFS and other activities are designed to support it. The process begins with small groups observation in which participants collect data on the field , for example in the case of coffee farmers collect information on one tree the number of healthy stems, number branches, ripe cherries, weeds species, pests under or inside the branches, soil moisture level, organic matter content, shade level, disease symptoms,etc. Following field observation farmers return to the meeting place and start presenting their findings using drawings on a large piece of paper. The drawings may include:

- Pest, weeds and natural enemies found in the fields sorted in their category
- The plant or animal showing the size to indicate the stage of the growth, leave color, number of tillers
- Important feature of the environment, such as the water level in the field, sunlight, shade trees, weeds

Participants are required to draw what they found on the field during their observation each time they meet according to their plan. While drawing the participants analyze the data and discuss and set management action decisions to be carried out in the field. The role of the facilitator in this case is central to AESA process to ensure balanced and participatory discussion. For this purpose a facilitator should have good agricultural background to ask and probe for further interactions and learning. He/she also ensures whether they have appropriate management decision based on their findings.

The Study Groups

Most Field Schools are organised for groups of about 25 persons with common interests can support each other, both with their individual experience and strengths, and to create a "critical mass". As individuals, trying something new is often socially inappropriate (e.g. reducing sprays, cover crops), but with group support, trying something new becomes acceptable. The number of 25 is roughly the number that can comfortably work together with one facilitator. Usually these 25 are sub-divided into groups of five persons so that all members can better participate in field observations, analysis, discussion, and presentations.

Special Topics

FFS also includes 'special topics' designed to help farmers uncover unknown ecological relationships. Once internalized, these concepts help farmers help farmers make better management decisions. Special topics cover issues that may interest farmers to know. It might be different and can be requested by farmers to be discussed. The facilitator can invite guests who have better understanding on the issue. Or they can set expert to determine and uncover their ignorance on the issue. But the issue should be linked to their school concern directly r indirectly. AESA and special topics also develop farmers' research capacity by stimulating comparison of the outcomes of different management decisions and by providing regular opportunities for data gathering and analysis.

Group Dynamics Exercises

Each FFS meeting includes group dynamics exercises to strengthen teamwork and problem solving skills. Promote creativity and create awareness of the importance and role of collective actions. The facilitator suggests a problem or challenge for the group to solve. Sometimes you may go for puzzles and pose a challenge and require innovative solution.

Technical Sound Facilitator

A good facilitator is vital to catalyze the process, encouraging analysis, setting standards, posing questions and concerns, paying attention to group dynamics, serving as mediator who raises new questions rather than offers answers is more likely to flourish in an FFS Environment. The Field School is usually initiated by an extension staff member of the government, farmers' organization, or NGO. But in all cases the person must have certain skills.Most important is that the person is skilled at growing the crop concerned. In most countries, the extension staffs have never grown crops 'from seed to seed' and most often lack confidence. For this reason, most IPM programmes have begun with training field staff in season-long courses which provide basic technical skills for growing and managing an IPM crop. Some people have called this the "Farmer respect course" in that field staffs come to realise how difficult farming is, and why farmers do not immediately "adopt" their "extension messages". Facilitation skills and group dynamic/group building methods are also included in this season to strengthen the education process in the Field Schools. An uncertain trainer is a poor trainer.

FFS study Fields

- The Field Schools are always held in the community where farmers live so that they can easily attend weekly and maintain the Field School studies. The extension officer travels to the site on the day of the Field School.
- The Field School has a small (usually about 1000 m^2) field for group study. This is the core of the Field Schools.
- This field is essential for a Field School because farmers can carry out studies without personal risk allowing them to take management decisions that they might not otherwise attempt in trials on their own farm.

Case for Modified coffee IPM-FFS in Ethiopia

In 2004/2005 about 21 FFSs were established on coffee wilt disease (CWD) control in major growing regions of Ethiopia. The deadly CWD was new to farmers and the symptom of the disease was confusing with other similar diseases of coffee and farmers were found reluctant to control.There were two issues to be addressed: Making farmers and extension workers aware and develop skill and knowledge to identify the diseases and also develop effective local sanitary measures halt new infections. A modified CWD FFS was established in Jima, Sidama and Yirgacheffe areas where the disease pressure is too high. Based on the participatory diagnosis and research recommendations seven treatments which are collective solutions were designed and set for trial on selected farmer's field. FFS, composed of 30 members were established around the trials by fitting to the coffee production system around the trial sites. The Generic FFS format for IPM was modified in terms of size of the study group, size of study field and duration of the Cycle. It is not possible to run from seed to seed and therefore a young coffee of 3 years were taken as they undergo fast growth and responsive to treatment.

Treatments were: uses of ash, mulching, fungicide spray, Fungicide stem paint, herbicide/roundup, shade regulation and hand weeding and slashing/control

Half hectare coffee field is used which is too large compared to the Normal FFS field which is less than $100m^2$. Modifications were also made on the frequency and observation of the plant compared to the weekly and plot for annual crops.

Observation of the root system was not possible but observation of the full canopy was made. Focus only on three selected trees against other plots trees.

The special topics were:

- Pruning, stumping and sucker control of old coffee
- Shade management
- Proper intercropping practices
- proper weeding and hoeing
- Use of mulch
- Planting leguminous plants such as desmodium
- Compost preparation
- Proper harvesting of cherries
- Soil and moisture conservation
- Proper use of agro chemicals

Challenge and limitations

- Application of FFS to tree crops and coffee in particular is new to Ethiopia
- Initially caused suspension on the effectiveness of the approach for coffee and the disease
- Tendency of facilitators to teach farmers in the traditional approach
- Use of dynamic exercise and icebreaker is challenging in the first part
- High turnover of trained facilitators and extension workers
- Use of writings to present AESA against drawings
- Some questions by farmers which the researchers and extension workers do not have solution/puzzles
- Lack of input for farmers to try on their fieldsPerennial behavior of the crop poses challenge to see impact in the season
- Low attendance of farmers in the beginning.
- This provides farmers a way of testing a new method themselves before applying it to their own fields. It also allows for more interesting research topics such as defoliation simulations in which leaves are removed.
- The arrangement for this field varies based on local conditions. Some villages have communal lands that can be used for free, some villages may request on inputs, others areas may request compensation in case of lower yields in experiments, etc.
- It is important to remember however that this land is to be maintained by the group - not by the facilitator alone - and is not a typical “demo-plot” as traditionally used in many programmes.

Evaluation and Certification

All Field Schools include field based pre- and post-tests for the participants. Farmers with high attendance rates and who master the field skill tests are awarded graduation certificates. For many farmers, the Field School is the first time that they have graduated from any school or received a certificate in recognition of their farming skills, a point of great pride to many families.

The IPM-FFS is crucial to use the farmers' knowledge and keep the crops safe from pests affecting fruits, vegetables and cereal and industrial crop production In Ethiopia.

White Mango Scale: A New Insect Pest of Mango in Western Ethiopia

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Introduction

Among the fruit crops cultivated in Ethiopia, mango is preceded only by banana; while in southwest Ethiopia, mango is the first fruit crop grown. Occurrence of a new pest on mango trees was recorded in Green Focus Ethiopia Ltd. farm in 2010. The new insect pest is identified as white mango scale, *A. tubercularias*. It then distributed to four East Wollega zone weredas, Oromia regionand differentparts ofEthiopia. In 2014, the insect pest was reported from Tepi, South Ethiopia.

Mango scale

The soft-bodied females and early-instar males of the tribe Diaspidini live beneath a scale covering made of wax secreted by the insect and mixed with shed exuviae of earlier instars. The scale covering of males is usually smaller and more elongate than that of the females. The first instar, or "crawler," stage is mobile and able to spread to other plants

Damage

Mango scale injures the leaves and fruits, affecting the commercial value of the fruits and the country's export potential. This totally affects the ambition for foreign exchange earnings. Young trees are particularly vulnerable to excessive leaf loss and death of twigs. This will in turn affect the expansion and the production of mango in Ethiopia.

Management practices

The spread of the white mango scale is very fast and the following suggestions are made to stop its distribution and damage.

- Training and awareness creation for the experts and the public at large.
- Involvement of Federal and Regional government and non-government organizations to manage the pest
- Selection of proper mango variety that is well adapted to the local conditions (it is advisable to communicate with agricultural research centers like Melkassa to find locally adapted varieties)
- Selection of good and diseased-free seedlings.
- Proper fertilization and irrigation of the mango farm
- Planting of intercrops to improve the field's diversity and to encourage natural enemies (eg sesame, soybean, haricot bean)
- Implementation of recommended pruning practices
- Proper plant sanitation by removing and pruning infested plant parts and field sanitation by keeping the area free of weeds (eg, savanna grass) and other plant residues.
- Mulching to enhance natural enemies and increase soil fertility
- Monitoring of mango plants regularly at least fortnightly (sufficient number of scout men and plant protection experts are required for regular monitoring and data recording).
- Apply safe insecticides like Applaud (growth regulator) and white oil 2% and reduce broad spectrum insecticides. High power sprayers are needed for proper application of pesticides on mango trees. The use of Applaud in mangoes is registered in many countries across the world for the control of white mango scale. Monitor scale populations and apply when the majority of crawlers have emerged. This usually coincides with tree flushing after harvest and when fruit are 1.5 to 2.0 cm across.

  Applaud at label rates of 30 to 60 mL/100L water has been demonstrated to be safe to a range of predatory and beneficial insects including bumblebees, parasitoid wasps such as *Aphytislignanensis*, *Leptomastixdactylopii*and *Encarsia*spp., predatory mites such as *Phytoseiuluspersimilis*and *Typhlodromusoccidentalis*

Cotton Mealy Bug (*Phenacocccussolenopsis*)

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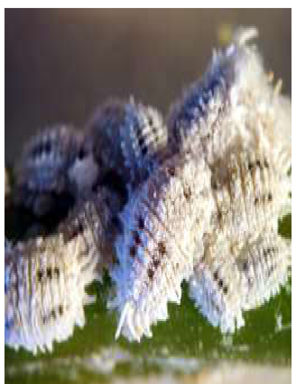
Introduction

Cotton mealy bug , a new insect pest on cotton, appeared in MelkaSadi locality in July 2010. During this time, the infestation was at isolated spots and the damage inflicted was insignificant. In 2011, however, the pest heavily infested wide area of cotton fields in different localities of Awash Valley. In 2013 it spread throughout major cotton growing areas and inflicted a lot of damage on cotton production in Ethiopia.

Cotton mealy bugis found worldwide. It is found countries of North America, South America, Africa, Asia and Australia.

Females of *P. solenopsis*are wingless and males are winged (see fig. 1). The dorsal side of the female is covered with waxy hydrophobic secretions which protects them from insecticides and natural mortality factors. The margin of the body is surrounded withwax filaments which are one fourth of the entire length of the body. It has a pair of black spots on the dorsal headregion and three pairs of black markings on the dorsal thoracic region.



Females

Male

Figure 1. Male and female of *P. solenopsis*

Biology

The pest reproduces largely by parthenogenesis with ovoviviparity dominating over the oviparity. The nymphal instars are 2 for males and 3 for females. The fecundity ranges from 128 to 812 crawlers per female. Longevity of female ranges from 32

-35 days and the total life cycle lasts for 55-60 days. Males are none feeding and it lives for a maximum of two days.

Damage

Female *P. solenopsis* sucks sap from the host plant phloem tissues, removing biomass and water. As a result, attacked cotton plants remain stunted and produce fewer bolls of a smaller size; leaves become distorted, yellow and eventually drop off. After feeding, the insect egests honey dew resulting in sooty mold growth which fouls plant surfaces, blocks stomata, so impeding respiration and photosynthesis, and hence reduce yield. The honeydew also adversely affects fiber quality of the produce.

Host rage

This pest is extremely polyphagous in nature and attack a wide range of plant speciesincluding field crops, vegetables, ornamentals, weeds, bushes and trees. Field crops infested by the cotton mealy bug include tomato, water melon, okra, green pepper, sweet potato and sesame. The pest is also harbored by different weed plants such as *Perthenium*, *Xanthium*, *Datura*, *Amaranthus, Abutilon,* and *Hibiscus* etc.

Spread

Mealybugscan spread by biotic factors such as domestic and wild animals, ants, insect pollinators, humans and abiotic factors such as wind, water, seed cotton, and farm machines.

Management

Chemical control

Use Selecron 720 EC at the rate of 2L/ha for early infestation. The chemical should be mixed with 200-300L/ha. For late infestation, Dimethoate 40% EC at the rate of 2L/ha can be used.

Cultural control

Cotton residues and debris should be removed from the fields immediately after the last picking and maintenance of host free period. Removal of weed plants within and around cotton filed also significantly reduce the pest. Only sulfuric acid delinted seeds should be used for sowing as fuzzy may harbor infective stages of mealybug, especially crawlers. Rotation of cotton with cereal crops like maize, sorghum, wheat etc can also be used to break over season cotton mealybug population buildup.

Mechanical control

Manual picking of mealybugs from plants that are not severely infested may help in case of very low infestation.

Biological control

Leaving buffer area at the adage of cottonfields to maintain efficient predators like ladybird beetles which suppress pest population.

Biology, Host Range and Management of Sesame Seed Bug *ElasmolomusSordidus* inNorth-Western Ethiopia

GeremewTerefe and MeuzBerhe

Introduction

Sesame seed bug *Elasmolomussordidus* (Fabricius) synonyms *Aphanussordidus*(F.) or *A.* littoralis (Dist.) has a wide distribution range in Africa and Asia. It has been recorded from West Pakistan, India, China, Senegal, Malawi, Somalia and the Sudan (Schmutterer, 1969). Crowe et al. (1977) reported as a major pest of sesame in North West Ethiopia. No record of it elsewhere in the country. Sesame seed bug was reported to attack the seeds of sesame, and groundnuts, but has also been recorded feeding on grasses, sedges, cotton and bananas in Nigeria (Schmutterer, 1969).

Prevalence

In Ethiopia the sesame seed bug prevalence and damage was known long ago however, its distribution was restricted to North Western part of the country and it is so important only in years of outbreaks. However, the first recorded report in sesame seed bug outbreaks were made from the North West by Walker &Boxall (1974) and later by Crow, T. J. (1977). Studies made from 2006 to 2007 in three woredas of western Tigray (KaftaHumera, Tsegede, Shiraro) and three woredas of Semen Gondar zone (Metema, TachArmacho and Tegede on randomly selected fields and the nearby living and warehouses indicated that the pest is well established in all the surveyed woredas, and kebeles like, Central, Bereket, Mycadra, Nugara, Banat and Adebay, Humera, Gendewuha, Sanja, Serequa, Ergoye, Metema, Shinfa, Delelo, AbrhaJira and Abderafi.

Damage and Yield Loss

Sesame is usually attacked in the field when pods are open, after the plants have been cut and put together in stacks for drying and in ware houses. The pest incurs both physical damage (weight loss, colour change, and shape) and quality loss (oil yield, odour). The nymphs and adults suck the oil from the seeds which shrivel and become bitter and worthless. Infested seeds are poor in germination and loose vigor. Studies undertaken at Humera both under laboratory and field conditions indicate that, the pest can cause up to 46% weight loss if the bag is left open for 11 days. If infestation is high and control measure is not taken losses could be as high as 100%. Apart from the weight loss the qualitative loss is more pronounced. The oil content reduces by more than 50% on sacked seeds (personal communication). Even if oil is pressed it is bitter and the color of the oil is unattractive.

Biology

Sesame seed bug is a social insect that leave in mass. The bug has three developmental stages, egg, nymph and adult. Three distinctly colored and sized seed bugs have been observed in Northwestern part of the country, Metema and Humera. The variation is most common at Humera than it is at Metema. The biggest type has dark color with distinctly visible two white circular spots on the dorsal wing. It is 12-13mm long and 1.5 to 2mm wide and is prevalent from Humera via Dansha to Sanja (TachArmacho). The second type is bright grey colored from both sides and has inverted cup shaped black marking on the abdomen. The nymphs are beautifully designed with brown and white lines on the thorax and abdomen. The third type is dull grey and has a v-shped marking on the thorax and the abdomen. Adult bug is 7-10 mm long and 2-3 mm wide. The females lay eggs in batch on surface soil 5-7mm deep, or singly or in small groups on capsules, on stalks, or on crop remains, under logs, timber, old ragged clothes, leaf remains, thrown corrugated thins and grasses that shade the egg from desiccation. The preferred site of oviposition is under the stack/hilla or after threshing under the stalk of sesame known as Jawjew. Egg is sausage shaped, about 1-1.2 mm long and 0.5mm wide, changing from white to pale yellow then to pinkish red and near hatching to red. Egg development takes from 5-7 days, while nymphal stage lasted 14-21 days. Adult longevity ranged from 7-29 days. Generally, the total longevity period, egg to adult death ranged from 39-54 days. Studies made in Nigeria under laboratory condition indicated that the pest develops into six nymphal stages within 1-1.5 months. This is in full agreement with the current finding which states that the nymphal stage alone last about 29 days.

Host Range

Bugs were found feeding on many species of weeds, trees, and vegetable crops, but the most preferred host is sesame. Seed bugs sack the contents of the capsule before opening and later when the capsules open they start to feed on seeds during drying and in warehouses. Fallen seeds on the ground are the main source of food in the dry season (October to April). Seed bugs were also seen carrying away seeds and store around their living place and in cracks for dry season feeding. Another source of food in the dry season is feeding on alternate hosts, both annual (sorghum, pepper, tomato, bind weeds, zanthium, mulukia, amira/humeray, wariat, adar, chewchewit, topaz, demayto ... etc) and perennials (accacia, neem, shewit, meki, geba/kurkura, hagay, papaya, banana, ... etc). These plants also serve as food for the newly emerged nymphs, probably from first to second instars. Generally, seed bugs were observed sucking sap from many annual and perennial plants (with green, fleshy or succulent parts near the jawjew or threshing point/Awudima. Therefore, this insect pest seems to be none selective in the absence of sesame seed during the dry season.

Control

Cultural

Soon after harvest stalk removal, field clearing and ploughing under, alternate host destruction around fields, warehouse and storage cleaning had a significant impact on survival and fecundity of sesame seed bug.

Botanicals

Using 5% neem seed kernel and 10% neem leaf extract and formulated neem oil (Nimex 0.03%) could not yield effective control. Five percent seed kernel extract and 10% leaf extract showed 0% control while neem oil yielded only 13% control after 48 hours of spray.

Biological

Numerous species of bio-control agents (predators and parasites) were found feeding on seed bugs. Among the recorded predators, ants of different species, termites, spiders, lizards were the major ones found hunting for nymphs and adults. At Humera and the vicinity an effective wasp, egg parasite *Grionini sp.* was known to causes 40-80% egg parasitism. The wasp most likely occurs in all places where seed bug egg is available under sesame stalks. However, the number varied from place to place.

Chemical

Even though there is no registered insecticide for the control of sesame seed bug in Ethiopia, malathion 50% EC or Ethiosulfan 35% EC is applied 1-2 times at the base of sesame stalks in stacks. Dusting the base of stack and the soil around them with Ethiolathion 5% Dust and carbaryl 85% WP was well practiced. Fenitrothion and diazinone could also be used as foliar spray before harvest. In warehouses and storage areas malathion 50% EC, Carbosulfan 25% ULV, Ethiosulfan 25% ULV, Lambda-cyhalothrin (Decis 0.5% ULV and Karate 0.8% ULV) are very effective even at very low rates. For effectively control spray applications should be made in breeding sites but not on feeding spots such as piled sack and must be repeated every three days until nymph emergence stops.

Integrated Management

Seed bug eradication might be difficult as the insect feed on a number of plants in the absence of sesame in the field. However, its management is possible through the integration of control options. Combining cultural and chemical control tactics to manage the seed bug has proved effective. Sanitation measures both at field and storages have either greatly eliminated or reduced bug numbers. These include early harvesting and threshing; removal of the stalks soon after harvest or threshing; reducing seed loss during threshing, winnowing and transporting; destruction of weeds and other alternate hosts that could harbor the pest; storing in polyethylene bags with inner lining and in standard warehouses; and keeping cleanness of stores and sealing off of all openings around the stores and applying malathion or dimethoate 2 l/ha on breeding sites.

Citrus Woolly Whitefly and Major Insect and Mite Pests of Tomato and Cabbage: Recognition and Management

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1. Tomato

1.1 Spider mites

Spider mites, *Tetranychus* spp. (Acarina: Tetranychidae), are the most important mite pests of tomatoes. They are more prevalent and inflict heavy damage in tomato produced under irrigation in the hotter seasons.

Description and biology:

Spider mites are tiny; they rarely exceed a size of 0.5 mm. They are oval in shape with arched back and have eight legs, with the exception of the larval stage, which has six legs **(Plate 1.1).**Spider mites are normally active within a temperature range of 16-37 ^{o}C.They flourish at relatively low humidity. A new generation will develop every 10-13 days in a temperature range of 24 to 26 ^{o}C. The lifespan of a spider mite is 13-32 days. It includes five stages: egg, larva (first instar), and two nymphal stages (second and third instars), and adult. A female may lay over 100 eggs during its lifespan on leaves, stems or fruits. Several species of spider mites affect tomato. Of these, three are known to be important in Africa. These include the tobacco spider mite, *Tetranychusevansi Baker* & Pritchard, the two-spotted spider mite, *T. utricae*Koch, and the common red spider mite *T. cinnabarinus*(Boisduval). Spider mites spin silk threads that anchor themselves and their eggs to the plant. This silk protects them from some of their enemies and even from pesticide applications. Spider mites are most numerous in hot, dry weather. Their populations normally decline after rain. Wind plays an important role in the dispersal of spider mites. Thus, other crops, wild plants or weeds can serve as a source of infestation. They can also be dispersed on clothing and implements.

Damage:

Infested leaves first show a white to yellow speckling and then turn pale or bronzed, as the infestation becomes heavy **(Plates 1.2, 1.3 and 1.4).** Spider mites prefer the lower surface of the leaves, but in severe infestations will occur on both leaf surfaces as well as on the stems and fruits. Under heavy infestation the plant can be completely covered with webbing **(Plate 1.4).** High spider mite infestations cause defoliation, which leads to production of smaller and lighter fruits. Spider mite attack may also cause speckling of the fruits **(Plate 1.5).**

Control options:

Before applying any control measures, regular inspections should be done to determine the presence and level of infestation of spider mites.

Chemical control

- Miticides are preferred to insecticides in chemical control of spider mites. Examples of miticides for spider mites control in tomato include Mitigan (common name Dicofol), Apollo (common name Clofentezine) and Nissorun (Hexythiiazox). Insecticides with a good controlling effect may also be used.
- Spider mites rapidly develop resistance to pesticides, particularly when they are used for several consecutive seasons. When spraying, rotation of acaricides with different chemical composition is essential to avoid or delay development of resistance.
- Appropriate doses and recommended rates of application should be followed.
- Some insecticides can enhance spider mite reproduction. In **addition**, the indiscriminate use of broad-spectrum insecticides eliminates natural enemies. Their use may lead to mite outbreaks. To keep populations of spider mites at a low level, the use of broad-spectrum insecticides, especially pyrethroids, should be avoided as much as possible and plants should be irrigated regularly.

Hygiene (Cultural control)

- Keep the field free of weeds,
- Remove and burn or compost crop residues immediately after harvest
- Avoid planting next to an infested field

Biological control

Several species of predatory mites are known from eastern and southern Africa which are capable of controlling infestations provided they are not disturbed by the severe use of broad-spectrum insecticides and the crop is irrigated properly.

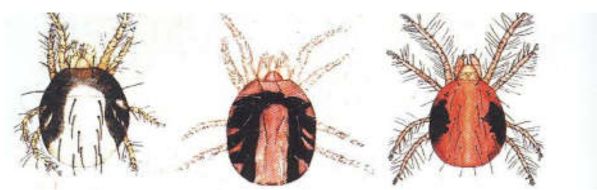

Plate 1.1.1. Spider mites

Plate 1.2. Leaf damage caused by spider mites

Plate 1.3. Tomato plant damaged by spider mites Plate

1.4. Tomato plants with a high infestation of spider mites

Plate 1.5. Spider mite damage on tomato fruit

1.2 Fruit worms

Three species of fruit boring worms are known to inflict damage on tomato in Ethiopia. These include the recently introduced aggressive leaf mining and fruit boring species, the south American tomato leaf miner, *Tutaabsoluta* (Meyrick) (Lepidoptera: Gelechiidae) and the resident species, the potato tuber moth, *Phthorimaeaoperculella* (Zeller) (Lepidoptera: Gelechiidae) and the African boll worm *Helicoverpaarmigera*(Hubner) (Lepidoptera: Noctuidae). The South American tomato leaf miner and the potato tuber moth are micro Lepidopterans (small sized moth) with huge resemblance in biology and nature of damage. Hence, for practical reasons, the damage symptoms and control options described under for the South American tomato leaf miner is also applicable for the potato tuber moth

1.2.1. *Helicoverpaarmigera*(Hubner) (Lepidoptera: Noctuidae), the African bollworm, the tomato fruit worm,

Description and Biology

The African bollwormattacks a variety of food and cash crops. The adult of the African bollwormis a stout moth of approximately 30 mm in length. Moths are active at night and lay 500-3000 tiny, round, yellowish eggs, which darken before the larvae hatch. Female moths are attracted to tomato plants in the flowering and fruiting stages. Eggs are normally laid near or on flowers or small fruits, usually on the outer section of the plant. Young larvae are generally yellowish-white to reddish-brown in color. They have a black head and several rows of black tubercles, each with two bristles along their backs that give them a spotted appearance. Soon after hatching, the larvae move to green tomatoes, where they bore deeply into the fruit **(Plate 1.6).** The fully-grown larvae are about 40 mm long. They vary in color from almost black, brown or green to pale yellow or pink and they are characterized by lengthwise alternating light and dark colored stripes, with a typical light stripe along each side of their bodies **(Plate 1.6).** The fully-grown larvae drop from the plant and burrow into the soil to pupate. The pupa is light brown in color. Adults emerge in 1-2 weeks, mate and can begin to lay eggs 48 hours after emergence.

Damage

Caterpillars of the African bollwormfeed on leaves, flowers and fruit. Caterpillars feeding on flowers and fruits cause the main damage. When flower buds are attacked, flower abortion occurs. Caterpillars prefer green fruit and seldom enter ripe fruit **(**Plate 1.7**).** They usually bore from the stem end, causing extensive fruit damage and promoting decay caused by secondary infections **(**Plate 1.8**).**

Control options

Cultural control

- Tilling and plowing old tomato fields expose pupae which are killed through exposure to the sun and natural enemies.
- Hand picking and destruction of eggs is feasible at low infestations.
- Using trap crops such as cucumber reportedly reduces the severity of attacks on tomatoes. Maize and sorghum have been recommended as trap crops to divert the African bollworm from cotton elsewhere and pepper in Ethiopia.
- Destruction of weeds which may harbor developing larvae is important for preventing fruit worm infestations.

Chemical control

- A considerable number of insecticides are reported to afford good control of fruit worms. Examples include the pyrethroid insecticides such as deltamethrin and Lambda cyhalothrin.

- Selective pesticides, which preserve natural enemies, are preferred. For example, pesticides based on the pathogen *Bacillus thuringiensis,* or some 'plant-based pesticides such as neem products can be used, with minimal detrimental effect on natural enemies.

Host plant resistance

- Two tomato varieties released from Melkassa Agricultural center namely ‘Melka salsa’ and ‘Melka shola’ show better resistance to African boll worm and the potato tuber moth.

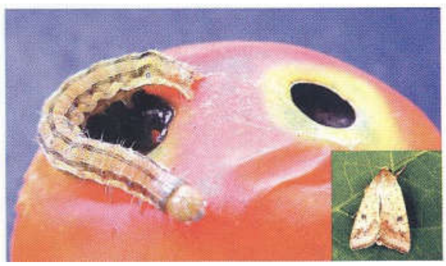

Plate 1.6. Tomato fruit worm *Helicoverpaarmigera* larva; adult moth

Plate 1.7. Tomato fruit damaged by *Helicoverpaarmigera*

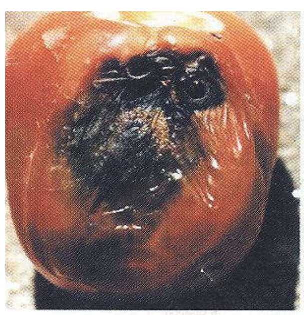

Plate 1.8. Fruit damaged by*Helicoverpaarmigera*, showing secondary infection

1.2.2. The South American tomato leaf miner, *Tutaabsoluta* (Meyrick)

Description and Biology

*Tutaabsoluta*is a micro lepidopteran insect. The adults are silvery brown, 5-7 mm long (Plate 1.9). They (adults) are nocturnal and hide between leaves during the day time. Duration of the developmental cycle is temperature dependent. A generation may take 76, 40 and 24 days at 14, 20 and 27°C respectively (Plate 1.11). The minimal temperature for biological activity is 9°C. After copulation, females lay individual small (0.35 mm long) cylindrical creamy yellow eggs (Plate 1.10). Recently hatched larvae are light yellow or green and only 0.5 mm in length. As they mature, larvae develop a darker green color and a characteristic dark band posterior to the head capsule. Four larval instars develop. Larvae do not enter diapause when food is available. Pupation may take place in the soil, on the leaf surface or within mines.

Plate 1.9 Adult *T. absoluta* with wings folded to show the fringed hair on the hind wing

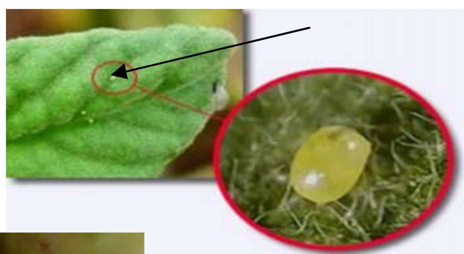

Plate 1.10 Eggs (top) and larvae (bottom) of *Tutaabsoluta* on leaf and fruit of tomato.

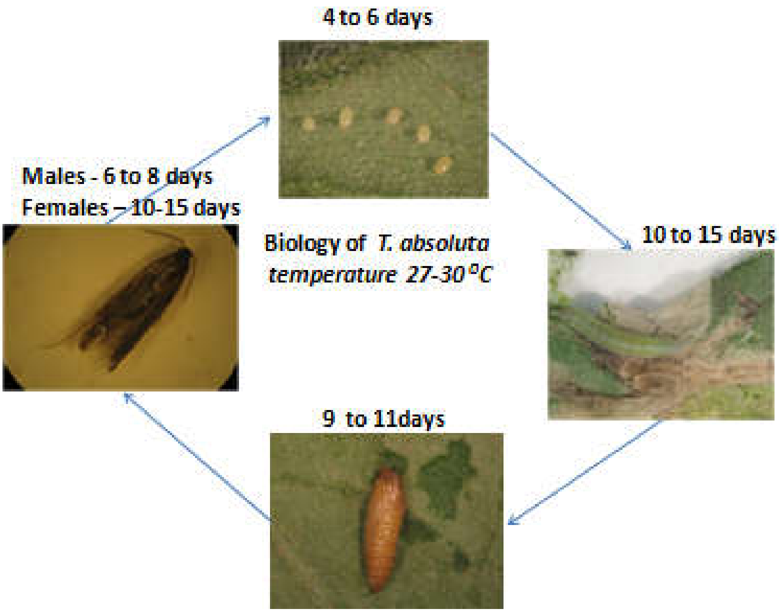

Plate 1.11 Biology of *T. absoluta*

Damage:

Infestation of tomato plants occurs throughout the entire crop cycle. Feeding damage is caused by all larval instars and throughout the whole plant. On leaves, the larvae feed on the mesophyll tissue, forming irregular leaf mines which may later become necrotic (Plates 1.12, 1.13). Larvae can form extensive galleries in the stems which alter the general development of the plants (Plate 1.14). The larvae burrow into the fruit, forming galleries which represent open areas for invasion by secondary pathogens, leading to fruit rot (Plates 1.15, 1.16). The pest also feeds on the growing tip and halts plant development. Damage can reach up to 100%.

Plate 1.12 Leaf mining/blotching inside the tomato leaf by *T. absoluta*

 

Plate 1.13 Light to medium leaf mining/blotch (left) and total leaf drying (right) due to *T. Absoluta*infestation (Observed at Almeta farm, Koka, February, 2013)

 

Plate 1.14.Stem tunneling on tomato   Plate 1.15Tomato fruit damaged by *T. absoluta*

Management options

The basis for sustainable management of *Tutaabsoluta* is the integration of cultural, behavioral, biological, and chemical control.

Cultural control

Cultural control of *Tutaabsoluta* should emphasis on field prevention of infestation and hygiene. This includes

- Use of pest-free transplants
- Removal and destruction of wild weed host plants such as *Solanum* and *Datura* and weedy crop hosts such as potato and egg plants (see pictures below)
- Selective removal and destruction of infested plant material
- Removal and destroying damage fruit from the field. Infested fruit sorted out as unmarketable should not be left around the farm. These are important source of new infestation. Keep them in a sealed plastic bag for about a month. During this period, the insects in the fruit will die and the fruits can be used for fertilizing the soil. crop residue removal
- Allow a minimum of 6 weeks from crop destruction to next crop planting
- Between planting cycles, cultivate the soil and cover with plastic mulch or perform solarisation. This prevent the insect pupae from transforming to adult and hence reduce egg number or new infestation
- Crop rotation with non solanaceous plants; and

- In green house tomato production, the entrance room needs to be double door. Covering the entrance room with a black polyethylene sheet reduce the influx of the moth to the green house. Care should be taken to seal holes that can allow the moth to move to the green house.

Biological control

- A good number of parasitoids, predators and pathogens are known to give control of the pest. Of these the predators *Nesidiocoristenuis*and *Macrolophuspygmaeus*; and the entomopathogen*Bacillus thuringiensis* are regarded effective biological control agents to reduce the pest population and its damage.; and
- The egg parasitoids *Trichogramma* spp. have also been reported effective biocontrol agents against the pest in green house tomato production. Implementation of biocontrol using predators and parasitoids is much easier in green house tomato production through periodic release (Augmentative biological control).

Pheromonal control

- Pheromones are used both for monitoring population for timing treatment application as well as mass trapping of males to prevent them from mating. This reduces egg load and subsequent infestation in the field (Plates 1.17).

Plate 1.17. Delta trap with sticky board (left) for monitoring and tray filled with water (right) for mass trapping of *T.absoluta*

Chemical Control

- Insecticides form an integral component in the management of *Tutaabsoluta*
- Organophosphates (example- Selecron) and pyrethroids (deltamethrin) were found ineffective under Ethiopian condition in 2013.
- Experiments conducted at Koka in 2013 showed that Diamide insecticides (eg. Ampligo and Coragen) and Spinosyns (example - Radiant and Tracer) are effective in controlling the pest.
- Care should be taken when using insecticides for the control of *Tutaabsoluta* as it is capable of developing resistance fast because of its short generation and high reproduction.

1.3 Whiteflies

Description and Biology

Whitefly adults resemble very small moths. They have a coating of white, powdery wax on the body and wings (Plate 1.18). Eggs are elliptical, about 0.2-0.3 mm long, attached vertically to the leaf surface by a short stalk, which is inserted into the leaf tissue. They are normally laid in an arc or circle comprising 20-40 eggs on the underside of young leaves. The first juvenile stage crawls on the leaf surface for some time before settling and fixes itself on the lower surface 1-2 days after hatching. It then starts sucking and excretes tiny wax filaments from the edge of its body. During the period of larval development, the tomato plant continues to grow and thus the juvenile stages are found on the lower leaves. The 'puparium' (scale-like final juvenile stage) is flat and whitish to yellowish in color. The life cycle in warm weather takes 3-4 weeks to complete.

Damage:

- Whiteflies are serious leaf-sucking pests that remove plant nutrients and weaken the plants.
- Feeding by whiteflies causes yellowing of infested leaves.
- Whitefly larvae excrete a clear, sugary liquid known as 'honeydew'. This honeydew covers the leaves and supports the growth of black sooty mould, which may reduce plant growth and fruit quality.
- The main damage caused by whiteflies to tomatoes is indirect as they are the vectors of viruses. It is an efficient vector of the Tomato Yellow Leaf Curl Virus (TYLCV).

Small numbers of whiteflies do not cause major direct plant damage and therefore do not justify chemical intervention. However, even small numbers of whiteflies may need to be controlled in areas where TYLCV is common.

Control options:

Cultural /physical control

- Time of sowing and transplanting can be an effective cultural approach for disease management. Avoid the season when whiteflies are more likely to occur Tomato Transplanted after February suffer greater damage due to the tomato yellow leaf curl virus around Merti Jeju and Nura era farms of the Upper Awash Agro-industry Enterprise.
- Weeds play an important role in harboring whiteflies between crop plantings. They also often harbor whitefly-transmitted viruses. Therefore, attention should be paid to removing weeds in advance of planting tomatoes. Tomato fields should also be kept

weed-free.

- Preventing physical contact of the whiteflies with the plant can prevent the transmission of virus diseases. Covering tomato seedling nurseries with nylon nets protects seedlings from whitefly infestations. These methods have been reported to reduce the transmission of the TYLCV and delay the spread of the virus in different countries.

Chemical control

- Some of the less toxic, selective active ingredients reported to have an effect in controlling whiteflies worldwide include, among others, amitraz (e.g. Mitac®), burpofezin (e.g. Applaud®), imidacloprid (e.g. Confidor® Gaucho®) and pymetrozine (e.g. Endeavour®, Fulfill®).
- Neem-based insecticides are reported to provide good reduction in egg laying of B. *tabaci,* inhibit growth and development of nymphs, and significantly reduce the risk of TYLCV.

Biological control

- Whiteflies are attacked by a number of natural enemies such as parasitic wasps *(Eretmocerus*spp. and *Encarsia*spp.), phytoseiid mites *(Amblyseius*spp. and *Typhlodromus*spp.) by lacewings and ladybird beetles. Conservation of these and other natural enemies is important.

Plate 1.18. Whiteflies on tomato

1.2. Cabbage

1.2.1 Diamondback moth

Description and Biology

Diamondback moth,*Plutellaxylostella*(L.) (Lepidoptera: Plutellidae) is a serious pest of brassicas and attacks all *Brassica* spp. It is very common and widespread. It is completely cosmopolitan. In Ethiopia this pest inflict heavy damage in the major brassica producing regions of Arsi highland and central rift valley region.

Total crop failure is not uncommon in seasons of heavy infestation in the central rift valley cabbage fields

The adult is a small greyish-brown moth, about 8 mm in length, with a wingspan of about 15 mm. It has a characteristic diamond pattern on its back, which can be seen when its wings are closed at rest, hence its common name **(**Plate 1.1.26**).** Eggs are tiny, white, flat and oval-shaped. They are laid on the leaves, either singly or in small groups. A single female can lay more than 400 eggs. The incubation period is 3 to 8 days depending on the environment (e.g. temperature). Larvae are pale green and widest in the middle part of the body **(**Plate 1.1.27**)** and measure 12 mm when fully grown. Larvae are active, and when disturbed wiggle violently and drop to the ground, remaining suspended only by a silken thread. The total larval period varies from 14-28 days. There are four larval instars. Pupation takes place inside a silken gauze-like cocoon that measures about 9 mm long, which is stuck to the underside of the leaf. The pupa is greenish at first and changes to a brown colour as the moth develops. It remains visible to the naked eye within the cocoon **(Plate 1.1.27).** The pupal period lasts 5-10 days. The adult lifespan is 16-17 days (Plate 1.1.28).

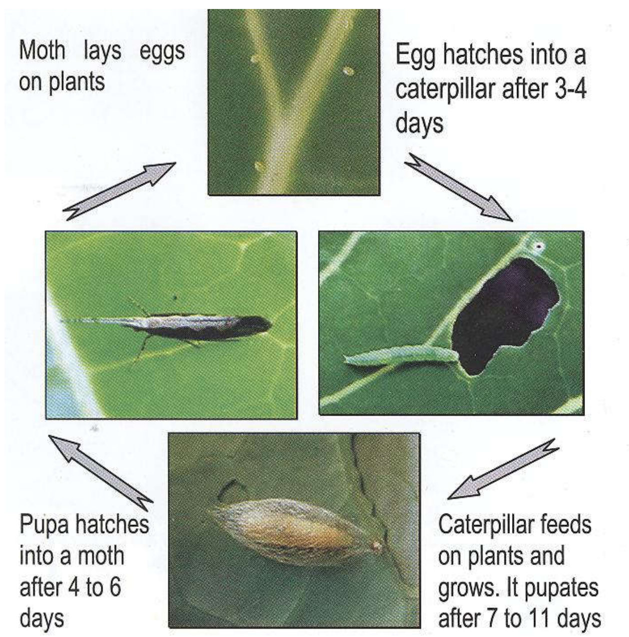

Plate 1.1.28: Life cycle of Diamondback moth

Damage

Feeding by larvae causes damage to leaves. Newly hatched larvae feed on the underside of the leaf, penetrating the epidermis and mining through it. Later instars also feed on the underside of the leaf, except that they either cut round holes through it (making the leaf appear 'windowed') or they scratch off the tissue, leaving the epidermis of one side untouched so that attacked leaves appear skeletonized.

Control options:

An integrated and ecologically compatible approach incorporating the use of parasitoids, combined with cultural methods and a more judicious use of insecticides constitutes a more sustainable management strategy for DBM.

Chemical control

- Chemical control is becoming ineffective due to the ability of the pest to quickly develop resistance against pesticides. For example, the pyrethroid insecticide lambda cyhalothrin is ineffective to control the pest on brassica fields of Central rift valley region in Ethiopia.
- Alternative products such as bioinsecticides and botanicals need to be used instead. For instance, the microbial pesticide *Bacillus thuringiensis* var. *kurstaki*is widely used. At weekly sprays and a rate of 0.5 kg/ha, *Bt*provides effective control of this pest. However, continuous use of *Bt*can induce development of resistance. Neem-based products give good control of DBM and are relatively harmless to natural enemies and nontoxic to warm-blooded animals.
- Recent experiments on chemical control of the pest in Ethiopia showed that the insect growth regulator Rimon 10% EC (common name Novaluron) can provided effective control of the pest on cabbage in the central rift valley of Ethiopia

Cultural control

- Intercropping brassicas with repellent plants such as tomato reportedly reduces DBM infestation on cabbage. When intercropping with tomato, the cabbage should be planted 30 days after tomato.
- Sprinkler irrigation - when applied at dusk, the sprinkler irrigation disrupts the DBM flight activity and oviposition. It also results in run-off of DBM larvae, increasing their mortality. However, use of sprinkler irrigation *may* lead to increase of diseases such as black rot and downy mildew.

Biological control

- Insect species parasitisingDBM are numerous. In Ethiopia, eight parasitoid species have been recorded parasitizing the diamondback moth. Of these three are predominant. These include *Diadegma* sp., *Oomyzussokolowskii* and *Apanteles*.
- The larval parasitoid *Diadegmasemiclausum* (Hymenoptera: Ichneumonidae) is successfully used in classical biological control programmes in the highland brassica

production in several countries including Ethiopia.

1.2.2 Aphids

Aphids are considered a major pest of brassica next to diamondback moth in Ethiopia. The mealy cabbage aphid*Brevicorynebrassicae*(L.)is virtually restricted to members of the Cruciferae. It is a serious pest of cabbage and other cruciferous crops.

Description and biology:

Aphids occur in colonies. Adult aphids are small- to medium-size. They can be winged or wingless. Wingless forms are the most prevalent. Normally, females give birth to living young. Cabbage aphids are usually found in colonies on the underside of leaves.

Adults of the mealy cabbage aphidmeasure 1.6-2.8 mm in length. They are greyish-green or dull mid-green in color and are covered with a fine waxy grey mealy powder (Plates 1.1.30 and 1.1.31). Cornicles are short and dark and there are irregular dark bands on the abdomen under the powdery wax covering. Winged forms have a dark head and thorax and black transverse bars on the back of the abdomen. Under laboratory conditions, fecundity averages 14.9 and 86.4 nymphs per female, at 30°C and 15°C, respectively. Adult lifespan varies from 8 days at 30°C to 28 days at 10°C. Survival is least at temperatures above 30°C. Mortality is lowest at 20°C, which is also the optimum temperature for its development.

Damage

- Damage is by direct feeding and by virus transmission. Direct feeding by aphid colonies causes leaf curl, discoloration, stunted growth and even death of the infested plants.
- In heavy infestations, copious amounts of honeydew are produced on which sooty mould fungus grows. This reduces the quality of the crop.

Plate 1.1.30. The cabbage aphid

Plate 1.1.31 Cabbage plant damaged by aphid

Control options

Biological control

- Aphids are naturally controlled by parasitic wasps of the families Aphidiidae and Aphelinidae, predators (ladybird beetles, hoverflies, lacewings etc.) and pathogens *(Entomophthora*spp.). The most important parasitoid of the cabbage aphid in Ethiopia and many countries of the world is the braconid*Diaeretiellarapae*.

Cultural control

- Destruction and removal of crop residues immediately after harvesting minimizes the spread of aphids to adjacent crops.
- Intercropping brassicas with other crops such as beans reduces B. *brassicae*infestation.

Chemical control

- Mealy cabbage aphids are difficult to control due to the waxy covering which repels water. However, pyrethroids such as cypermethrin, deltamethrin and lambda cyhalothrin have given good control.
- Neem seed extracts (15 to 30 kg /ha) have given effective control of the pest with minimal effect on its predator, hover fly from studies conducted in the central rift valley of Ethiopia.

1.3. Citrus woolly whitefly

As many as 200 eggs are laid by one female and the eggs hatch in a week time. The eggs are laid on the underside of leaves .Eggs are sausage shaped (laid in circle or semi-circular pattern). Immatures (nymphs) are flattened and oval. As nymphs age, they cover themselves with "woolly" white waxy filaments and hence the name woolly whitefly. There are four nymphal stages lasting a total of 15 days or more depending on the weather. The first instar is mobile and the rest are sedentary. The adult emerges by splitting the last instar (pupa) vertically. Woolly whitefly requires about 3 weeks to complete its life cycle in warm weather.

Damage

- The dense colony of immatures is the most conspicuous sign of WWF infestation
- The immatures are distinguished from other whiteflies by the mass of waxy white filaments covering their surface
- Resemble tangled strands of wool hence the name - woolly whitefly
- Wilt and drop of leaves
- Honey dew droplets result tree blackening

- Reduction in photosynthesis leading to reduction in fruit size

Control

Chemical control

- Chemical treatment of whiteflies is not effective. Temporary suppression may be achieved only to be followed by a resurgence of the pest
- Foliar application of white oil, cyhalothrin or selecroncan control the pest
- Spray with soap solution. Eg by mixing 30 ml of liquid soap with 15 liter of water

Biological control:

- Several effective parasites are known. Examples include *Calesnoacki* (HymenopterAphelinidae)
- Ants which collect honeydew disrupt the natural control system. Ants must be controlled by preventing their access to the tree

Legislative and Cultural control

- Quarantine movement of nursery stock
- Hosing the lower leaf surface of trees infested with WWF with high pressure water (home)

2.3 Pictures of major insect pests of citrus and mango and their damage symptoms

Adult WWF

Second instar WWF and eclosed eggs

Third and Fourth instar WWF covered by waxy filaments

Sooty mold growth from wwf honey dew

Dense colony of WWF

WWF severely infested trees showing wilting, leaf drop and branch

Woolly whitefly on citrus

Integrated Disease Management for Sustainable Food Legumes Production

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Introduction

Food legumes are integral components of the different farming systems, cultivated in the highlands, mid-altitudes and lowlands of Ethiopia. These include faba bean (*Vicia faba* L.), field pea (*Pisumsativum* L.), chickpea (*Cicerarietinum* L.), lentil (*Lens culinaris*Medik.), grass pea (*Lathyrussativus*), lupine (*Lupinusalbus* L.) and fenugreek (*Trigonellafoenum*-*graecum* L.) whose cultivation is generally limited to the mid and higher altitudes (1800 – 3000 m.a.s.l.); and haricot bean (*Phaseolus vulgaris* L.), cowpea (*Vignaunguculata*), mung bean (*Phseolusaureus*) and soybean (*Glycine max*) which are normally produced in low to mid altitude (≤ 1800 m.a.s.l.) areas. Production and productivity of these crops are affected by many biotic and abiotic factors. Among the biotic factors, diseases are important as they are known to negatively affect food legume crops productivity in all of their production regions of the country. In general, the biotic diseases that affect food legumes are caused by fungi, bacteria, viruses, nematodes and flowering parasitic plants, whereas the abiotic stresses include waterlogging, hail-stone damage, cold/heat stress, herbicide injury and nutrient deficiencies.

In this training manual, some of the biotic and abiotic diseases of food legumes occurring in Ethiopia are summarized with brief descriptions of their geographical distribution, economic importance, symptoms/signs, causal organisms/agents and practical methods of control. Also, pictures showing their symptoms and/or signs have been included to assist in their correct diagnosis.

Integrated Disease Management (IDM)

Crop protection researchers in Ethiopia have developed a series of options involving chemical and non-chemical disease control measures (crop & stubble management, tillage, etc.) and resistant varieties, which form the basis of integrated management strategies to reduce yield losses from diseases in the food legume crops. Integrated disease management (IDM) is designed to maximize benefits to the farmer by improving the health of the food legume plants. The application of IDM to the food legume crops enables farmers to choose management strategies suited to their situations and needs. The use of an integrated management system reduces the levels of diseases in the food legume crops, reduces the inappropriate use of chemicals, provides alternatives for disease management and improves the yield and quality of the food legumes, thereby increasing farmer income.

The main strategies of IDM are:

1. **Reduction of inoculum;** (the disease causing structures or reproductive units e.g. spores & sclerotia) through careful site selection, control of volunteer and alternative hosts and stubble management.
2. **Exclusion of the pathogen;** through the use of clean seed, farm hygiene, seed treatment and regulatory measure (quarantine).
3. **Protection of the host;** through the use of varietal resistance, wider row spacing and fungicides.

Regular Disease Monitoring

Diseases are monitored by regular and careful inspections. The inspections also identify conditions contributing to disease problems. The IDM expert then decides what actions are necessary, if any, based on the biology and habits of the disease involved. Priority is given to non-chemical pest management techniques, particularly those that can prevent a recurrence of the problem. Pesticides are used when necessary, but only in a way that minimizes potential exposure to people and the environment. Records are kept to track problems, prevent recurrences, and evaluate the results of pest management actions. Inspections need to be undertaken in a range of locations/spots in a given field, preferably following a 'Z', 'V', 'W' or an 'X' pattern. Inspect the crop 10-14 days after each rainfall event for most of the major foliar diseases.An IDM program consists of a cycle of monitoring, control and evaluation. The monitoringcomponent of an IDM program is essential to its success. **Monitoring is a documented, systematic inspection conducted at regular intervals.** It keeps you informed about all aspects of the disease situation and conditions at the site. Regular monitoring includes the following:

- Identifying and locating diseases
- Identifying areas of critical sensitivity (locations in a farm, etc.)
- Estimating intensity (prevalence, incidence & severity) of the disease
- • Identifying the factors that are contributing to the disease problem (poor sanitation, waterlogging, etc.)
- Reporting management practices that could affect diseases
- Identifying nontarget species that could be killed or injured
- Assessing possible biological control agents if any

- Assessing environmental conditions (temperature, humidity, weather or seasonal
- changes)

IDM Service Visit

The procedures followed by an IDM expert are different from those followed by someonedoing traditional pest control. As an IDM expert, you will spend far more time inspectingthe farms and communicating with farmers than you will in simply applying pesticides. You will be making many more decisions about what specific control measures to take. You will need to be better at identifying diseases, and know more about pathogen biology and habits.

The first task in a routine farm/service visit would be to review the ***IDM Logbook*** (or books) to see if any disease problems have been reported, and to review what had been done at the last few service visits. Next ***inspection*** needs to be conducted in food legume farms looking for diseases and evidence of disease problems (symptoms/signs). If a disease is ***identified***and its damage is above a predetermined ***action threshold*** level, then some kind of control action is required. For each disease problem, you would make a ***decision*** about what control tactics to use given the identity of the disease/pathogen, the extent of the problem, and the sensitivity of the site. You would try to use ***nonchemical pest management*** tactics, whenever possible. For example, you might go for rouging/ removing of infected plants.

Biotic diseases

Among diseases affecting food legumes in Ethiopia, the ones caused by fungi are the most important. These diseases affect different parts of the food legume plants and are caused by diverse groups of fungi. Some of these affect foliage/stem and pods/seeds; and others affect roots and stems.

Faba bean

Among the foliage/stem diseases of faba bean caused by fungi are chocolate spot, rust and ascochyta leaf spot. Of these, chocolate spot, rust and black root rot are the three economically important faba bean diseases.

Chocolate spot

The disease is widespread in almost every part of the country where the crop is grown. The disease can reduce yields by 34-62 per cent under conditions favourable for disease development. Complete crop failure due to the disease is not uncommon if a long-lasting favourable environment for disease development prevails in an area. The optimum environmental conditions are temperatures between 15 and 23°C with at least 70 per cent relative humidity (especially in the mornings) and frequent rain. Yield reductions can result from infection of flowers which causes them to abort without forming pods. Aggressive development of stem infection late in the season can also cause the crop to lodge. In addition, seed from badly affected plants may have a reddish-brown discolouration, which lowers its market value.

Chocolate spot is caused by *Botrytis fabae,* and the pathogen *B. fabae* can survive either as sclerotia in the soil or on crop debris, in infected seed, or on self-sown volunteer plants. It survives as sclerotia in infected plant debris for more than a year. In previously unaffected areas the disease often becomes established by the sowing of infected seed. In subsequent years, the initial infection usually occurs when spores formed on old bean trash are carried by wind into new crops. These spores may move long distances. Once the disease becomes established it rapidly spreads within a crop, and within 4-5 days of infection spores can be formed on infected tissue and initiate secondary spread of the disease.

Symptoms

Symptoms range from small round and red-brown spots on the leaves to complete blackening of the entire plant. Leaves are the main part of the plant affected, but under favourable conditions for the disease it also spreads to stems, flowers and pods (Fig. 1).

Fig. 1. Chocolate spot development on faba bean plant, leaf and pod.

Two stages of the disease are usually recognised. First, a non-aggressive phase, when discrete reddish-brown spots are sprinkled over the leaves and stems, and then an aggressive phase, when spots darken in colour and coalesce to form larger grey-brown target spots (Fig. 2) that may eventually cover the entire plant. Small black sclerotia may sometimes be found inside the stems of badly diseased plants.

Fig. 2. Characteristic chocolate spot on leaflets of faba bean plant

Control

Chocolate spot can be managed through an integrated approach including the use of resistant varieties, cultural practices and strategic use of foliar fungicides. An integrated approach is the key to successful management of chocolate spot blight in faba bean.

Sowing date

Late sowing of faba bean shortens the duration of environmental conditions suitable for chocolate spot epidemic and thereby reduces the crop attack by the disease. However, seed yield harvest from late sown crop is substantially less than that of early sown crop.

Crop rotation

A break of at least 4 years should be observed between faba bean crops. Aim to separate this year's faba bean crop from last year's faba bean stubble by a distance of 500m.

Host plant resistance

Use of the variety a variety with the highest level of resistance to the pathotype of *B. fabae* prevailing in a given area provides good control of the disease. In this regard, CS 20 DK is resistant to all of the known pathotypes in the country except pathotype 2 (Kulumsa 1 pathotype/isolate). See the publication:

Increasing Crop Production through Improved Plant Protection Vol. 1 for more information.

Chemical control

A successful fungicide program relies on crop monitoring, correct disease identification and timeliness of spraying with the correct product. Two to three fungicide sprays of chlorothalonil (2.5 kg/ha) or mancozeb (0.7 kg/ha) after disease initiation have proved effective in controlling the disease. Be aware of the critical periods for disease management.

Harvesting time

Plan to harvest as early as possible to minimize disease infection on seed.

Rust

The disease is important in lower and intermediate altitudes (≤ 2300 m.a.s.l.) and off-season crops. Depending on the severity of rust infection, the seed yield loss ranges from2 to 15% for lower altitudes and 14-21% for intermediate altitudes. The rust usually comes late in the season, and is minor and economically unimportant in the highland areas of the country.

The disease is caused by *Uromycesviciae-fabae*. It is a macrocyclic and an autoecious fungus, completing its life cycle on faba bean. The disease first occurs during the flowering/early podding stage as aecia which may develop into secondary aecia or uredia. The resulting urediniospores lead to a further disease spread in the cropping season. And later in the season, telia develop mainly on the stems. The fungus survives the *Bega*seson (the no-crop season) as teliospores. It can be spread with seed as a contaminant in the form of small pieces of infected plant debris. High relative humidity, leaf wetness (dew) for a few hours with temperatures of 20-22 °C favour rust infection.

Symptoms

Rust starts with the formation of yellowish-white pycnidia and aecial cups on leaves and on pods, singly or in small groups in a circular form. Later, brown uredial pustules, oval to circular and up to 1 mm diameter, develop on either side of leaflets, branches stems and pods. The telia, which are formed late in the season, are dark brown to black, elongated and are present mainly on branches and stems.

Control

Remove infected plant debris that is mixed with faba bean seed.

Preventive fungicide sprays of mancozeb [dithane M-45 (2.5 kg/ha)] starting at disease initiation (5% infection level) at flowering or early pod setting proved effective in controlling the disease. Mixed cropping of faba bean and field pea with 34 : 16 and 28 : 17 faba bean to field pea proportion may help reduce disease severity.

Black root rot

Black root rot is one of the important diseases of faba bean in Ethiopia. Complete crop loss could occur due to black root rot when there is favorable conditions for disease development. A yield loss of about 45% due to this disease was recorded from farmers' fields. The disease is caused by *Fusarium solani*. And the fungus is soil-borne as chlamydospores and favored by high soil temperatures (22-28 °C). The disease is severe in in black clay soils (Vertisols) with high soil moisture (waterlogging).

Symptoms

Infected plants show leaf chlorosis that progress from lower to upper leaves. Also, the affected plants show rotting of the main and secondary rots, which are characteristically black in color; hence the name black root rot.

Control

Planting crops that are not hosts of *F. solani* such as Noug (*Guizotiaabyssinica*) and rapeseed (*Brassica napus*) in rotation with faba bean may reduce inoculum level in the soil. Proper drainage of faba bean fields helps to minimize the effect of the disease. The use of resistant varieties provides good control of this soil-borne disease. Several resistant varieties have been released in the country. These include Wayu, Selale, Lalo and Dagm. `

Emerging faba bean diseases

These are biotic diseases that have either existed as innocuous diseases, but have recently attained pest status, or those diseases that have been inadvertently introduced into the country in recent years. For instance, the occurrence of faba bean gall, also called blister, warty scab or bubble disease (commonly known as *kormid*), in Ethiopia was first reported in 2010 and is now widely distributed in many parts of the country (northern Shewa, Wello, Gojam, Gondar and Tigray). Crops with plants of severe infection may lead to 100% yield loss. The disease occurs both at seedling and flowering/adult plant stage. Although work on the precise identification of the causal agent and its biology is in progress, symptom pictures and descriptions of the disease elsewhere suggests that the disease is caused by OlpidiumviciaeKusano which is a kind of fungus. The disease is reported to occur in Sichuan province, China. Apparently, the geographical distribution of the disease is limited to ecological zones above 2400 m altitude suitable for faba bean production in Ethiopia. .

Symptoms

The initial symptom is commonly green and sunken on the upper side of the leaf (Fig. 3) and bulges out on the lower side [surface (Fig. 4)]. Later it becomes brown in colour and extends to the stem (Fig. 5). Often times, infected leaves roll-up (Fig. 5). Under high disease pressure, the blisters/swellings cover the whole lower leaves and stems (ca. 65% of the lower plant part). As infection progresses the lesions on the leaves change from circular to irregular shape and increase in size and coalesce. On matured leaves, the coalescing lesions become necrotic and are surrounded by white lesions. Severely infected plants become stunted/shrunk and eventually die.

Fig. 3. Green and sunken lesions/blisters on the upper side of faba bean the leaf.

Fig. 4. Galls on the lower side of faba bean leaves.

Fig. 5. Brown blisters/lesions/galls on leaves and stems of faba bean.

The pathogen survives and rests (oversummers and/or overwinters) as sporangia on diseased/infected plant debris and these serve as the initial infection sources. After seeds of faba bean are sown in a cropping season, the resting sporangia germinate and produce zoospores which then infect seedlings of faba beans. Once the disease establishes itself in a faba bean crop, zoosporangia are constantly produced on infected plant tissues and liberate zoospores which then become a reinfection source. The zoospores are known to be dispersed by air and rain/water splash in short distances. The frequency of reinfection by the pathogen is high.

Control

No definite research-based control measures have been recommended yet in the country. However, some promising fungicides have already been identified by the research system in Ethiopia. These include Chlorothalonil and Metalaxyl (Ridomil®). Avoid continuous cropping of faba bean and application of animal manure mixed with infected plant debris as these increase disease incidence. Application of faba bean agronomic practices recommended for the area and/or variety helps greatly in reducing disease intensity.

The aforementioned cultural practices and chemicals might be considered as components of the integrated faba bean gall management (IFGM) program/approach. Hopefully, component tactics of the IFGM would eventually increase as more control options become available through research.

Field pea

Many diseases of field pea were recorded in Ethiopia. Of these, ascochyta blight/spot and powdery mildew are the two economically important field pea diseases.

Ascochyta blights

Among the three *Ascochyta* spp. causing blights on field pea *Ascochyta pinodes* is amajor disease of field pe in Ethiopia. Severe infection of ascochyta blight causes a substantial seed yield reduction of about 22%. A complete loss of yield due to ascochyta blight is common, especially in hot- spot areas such as Dembi where there is high natural infection of the disease The disease reduces seed yield through defoliation that eventually affects pod set and seed size. The pathogen survives as sclerotia, chlamydospres or pychnidia on straw fragments and in the soil, and as infection in the seed.

Symptoms

The pathogen infects all the above ground parts including the seeds. It causes spotting and blighting mainly on field peas grown in the wetter parts of the country.

Control

Growing of field pea in mixture with faba bean reduces ascochyta blight infection on field pea. Considerable reduction in disease severity could result from a 2 : 1 faba bean to field pea mixture. Use of clean seed, and disking and ploughing under of infected plant debris could reduce the disease incidence. Use of resistant varieties is the best method for controlling the disease. Most of the existing improved cultivars are tolerant to the disease and provide reasonable yield under moderate disease pressure. Seed treatment with carbendazim provides early protection of seedling infection. Foliar application of chlorothalonil, benomyl, thiophanylmethyl and metalaxyl could also control ascochyta blight in field pea and increase seed yield reasonably.

Powdery mildew

Powdery mildew is the second important disease of field pea following ascochyta blight. The disease is favoured by dry and hot days followed with cool nights that allow dew formation. The disease is highly prevalent in places such as Kulumsa where the chilling wind blows from Mount Chilalo in nights, and the days are often dry and hot. The disease is caused by *Erysiphepolygoni* (*Oidium* sp.). the disease is severe in the dry season on late sown field pea crops.

Symptoms

Leaves, stems and pods may all become infected causing the whole plant to wither. Infected plants show a white powdery film and severely affected foliage looking bluish-white. Tissue below infected areas may become purplish.

Control

Foliar spray of benomyl (2 kg/ha) at the initiation of infection (infection level of about 5%) provides the best protection against mildew.

Chickpea

Numerous diseases were reported on chickpea in Ethiopia. The major threats to the production of the crop are diseases of fungal origin- the major ones being wilt/root rots and ascochyta blight.

Wilt/root rots

Wilt/root rots occur in the major chickpea growing areas of Ethiopia. Of these, the major ones are fusarium wilt and dry root rot. When conditions are favourable for disease development, wilt/root rots can cause a yield reduction of up to 50%. Most wilt/root rots pathogens occur simultaneously on a plant and infect roots and stems. However, there are differences in the progess of epidemics. Collar rot (*Sclerotiumrolfsii*), black root rot (*Fusarium solani*) and wet root rot (*Rhizoctonia solani*) occur much earlier in the crop growth stages causing death of seedlings. Dry root rot (*R. bataticola*) prevails at later stages of growth, whereas fusarium wilt [*Fusarium oxysporum*f.sp. *ciceris* (FOC)] relatively occurs throughout the life of the crop. Optimum soil temperature for development of FOC, R. solani, and F. solani is 25 °C, whereas that of *R. bataticola* and *S. rolfsii* is 30°C. *R. bataticola* is favoured by low soil moisture; on the contrary *S. rolfsii* and *R. solani* are prevalent in wet soil.

Symptoms

Fusarium wilt appears in field in patches at both seedling and adult stages (Fig. 6). Seedling wilt is characterized by sudden drooping followed by drying of leaves and the whole seedling and apparently healthy looking roots with reduced proliferation. The adult symptoms appear at flowering to late pod-filling stage and are characterized by sudden drooping of the top leaflets of the affected plant (Fig. 7 & Fig. 8), leaflet closure without premature shedding, dull green foliage color followed by wilting of the whole plant or individual branches, apparently healthy looking root system with a slight reduction in the lateral roots which are as difficult to pull out as the healthy plant, and no internal discoloration of vascular system in most cases.

Collar rot infected chickpea seedlings, generally found in small patches in the field, lie flat on the ground. They may have yellowing of lower leaves, depending upon the stage at which the seedling became infected. The characteristic symptoms are seen near the collar region which is rotted and constricted (Fig. 9).

Control

Destruction of undecomposed organic matter such as wheat stubble at the time seedbed preparation offers effective control of collar rot. The best method of controlling fusarium wilt of chickpea is to use resistant varieties, a number of which are now released in the country. These include cultivars Arerti, Chefe, Habru, Akaki and Worku. A combination of fungicides Vitavax and Thiram offers a good protection against fusarium wilt, dry root rot, wet root rot and collar rot.


Fig. 6.Fig. 7.


Fig. 8.Fig. 9.

Ascochyta blight

The disease occurs in the major chickpea growing areas of the country. It is one of the major limiting factors for chickpea production in the main cropping season (*Meher* season), and can cause heavy yield losses if not controlled. The disease is caused by a fungus, *Ascochyta rabiei*. It attacks almost all aerial parts of the plant, and attacks seedling and adult plants. It survives in infected plant debris and infected and/or contaminated seeds. Also, it could be a threat to *Meskerem*-sown chickpea if environmental conditions are favorable for disease development at any growth stage of the crop.

Symptoms

All above ground parts of the host are affected at different growth stages. Brown spots, surrounded by dark margins, are seen on the leaflets and pods (Fig. 10) as well as stems (Fig.11). The center of the spot is light coloured and speckled with tiny, black fruiting bodies that are characteristic of the disease (Fig. 10). Seeds from heavily infected plants become purplish brown, shrivelled and greatly reduced in size which adversely affects their quality.

Control

Use of clean seed is advisable. Seed dressing with fungicide such as thiabendazole (0.1 – 0.2%) and benomyl (0.2%) is recommended to control the seed-borne infection. A 3-year crop rotation along with removal and destruction of infected plant debris and/or deep plowing reduce soil-borne inoculum and thereby the blight. Foliar applications of chlorothalonil-based fungicides (2 – 3 l/ha) at the appearance of the disease symptom repeated two to three times at 15 days interval substantially reduce the disease and increase seed yield. Use resistant varieties, several of which are now available in Ethiopia. These include *kabuli* chickpea cultivars, Arerti, Chefe and Habru, and *desi* cultivar Minjar.

Fig. 10.

Fig. 11.

Lentil

Rust

The disease is important on a country-wide scale capable of causing complete yield loss. Rust severity ≥ 4.7% (damage threshold level) at the critical stage, early flowering, substantially reduces seed yield. The disease is caused by *Uromycesviciae-fabae*. It is a macrocyclic and an autoecious fungus, completing its life cycle on lentil. It can be spread with seed as a contaminant in the form of small pieces of infected plant debris. High relative humidity, leaf wetness (dew) for a few hours with temperatures of 20-22 °C favour rust infection.

Symptoms

Rust starts with the formation of yellowish-white pycnidia and aecial cups on leaves and on pods, singly or in small groups in a circular form. Later, brown uredial pustules (12), oval to circular and up to 1 mm diameter, develop on either side of leaflets, branches stems and pods. The telia, which are formed late in the season, are dark brown to black, elongated and are present mainly on branches and stems (13). Teliospores help the fungus survive the Bega (no-crop) season.

Control

Remove infected plant debris that is mixed with lentil seed. Preventive fungicide sprays of mancozeb [dithane M-45 (2.5 kg/ha)] starting at disease initiation (5% infection level) at flowering or early pod setting proved effective in controlling the disease.Use of resistant varieties is the best method for controlling lentil rust. In Ethiopia, most of the officially released lentil cultivars are resistant to rust. These varieties are now available for use in the country.

Fig. 12.

Fig. 13.

Ascochyta Blight

Ascochyta blight is lentil's third most important disease after rust and wilt/root rots. The disease is caused by *Ascochyta fabae*f.sp. *lentis*. The disease is both stubble and seed borne. Progress of foliar blight is rapid and epidemic level can be reached under cool and wet weather conditions because spores are disseminated by rain splashes. The fungus may remain viable in the seed for more than a decade. It survives 1-5 years on the soil surface. It loses its viability within 20 weeks at a soil depth of 16 cm.

Symptoms

All above ground parts of the host are affected at different growth stages. Brown spots, surrounded by dark margins, are seen on the leaflets and pods as well as stems. The center of the spot is light coloured and speckled with tiny, black fruiting bodies that are characteristic of the diseas. Seeds from heavily infected plants become purplish brown, shrivelled and greatly reduced in size which adversely affects their quality.

Control

Use of clean seed is advisable. Seed dressing with fungicide such as thiabendazole (0.1 – 0.2%) and benomyl (0.2%) is recommended to control the seed-borne infection. A 3-year crop rotation along with removal and destruction of infected plant debris and/or deep plowing reduce soil-borne inoculum and thereby the blight. Foliar applications of chlorothalonil-based fungicides (2 – 3 l/ha) at the appearance of the disease symptom repeated two to three times at 15 days interval substantially reduce the disease and increase seed yield. Use of resistant varieties, several of which are now available in Ethiopia, provides good control of the disease.

Wilt/root rots

Wilt (*Fusarium oxysporum*f.sp. *lentis*), collar rot (*Sclerotiumrolfsii*), wet root rot (*Rhizoctonia solani*) and dry root rot (*Rhizoctoniabataticola*) are the soil borne diseases affecting lentil in Ethiopia, the major one being fusarium wilt. Optimum temperature for growth of *F. oxysporum*f.sp. *lentis* is 25 °C. Fusarium wilt is essentially a soil-borne fungus, though external contamination of seeds by the fungus is usual and high levels of the fungus may be carried in plant debris.

Symptoms

Fusarium wilt appears in field in patches at both seedling and adult stages. Seedling wilt is characterized by sudden drooping followed by drying of leaves and the whole seedling and apparently healthy looking roots with reduced proliferation. The adult symptoms appear at flowering to late pod-filling stage and are characterized by sudden drooping of the top leaflets of the affected plant, leaflet closure without premature shedding, dull green foliage colour followed by wilting of the whole plant or individual branches, apparently healthy looking root system with a slight reduction in the lateral roots which are as difficult to pull out as the healthy plant, and no internal discolouration of vascular system in most cases. Characteristic symptoms of lentil collar rot are similar to that of chickpea collar rot (Fig. 9).

Control

Destruction of undecomposed organic matter such as wheat stubble at the time of seedbed preparation offers effective control of collar rot. The best method of controlling fusarium wilt of chickpea is to use resistant varieties, a number of which are now released in the country. A combination of fungicides Vitavax and Thiram offers a good protection against fusarium wilt, dry root rot, wet root rot and collar rot.

Common bean

Common bacterial blight

Common bacterial blight (CBB) is among the main diseases of common bean in Ethiopia. It is caused by *Xanthomonascampestis*pv. *phaseoli*. The type of cropping system and crop growth stage influence CBB severity and the amount of yield loss in common beans. A yield loss of as high as 21% could result due to CBB infection in common beans. Also, CBB could lower seed quality of infected bean plants. The disease causing bacterium survives in the soil, infected plant debris and seeds.

Symptoms

Fig. 1. Initial symptoms associated with common bacterial blight on underside of bean leaves consist of water-soaked lesions.
Fig. 2. More advanced lesion of common bacterial blight on top surface of bean leaf showing beginning of chlorotic (yellow) halo around lesion.
Fig. 3. Numerous lesions of common bacterial blight on bean leaf.
Figure 4. Striking water-soaking symptoms of common bacterial blight on bean pods.
Figure 5. Advanced symptoms on bean pods, with appearance of characteristic brick-red areas in center of lesions.

Control

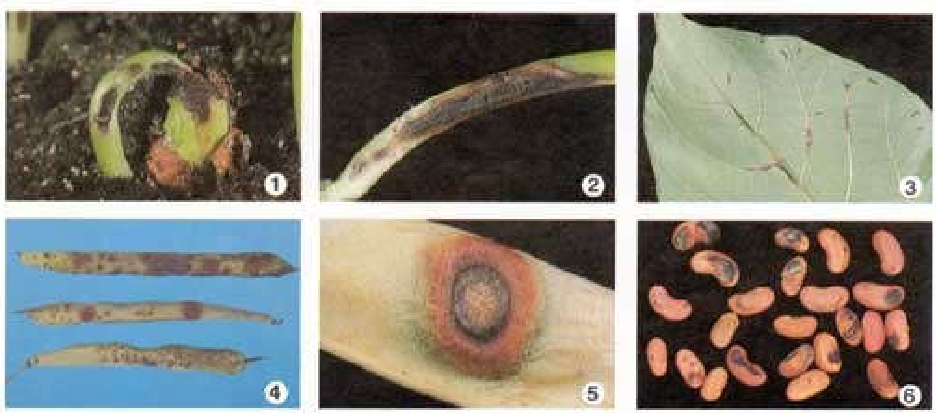
A combination of field sanitation, crop rotation, planting healthy seeds, early incorporation of bean debris into soil, seed treatment and resistant cultivars provide effective management of CBB. Avoid movement through and work in fields when plants are wet. This simple cultural practice can greatly reduce blight disease development and spread. Numerous haricot bean varieties that possess good level of CBB-resistance are available in the country. Cultivar mixtures can be used as a component of integrated CBB management program for food type common beans. For instance, varietal mixtures with the resistant variety, Gofa (G-2816) consistently reduce CBB intensity, area under disease progress curve (AUDPC) and rate of disease progress (*r*) on the susceptible cultivar, Red Wolaita. Sprays of fixed copper bactericides (fungicides) may provide some control once disease appears.

Anthracnose

Bean anthracnose caused by *Colletothricumlindemuteianum* is a wide spread destructive disease of common bean in Ethiopia. The disease can cause a huge yield loss in susceptible common bean cultivars such as Roba-1 and Mexican-142. The pathogen survives in infected seeds, plant debris and soil.

Symptoms

Seedlings grown from infected seeds often have dark brown to black sunken lesions on the cotyledons and stems (Figs. 1 and 2). Severely infected cotyledons senesce prematurely, and growth of the plants is stunted. Diseased areas may girdle the stem and kill the seedling.Under moist conditions, small, pink masses of spores are produced in the lesions. Spores produced on cotyledon and stem lesions may spread to the leaves. Symptoms generally occur on the underside of the leaves as linear, dark brick-red to black lesions on the leaf veins (Fig. 3). As the disease progresses, the discoloration appears on the upper leaf surface. Leaf symptoms often are not obvious and may be overlooked when examining bean fields.The most striking symptoms develop on the pods. Small, reddish brown to black blemishes and distinct circular, reddish brown lesions are typical symptoms (Fig. 4). Mature lesions are surrounded by a circular, reddish brown to black border with a grayish black interior (Fig. 5). During moist periods, the interior of the lesion may exude pink masses of spores. Severely infected pods may shrivel, and the seeds they carry are usually infected. Infected seeds have brown to black blemishes and sunken lesions (Fig. 6).



Control

Growing common bean in cultivar mixture containing at least 50% of a resistant cultivar can provide adequate control of the disease. Genotypes Widusa, GLP X 1132, A 482, A 193, G-7, HAL 5 and G2333 possess high level of resistance to anthracnose. Also, genotypes RAZ-18 and REN-20 possess combined field resistance to anthracnose and angular leaf spot. A combination of dressing common bean seeds with benomyl and a foliar spray of bean plants with difenoconazole or foliar application of difenoconazole alone adequately protects common beans against anthracnose. Field sanitation, crop rotation, planting healthy seed and early incorporation of bean debris into soil should also be considered as components of integrated anthracnose management program.

Rust

Rust (*Uromycesappendiculatus*) is one of the major common bean diseases occurring in most parts of Ethiopia. The yield loss in common beans due to rust could reach as high as 85%. The loss is mainly related to the reduction in the number of pods per plant. The intensity of rust is influenced by cropping system, geographical area, altitude and season.

Symptoms and signs

Symptoms initially appear as small yellow or white slightly raised spots on upper and/or lower leaf surfaces (Figure 1). These spots enlarge and form reddish-brown pustules, also called uredinia, that are about 3 mm or smaller and contain thousands of microscopic spores called urediniospores. These spores can re-infect plants under favorable conditions and continue the disease process, or can serve as a method of long distance dispersal of the pathogen. Pustules may be surrounded by a yellow border (Figure 2). Spores are readily released from pustules and give plants and anything they contact a rusty appearance. Rust can be distinguished from other foliar diseases because the rust-colored spores will rub off, while with other foliar diseases, nothing rubs off.Severe infections cause leaves to curl up, dry up, turn brown, and drop prematurely. A severely rusted bean field often appears scorched. Pod set, pod fill, and seed size can be reduced if infection is severe. Green pods, and occasionally stems and branches, also may become infected and develop typical rust symptoms. Near the end of the season, pustules undergo a subtle change and form telia containing brownish-black spores [teliospores (Figure 3] signaling the end of the current infection cycle. The rust pathogen survives between one cropping season and the other through the teliospores.



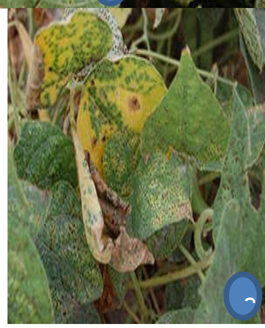


Figure 1. Early uredinial pustules consisting of small, raised white spots.
Figure 2. Advanced uredinial pustules surrounded with yellow borders containing reddish-brown repeating spores.
Figure 3. Pustules late in season containing dark, overwintering teliospores.

Control

Intercropping and varietal mixture greatly deter the movement of rust spores in a bean crop resulting in reduced disease incidence and severity. Most of the released varieties are resistant or moderately resistant to rust. These include AFR-722 (*Ibado*), RWR-719 (*Omo-95*), Dicta-105 (*Nasir*), Dor-554 (*Dimtu*) and Batagonia. Sprays of triazole fungicides such as tebuconazole may provide some control once disease symptoms appear.

Diseases of Wheat in Ethiopia

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Introduction

Total wheat and barley production area is expanding in Ethiopia. Likewise, use of inputs like nitrogen fertilizers is also increasing. Moreover, cereal (wheat) mono-cropping practice is remained a challenging problem as a lot of farmers in major wheat production areas hardly practice crop rotation. With production area expansion, increasing production inputs and lack of crop rotation, over years presence of green bridge between seasons, warm to cool humid climate prevailing in the highlands, presence of complex wheat and barley diseases: rusts, septoria , scald, net blotch, head scab, root and crown diseases in wheat and barley fields and presence of infectious propagules of the various fungal and other diseases complicate disease management. Under such complex circumstances, diseases better managed by integrated disease management approach. This approach manages disease/s damage by the most economical means, and with least possible hazard to people, property, and the environment. This concept is not well understood and integrated to wheat and barley production system in Ethiopia. It is believed that farmers can learn the importance of integrated disease management and its components from trained subject matter specialists. Thus, the objective of this training is to discuss the integrated diseases management and its components

Integrated Disease Management

Growing a crop by manipulating various management means in order to reduce diseases and their impact on the crop and e minimizing impact on the environment and society, is termed an integrated disease management(IDM). Integrated disease management involve pre-plant disease management decisions (influences before season) and disease management decisions to be taken during and post-harvest handling of the crop.

Concept of a Biotic Plant Disease

Infectious plant disease results from continuous irritation by a pathogen that leads to the development of symptoms. A plant is healthy, when it is able to perform its physiological functions. When a plant is attacked by a pathogen, cells and tissues of the attacked plants are weakened or destroyed and plants lose their ability to perform essential physiological functions, resulting in a range of possible disease symptoms or death. Pathogens incite disease in several ways: (1) weakening the plant by absorbing food from it, (2) disrupting nutrient and water transportation and (3) consuming cell contents. E.g., root rots interfere with water and nutrient absorption. Leaf spots, rusts, blights interfere with the plant's photosynthesis. Ear infections interfere with reproduction and thus, grain development. The Disease Triangle is a term used to explain how key factors interact to cause a disease. The amount of disease is influenced by how closely these factors fit together. If a virulent pathogen and a susceptible host are present, but the environmental factors necessary for disease development do not exist, then very little or no disease will develop. Disease is not only occurring, but increasing, over time develops into an epidemic.

How Disease Develops: The Disease Cycle

Regardless of the type of disease, the host or its cause, disease development follows a certain pattern, known as the disease cycle. Disease cycle involves inoculation (depositing of a pathogen onto the host) penetration (entrance of the pathogen), infection (pathogen derives nutrient from the host) invasion and symptom the initial step in the cycle is inoculation. Inoculation can be accomplished by wind, human vectors and mechanical and animal vectors (rusts); splashing water (septoria). Penetration occurs by passive (through natural openings) or active (direct penetration) means. Importance of wheat and barley diseases, proper disease Identification and understanding of the environmental factors that influence disease increase.

Distribution:

According recent wheat disease surveys, yellow rust, septoria leaf blotch, leaf rust and stem rust have encountered in wide wheat producing agro ecologies (Table 1). Scald, net blotch, leaf rust, barley stripe and spot blotch diseases are widely distributed in barley fields. Likewise, other disease such as take all, eyespot, root rot head scab, smuts are common both and wheat agro ecologies.

Table 1. Distribution of major wheat diseases in 2011in Ethiopia

Region	Surveyed fields	Infected fields				Remark
		Yellow rust	Stem rust	Leaf rust	Septoria leaf blotch	
Tigray	52	33	4	6	29	
SNNPs	14	7	2	6	3	
Amhara	250	193	9	28	48	
Oromiya	465	273	158	101	270	
Total	781	506	173	141	350	

Understanding of the important diseases in the producer's region, their identification, means of spread and response to environmental conditions is important in the critical decision-making process necessary to produce wheat profitably and in an environmentally sound manner.

Foliar, floral, root and foot diseases are constraining wheat and barley production in Ethiopia.

Foliar diseases and environments favoring their development:

Septoria

Septorial diseases in wheat is caused by two fungal pathogens called *Septoria tritici* and *Septoria nodorum* .Septoria disease in barly is caused by *S.passerini/S.avenae* f.sp.*triticiea*

Septoria tritici blotch symptom

Lesions are irregular in shape and limited by leaf veins. Dead/Small/sunken/ grayish tan with black specks (pycnidia) occur in lesions from where masses of spores exude upon wetting by rain or dew (Figure 1).

Septoria nodorum symptom: Lens-shaped lesions are surrounded with a yellow-green border. Pycnidia are distributed randomly and are more common on nodes/ stems/ leaf sheaths/ glumes. They may or may not present in the centre of the lesion.

Septoria passerini symptom: Lesions are light- brown to yellowish to green(from the center to margin).pychnidia, black specks formed on tan to brown necrotic areas, lesions.

Epidemiology

Inoculum: Mycelium, airborne ascospores and pycniospores are the infecting pathogen part.

Inoculum source: Infected seed, volunteer wheat crop, susceptible grasses and infested crop debris/straw supports theinoculums.

Means of Dispersal: Rainfall splash and wind

Weather favors septoria development: Frequent rains, higher rainfall, moderate temp between 15&20C, cooler climate and windy weather favor septorial diseases

Loss : Reduce number of seed and size(figure7)

Yellow Rust *(Pucciniastriiformis)*

Symptom: Narrow-yellow orange pustules oriented linearly on leaves are produced between vascular bundles (figure 2). Telial stages are formed at the place of uredia at the latter stages of the crop

Epidemiology

Inoculum: aeciospores and urediospores serve as an inoculum

Inoculum source: volunteer wheat, grasses, infected distant wheat and barley fields and alternate host serve as inoculums sources. The latter one is a source for aceaspores .The rest are sources for urediospores.

Means of Dispersal: Urediospores spread (up to 800-2000km) by wind, human (**i**nternational jet travel) and Human vector

Weather for favoring infection are: The minimum, optimum and maximum temperature favoring yellow rust infection 0°C, 11°C and 23°C, respectively.

Disease: Stem rust (*P. graminis* f. sp. t*ritici,)*

Figure 3

Symptom: Brick red-brown pustules developing as chlorotic spots on stem/leaf/leaf sheath/ spikes/ glumes, awns and pustules erupt through tissues of all infected plant organs are the distinct symptom for stem rust. Pustules **eventually changed to shiny/teliospores(figure3)**

Epidemiology:

Inoculum: Aeciospores and urediospores

Inoculum source:same to yellow rust

Means of Dispersal: same to yellow rust

Weather: Temperature required for spore germination is 2 -30°C.whereas the optimum temperature is 15° to 24°C. Stem rust sporulates within a range of temperature of 5°C - 40°C. 30°C is the optimum temperature for sporulation. Maximum stem rust infection is attained when a dew period of 8 to 12 hrs combined with 18°C. Severe stem rust can occur at lower altitudes due to prevailing of warm and humid climates of this ecology.

Loss: reduce seed size by reducing green tissue on the upper leaves. Reduced seed size (Figure7) and reduced test weights lower the price paid to the producer, and marketability of the crop

Root and foot rot diseases and environments favoring their development:

Root and foot rot affect both wheat and barley: Root and foot rot diseases are caused by two groups of pathogens, soil inhabitants and soil invading pathogens.Soil inhabitant root and foot rot causing pathogens causing common root and foot rot are*Bipolarissorokiniana,Fusariumgraminearum, Fusarium culmorum, Pythiumspp*and*Rhizoctoniacerealis.*Soil inhabitant pathogens survive saprophytic ally on materials available in the soils for yrs in absence of wheat. Soil invaders pathogens are represented by *Gaeumannomycesgraminis* and *Pseudocercosporellaherpotrichoides*. Soil invaders pathogens cannot survive in the soils at absence of wheat. These pathogens cause take-all and eye spot.

Effect of the root and foot rot diseases

Root and foot diseases reduce crop stands by killing the whole plants or one or more tillers on each plant, head numbers. They also results in prematurely ripening and bleached heads and shriveled grains (figure7).

Symptom of Root and foot rot: Plants infected with root and foot rot are stunted and chlorotic. When*Bipolarissorokiniana*is involved,brown,dark-brown or blackened lesions are formed on coleoptiles, crown and lower nodes**,** sub crown internodes, roots and culms of the plant and are observed when root systems are washed and examined. Lesion severity increases throughout the growing season. Soilborne Fusarium spp invade the base of sub crown internode secondary roots as they emerge from the crown and resulted in few tillers and large irregular patchy areas. The lower internodes of plants with whitehead symptoms will be dark to light brown in colour when *Fusarium* spp are involved. Both fungi destruct lower internode, sub-crown internode and result in whitehead as the plants approach maturity and of diseased plants seen in randomly or irregular patches in infested fields(figure 6). Fusarium spp. infection from inoculum arising from seed results in death of seedling before and after emergence. Cottony pink mycelium develops within culm between the culm and lower leaf sheath as the *Fusarium .spp*. and discolored culm tissue extend to 2 or 3 internodes above the soil (figure 4).

Eye spot/straw breaker: Eye spot/straw breaker is a foot disease caused by *Pseudocercosporellaherpotrichoides.* The disease is more prevalent where wheat is repeatedly grown and climate is cool and moist.

Effect: the disease can kill entire plants outright or girdle the culm and causes lodging and renders harvesting. Individual tillers can be weakened or killed by lesions. The disease also reduces kernel size and numbers(Figure7). The premature diseased tillers produce whiteheads with incompletely filled seeds. Whiteheads support sooty mold in humid climates.

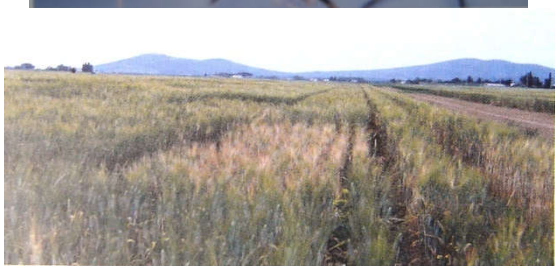
Symptom: Conidia of the fungus germinate and directly penetrate coleoptiles and leaf sheath and through stomata near the ground level. Initially, lesions grow superficially on leaf sheaths at or near soil surface and with time grow wider and longer and stepwise penetrate the culm. Elliptical or eye shaped lesion darkened at the center is the typical characteristics of the disease (figure5). Well developed lesions cannot be removed by stripping off leaf sheaths. Under severe infection, wet gray mycelium is developed within the lumen of the culm beneath severe lesions.

When the culm is split open just above the crown, fluffy gray mycelium of the fungus can be seen in the hollow center of the stem beneath the eyespot lesion.

Take-all: Take-all is recognized as a disease of the roots, the crown stem base (foot) and caused by *Gaeumannomycesgraminis*var. *tritici*(Sacc.) Arx&Oliv. (syn. *Ophiobolusgraminis*Sac.)

Effect: take-all reduces seed yield by almost 50% by killing tillers prematurely or forming shriveled seeds (figure7).

Symptom of Take all: Roots are infected as they grow through the soil near the infested debris. Under severe cases, diseased plants are stunted, chlorotic and with uneven height and fewer tillers that ripening prematurely and show sterile white heads (figure 6). Diseased plants pull up easily or break off near the soil line. Under examination, a deep black charcoal-like discoloration of the roots and lower internodes of the wheat plants is seen (figure 6). This particular character distinctly differ take-all from symptom caused by *Fusarium*. Microscopically, a superficial black network of mycelia is present on infected root surfaces.



Epidemiology

Inoculum for root and foot rot diseases: Conidia, chlamydospores and mycelium (Fusarium spp.), mycelium and conidia (Bipolarissorokiniana), dormant Oospores and zoospores (Pythiumspp), mycelim or conidia(P. herpotrichoides) , hyphae and ascospores(Gaeumannomycesgraminis) are the inoculum for root and foot rot diseases.

Inoculum source: Infested crop residue, infested soil, infected seed, grass weeds, volunteer wheat and other cereal crops, and infested other wheat fields or other host crops serve as inoculum source for this disease.

Means of dispersal: The inoculum causing root and foot rot diseases spread by wind, farm machinery, living organism, water-splash, runner hyphae and by moving infested soil and debris from one field to the other

Favorable condition for root rot and seedling blight: Most root rots are favored by cool, wet conditions shortly in the early spring when new growth is initiated. Imbalanced fertilization, high nitrogen and low phosphate also encourage root rots.

Favorable condition for eyespot: Eye spot is favored by high soil moisture, a dense crop canopy, recurrent host crops, reduced tillage, early seeding and high humidity near soil level. Cool springs prolong sporulation and infection periods. Plants may be predisposed to infection in spring by frosts and nitrogen fertilization.

Figure 7.Shrivielled seeds due to diseases such as rusts, sptoria, foot and root rot diseases among others

Floral diseases and environments favoring their development:

Smut diseases: Common bunt caused by*Telletiatritici, T. laevis(T.foetida,T.levis, T.foetens*) and loose smut incited by Ustilagotritici occur on wheat in Ethiopia. Covered smut and loose smut in barley are caused by Ustilagohordei and Ustilagonuda , respectively. Pathogens causing common bunt and covered smut infects the plant at the seedling stage whereas loose smut causing pathogens infects the flowers of the plant at flowering stage of the crop.

Loose smut: Loose smut has a worldwide occurrence as the pathogen spreads to long distance and from place to place by man (infected seed) and wind

Symptom: Diseased heads emerge earlier than heads of healthy plants. Smutted heads are blackened and clearly visible among emerged green healthy plants at heading (figure 8). Lower internodes and upper internode are longer and shorter, respectively, than in healthy plants. Kernels in spikes are replaced by masses of teliospores. Membranes enclosing spores rupture and spores released and naked rachis is seen in the field.

Epidemiology

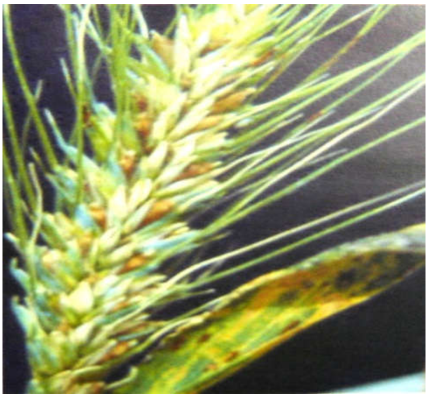
Inocolum: and inocolum source: Teliospores from*Triticum*spp, *Secalecereale,* X *TriticosecaleHordeum*spp and dormant mycelium in infected seed are the inoculum for wheat loose smutdiseases.

Means of dispersal:wind and humans are the two principal means by which the inoculum, teliospores and infected seeds are disseminating to nearby florets of wheat and to the other fields.

Weather: Cool, moist climate favors loose smut. Temperature ranging from 20° to 25°C and 95% RH is optimum for teliospore germination and development. Excessive heat and dry air inhibit spore germination, germ tube growth, and delay penetration into ovary and thus fungus cannot reach the growing point.

Effect and Yield loss: Seedlings from infected seed are week and succumb to low soil temp, drought, compacted soil, deep seeding, water logging, frost and die before emergence/stunted.:Yield loss is proportional to infected tillers as the kernels in the spike of the infected tillers entirely replaced by masses of teliospores.

Commonbunt:



Symptom : Infected plants are stunted or slightly stunted and infected heads emerge later than normal heads after heading. Light to dark brown bunt ball filled with mass teliospores is covered by thin periderm that can be ruptured mainly during harvesting and threshing of the crop(figure 9). Diseased spikes have a smell of rotting fish.

Yield Loss. Common bunt disease reduces both yield and quality. Moreover, grains contaminated with bunt spores have pungent and fishy odors and darkened appearance. Such a grain is either discounted in value or not accepted at the market.

Covered smut

Symptom: Smut heads emerge at about the same time as normal healthy heads. Kernels are replaced by teliospores, tough membranes remains intact

Epidemiology

Inoculum:teliospores

Inoculum source: soil, infested seed, bunt balls mixed with seeds. teliospores can be viable for 2years in soil and for many years on stored seed

Infection:teliospores germinate and the hyphae of the fungus infect the coleoptiles before plants emerge from the soil.

Weather favoring bunt and covered smut:cool and moist soil with 5° to 15°C is optimum for bunt in wheat and covered smut in barley. Infection is slight with a temperature of more than 20-22°C

Importance of disease identification: Accurate disease identification by the farmers is important for making decisions about management methods aimed at specific diseases or the need to apply specific management measures in a timely fashion. A few days' delay in applying a fungicide or applying the wrong fungicide may result in poor disease management and significant yield or quality reduction. Farmers often have relied on assistance from development agents and subject matter specialist and other trained specialists for disease diagnosis. However, farmers must be recognizing common wheat diseases problems by themselves in wheat field. This is necessary to determine the type of management needed depending on diseases detected as diseases caused by viruses or bacteria will not be managed by applying a fungicide. A low severity of stem rust at the early dough stage usually does not effect on yield and yield components and does not require treatment. Disease diagnosis is aided by knowing the cultivar. A low level of severity early in the season on a susceptible cultivar can indicate the disease has the potential to increase quickly and have a serious impact on the crop yield.

Wheat Disease Management

Disease management is a key component of high-yielding wheat and barley varieties. Some diseases, example, take-all must be managed proactively and cannot be affected once they are established. Other diseases, such as foliar diseases caused by fungi, can often be managed by the timely application of foliar fungicides. Generally, wheat growing farmers place too much emphasis on disease management using foliar fungicides whereas barley growing farmers give little attention for diseases management in Ethiopia. Most wheat and barley diseases can be best managed by the use of multiple disease management tactics: proactive (crop rotation, delayed planting, resistant varieties, proper fertility, seed treatment fungicides) and reactive (application of foliar fungicides).

Role of pre-planting decisions in wheat diseases management

A significant portion of their total disease management program of wheat and barley producers is in place once the seed is in the ground. By that time, decisions have been made about crop and cultivar selection, method of tillage/seedbed preparation, seed quality, seed treatment, planting date, seeding method and rate and soil fertility. Individually and collectively, these decisions can play an important role in influencing which diseases develop, their severity and their effect on crop yield and test weight.

Resistance by wheat type: Durum wheat has better resistance to *S. tritici*than spring bread wheat. However, winter bread has better resistance septoria than spring bread wheat. Resistance septoria is conditioned by dominant, partially dominant, recessive and additive

Variety Selection

Decisions relating to variety selection are, perhaps, the most important decisions that can be made in diseases management. Every commercially available wheat and barley variety has a unique range of reactions to diseases in a given region (next table). The type and number of the varieties can determine the importance of certain diseases. Failure to consider the ramifications of variety selection in managing diseases is a costly mistake. Selection of two or three varieties with the greatest amount of available resistance to the diseases most common on a farm or in the community is important. To do this, some idea about the disease history on the farm is necessary. If that information is not readily available, development agents may help. This information won't be as good as actual data from the grower's own farm, but it is far better than basing decisions on no information. Planting more than one variety is recommended because it is common for a single disease to damage a single variety severely, consequently the risks are reduced. The fictional life time of various varieties having major resistance genes increased by: sequentially planning of varieties overtime, interregional diversity, interfiled diversity intra-field diversity and combination of resistance genes into a single cultivar, d pyramiding or stalking. Stem rust resistant variety developed by gene pryramiding lasted for 30 years in North America. Thus, resistant varieties with resistance combination backgrounds to yellow rust and stem rust and their diversification are used to increase the functionality of effective resistance genes.

Resistance: Those in which loose smut is not sporulating, few ovary wall is penetrated, have little mycelium in the pericarp and have smaller angle of opening of palea and lemma at flowering and have short time florets stay open or have shrtime of anthers extrusion have good resistance to loose smut.

Table 2. Bread wheat varieties with varying rusts resistance

Cultivar	Year of release	Stem rust	Stripe rust
K6295-4A	1980	Moderately Resistant	Moderately Resistant
ET-13 A2	1981	Moderately Resistant	Moderately Susceptible
Madawalabu		Moderately Resistant	Resistant
Sofumer		Moderately Resistant	Moderately Resistant
Pavon 76	1982	Moderately Resistant	Moderately Susceptible
Mitike	1993	Moderately Susceptible	Moderately Resistant
Tusie	1997	Moderately Susceptible	Moderately Resistant
Sirbo	2001	Moderately Susceptible	Moderately Susceptible
KBG-01	2001	Resistant	Moderately Susceptible
Meraro	2002	Moderately resistant	Resistant
Digelu	2005	Moderately Resistant	Moderately Resistant
Millennium	2007	Resistant	Moderately Susceptible
Picaflor	2010	Moderately Resistant	Moderately Susceptible
Danphe (Danda'a)	2010	Moderately Resistant	Moderately Resistant
Hoggana	2010	Resistant	Moderately Resistant
Shorima	2010	Resistant	Moderately Resistant
Huluka	2011	Resistant	Moderately Resistant
Hidase			

Escape:both bread wheat and durum susceptible cultivars grown during April to August crop season escape yellow rust and stem rust epidemics

Crop Rotation: Crop rotation helps to manage the wheat and barley pathogens that survive between wheat crops in wheat residue such as septoria spp.,*Gaeumannomycesgraminis,Pseudocercosporellaherpotrichoides.Bipolaris sorokiniana*and *Fusarium culmorum*, *F. graminearum*,Pythium, *Pyrenophorateres*, *Rhynchosporiumscalis*). Planting crop other than wheat and barley in a wheat and barley field reduces the level of pathogens specific to wheat and barley decline as soon as the residue of previous wheat and barley crops deteriorates. Lower level of pathogens is translated into less disease pressure in fields where wheat is produced next season. In fact, rotating fields out of wheat is the only practical means of controlling take-all. Generally, the effect of rotation one diseases can be negated by spores blowing into fields from neigh boring fields. High land pulses, rape seed, potato and maize are some of non-host crops to grow in wheat and barley rotation. Sorgum and Oats are also to help in wheat rotation to reduce take all..

Tillage: Tilling wheat stubble hastens the breakdown of residue that harbors certain disease organisms (reduce levels of take-all, eyespot, septoria leaf blotch, spot blotch and tan spot). One year rotation helps except where take all levels is high. Infested residue (/infested straw, stubble) and volunteer wheat and barley crops can be also removed by burning and feeding to animals. Avoid stubble mulch and minimum or conservation tillage.

***Seed Quality, Seed Fungicides, SeedingRate and Planting Method*:**All of these parameters can influence stand establishment and seedling development. To achieve the desired stands and yield, there must be excellent seed germination followed by emergence and development of seedlings. Using high-quality (certified) seed treated with a broad-spectrum fungicide and good planting techniques foster good stand establishment. Excess stands, however, encourage foliar and head diseases by reducing air circulation and light penetration into the canopy later in the season. Thinly seeded fields maintain low relative humidity within the canopy and limit eye spot epidemics.

Planting Date: Early planting results in severe septoriatritici blotch around Holettat. Likewise as reported elsewhere abroad, early planting increases the risk from barley yellow dwarf and take-all diseases

Nitrogen Fertilization: Excess nitrogen can results in lush stands and encourage excessive crop growth and density and promote problems of most fungal foliar diseases: rusts, leaf blotch complex, powdery mildew, net blotch, barley leaf scald and BYDV. Also, high nitrogen increase biomass that in turn results in crop lodging and in higher moisture/humidity within the canopy that in turn favor fungal diseases. Balanced fertilizer reduces the disease epidemics resulted from *Pythium spp*. and *Gaeumannomycesgraminis*. Apply phosphate to the soil to promote rapid root growth.

Fungicide Seed Treatments: Slow seed germination predisposes developing seedlings to infection by seed- and soil-borne fungi in wheat and barley: *Pythium spp.Fusarium, Rhizoctonia, Septoria and Stagonospora, pyrenophoraters, tricis*and *U. nuda, Telletia spp.* Infection from these pathogens result in fewer emerged seedlings and reduced vigor of the seedlings that do emerge. It is advisable to treat seed with a good general-use fungicide to protect seedlings from adverse soil conditions if they develop after planting. Fungicide seed treatments enhance germination of marginal-quality seed lots such as seeds infected with*Fusarium*, and bring seed germination up to acceptable levels. Poor response of low-to-moderate germination seed lots to fungicides suggests high percentage of dead seed, mechanical damage or some factor apart from disease.

The use of seed treatment fungicides, such as carboxin, allowed seed lots to be "cleaned up" by eliminating loose and common bunt from infected seed.Most new-generation sterol inhibiting seed treatments are marketed as a mixture with either thiram or captan in order to control common soil-borne pathogens. Seed treatment fungicides should not be considered as a total replacement for spring-applied foliar fungicides since no seed treatment provides season long control of foliar diseases. However, environmentally, seed treatment fungicides are desirable because of their low toxicity, low use rates, rapid breakdown and target application strategy. It must be noted that poor coverage equals poor results and, perhaps, a waste of money. Having seed treated by a professional eliminates poor fungicide distribution and variable rates on seed as potential problems.

Table.3 Effective seed treating fungicides seed- borne and soil-borne pathogens in wheat

Common name	Effective for
Seed dressing	pathogens
Vencit 200,	Fusarium
Panoctin 200	septoria
Vitaflo 250,	Helminthosporium
Vitavax(carboxin), Prochloraz	Tilletia, Ustilago tritici
Thiram	Tilletia

Rouging: Rouging out of smutted plant heads out of the field and burying or burning them reduces seed infection level in the current crop. This operation must be done as early as possible.

Foliar Fungicides

Fungicides must be applied in the early stages of a disease epidemic. Applying fungicides too far in advance, or waiting too long to apply results in poor disease management and have little or no economic benefit. Also, there is no economic gain from using foliar fungicides if yield-reducing levels of disease fail to develop, if crop yield potential is too low to cover costs and if foliar fungicides applied on diseases caused by bacteria, viruses or nematodes, loose smut and take-all. Some effective foliar fungicides reported to effective in Ethiopia are given in the next table 4 and figure 2).

Table 4: Effective foliar fungicides on foliar diseases in wheat

Common name	Trade name	rate	Effective for
Propiconazole	Tilt 250EC	0.5-1l/ha	Septoria blotches & rusts
Propiconazole	Bumper	0.5l/ha	Yellow rust
Flutriafol	Impact	0.5-1l/ha	Septoria blotches & rusts
Triadimefon	Bayleton	0.5-1kg/ha	Yellow and leaf rusts, septoria
Triadimefon20%EC	Prevent	0.65l/ha	Yellow rust
Fenpropimorph		1l/ha	Yellow and leaf rusts
	Mancozeb	**1kg/ha**	**Septoria**
Chlorothalonil	**Bravo 500**	**1.125kg/ha**	**Septoria blotches**
Propiconazole	Topzole 250EC	0.6l/ha	Yellow rust
Tebuconazole	Orius 250EW	1l/ha	Yellow and stem rusts
Tebuconazole	Natura 250EW	0.65l/ha	Yellow rust
Epoxiconazole	Soprano	0.75l\ha	Yellow and stem rusts
	Amistar xtra 280Sc	0.65l/ha	Yellow rust
Propiconazole	Progress 250EC	0.5l/ha	Yellow rust

Steps to take towards making foliar fungicide use decisions:

Scouting fields: Scouting for diseases is important for two reasons. Scouting diseases per annum helps to build an on farm database that can be used to select appropriate disease management tactics for future crops. Disease scouting also helps to determine, if and when, to apply fungicides within a given season. Data from properly scouted are used to determine disease management options. Farmers can contact development agents and subject matter specialists for the latest recommendations. Scouting wheat and barley fields to determine crop growth stage and current disease situation is critical for making good fungicide-use decisions. Observe the entire field and make decision on the average disease situation rather depending border of fields. This requires assessing disease levels in eight to 10 randomly selected sites. It is also important to determine the growth stage of the crop. Because, all fungicides are applied within specific growth-stage restrictions and fungicides provide the greatest benefit when plants are protected from disease between flag leaf emergence and soft dough stage. Tilt, for example, legally cannot be applied once the flag leaves in a crop are fully expanded (GS 39)

Determine the number of potential fungicide applications: After accomplishing scouting fields, determine number of fungicide applications to make. Most producers may prefer one time whereas few like two times spray. With one time spray, time of application is crucial. Based on research and experiences, a single application during heading performs better than a single application made at flag leaf emergence in most situations. Because single applications at flag leaf emergence frequently allow late-season disease pressure to build to excessive levels. As a result, the crop is damaged even though early diseases may have been kept in check. Heading applications, on the other hand, usually limit disease build up on the flag leaf, the second leaf down and the head, even though disease is allowed to develop unchecked early in the season. Protection of the flag leaf and below it and the head is much more important to yield and grain quality than is protection of lower leaves. Fungicides are of little or no value once the flag leaf and head are severely diseased. The best way to limit this risk is to start scouting operations during flag leaf extension. Two fungicide applications, early followed by a late application often out yield even the best single application. As a general rule, the extra treatment at least pays for itself if early disease pressure is moderate to heavy and crop prices are good.

Know the disease reaction of the wheat variety planted. Foliar fungicides are not necessary on wheat and barley varieties rated as resistant or moderately resistant to a particular fungal disease.

Estimate crop yield potential. Sufficient yield potential will justify a foliar fungicide application. Fungicides protects only yield already built into a crop. The higher the yield potential of a crop, the more the farmer is benefited economically from applying a foliar fungicide if disease becomes a problem.

Know the disease(s). Diseases encountered are to the ones important such as rusts and leaf blotch complex. Fortunately farmers are benefited by applying fungicides on diseases that reduce yield.

Determine disease levels. Fungicides applied early in an epidemic are most effective. Fungicides application before disease is visible and waiting too long before fungicide application results in no economic benefit. Exame symptoms on lower leaves and determine when to apply a fungicide(e.g., if you see leaf blotch complex on two leaves below the flag leaf and the rain is available, there is a good chance for flag leaf and head infection) . Of course, the greatest obstacle is how to determine effective, economical use of foliar fungicides and to determine enough disease to justify a foliar application of a fungicide. There is no research based threshold guidelines coined to help farmers in Ethiopia to make fungicide use decisions. However, fungicides applied on yellow rust and stem rust at 5% and 2%, respectively, along with common sense about crop growth stage, varietal resistance and weather situation. The thresholds indicate that yield loss caused by one or more of the diseases is likely; however, they do not mean losses will definitely occur.

Fungicide selection. Apply all fungicides according to label specifications and registration. Product labels provide detailed use instructions and product limitations.

Understand the risks. One of the problems farmers have is inability to determine if disease-favorable conditions will persist after a fungicide is applied. Fungicides are valuable only if yields and test weights are threatened by disease and fungicides are of limited value if other diseases develop that are not managed by those fungicides(all viruses, bacterial diseases, take-all, loose smut and head scab). Fungicides may be of limited value if yields and test weights are reduced by non-disease factors (frost, lodging, delayed harvest and poor grain fill period).

Integrated Weed Management

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1. Introduction

A. Weed

Weed is a plant growing where man does not want it to be. Weed species usually possess several characteristics which enable them to compete effectively with crop plants and therefore to survive over the generations in association with crop production. Such characteristics include the following:

a. the ability to flower and produce seeds in a short period of time. It enables the weed species to complete their life cycles even if the favorable season for growth is short. In some cases it also enables them to produce several generations each year.
b. the ability to produce large number of seeds
c. the presence of efficient mechanisms for seed dispersal. The main agents for weed seeds dispersal are wind, animals (including man) and water.
d. the presence of allele-chemicals that inhibit germination and growth of crops
e. the possession of specialized seed dormancy mechanisms; impervious seed coats, the presence of growth inhibitors and requirements for exposure to certain temperature or light treatments.
f. the ability to survive in a wide range of environments
g. the presence of perennating organs; rhizomes, corms, tubers and bulbs that enable to sprout/regenerate after any areal damage or to produce new plants from the parent plant without seed. They also serve as food storage units that enhance survival.
h. the ability to propagate vegetatively; from pieces of stems and roots
i. the ability to resist/tolerate chemicals
j. the ability to associate with crop plants; genetic and/or crop production relationship

B. Impact of weeds

Impacts of weed could be:

- Economical on agriculture
- Environmental on biodiversity
- Social on human health
- Cross-sectoral on two or more of the above mentioned sectors

One of the most easily observable effects of weeds is that they decrease crop yields. This occurs mainly because the weeds compete with the crop plants for water, mineral nutrients and light.

- The ability of the crop plant to compete against weeds varies with the stage of development of the crop plant. For most crop plants, certain stages of development are particularly sensitive to weed competition. Usually, the competitive ability of the crop plant is low during the seedling and early vegetative stages, but tends to improve as the season progresses. Once such stages have been identified, the farmer ensures maximum weed control at those times, while permitting less stringent weed control during the other less critical stages.
- The density of the crop plant can also influence its competitive ability against weeds. A high crop density, by providing a dense canopy, may control weed seedlings by depriving them of light.
- Averaged crop losses due to weeds competition are estimated as about 25%, but may be as high as 50% or even 80% with certain food crops.

In some cases weed plants or their residues inhibit crop plants by producing toxic substances/exudates that hamper the germination, growth and development of the crop plants.Another form of aggressive competition occurs when the weed plants are actually parasitic on the crop plant. Eg . *Cuscuta, Orobanche, Striga* spp. Weeds can also reduce yields indirectly by serving as alternate hosts and/or reservoirs for various diseases and insect pests of crop plants. Eg. *Setariapumila*vis*Clavicepspurpurea* (ergot). Weeds often reduce quality of the harvested crops. Weed seeds often contaminate the harvested grain, and reduce its quality and market value.Some weeds increase the tendency for some crops to lodge or to go over, flat. Eg. *Convolvulus arvensis.*Weeds in pasture can be a nuisance or even a danger to livestock. Such weeds may be spiny or poisonous and therefore cause considerable discomfort or even the death of the livestock which ingest them.There are weeds causing allergic reaction in humans, mainly due to wind-born pollen and while hand pulling the plant. Other farming situations in which weeds cause problems include the damage to farm machinery through clogging as well as clogging of canals and irrigation channels by weeds. In terms of economics, weeds add considerably to the cost of crop production, i.e., budget on various weed control measures. They also waste an excessive proportion of farmers' time, thereby acting as a brake on development. Sometimes there are failures in success after applying well budgeted and time taking control treatments due to several reasons.

Weeds are one of the most important factors for less productivity of crops in Ethiopia. Then, it is boldly very clear that proper weed management can increases the crops productivity at large. Thus, weeds must be controlled for profitable crop production to take place.

II. Weed management

Understanding arable land weed communities are a prerequisite for effective weed management, being weed distribution is regional in nature.Major categories of weeds include invasive, parasitic and non-parasitic weeds.

A. Major weed categories

1. Invasive weeds: Good examples of invader weeds in Ethiopia are *Partheniumhysterophorus.*It is a prolific seed producer (a plant can produce up to 25,000 seeds) and can complete life-cycle in 28 days. Causes allergenic reaction and skin irritation to animals, human.Allelopathic and competitive, so inhibits growth and seed production of useful crops. It also causes destruction of native biodiversity.*Parthenium* causes a total habitat change in grasslands, open woodlands, river banks and floodplains. Reduces the pasture carrying capacity by up to 90% and toxic to animals, and taints milk and meat. Prolonged skin contact can result in allergenic eczematous contact dermatitis. Inhalation of pollen cause allergenic rhinitis which can develop into human bronchitis or asthma.

PartheniumProsopisjuliflora

- Parhtenium : Prolonged skin contact can result in allergenic eczematous contact dermatitis
- *Prosopisjuliflora* It roots up to 10-15 m deep – maximum depth of 53 m recorded. A mature tree can produce 60 000 seeds. Very aggressive and rampant invader of an area, replacing several plant species; grasses, shrubs and trees. It has invaded more than 700 000 ha in Ethiopia. It is also a problem in Kenya, South Africa, India, Somalia, Djibouti, Eritrea, Sudan, Chad, Niger, Mali, Namibia, Botswana and elsewhere. Invades road sides and homesteads, and then reduces visibility and impedes movement that its thorns threaten

human and livestock health. It also invades productive lowlands that it enters cotton fields and the irrigation canals incurring high cost of crop production.


Lantanainvasion and encroachment problems on *Eichhorniacrassipes* degraded and productive areas

- *Lantana camara.* It causes invasion and encroachment problems and toxic to animals.
- *Eichhorniacrassipes.* Blocks smooth movement of water via the canals, and causes for the loss of water by evapo-transpiration. Prevents access for animals to drink and people to fetch the water, and also hampers fishing and booting activities.

Parasitic weeds:A dense infestation of parasitic weeds can cause 100% yield loss on host crops

Cuscutacampestries

*Orobanche*spp

*Striga hermontica*infestation in maize

Non-parasitic weeds

A. Broad leaf weeds


Amaranthusspp/aluma/ *Argemonemexicana L.*


Chenopodiumspp/amedmado; adala/*Convolvulus arvensis* /Tatu/

Galinsogaparviflora/abadebo; balcha/

Grass weeds; They are noxious weeds of small grain cereals production system

Bromuspectinatus/gench;wavilo/ *Loliumtemulentum* /enkirdad/

PhalarisparadoxaAvenafatua/sinar/
/sinisi; asendabo/

However, this day frequent usage of broad leaf weed killer herbicides and mono-cropping of crops shifted weed flora composition by favoring the grass weeds. Appropriate weed management technologies should be economically justifiable, technically feasible, socially acceptable and ecologically safe.

B. Weed control methods

Weed invasions can be stopped at several stages:

The best stage is *Prevention* that stops a particular weed species from being introduced. It is practiced by using weed free crop seeds and equipment, and keeping fence lines, road sides and wasteland areas free of weeds to reduce sources of infestation.

The second t is *Eradication.* It is destroying or removing a new invasion through early detection and rapid response. The third is *Containment.* It is stopping an invasion from spreading. Final option is *Control* of established invasions and *restoration* of affected systems (expensive and time consuming).Some preconditions for successful weed management projects/programmes are available techniques and capacity that can work, support from key decision makers, sufficient funding, and public awareness and support.

There are four main measures in controlling weeds;

- Cultural
- Physical/mechanical
- Biological and
- Chemical control

1. Cultural control; Cultural practices play an important role in weed management. A vigorous, competitive crop produced through good cultural practices is the best defense against weed competition.

- Crop rotation: cereals after legumes, oil crops, etc. Diversified rotations that use many different crops provide more opportunities for varying weed control practices and crop managing cultural practices. Each crop has its own set of cultural practices that creates niches for certain weeds and rotation changes available niches and weeds. Some crops are more aggressive than others in competing against weeds, smother weeds by growing faster. Other crops observed inhibiting the seed germination and weeds plant growth. All members of the mustard family (Brassicaceae-rape seed) contain mustard oil that-inhibit seed germination and plant growth. Then, a weed species couldn't able to adapt to such changing systems.

- Fallowing: cereals after fallowing the land with out affecting yearly production, by allocating certain part of the farm land for fallowing over years. If no grazing made by higher animals, the fallow land should be subjected to occasional tillage as method of controlling weeds, not to permit weeds to deplete the soil moisture and produce seeds. In principle, for better productivity of a farm, plant production shouldn't be separated from animal production. Grass weeds produce large number of seeds which gives a chance to be escaped during weed control practices and difficult to identify them easily from cereal crop for early hand pulling, but being shorter in seed longevity, crop rotation and fallowing can help to reduce their seed bank at large.

- Straw burning: Straw burning kills many seeds and reduces the dormancy of the survivors, except under serious infestation condition its impacts on soil microorganisms shouldn't be forgotten.

- Intensive tillage: Intensive tillage that included dry season plowing found preferable to control *Cyperus* and *Digitaria* spp. It is meant to expose seeds and weed plant materials to dry season sun light for desiccation. Second or 3rd round plowings before planting help to control already emerged weeds and to prepare seed bed. Conventionally cereal crops require smooth seed bed which is free of weed and crop residues. For annual weeds, ploughing bring out weed seeds that have remained buried in the soil to the surface. They then begin to germinate and if shallow tillage is done shortly afterwards the weed seedlings destroyed. For perennials, repeated tillage at relatively short intervals may be necessary. Each tillage operation destroys the top growth, and forces the weed plant to produce new growth at the expense of underground reserves. Eventually these reserves are exhausted and the plant dies.

- Proper planting time, depth and pattern, fertility management, high seed rate, and growing competitive variety: Proper planting time, depth, pattern, high seed rate and growing competitive variety to have well established and good crop stands that can fully cover the farm area and then suppress weed growth. Early and shallow sowing enables crop plants established before the main flush of weed germination. Then, shade susceptible weed seedlings can not compete with an already established crop. Delaying crop sowing enables the main flush of weed seedlings to be controlled before planting. However, crop yields are generally reduced by late sowing. Raw planting enable to implement control measures separately and to favor the crops too (eg. targeted fertilization). Weeds competitive effect is greatest at low soil fertility levels, and is reduced with fertility management supplemented with other proper weed management practices. Where fertilizer is broadcast, the entire weed community is fertilized along with the crop. Where fertilizer is banded in the row, only the crop gets fertilized.

2. Physical/mechanical control

- Digging or bulldozing
- Hand weeding: Early hand weeding especially to supplement herbicidal treatments
- Chopping/slashing
- Cultivation or hoeing
- Ring-barking
- Rouging: Remove escaped weeds by hand weeding before they seed themselves

3. Biological control

- Uses stimulated host-specific natural enemies (Pathogens, parasitoids, predators, etc) to bring long-term or sustainable control of the target weed
- Offers cost effective and environmentally friendly solution
- It is most efficient where a single troublesome weed species is predominant

Aim of weed bio-control is to reduce the invasive potential of the target plant to a level where the weed plant is no longer problematic but nottotal eradication of the target weed plant.

4. Chemical Control

Involves the use of herbicides:

- Contact or systemic herbicides
- Pre-emergence or post-emergence herbicides
- Long or short residual herbicides

Applications:

- On soil application
- Foliar spray
- Cut-stump treatment
- Ring-barking and herbicide application
- Injection

It is advisable to use herbicides with different killing effects to reduce shifting of weed population. Rotating herbicides with different modes of action (from different herbicide groups and families) or use of herbicide mixture (if compatible) will delay the development of herbicide resistance or reduce shifting of weed population. Contact herbicides are usually effective in eliminating annual weeds, while systemic once are useful in controlling perennial weeds because underground perennating organs and roots are killed in addition to the shoot. Soil-acting herbicides are applied to the soil where they retard or inhibit the germination of weed seeds. It shouldn't be forgotten that herbicides application cannot compensate for bad crop rotation or bad soil tillage, and continuous usage of herbicides is costly and eco-pollutant. Where necessary, select chemicals those are both safe and effective, and apply in the first three weeks after emergence because after this period weed will be suppressed by the crop. Do not overuse herbicides that resistance might make them obsolete. Do not use any herbicide which is dangerous or persistent. There is no effective and sustainable sole weed control method. Thus, it is found very important to integrate different weed management tactics (preventive, cultural, mechanical, biological and chemical methods) in a cropping system-based weed management strategy.

C. Integrated Weed Management (IWM)

A long-term effective weed management strategy is based on the practical application of the ecological concept of 'maximum diversification of disturbance', which means diversifying crops and cultural practices in a given agro-ecosystem as much as possible. This results in a continuous disruption of weed ecological niches and hence in a minimized risk of weed flora evolution towards the presence of a limited number of highly competitive species. Besides this, a highly diversified cropping system also minimizes/reduces risk of the development of herbicide-resistant weed populations.Weeds are less able to adapt to a constantly changing management system that uses many different control practices, unlike a program that relies on one or two weed control tools. Here, the following methods can be integrated for an effective control of weeds.

Example: On farmers' field IWM verification test result around Ambo, West Shoa Zone, Ethiopia

Table 1. Recommended weed management practices on Maize

Control methods	Recommended practice
Ploughing	3 Ploughings: 1st at dry season to eliminate perennial weeds; 2nd before planting to control emerged weeds 3rd at planting to prepare seedbed
Crop husbandry	Planting: soon after the rain comes Spacing: 30 cm x 75 cm Fertilizer rate: 75 N + 75 P_2O_5 kg/ha Seed rate: 25 kg/ha Even seeding depth: 5 – 7 cm
Hoeing and slashing	1st weeding: hoeing at knee height 2nd weeding: slashing before flowering
Chemical control	Lasso-atrazine, pre-emergence

Table 2. Maize mean grain yield, 2005/6

Plot	Yield (Kg/ha)			Yield increase (%)		
	Meti	Toke	Mutulu	Meti	Toke	Mutulu
Recommended	3500	3800	6300	169	137	50
Farmers' practices	1300	1600	4200	-	-	-

Integrated Weed Management in maizethat involved use of improved and clean seed, proper time and frequency of ploughing, sowing time and rate, fertiliser type and rate, rate and time of herbicide application, time of hoeing and slashing gave considerable yield advantage over farmers' practices for maize and suggested to be adopted by farmers in the areas.In general it is vital to integrate different weed management methods for sustainable agricultural productivity.