Facilitating the Implementation and Adoption of Integrated Pest Management (IPM) in Ethiopia

Planning workshop from October 13-15th 2003 at the Melkassa Agricultural Research Center, EARO.
Jointly organized by the Association for Advancement of IPM (ASAI) and the Ethiopian Agricultural Research Organization (EARO)

By Esheteu Bekele, Ferdu Azerefegne, and Tsedeke Abate

February 2006

DCG Proceedings No. 17
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### Acronyms

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<tbody>
<tr>
<td>IPM</td>
<td>Integrated Pest Management</td>
</tr>
<tr>
<td>ASARECA</td>
<td>Association for Strengthening Agricultural Research in Eastern and Central Africa</td>
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<td>ASAI</td>
<td>Association for Advancement of IPM</td>
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<td>EARO</td>
<td>Ethiopian Agricultural Research Organization</td>
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<td>GDP</td>
<td>Gross Domestic Product</td>
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<td>FAO</td>
<td>Food and Agriculture Organization</td>
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<tr>
<td>USAID</td>
<td>United States Agency for International Development</td>
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<tr>
<td>MoARD</td>
<td>Ministry of Agriculture and Rural Development</td>
</tr>
<tr>
<td>AMAREW</td>
<td>Amhara Micro-enterprise Development Agricultural Research Extension &amp; Watershed Management</td>
</tr>
<tr>
<td>SARI</td>
<td>Southern Agricultural Research Institution</td>
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<td>SEG</td>
<td>Safe Environment Group</td>
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<td>SG200</td>
<td>Sasakwa Global 2000</td>
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<tr>
<td>IPMCRSP</td>
<td>Integrated Pest Management Collaborative Research Support Program</td>
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<tr>
<td>ARARI</td>
<td>Amhara Region Agricultural Research Institute</td>
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Foreword

These proceedings are an outcome of a workshop titled “Facilitating the Implementation and Adoption of Integrated Pest Management (IPM) in Ethiopia” that was held on 13-15 October 2003, at the Melkassa Agricultural Research Centre (MARC) of the Ethiopian Agricultural Organization (EARO). The workshop marked the launching of the Association for Advancement of IPM (ASAI) and was jointly organized by ASAI and EARO. ASAI is a professional association established by volunteer Ethiopians with a wide range of experience in agricultural research and development.

A total of 16 papers were presented and discussed in the workshop. Each paper was prepared and presented by senior scientists in their respective fields of expertise or research and development responsibility. The papers dealt with such varied subjects as IPM per se, pest problems of specific commodities, crop protection education, use of botanicals in pest management, plant biodiversity, agricultural extension, soil and water management, and small-scale irrigation. We regret to say that a few of the papers presented do not appear in the proceedings in full text because their authors did not meet the dateline for submitting the final document.

I am very grateful to EARO Management for sponsoring the Workshop. The cost of publishing these proceedings was covered by the generous financial support from the Drylands Coordination Group (DCG) of Norway through the funds made available to CARE-Ethiopia by the Norwegian Government. The contribution of the management and staff of MARC in providing the assembly hall and facilitating the Workshop is highly appreciated.

Tsedeke Abate
President, ASAI
Opening Address

Ato Fikre Markos
Head, Crop Protection Department
Ministry of Agriculture and Rural Development
Addis Ababa, Ethiopia

Good morning, Ladies and Gentlemen!
It gives me great pleasure to have the opportunity to speak in front of my friends and former colleagues, and to open this important meeting of IPM Planning Workshop. As a former crop protection staff myself and having had the opportunity to work closely with some of the senior people involved in this workshop, I take great pride to be part of this initiative.

As you all know, our country is in a very dire situation in terms of food insecurity; more than 20 percent of our total population is at risk of starvation. Environmental degradation is taking place at an alarming speed; we have suffered more frequent droughts in recent years than ever before; and poverty is on the increase both among urban and rural communities.

Ladies and Gentlemen, Distinguished Guests:
It is not only ironic but also shameful that a country like ours which is endowed with the kind of natural resources it has (about 31 million ha of potentially productive land, a huge amount of water resources, a wide range of agro-ecological zones that would help us produce a large number of crops and raise a wide range of livestock), should look up to the outside world for food aid.

It is not only ironic but also shameful that a country like ours that was once considered the breadbasket of Africa should be at the mercy of foreign assistance – especially food assistance – for its mere survival.

It is not only ironic but also shameful that a country like ours that was once a net exporter of food commodities should be knocking at the doors of well off countries for food aid and to heal its economic ills. I think a time has come for us to ask ourselves what went wrong with us!

Ladies and Gentlemen, Distinguished Guests:
It is my hope that everything is not doom and gloom about our country. We should all take heart in the knowledge that concerned citizens and institutions of this country have come to realize that things cannot continue the way they are going at present, if we are to survive as a sovereign and proud nation. It is encouraging to see that EARO in collaboration with ASAI (Association for Advancement of IPM) have taken this important initiative to make contributions to the efforts that are being undertaken by our government, private citizens, and various institutions to make life better for our country and our people.

What is even more encouraging about this initiative and the workshop is the fact that it is a homegrown initiative – something that has not been imposed upon us from outside in any form or shape. To me this is a good sign that shows the maturity of our scientists. You may wonder why I should emphasize this; but I would like to remind you of our common adage “ye hagerun serdo be hageru berie” (which roughly translates as – if you want to get rid of the most noxious weed in your backyard, use bullocks who know that backyard).
Very often, initiatives are undertaken; projects are prepared; funds are obtained; and important activities are executed and wonderful sounding reports are written. And then what happens? Little remains of the enthusiasm and publicity once the projects are concluded and the experts gone.

It is also my hope that this kind of initiative would stimulate other citizens and institutions to take similar steps so that we could accelerate the pace of research and development for our country.

Ladies and Gentlemen, Distinguished Guests:
The agenda in front of you suggests that you are going to be dealing with some exciting and at the same time complex and challenging topics dealing with not only IPM but also over all Integrated Production and Pest Management over the next three days. I note that the discussion papers are prepared by distinguished scientists in their respective fields. I also see that all stakeholders in agricultural research and development are represented. This in itself is a very important first step to the success of this initiative.

I would like to commend EARO and ASAI for taking these steps. I say this because I know that we can succeed only if we plan together and work together, because as stated earlier, our problems are complex and challenging which cannot be solved by limited individuals or institutions.

Ladies and Gentlemen, Distinguished Guests:
Finally, I would like to bring to the attention of all participants that the true success of such initiatives would be measured in terms of what it could eventually deliver. Today we are witnessing a successful gathering of all stakeholders. Tomorrow we would like to see results of the IPM Initiative that would benefit the end user – the farming community, small and large.

With those short remarks I take the honor to declare this Workshop open.
1. IPM in Ethiopia: The Current Status

Tsedeke Abate
Association for Advancement of IPM (ASAI)
PO Box 359, Nazareth, Ethiopia

Abstract
This report presents an overview of IPM research and development efforts in Ethiopia. The concept of IPM is described and the need for its implementation in this country is emphasized. Examples of major insect pests and their management practices are provided. It is reported that research has produced IPM-related technologies that could be implemented but so far beneficiaries of those efforts have been commercial crops such as coffee, cotton and horticultural crops (citrus and vegetables, in particular). It is argued that the major constraint to IPM implementation in Ethiopia has been not so much the dearth of available technologies, but rather a lack of sustained efforts to implement it, especially under small-scale production conditions.

It is pointed out that the priority for control tactics would depend on the type of the pest problem, but in general, cultural practices, host plant resistance and biological control may receive major attention as part of future IPM programs, particularly for pest management in small-scale agriculture. The use of safer, environmentally friendly synthetic pesticides that are compatible with IPM, would be an important component of IPM in commercial agriculture and high value crops.

It is concluded that the future of IPM in Ethiopia shall depend primarily on the dedication and commitment of national professionals. Policy support from government and material support from the donor community would also play crucial roles.

Introduction

General Perspectives
Crop protection research in Ethiopia dates back to the establishment of the then Imperial Ethiopian College of Agriculture and Mechanical Arts (now Alemaya University) in the late 1950s. The emphasis during that period was on survey and identification of arthropod pests associated with crop damage. The establishment of the Institute of Agricultural Research (now Ethiopian Agricultural Research Organization) during the second half of the 1960s saw a more focused and organized approach to research on general crop pest management aspects.

Initiatives have been undertaken to establish the identity, geographic distribution and (to some extent) economic importance of arthropod pests. IPM oriented research was launched at EARO during the early 1980s. Research on IPM initially focused on horticultural crop pests – particularly on scale insects in citrus – and later expanded to include almost all major pests in major crops. Studies have been conducted on cultural and chemical control practices, screening for host plant resistance, and establishing the identity and complex of natural enemies of major pests (Abate 1997a). Studies have also been undertaken on population dynamics of some pests and their natural enemies.
To date, a fair amount of knowledge exists on IPM of several crop pests in Ethiopia. Some of it has already been put into practical use, some studies are currently ongoing, and a lot remains to be done in the times ahead. In this report the author reviews the current status of IPM in this country and forwards suggestions for implementing the existing knowledge and taking initiatives for further research and development.

**Country Background**
Ethiopia is a country of more than 1.1 million km$^2$, located in the Horn of Africa between approximately 4° and 15° north latitude and 32° and 49° east longitude. Agriculture is the most important enterprise providing employment for more than 85 percent of the country’s population. It accounts for about 50 percent of the total GDP and 90 percent of export earnings. Approximately 31 million ha (ca. 28%) of the total land area is agricultural land but an average of about 9 million ha (ca.29% of the potential area) is cultivated annually.

Ethiopia has wide ranges of agro-ecological diversity and therefore produces wide ranges of crops and animals. The areas in the north and north central parts of the country are dominated by cereal-based farming systems whereas root crops-based agriculture is most dominating in the south. Major crops include cereals (such as tef, maize, sorghum, barley, wheat, finger millet), roots and tubers (enset, sweet potatoes, potatoes), pulses (dry beans, faba bean, dry peas, grass pea, chickpeas, lentils), oilseeds (rapeseed, groundnuts, safflower, sesame, seed cotton, castor beans, linseed), vegetables (tomatoes, onions and shallots, chili pepper), fruits (bananas, citrus, pineapple, mangoes) and cash crops (coffee, tea, sugarcane, cotton, tobacco).

While cash crops such as coffee and tobacco have shown sustained yield increases over the years (FAO Agricultural Database 2002), it has not been possible to attain sustainable increased yield of food crops. Yields of food crops per unit area of land have either declined or stayed almost stagnant over the years; by contrast, the overall cultivated area has shown substantial increases (Fig. 1).

Pests and diseases, coupled with a low level of improved agricultural technology, recurrent droughts, and decreases in soil fertility levels are some of the major contributors to the low and unstable crop yields in Ethiopia.

**Agro-Ecology And Farming Systems**
Ethiopia is a country that has great agro-ecological diversity, with altitudes ranging from below the sea level to greater than 3000 m above sea level. It thus enjoys desert to alpine climates. The country is divided into 18 agro-ecological zones and some 62 sub-zones on the basis of temperature and moisture (Anon 1993).

The farming systems in Ethiopia can be divided into four broad categories. These are a) the cereal-based farming systems commonly practiced in central and north-central parts, b) the root crops-based (mainly enset) in southern and south-central parts, c) pastoral system in the extreme low altitudes, and d) shifting cultivation. A detailed review of the farming systems in Ethiopia can be found in Stroud and Mekuria (1992).

Approximately 95 percent of the food produced in Ethiopia comes from small-scale production, where farming technologies are primarily traditional. Landholdings range between 0.5 and 3 ha; land preparation is done by oxen-drawn ploughs (the maresha) or by manually operated tools; seeding is done by broadcasting; and weeding is dependent on labor-intensive practices.
Facilitating the Implementation and Adoption of Integrated Pest Management (IPM) in Ethiopia

Typically, agricultural production in all farming systems in Ethiopia takes place under very diverse conditions. A great majority of Ethiopian farmers grow several crops in association. Farmers’ fields always consist of plots of several crops either intercropped or grown side by side. Generally, these diverse traditional systems enhance natural enemy (parasitoids and predators) abundance and keep pest numbers below economic levels.

Figure 1: Cultivated area (bars) and yield (lines) of major cereals and pulses in Ethiopia

**Agricultural Inputs Consumption**
Agricultural inputs here refer to improved seed, manufactured fertilizers, and pesticides. Only the last two shall be dealt with here. Further details can be found in a recent USAID/Ethiopia study (Abate and Tesfahun Fenta 2003).

**Fertilizer consumption** – Fertilizer consumption by small-scale farmers has been very low, but this has changed substantially in recent years following the government’s agricultural intensification policy. The volume of fertilizer imports for the period from 1996 to 2000 was estimated at 160,000 MT per year; this is approximately a 2.4-fold increase over the period from 1986 to 1990 (Fig. 2). The average annual value of fertilizer imports for the period from 1996 to 2000 was about US$ 43.9 million whereas it was estimated at US$ 28.9 million for the period from 1986 to 1990.
Phosphorus and nitrogen fertilizers accounted for approximately 54 percent and 46 percent, respectively. Use of potassium fertilizers is negligible.

Based on FAO data for 1996 to 2000, Ethiopia’s per capita fertilizer consumption (15.7 kg/ha/yr) is less than that for Kenya (31.6 kg/ha/yr), but compares favorably with other ASARECA countries such as Tanzania (6.2 kg/ha/yr), Sudan (3.4 kg/ha/yr), Rwanda (0.4 kg/ha/yr) and Uganda (0.3 kg/ha/yr).

**Pesticide consumption** – Up until 1998, all pesticides in Ethiopia were imported from abroad. Currently, however, the Adami-Tulu Pesticide Processing plant, situated in the Rift Valley, formulates insecticides locally and has an average capacity of producing about 16 percent of the country’s total imports of pesticides (Abate & Tesfahun Fenta 2003).

Data for pesticide imports to Ethiopia are available for the period from 1983 to 20002. These are presented in Fig. 3 below. In general, imports declined over the period mentioned above. For example, during the years between 1983 and 1990, average annual pesticide imports amounted to about 4,550 metric tons, valued at about US$ 21 million. By contrast, the average annual imports for the period from 1994 to 2002 were 1,775 metric tons worth about US$ 8 million. Based on 1983-99 data, this would mean that the national average pesticide consumption is about 0.26 kg/ha/yr (Fig. 4). This is a significant decline compared to the previously reported national average of about 0.33 kg/ha/yr (see Gordon et al. 1995, Abate 1997b).

The sharp decline in 1991 was due to a lack of foreign exchange towards the end of the previous military government. Apparently there are two reasons for the decline of pesticide imports over the last several years. First, the state farms, that were the major users of pesticides, have been transformed into market-oriented business (as opposed to centralized economy) and second, the Adami-Tulu Pesticide Processing plant started manufacturing insecticides in 1998, thus minimizing the need for import.
Figure 3: Pesticide use trends in Ethiopia
Source: Original data from Ethiopian Customs Authority

Figure 4: Source: Original data from Ethiopian Customs Authority
Source: Abate and Tesfahun Fenta (2003)

Major Insect Pests of Ethiopia

Migratory Insect Pests
These are insect pests whose geographical distribution and economic importance transcend national boundaries. Migratory pests have regional or international significance. In Ethiopia
migratory insect pests include the African armyworm (*Spodoptera exempta*), the African migratory locust (*Locusta migratoria migratorioides*), and the desert locust (*Schistocerca gregaria*). The African armyworm is perhaps the most frequent of all the migratory pests; its invasion occurs almost every 2-3 years. By contrast, invasion by the desert locust in present day Ethiopia has not occurred since the 1958 plague.

The African armyworm attacks all crops in the grass family (tef, maize, sorghum, barley, wheat) in all areas of Ethiopia. The locusts have a much wider host range; the African migratory locust occurs mostly in the drier eastern parts of the country.

The Crop Protection, Technology and Regulatory Division of the Ministry of Agriculture, in collaboration with regional state (bureaus of agriculture), regional, and international organizations, is responsible for monitoring and control operations of migratory pests. The Government provides pesticides (usually obtained through donations) free of charge whenever outbreaks of migratory pests occur.

**Regular Insect Pests**

Regular (or non-migratory) insect pests are those pests whose geographical distribution is confined to one or more administrative regions within the country. Most of these pests occur regularly. The majority of insect pests of economic importance in Ethiopia belong to this category of insect pests. Examples of major regular insect pests are presented in Table 1 below. The responsibility for monitoring and control operations against these pests rests with farmers; crop protection staff in the bureaus of agriculture of regional state governments provide technical support. Until recent years, extension services have provided pesticides free of charge. At present, however, farmers are responsible for purchasing their own pesticides. Nonetheless, a special taskforce may be established and pesticide stocks intended for migratory pests may be used in situations when pest outbreaks are considered to be threatening food security of a certain area on a wider scale (Abate and Tesfahun 2003).

**Emerging Insect Pests**

These are insect pests that have either existed as innocuous organisms, but have recently attained pest status, or those insect pests that have been inadvertently introduced into the country in recent years. For instance, the citrus leafminer (*Phyllocnistis citrella*) that has occurred as a minor pest of citrus is now widely distributed in the Awash valley and in many other parts of Ethiopia. Even though heavy infestations occur on flush leaves its population appeared to be checked by the action of natural enemies (Abate 1988b, 1997b). The hymenopteran parasitoids, *Cirrospilus* spp., are commonly found attacking the leafminers in the upper and middle Awash areas. Other examples of insect pests in this category include the Mediterranean fruit fly (*Ceratitis capitata*) and the false codling moth (*Cryptophlebia leucotreta*), both of which had been under effective cultural and natural biological control since their flare up in the 1970s until recent years.

The reason for the change in the pest status of these insects is not fully understood. Such changes usually result from excessive use of insecticides targeted against other major insect pests, or from changes in the production system, which may affect the natural habitats.

The pea weevil (*Bruchus pisorum*) was accidentally introduced into Ethiopia (perhaps with food aid and/or seeds for research purposes) sometime in the mid 1970s and is widely distributed in Amhara National Regional State (ANRS). It is now one of the major insect pests of field peas in ANRS.
The vegetable leafminer (\textit{Liriomyza trifolii}) was first recorded from Melkawerer in 1982 (Abate 1988b) but by mid 1990s it has become established as a major pest of many vegetables (including tomatoes, onions, and snap beans) in the upper Awash areas. How it was introduced to Ethiopia is not known.

Most recently, the woolly whitefly (\textit{Aleurothrixus floccosus}) was reported from the Nazareth, Melkassa and Ziway areas on citrus during 2001 (Emana Getu et al. 2003). This native tropical American species is known to be an important introduced pest of citrus in the United States, Europe and North Africa.

**The IPM Concept**
The IPM concept has evolved over the years (e.g. Smith 1978, Luckman & Metcalf 1982, Flint & Molinar 1991, Moore 1995), mostly in the context of large-scale agriculture, where the main aim has been to reduce reliance on pesticides. The success of IPM under such conditions is often measured in financial terms, such as savings on pesticides (FAO 1993) and subsequent reductions in costs to the environment and other externalities. Under the Ethiopian context, however, such savings are insignificant as pesticide use is very low. A major objective of IPM here would be not to reduce pesticide use, but to prevent (or at least to delay) breakdown of the agro-ecosystem that has existed for centuries, and to prevent unnecessary stockpiling of pesticides and the inevitable consequences of accumulating obsolete pesticides.

Subsistence farmers in Ethiopia, and elsewhere in Africa, traditionally use a combination of several pest management practices (such as cultural control, habitat manipulation, mechanical and physical control, natural biological control, host plant resistance, use of locally available materials) such that regular insect pest outbreaks of the magnitude experienced in commercial agriculture are rare (Abate & Ampofo 1996, Abate 1997a, Abate et al. 2000). Use of some cultural practices, particularly intercropping and methods encouraging habitat diversity, create an environment conducive to natural enemies (parasitoids and predators) and can be considered a type of natural biological control. Thus, the small-scale farmer is a general practitioner of IPM.

Defined in this context, IPM is an ecologically sound, environmentally friendly, and economically affordable pest management approach that employs optimum blends of control measures to keep pest numbers below economic level. IPM focuses on long-term prevention of pests and their damage. It does not exclude the use of pesticides, but predicates that all other means must be explored and pesticide use should be considered as a last resort. IPM is more effective than synthetic pesticides (in the long run), generally requires less capital investment, and can be used preventatively to eliminate or minimize the need for applying pesticides.

According to USAID (2003) some of the important attributes of IPM are that:

- It is farmer-based
- It is knowledge-intensive
- It encourages natural control
- It aims to ‘prevent’ pest problems
- It permits safer pesticide use
- It uses indigenous techniques
- It promotes safer techniques
- It focuses on host plant resistance.
Examples of IPM-Related Activities
The most recent reviews of the status of IPM in Ethiopia, covering the period from the early 1980s through 2002, can be found in Abate (1997a) and Abate and Tesfahun Fenta (2003). This report presents highlights of those reviews on IPM research and development in this country.

Existing IPM-Related Practices

Bollworms and leafhoppers in cotton – The bollworms (*Helicoverpa armigera*, *Pectinophora gossypiella*, *Earias* spp., *Diparopsis watersi*) and leafhoppers (*Empoasca* spp.) are some of the most important insect pests of cotton in Ethiopia. The use of “closed season” or “dead season” has kept the pink bollworm (*P. gossypiella*) below economic level. Improved understanding of the biology of the other bollworms and the contribution of natural enemies to their control has enabled to reduce the frequency of insecticide application to the minimum possible. The introduction of long staple ‘Acala’ type cotton varieties has relegated the cotton leafhoppers to a minor pest status; the insecticide sprays aimed at the bollworms also provided additional control of the leafhoppers (see Abate 1997b).

Scale insects on citrus – The red scale (*Aonidiella aurantii*) was the major insect pest of citrus during the late 1970s. Use of a selective insecticide (mineral oil, using the right type of spray equipment) timed at peak breeding period of the pest and highest activity of natural enemies has enabled to reduce the frequency of insecticide application from more than a dozen to 1-3 sprays per year. Red scale has been under effective IPM since the early 1980s. Native species of the hymenopteran parasitoid (*Aphytis* sp.) and the ladybird beetles *Chilocorus distigma* and *Hyperaspis senegalensis* are some of the most important natural enemies that contribute to the natural biological control of red scale and other armored scales in Ethiopia.

Insect pests of coffee – The antestia bug (*Antestiopsis intricata*), the blotch leafminer (*Leucoptera caffeine*) and the coffee berry borer (*Hypothenemus [=Stephanodores] hampei*) are among the most prevalent insect pests of coffee in Ethiopia. However, they do not usually reach economic level, perhaps because of the lack of environmental conditions conducive for their population growth (Million Abebe & Bayisa Mormene 1985). Traditional coffee growing conditions in Ethiopia provide the coffee tree with optimum shading and create conditions suitable for natural enemies. For instance, the hymenopteran parasitoids *Asolcus suranus*, *Anastatus antestiae*, and *Hadronotus antestiae* caused 40 to 50 percent egg mortality of the antestia bug (Million Abebe & Bayisa Mormene 1985).
Table 1: Examples of major regular insect pests in Ethiopia

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Common name</th>
<th>Crop(s) attacked</th>
<th>Geographical distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Busseola fusca</em>, <em>Chilo partellus</em>, <em>Sesamia calamistis</em></td>
<td>Stalk borers</td>
<td>Maize, sorghum</td>
<td>Widely distributed</td>
</tr>
<tr>
<td><em>Helicoverpa armigera</em></td>
<td>African bollworm</td>
<td>Cotton, vegetables, pulses</td>
<td>Widely distributed</td>
</tr>
<tr>
<td><em>Acyrthosiphon pisum</em></td>
<td>Pea aphid</td>
<td>Field pea, faba bean</td>
<td>Widely distributed</td>
</tr>
<tr>
<td><em>Pachnoda interrupta</em></td>
<td>Sorghum chafer</td>
<td>Sorghum, maize</td>
<td>Amhara, Afar, parts of Oromia, Tigray</td>
</tr>
<tr>
<td><em>Diatrphis noxia</em></td>
<td>Russian wheat aphid</td>
<td>Wheat, barley</td>
<td>Amhara, Tigray, Oromia</td>
</tr>
<tr>
<td>Several species</td>
<td>Grasshoppers</td>
<td>Tef</td>
<td>Amhara, Oromia</td>
</tr>
<tr>
<td><em>Decticioides brevipennis</em></td>
<td>Welo bush cricket</td>
<td>Tef</td>
<td>Amhara</td>
</tr>
<tr>
<td><em>Ophiomyia phaseoli</em>, <em>O. spencerella</em></td>
<td>Bean stem maggot</td>
<td>Haricot bean</td>
<td>Widely distributed (more important in southern Ethiopia)</td>
</tr>
<tr>
<td><em>Phthorimaea operculella</em></td>
<td>Potato tuber worm</td>
<td>Tomatoes, potatoes</td>
<td>Awash valley</td>
</tr>
<tr>
<td><em>Thrips tabaci</em></td>
<td>Onion thrips</td>
<td>Onions, shallots</td>
<td>Widely distributed</td>
</tr>
<tr>
<td><em>Brevicoryne brassicae</em></td>
<td>Cabbage aphid</td>
<td>Cabbage</td>
<td>Widely distributed</td>
</tr>
<tr>
<td><em>Aonidiella aurantii</em></td>
<td>Red scale</td>
<td>Citrus</td>
<td>Widely distributed</td>
</tr>
<tr>
<td><em>Ceratitis capitata</em></td>
<td>Med fly</td>
<td>Citrus</td>
<td>Awash valley</td>
</tr>
<tr>
<td><em>Cryptophlebia leucotreta</em></td>
<td>False codling moth</td>
<td>Citrus</td>
<td>Awash valley</td>
</tr>
<tr>
<td><em>Antestiopsis intricata</em></td>
<td>Antestia bug</td>
<td>Coffee</td>
<td>Widely distributed</td>
</tr>
<tr>
<td><em>Leucoptera spp.</em></td>
<td>Leafminers</td>
<td>Coffee</td>
<td>Widely distributed</td>
</tr>
<tr>
<td><em>Stephanodores (=Hypothenemus hampei)</em></td>
<td>Coffee berry borer</td>
<td>Coffee</td>
<td>Widely distributed</td>
</tr>
</tbody>
</table>

Available IPM Technologies

Stalk borers in sorghum and maize – Stalk borers are considered to be the most important insect pests of sorghum and maize in all areas of the country. Economically important species include the maize stalk borer (*Busseola fusca*), the spotted stalk borer (*Chilo partellus*), and the pink stalk borer (*Sesamia calamistis*). The first two are most widely distributed and damaging (Gebre-Amlak 1985, Emana Getu 2002, Abate and Selome Tibebe 2004). *Busseola* is important at higher altitudes (1700 m above sea level and higher) whereas *Chilo* and *Sesamia* are important in the mid-altitudes (below 1700 m).

Cultural control, including timely sowing and crop hygiene, is the major control measure (Gebre-Amlak et al. 1989, Ferdu Azerefegne 1991, Abraham Tadesse et al. 1993). Natural biological control is also achieved through several species of hymenopteran parasitoids (e.g. *Dolichogenida fuscivora* and *Procerochasmias nigromaculatus* on *Busseola*; *Cotesia sesamiae*, *Stenobracon (=Euvipio) rufus*, and *Pediobius furvus* on *Chilo*). Good control of stalk borers is also obtained with two applications (at 30 & 45 days of crop emergence) in the whorl of neem seed powder, at the rate of about 3 kg per hectare (Abate and Selome Tibebe, unpublished data).
Effective insecticides (belonging to the pyrethroid group of pesticides) are also available, but they are broad in spectrum and therefore their use has to be curtailed before they disrupt the natural enemy balance. More emphasis should be given to non-chemical control measures – cultural control (timely sowing in particular) and use of botanicals.

**Bean stem maggots in haricot bean** – A large amount of research results are available on components of IPM of bean stem maggots in Ethiopia and elsewhere in Africa (Abate & Ampofo 1996, Abate 1997a). Integrations of cultural practices (timely sowing, optimum plant density, intercropping with maize, and host plant resistance) provide an excellent opportunity for IPM of bean stem maggots. The hymenopteran parasitoids *Opius phaseoli* and *Sphegigaster* spp. cause significant mortality of bean stem maggot pupae.

**African bollworm in beans and vegetables** – Manipulation of habitat diversity plays a significant role in the population development of African bollworm (*Helicoverpa armigera*). Strip-cropping of beans and tomatoes with maize, and hot pepper (*Capsicum*) with lupine (*Lupinus* sp.) serves as a trap for attracting the egg laying adult female moth (Abate 1988a). Heavy parasitism of African bollworm also occurs on the trap crop offering the opportunity for easy hand collection and mechanical destruction.

It is not uncommon to see farmers using maize/bean intercrops or strip-cropping of vegetables with maize in many parts of Ethiopia; the latter is more common in irrigated vegetable producing areas of the upper and middle Awash valley.

**Fruit worms in tomatoes** – Larvae of the potato tuber moth (*Phthorimaea operculella*) and African bollworm are the major pests of tomatoes grown under irrigation in Ethiopia. Research has identified optimum plant density and varietal resistance as important components of IPM of fruit worms on tomatoes (IAR 1986, Abate & Gashawbeza Ayalew 1997). The tomato cultivars ‘Serio’, ‘Pusa Early Dwarf’, ‘Pusa Ruby’ and ‘Seedathing’ have been identified as resistant to fruit worm damage and released for commercial production.

**Ongoing IPM-Related Research and Development**

Currently there is a large number of ongoing research activities against important crop pests being undertaken by the Ethiopian National Agricultural Research System. Some examples are provided below.

**Sorghum chafer in sorghum** – The sorghum chafer (*Pachnoda interrupta*) is one of the most important insect pests of sorghum, particularly in Amhara National Regional State (ANRS). Preliminary data from ANRS plant health clinics suggest that yield losses due to this pest range from 19 to 41 percent. Its biology is not completely understood. Currently there is ongoing research being conducted by the Ministry of Agriculture and other national organizations, with funding from FAO. Hand collection and mechanical destruction of the adult beetles from sorghum heads and insecticide baiting (with carbaryl 85% wp) have shown promising results. Further verification studies are needed to fully integrate control measures.

**Pea aphid in field peas and faba bean** – The pea aphid (*Acyrthosiphon pisum*) is perhaps the most important insect pest of field pea (*Pisum sativum*) and other cool season legumes in most parts of Ethiopia, especially in the mid-altitude areas (1500-1800 m above sea level). There have been reports of farmers abandoning pea production due to damage by this insect. Farmers’ management strategy against the pea aphid includes dusting with wood ash or cereal flour, intercropping with faba bean, and spraying with fermented cow or goat urine mixed with water.
Research results on chemical control are also available (Kemal Ali 1997), but these have little relevance to small-scale production conditions. Researchers also recommend host plant resistance against the pea aphid, but no varieties with an acceptable level of resistance have been identified and widely adopted by farmers yet. Biological control agents (such as the hymenopteran parasitoid *Aphidius smithi* and several predaceous ladybird beetles) are found attacking the pea aphid in many parts of Ethiopia, but their potential has not been explored.

**Pests of stored grains** – Storage pests of major economic importance in Ethiopia include grain weevils (*Sitophilus* spp.), grain moths (mainly *Sitotroga cerealella*), and bean bruchids (*Acanthoscelides obtectus*, *Bruchus pisorum*, and *Zabrotes subfasciatus*). Farmers use traditional methods for controlling stored product pests. Use of botanicals and cow or goat urine has been tested in many parts of Ethiopia, with some degree of success. Even though traditional methods offer some degree of protection for stored grains intended for seed purpose, they will have limited use for protecting grains for commercial purposes. Several constraints, including their social acceptability, have to be overcome.

Use of commercial fumigation and application of pirimiphos-methyl (Actellic 2% Dust) will remain the major option for managing storage pests in commercial warehouses and farmers’ cooperatives. What would be needed is training on safe handling procedures.

**Discussion**

I have tried to give an overview of IPM-related research and development efforts over the years in Ethiopia. Those efforts have resulted in identifying the major pests of important crops, their biology and natural enemy complex. The Ethiopian Agricultural Research System has produced substantial amounts of IPM-related technologies particularly over the last two decades.

The major achievements include development and implementation of IPM technologies against such pests as bollworms and leafhoppers in cotton, the antestia bug and leafminers in coffee, scale insects in citrus, and fruit worms in vegetables. It is fair to say that the main beneficiary of IPM technologies in this country has been the commercial sector rather than the small-scale farming community.

It appears that the major constraints to IPM implementation in Ethiopia are twofold. First, there has been too much emphasis on improving commercial crops such as cotton and other high value crops that are intended either for export or are import substitutes. Secondly, like many other disciplines, IPM research and development efforts have suffered from the lack of continuity and policy support for IPM in particular and crop protection in general. Part of the problem with the lack of policy support stems perhaps from the lack of understanding of what IPM is all about. Very often, IPM is equated with total abandonment of use of external inputs, particularly pesticides, and therefore those who stand for IPM are activists rather than contributors to government policy of improved food security. It is my hope that our future efforts will pay enough attention to creating awareness about IPM, through education, to dispel this misconception.

Furthermore, the very fact that Ethiopian agriculture is primarily subsistent has also played some role towards not obtaining enough attention from donor communities. In the context of commercial agriculture in the western world and those countries that have passed through the so-called green revolution, the success of IPM has been measured in terms of savings from reduced pesticide use (FAO 1993). Obviously there is little pesticide use in Ethiopia (as is the
case in most Sub-Saharan Africa) and therefore there will be little savings in this respect. The main aim of IPM in the Ethiopian context shall be to prevent the possibility for total reliance on pesticides, thereby avoiding environmental and human hazard concerns and unnecessary accumulation of obsolete pesticides.

Currently there are a good number of IPM technologies that can be employed with little refinement. Examples include stalk borers in sorghum and maize, stem maggots in beans, African bollworm in beans and vegetables, and fruit worms in tomatoes. There are also a good number of ongoing IPM-related research activities. It would be fair to conclude that the future of IPM in Ethiopia shall depend primarily on the dedication of national professionals; policy support from the government and material support from the donor community would also play a crucial role.

References


Abate T, Selome Tibebu. 2004 (under review). Stalk borers in sorghum and maize in Ethiopia: A quantitative analysis of their significance. Pest Management Journal of Ethiopia 7:


2. Global IPM Collaborations: Experiences of the IPM CRSP

Brhane Gebrekidan
Formerly Program Director, IPM CRSP, OIRD, Virginia Tech, Blacksburg, VA 24061-0334, USA; Currently Chief of Party, AMAREW Project, P.O. Box 61, Bahir Dar, Ethiopia

This presentation gives an example of a global IPM collaboration focusing on the experiences of the Integrated Pest Management Collaborative Research Support Program (IPM CRSP) with the hope that it will be useful to the national IPM efforts in Ethiopia. The paper covers the following aspects of the IPM CRSP: background, organizational and operational structure of the IPM CRSP, mode of collaboration, the Participatory Appraisal (PA) process, developing IPM packages, technology transfer, gender-related issues that affect IPM adoption, training and national capacity building, regionalization and globalization of IPM, information exchange, mutuality of benefits to the US and the host countries, and finally lessons learned.

Background
The Integrated Pest Management Collaborative Research Support Program (IPM CRSP) was initiated in 1993 with the financial support of the United States Agency for International Development (USAID). The main mission of the CRSP is to foster IPM through collaborative research between U.S. and developing host country institutions for their mutual benefit by improving their abilities to develop and implement economically and environmentally sound crop protection methods. The IPM CRSP is one of nine CRSPs supported and managed by the Global Bureau of USAID.

The purpose of the IPM CRSP is to develop and implement appropriate IPM techniques and strategies that will help reduce: 1) agricultural losses due to pests; 2) damage to national ecosystems; and 3) pollution and contamination of food and water supplies. The long term goals of the CRSP are to develop improved IPM technologies and institutional changes that will reduce crop losses, increase farmer income, reduce pesticide use and pesticide residues on crop products, improve IPM research and education program capabilities, and increase the participation of women in IPM decision making and program design.

Working towards this goal the IPM CRSP follows the following specific objectives:

- Identify and describe the technical factors affecting pest management.
- Identify and describe the social, economic, political, and institutional factors affecting pest management.
- Work with participating groups to design, test, and evaluate appropriate participatory IPM strategies.
- Work with participating groups to promote training and information exchange on Participatory IPM.
- Work with participating groups to foster policy and institutional changes.

The research activities of the IPM CRSP are based on close collaborations between scientists of the participating host countries and U.S. institutions. The participating host country sites of this CRSP are Albania, Bangladesh, Ecuador, Guatemala, Jamaica, Mali, The Philippines, and Uganda. Among the US partner institutions are: University of Georgia, Lincoln
University, Montana State University, Ohio State University, Penn State University, Purdue University, U.C. - Davis and Riverside, University of Maryland - Eastern Shore, North Carolina A&T University, Florida A & M University, Fort Valley State University, USDA, and Virginia Tech (VT) with VT as the lead and the Management Entity (ME) institution.

**Organizational and Operational Structure of the IPM CRSP**

Virginia Polytechnic Institute and State University (Virginia Tech) is the Management Entity (ME) for the IPM CRSP and is the primary grantee of USAID. The ME is accountable to USAID for all IPM CRSP programmatic and fiscal issues although certain site-specific responsibilities are delegated by the ME to the participating U.S. and host country institutions. Collaborative research arrangements between participating U.S. and host country institutions are governed by a Memorandum of Understanding (MOU) between the lead host country institution and the IPM CRSP ME. The MOU creates the official environment in which participating U.S. scientists and their host country partners can initiate and carry out collaborative research in the host country or region.

The Board of Directors deals with policy issues and advises the ME on these and other related matters. The Technical Committee (TC) reviews the research and training plans of the CRSP, participates in the development of the annual work plan and budget, and recommends them to the ME for implementation. The Site Committee (SC) has the primary responsibility of developing and implementing collaborative IPM activities related to research, training and networking for its specific host country or region. The External Evaluation Panel (EEP) is charged by the USAID Global Bureau with the overall evaluation of the IPM CRSP, which includes program direction and research collaboration with the host countries. The USAID Project Manager of IPM CRSP and other appropriate members in the USAID Global Bureau advise and guide the ME, the Board, and other entities of the CRSP in areas of policy, technical and program management, collaborating host country coordination, budget management, and review.

**Mode of Collaboration**

The eight prime sites of the IPM CRSP are spread out in five major regions, Africa, Asia, Latin America, the Caribbean, and Eastern Europe. The African programs focus on irrigated peri-urban horticulture as well as rain-fed cereals and legumes both the Latin American and the Caribbean programs emphasize non-traditional agricultural exports (NTAEs), the Asian programs concentrate on vegetables grown in rice/vegetable cropping systems, while the Eastern European program deals with IPM of a single crop, olive. At each site, U.S. and host country scientists collaboratively and jointly plan, implement, and report research activities. A Site Chair from a U.S. institution and a Site Coordinator from the lead collaborating institution in the host country take joint leadership in planning and implementing the IPM CRSP activities in the country.

**The Participatory Appraisal Process**

The foundation of the IPM CRSP approach is the use of the Participatory Appraisal (PA) in the determination of high priority crops, pests, and processes to follow in program implementation. Central to this approach is the involvement of the appropriate stakeholders such as scientists, extension personnel, farmers, policy makers, government officials, input suppliers, and non-government organizations (NGOs) in identifying the high priority pest problems in the site and the approaches to be used in solving these problems. Before initiating a program in a site, the IPM CRSP typically conducts Participatory Appraisals (PA) focusing
on the identification of agro-ecosystems, baseline surveys, existing pest management practices, high priority crops or cropping systems and their key pests, and other related topics. The results of the PA are jointly analyzed and written as a reference document by the U.S. and their host country partners and are used in defining the research, training and information exchange agenda of the IPM CRSP at the site. The priority crops and pests the IPM CRSP is working on at each site have been determined through the PA process.

**Developing IPM Packages**
The vast majority of the planned experiments in each host country are carried out on-farm with the direct participation of small-scale farmers where they contribute both land and labor. Through this scheme, farmers have the opportunity to be active partners in the implementation of the experiments and simultaneously observing the results for themselves. The active participation of farmers in this manner facilitates the direct transfer of the experimental results to the participating farmers and their neighbors. As a complement to the on-farm trials, a much fewer number of on-station, green house, and laboratory experiments are also conducted. Based on experimental results, replicated over locations and seasons, suitable IPM packages are determined and tried out on farmers’ fields, and eventually extended to a wider range of farmers in the host country and in the region.

**Examples of Successful IPM Packages in Selected Regions**
The IPM CRSP has developed successful IPM packages applicable to the various cropping systems where it is operating. These packages have been disseminated or are being disseminated to producers in the host countries. Selected examples from selected IPM CRSP regions are given below.

**Asia: rice-vegetable cropping systems (Philippines)**
IPM CRSP has been working on vegetable IPM in the rice-vegetable cropping systems since 1994, initially in the Philippines and more recently in Bangladesh. The IPM approaches used have dealt with weeds, diseases, and insects. In the case of the rice-onion cropping systems in the Philippines, the most serious weed problem in onion production is the nut sedge (*Cyperus rotundus*). The IPM CRSP has developed an economical weed management system that is suitable to onion producers in the Philippines where the results of the IPM CRSP show that the cost of farmers’ weed control practices can be reduced by 50% from one herbicide application followed by three hand weedings to one herbicide application and one hand weeding without reducing weed control efficacy and onion yields.

IPM CRSP research has also shown that the use of nuclear polyhedrosis virus (NPV) and *Bacillus thuringiensis* (Bt) in onion production can be a viable alternative to chemical insecticides to control the larvae of the key onion insect, *Spodoptera litura*. Thus, the use of NPV and *Bt* would greatly benefit onion farmers who are dependent on chemical insecticides for control of onion cutworms. Direct effects of this new technology are reduced pesticide use, better health of farmers and their families, and sustainable *Spodoptera* management. Farmers can in fact mass produce NPV themselves and use the technology on their fields, which will cut down on cost of crop protection by onion growers. As a result, the market quality of farmers’ onion produce will be greatly enhanced by the low insecticide residue levels, thereby meeting the export requirements of foreign markets. The application of these technologies in an IPM package can greatly benefit onion producers in the Philippines.
Facilitating the Implementation and Adoption of Integrated Pest Management (IPM) in Ethiopia

Africa: maize/bean cropping systems (Uganda)
In one of its African sites, in Uganda, the IPM CRSP has been involved in developing IPM strategies for insect and disease control in the maize/bean cropping systems of eastern Uganda where *Chilo partellus*, the low altitude stem borer, is the predominant cereal pest. The results of the IPM CRSP on-farm trials for three years have confirmed that the introduced wasp parasitoid, *Cotesia flavipes*, a potential biological control, is effective in significantly reducing the stem borer damage on maize. The parasitoid, which has now been established, both in eastern and northern Uganda causes parasitism on the *Chilo* stem borer of up to 23%. This biological control agent was multiplied and released in a collaborative activity involving a graduate student, the IPM CRSP, and ICIPE.

Further, in the same region, IPM CRSP on-farm trials on the common bean *Phaseolus vulgaris* have confirmed that bean grain yields can be increased by as much as 150% with Endosulfan seed dressing to control the bean fly (*Ophiomyia* sp.) and root rots (*Fusarium solani* and *Fusarium phaseoli*). Additionally, earthing-up or ridging at first weeding reduced bean fly damage and increased grain yield by about 35%. The combined use of the wasp parasitoid for maize stem borer control and seed dressing and earthing-up or ridging for bean fly control is being introduced to Ugandan farmers engaged in the maize/bean cropping system.

Latin America: horticultural export crops (Guatemala)
In Guatemala, since 1994 the IPM CRSP has been working on developing IPM technologies for non-traditional agricultural export (NTAE) crops of which snow pea is the leading commodity. The key snow pea pest in Guatemala is the leaf miner, *Liriomyza huidobrensis*. A wide range of IPM component technologies for snow peas have been developed by the IPM CRSP and introduced to small scale farmers. Snow pea producers participating in the IPM CRSP developed integrated pest management/integrated crop management programs composed of the use of certified seed, adequate fertilizer application, using wheat straw mulch, weekly scouting of pest levels, threshold based spraying of chemicals, and the use of the mobile yellow sticky traps reduced pesticide applications for the typical Guatemalan snow pea farmer from 13 to 4 in each cropping cycle. The establishment of an effective quality control program for snow peas that will guarantee 1) the quality of the product to the final consumer, and 2) the sustainability of the snow pea industry in Guatemala are main impacts of the IPM CRSP research. It is expected that in the next few years the majority of Guatemalan snow pea exporters will implement the IPM CRSP-generated integrated crop management (ICM) production programs. It is worth noting that most of the snow pea produced by small-scale farmers in Guatemala is exported to the U.S. market.

Caribbean: sweet potato (Jamaica)
In the Caribbean program of the IPM CRSP, one of the high priority activities dealt with developing IPM strategies for sweet potato (*Ipomoea batatas*) production under the conditions of small-scale farmers. As a result of these activities, in replicated on-farm trials, several USDA-developed sweet potato clones and Caribbean varieties demonstrated good resistance to the sweetpotato weevil *Cylus formicarius* which is an important insect constraint in sweetpotato production in Jamaica. Other components of a sweetpotato IPM strategy developed by the IPM CRSP in Jamaica included the use of sex pheromone baited traps, application of good cultural practices (field sanitation, removal of old sweetpotato vines, optimum irrigation, timely harvesting, and crop rotation), and chemical spraying based on insect number scouting and predetermined threshold levels.
Technology Transfer
The IPM CRSP works with national technology transfer agencies, cooperatives, NGOs, and other appropriate bodies to extend to producers the IPM technologies it has developed in a given site. Very often farmers are involved in on-farm testing of IPM technologies and demonstrations giving them the opportunity to observe and adopt results directly.

In the African site in Uganda, the national extension system has been active in disseminating IPM CRSP results to farmers. In the Latin American site in Guatemala, IPM CRSP developed pest management technology and information is transferred through grower workshops, technician seminars, and field demonstrations. In Jamaica, technology transfer training sessions for sweet potato and hot pepper farmers were conducted in different communities. In the Philippines, IPM CRSP scientists from the host country were active participants in the training programs in technology transfer. Training manuals, fact sheets, brochures, single page flyers, flip chart and book marks on a number of diseases and pests of onion and eggplant were prepared, evaluated and disseminated to the participants.

Gender-related Issues that Affect IPM Adoption
The IPM CRSP was designed, and has been implemented, with a strong gender-equity component. The CRSP is committed to the equitable involvement of women as both program scientists and beneficiaries. As a research program, the focus of gender-equity programming has been on research into the likely outcomes of IPM research activities for women and men, and on involving women farmers in these activities, in order to ensure that women’s livelihood strategies receive equal attention with those of men. With a view to sectoral growth as well as to equity issues, programming is designed to ensure that women who produce targeted crops are included in research and dissemination activities. Among the gender equity issues addressed is whether the adoption of IPM is likely to alter the gendered division of labor and resources within households in ways that would disadvantage women. Findings indicate that IPM adoption would not disadvantage women. However, the potential benefits of IPM adoption may not be as available to women as to men, as women are less likely to receive relevant technical assistance or to be involved in technology development. Across the IPM CRSP sites, women appear to have less access than men to IPM-related extension. Recommendations for the inclusion of women farmers in technology development, as well as in related extension efforts, have been made for several sites, including those in Uganda, Mali, the Philippines, Guatemala, and Jamaica. For example, in Mali and Uganda, these recommendations have resulted in attention to women’s crops and production constraints, and to technologies that improve women’s food processing enterprises. Half of the producer groups involved in IPM research in Uganda are female-oriented.

In the Philippines, household surveys and ethnographic research have demonstrated that even women who do not work in the fields often control funds used to purchase IPM technologies, and thus should be included in all information campaigns. Philippine women are somewhat more likely than their husbands to prioritize spending for pesticides, as they are less inclined to risk crop loss, but are also more likely to be receptive to cost-effective IPM practices.

The IPM CRSP has worked to ensure that both US and host-country women scientists are involved as investigators and women students are given opportunity for training. The IPM CRSP features an approach that is genuinely committed to gender equity issues. The commitment of the IPM CRSP to gender equity issues can be seen most clearly in the record of graduate training, host-country scientist participation, global gender-focused research, and increasing incorporation of women farmers in collaborative research and extension efforts.
Training and National Capacity Building
The IPM CRSP has given high priority to training of both host country and U.S. students in the various disciplines contributing to IPM research and implementation. The disciplines in which the trainees are involved cover the whole range of IPM-related topics including entomology, plant pathology, weed science, nematology, horticulture, agronomy, plant breeding, ecology, agricultural economics, statistics, geography, and sociology. The human resource development strategy planned for all the IPM CRSP sites is long-term in perspective, assuring a breadth of skills and capacities available for IPM research and implementation with emphasis on graduate student training at selected national universities such as the University of Mali, Makerere University in Uganda, and the University of the Philippines at Los Baños. Degree training of host country students has also been done in U.S. universities. Co-Principal Investigators (Co-PIs) from the U.S. often make several trips to the host countries each year to participate in both training and research. The IPM CRSP’s emphasis on process, including research planning and farmer participation, and the locally recognized need to advance multi-institutional and disciplinary research have been recognized by host country partners as a key contribution of the IPM CRSP to IPM related research in each host country.

Graduate students sponsored and supervised by the IPM CRSP have made substantial contributions to on-farm data collection and to IPM CRSP activities in the host countries as a whole. Short-term training for national scientists on various aspects of IPM has been conducted both in the US and the host countries. Several trips are made each year to the host country sites by USA based Co-PIs to participate in annual work plan development and to pursue collaborative research activities. Such visits and institutional relationships continue to be important in strengthening U.S. and host country linkages and moving the IPM CRSP research, technology transfer, and information exchange efforts forward in each of our regions.

One of the objectives of the IPM CRSP training and human capacity building is the institutionalization of IPM into the national system and crop protection policy. There are positive indications to show that IPM is being institutionalized at the national level. Some examples of the institutionalization of IPM in the host countries are a) the creation of a new department of Crop Protection at Makerere University partially stimulated by the IPM CRSP, b) the establishment of the IPM network for the Caribbean through the participation of the IPM CRSP, c) the incorporation of IPM as an integral part of the snow pea production and export system of Guatemala, d) the adoption of IPM as part of the national policy in both the Philippines and Bangladesh.

Regionalization and Globalization of IPM
Although the IPM CRSP operates in strategically selected prime sites, regionalization and globalization of IPM technologies and information is a primary goal of the IPM CRSP. Each of the prime site programs embodies a regionalization effort to disseminate IPM technologies and information generated in a given prime site. In the Caribbean region for example, the IPM technologies developed for sweet potato pest management in Jamaica have been extended to other Caribbean islands such as St Kitts/Nevis and St Vincent. In Uganda, the utilization of the wasp parasitoid for stem borer biological control is being used in Kenya as well through the efforts of ICIPE. In both Mali and Uganda, an integrated Striga management strategy for cereals, comprising resistant varieties, modest nitrogen application, improved cultural practices, and crop rotation are being promoted. In the Philippines and Bangladesh, the promotion of improved egg plant varieties along with grafting technology for bacterial wilt control are being introduced to farmers. The NTAE pre-inspection protocol, which has served
the Guatemalan horticultural exports effectively, is being introduced to the neighboring Honduras. Regional workshops and IPM CRSP global symposia held at regular intervals contribute significantly to the regionalization and eventually the globalization efforts of this CRSP.

### Information Exchange

IPM information exchange and dissemination nationally, regionally, and eventually globally is central to the mission of the IPM CRSP. To this end, the CRSP produces a wide range of publications such as refereed journal articles, books and book chapters, theses and dissertations, workshop proceedings, annual reports, working papers, www sites, extension publications, fact sheets, newsletters, magazine and newspaper articles, trip reports, and bibliographic data bases and distributes them widely. Most of these publications are available in hard copies at the Management Entity office of the CRSP and are distributed to selected recipients globally. The IPM CRSP web site [http://www.ag.vt.edu/ipmcrsp](http://www.ag.vt.edu/ipmcrsp) contains full contents or lead information on most of these products.

### Mutuality of benefits to the U.S. and the Host Countries

One of the main aims of the CRSP programs in general is to show mutuality of benefits both to the U.S. and the partner host countries. A good number of the IPM CRSP activities contribute to this overall aim. For example, most of the pest problems addressed in the host country site activities are widespread throughout the various regions and also occur in other parts of the world. Strategies developed to manage these pests economically and in a sustainable manner can be applied to countries where the IPM CRSP is not present. IPM methods have been developed for managing pests of onion and eggplant in Asia, NTAE crops in Central America, potatoes in Ecuador and Uganda, sweetpotato and hot pepper in the Caribbean. Working with such pests gives U.S. scientists global experience on the status and management of these pests. Advance information on emerging pest situations, which may threaten U.S. agriculture, could be obtained before the pests enter the U.S. Availability of safe and pesticide free imported foods, particularly from Latin America and the Caribbean, to the U.S. consumer is also a major benefit to the U.S. A broader concurrent benefit and feedback to the United States will be through a) the effects of economic growth in the IPM CRSP regions on trade and demand for U.S. products in international markets and b) improved relations with the various countries in politically sensitive areas of the world.

### Lessons Learned

A wide range of lessons have been learned by all the participating partners through the course of the implementation of the of this global IPM program. The salient features of the lessons learned are highlighted below.

- Genuine collaboration and equal partnership between U.S. and host country scientists has laid the foundation for continued global IPM promotion; a core global IPM community has been established.
- Participatory Appraisal (PA) has been the corner stone in the identification of the high priority pests and crops on which the IPM CRSP is working; the results of the PA have guided the activities of the IPM CRSP.
- The participation of farmers as active partners in conducting on-farm IPM experiments has been essential for focusing on the actual problems of farmers who have been active research partners and lead adopters of the results.
• It has been necessary to develop or adopt specific component technologies at each site before formulating a comprehensive IPM package to disseminate to farmers; sometimes this has involved the use of laboratory and green house experiments.
• Integration of IPM technologies and testing them at the farm and the community levels is essential prior to wide scale dissemination of IPM packages; farmers are introduced to such packages in their own or their neighbors’ fields.
• The IPM CRSP has developed and disseminated a wide range of successful IPM packages appropriate for the various regions in which it has been working including Asia, Africa, Latin America, and the Caribbean.
• The availability and/or development of relevant IPM technology for each pest/cropping system situation is a prerequisite if a technology transfer activity is going to be successful with farmers; approaching and working with farmers without the necessary technologies does not cultivate their confidence and respect.
• Attention to gender related issues in IPM technology development and extension activities is essential to address the special cases of women farmers and family members, women play crucially important roles in the production, marketing, and resource allocations of selected crops.
• Training of host country nationals and human capacity building are the foundations for sustained growth and maintenance of a national, regional, and indeed global IPM programs; the IPM CRSP has given the highest priority to this effort.
• Institutionalization of IPM and accepting it as a national policy can ensure the long-term viability of IPM in a given country; some of our host countries have taken significant steps in this direction.
• Continuing regionalization and globalization efforts of IPM are essential to bring more of the global crop production under IPM; some IPM CRSP generated IPM packages have been disseminated regionally.
• It is becoming increasingly clear that IPM is an information intensive approach and multiple tactics have to be employed to disseminate IPM globally; the CRSP has disseminated such information through the print media and electronic media as well as through workshops and field days.
• The IPM CRSP has demonstrated that there are mutual benefits both to the U.S. and the participating developing host countries in implementing a collaborative program such as this one; U.S. and host country scientists and students, host country farmers and U.S. consumers are among the beneficiaries of this collaborative program.

References


3. Experience with Management of Major Plant Diseases in Ethiopia

Eshetu Bekele
Plant Pathologist, Ethiopian Agricultural Research Organization (EARO)
P.O. Box 2003 Addis Ababa

Abstract
Earlier plant pathology research in Ethiopia focused mainly on survey, identification and documentation of diseases and their causes. As a result, a large number of biotic causes have been documented to affect many plants, some of which cause economic losses in yield and quality. With the shift from traditional to modern agriculture that usually employs genetically more uniform crop varieties and uses extensive practices, the development of new disease outbreaks and changes in disease trends towards epidemics have been encountered. The usually recommended resistant varieties or chemical control options alone could not be sustainably used due to many reasons.

In recent years, however, integrated disease management (IDM) has been taken seriously as a national plant disease management policy and a viable research agenda to curb some major disease problems in the country. Considerable efforts have already been made in IDM technology development as evidenced by some research results presented here. Integrated variety and fungicide control of yellow rust and stubble management, rotations and variety for the control of septoria blotches in wheat; faba bean and field pea mixtures for the control of chocolate spot and ascochyta blight; integration of variety, fungicide and planting date for the control of late blight in potato; and CBD resistant coffee varieties are some of the success stories in IDM in the country.

The great variability in the host plant, indigenous biological agents, and farming systems available in the country are essential resources and opportunities for successful IDM strategies. Optimized use of these resources through an appropriate IDM approach will increase yields and make agriculture more sustainable in Ethiopia.

Introduction
Plant pathology research in Ethiopia started when agricultural research was taken up by the College of Agriculture in the 1950s. Systematically organized research in plant pathology, however, began with the establishment of the then Institute of Agricultural Research (IAR) in 1966, and later on with the establishment of the Scientific Phytopathological Laboratory (SPL) in 1976.

Earlier plant pathology research focused on survey, identification, and documentation of diseases and the causative agents of economically important plants. As a result, a large number of fungal, viral, bacteriological and nematode caused diseases have been identified and documented. However, research emphasis was on a few major diseases of major crops. Recently, the plant disease problems were prioritized in the Plant Pathology Research strategy of EARO and some of the priority diseases are presented in Table 2.
### Table 2: Prioritization of diseases in crops

<table>
<thead>
<tr>
<th>Crops</th>
<th>Diseases</th>
<th>Crops</th>
<th>Diseases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tef</td>
<td>Rust***, Smudge**, Leaf spot**, Others*</td>
<td>Faba bean</td>
<td>Chocolate spot***, Rust***, Ascochyta**, Root rot/wilts**, Necrotic virus**, Others*</td>
</tr>
<tr>
<td>Wheat</td>
<td>Stripe rust***, Leaf rust***, Stem rust***, Septoria***, Eye-spot**, Take All <strong>, Scab</strong>, Tan Spot**, Others*</td>
<td>Field pea</td>
<td>Powdery mildew***, Ascochyta leaf and pod spot***, Others*</td>
</tr>
<tr>
<td>Barley</td>
<td>Scald***, Net blotch***, Leaf rust***, Eye-spot**, Smut**, Others*</td>
<td>Chick pea</td>
<td>Virus**, Root rot/wilts***, Ascochyta**, Others*</td>
</tr>
<tr>
<td>Sorghum</td>
<td>Smut***, Anthracnose***, Grain mold***, Downy mildew**, Charcoal rot**, Others*</td>
<td>Grass Pea</td>
<td>Powdery mildew**, Virus**, Others*</td>
</tr>
<tr>
<td>Finger Millet</td>
<td>Blast***, Others</td>
<td>Haricot bean</td>
<td>Rust***, Anthracnose***, CBB**, Angular leaf spot***, Floury leaf spot**, Web blight**, Root-knot nematode***, Others*</td>
</tr>
<tr>
<td>Sesame</td>
<td>Bacterial blight***, Phyldody**, Others</td>
<td>Enset</td>
<td>Bacterial wilt***, Nematode**, Others*</td>
</tr>
<tr>
<td>Noug</td>
<td>Shot hole**, Stem and leaf blight***, Powdery Mildew**, Others*</td>
<td>Potato</td>
<td>Late blight***, Bacterial wilt***, Virus**, Others*</td>
</tr>
<tr>
<td>Gomen Zer</td>
<td>Black leg***, White rust**, Downy mildew**, Others*</td>
<td>Sweet potato</td>
<td>Stem blight**, Others*</td>
</tr>
<tr>
<td>Ground nut</td>
<td>Cercospora leaf spot***, Rust***, Storage molds**, Others*</td>
<td>Root crops</td>
<td>Diseases**</td>
</tr>
<tr>
<td>Sunflower</td>
<td>Stem blight**, Nematode**, Others*</td>
<td>Garlic</td>
<td>Rust***</td>
</tr>
<tr>
<td>Grapes</td>
<td>Powdery mildew***, Downy mildew**, Others*</td>
<td>Allium</td>
<td>Purple blotch**, Bulb rot**, Downy mildew**, Others*</td>
</tr>
<tr>
<td>Papaya</td>
<td>Anthracnose***, Foot rot**, Nematode**, Others*</td>
<td>Cabbage</td>
<td>Black rot***, Club root**, Others*</td>
</tr>
<tr>
<td>Avocado</td>
<td>Phytophthora root rot***, Others*</td>
<td>Cotton</td>
<td>Bacterial blight***, Verticillium wilt**, Others*</td>
</tr>
<tr>
<td>Mango</td>
<td>Powdery mildew**, Others*</td>
<td>Kenaf</td>
<td>Root knot nematodes***, Fusarium root rot**, Others*</td>
</tr>
<tr>
<td>Coffee</td>
<td>CBD***, Rust***, Vascular wilt***, Bean darkening**, Root rot**, Damping off**, Others*</td>
<td>Sugarcane</td>
<td>Smut***, Others*</td>
</tr>
<tr>
<td>Tea</td>
<td>?</td>
<td>Chat</td>
<td>Powdery mildew**, Others*</td>
</tr>
<tr>
<td>Forest</td>
<td>?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


*** high priority , ** medium priority, * low priority

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**Importance of Plant disease in Ethiopia**

The importance of plant disease in reducing crop yield and crop quality is very much known by anyone engaged in agriculture. In Ethiopia the shift from traditional to modern agriculture,
resulting in the use of narrower genetic bases of crop varieties and more uniform and extensively used cultural practices, has allowed the development of new disease outbreaks and changes in disease trends and epidemics. Some examples to illustrate these situations are the increasing pressure of yellow rust in wheat production in Arsi and Bale, coffee berry disease (CBD) in plantation coffee, gray leaf spot (GLS) in maize, and leaf and fruit spot on citrus. Some yield loss estimates on selected crops and diseases are presented in Table 3. Many of these loss figures were produced from experiments conducted at research centers with ideal conditions for the diseases development and thus represent potential losses, but not actual losses in farmer fields.

Table 3: Yield loss estimates on plot basis in selected crops due to major diseases

<table>
<thead>
<tr>
<th>Crops</th>
<th>Diseases</th>
<th>Yield loss %</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>Stripe rust, Leaf rust, Stem rust, Septoria</td>
<td>96-100, 75, 60, 25</td>
<td>Eshetu (1986); Mengistu et al (1991)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>&quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>&quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mengistu et al (1991)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Eshetu (1986)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PPRC (1998); Getaneh (1998)</td>
</tr>
<tr>
<td>Tef</td>
<td>Rust, Smudge</td>
<td>10-25, 40-50</td>
<td>Eshetu (1986)</td>
</tr>
<tr>
<td>Sorghum</td>
<td>Smuts</td>
<td>1-25</td>
<td>IAR annual report 1995/95</td>
</tr>
<tr>
<td>Maize</td>
<td>Leaf blight</td>
<td>25-49</td>
<td>Assefa Teferi (1995)</td>
</tr>
<tr>
<td>Faba bean</td>
<td>Rust, Chocolate spot, Black root rot, Wilt/root rot</td>
<td>27, 3-18, 14-75, 30</td>
<td>IAR (1986); Birhanu et al (1992); -</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Potato</td>
<td>Late blight</td>
<td>15-67</td>
<td>Bekele et al (1996)</td>
</tr>
<tr>
<td>Tomato</td>
<td>Late blight</td>
<td>38-65</td>
<td>IAR (1983); Tesfaye and Habtu (1986)</td>
</tr>
<tr>
<td>Onion</td>
<td>Purple Blotch</td>
<td>26</td>
<td>IAR (1986)</td>
</tr>
<tr>
<td>Citrus</td>
<td>Fruit and leaf spot</td>
<td>43-65</td>
<td>Eshetu (1997)</td>
</tr>
<tr>
<td>Pepper</td>
<td>Pepper viruses</td>
<td>15</td>
<td>Agranovsky (1993)</td>
</tr>
<tr>
<td>Rape seed</td>
<td></td>
<td>32</td>
<td>Yitbarek (1992)</td>
</tr>
<tr>
<td>Coffee</td>
<td>CBD</td>
<td>24-30</td>
<td>Eshetu (1997)</td>
</tr>
<tr>
<td>Banana</td>
<td>Burrowing nematode</td>
<td>20-46</td>
<td>IAR (1983)</td>
</tr>
<tr>
<td>Kenaf</td>
<td>Root-knot nematodes</td>
<td>30</td>
<td>IAR (1986)</td>
</tr>
<tr>
<td>Enset</td>
<td>Bacterial wilt</td>
<td>100</td>
<td>-</td>
</tr>
</tbody>
</table>

Management options followed
In the earlier days of plant pathology research, management recommendations were more on host resistance and chemical control. Host resistance was mainly recommended for the control of cereals and other field crops while chemical control was mainly for the control of vegetable and fruit tree diseases. However, both options were also used in some cases like the control of yellow rust in wheat state farms and CBD in plantation coffee. Cultural control methods, such as sowing or planting date and rotations have also been used in some cases.

Recent emphasis of research in disease control is on integrated pest management (IPM). In order to distinguish between insect pests and pathogens causing diseases, integrated disease management (IDM) is sometimes used. However, there is a general understanding that the term pest includes plant pathogens and IPM also addresses plant disease management.

IPM as plant disease management strategy
Globally IPM is a preferred approach of managing agricultural pests, as stated under “Agenda 21” of the United Nations Conference on Environment and Development (UNCED, 1992). In the draft National Plant Protection Policy, IPM has been adopted as the best approach of pest management in Ethiopia. The Plant Pathology Research Strategy developed by the Ethiopian Agricultural Research Organization (EARO) also emphasizes IPM as the best option to be followed, when ever found practical (Table 4). The reasons for the global acceptance of IPM as the best approach of pest control could be different in different countries. Generally, in the developed countries overuse of chemicals to control agricultural pests could be the major cause for the shift towards IPM. The use of pesticides has dramatically increased the cost of pest control; its adverse effects on human, animal and on the environment at large have been painfully felt; it negatively affected the international trade of farm produces; and its frequent use has accelerated the development of new pests and/or resistant strains (races) of pests.

In developing countries like ours, overuse of chemical pesticides is unthinkable to be the cause for shifting to IPM. Chemical pesticide use in Ethiopia is very low, by any measure, even considering chemical pesticide usage of other African countries. Pesticide use by the state farms, that have been the major consumers of pesticides in Ethiopia, is presented in table 5. The share of fungicide was only 7% and was mostly used in the control of yellow rust of wheat and some vegetable diseases. Therefore, the need for IPM in Ethiopia arises not from overuse of chemical pesticides but from the experiences learnt from other countries, and the soundness of the IPM approach to the Ethiopian agriculture. IPM as the best strategy of disease management reduces costs, is environmentally friendly, avoids or at least delays the development of new pests, strains or races and increases acceptance of agriculture produces and products in international trade, all contributing to the sustainability of agriculture. IPM is an approach that combines two or more single factor management options. These single factor options could be host plant resistance, cultural practices, biological control, and minimized use of safe and effective agricultural pesticides. These combinations can be made at different levels depending on the nature of the disease and agricultural practices. Even at the genetic level, for example, cereal rusts with several prevailing races, can be controlled effectively by integrating several resistant genes into the respective races in a variety. Similarly, the use of two or more fungicides with different modes of action (e.g. systemic vs. contact action) can avoid or reduce the chances of developing resistance in some pathogens to a repeated use of these chemicals. Such practices provide durable resistance and can be considered as IPM approaches.
Table 4: Ranking of thematic areas and management options

<table>
<thead>
<tr>
<th>Thematic areas</th>
<th>Mycology</th>
<th>Virology</th>
<th>Bacteriology</th>
<th>Nematology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disease survey</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Crop loss</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Methodology</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Epidemiology</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Management</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

| Management         |          |          |              |            |
| Cultural           | c        | c        | b            | b          |
| Varietal          | b        | b        | c            | c          |
| Chemical          | e        | e        | e            | e          |
| Bio-control       | d        | d        | d            | d          |
| IDM               | a        | a        | a            | a          |


Table 5: Pesticide usage (kg or l) by the state farms (average for 1988-1992)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Pesticide Group</th>
<th>Insecticide</th>
<th>Herbicide</th>
<th>Fungicide</th>
<th>Rodenticide</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton</td>
<td></td>
<td>842,942</td>
<td>5,478</td>
<td>7,902</td>
<td></td>
<td>856,594</td>
</tr>
<tr>
<td>Cereals</td>
<td></td>
<td>47,395</td>
<td>285,772</td>
<td>45,128</td>
<td>272</td>
<td>388,067</td>
</tr>
<tr>
<td>Citrus</td>
<td></td>
<td>28,245</td>
<td>6,846</td>
<td>12,402</td>
<td>9,772</td>
<td>47,493</td>
</tr>
<tr>
<td>Vegetables</td>
<td></td>
<td>16,500</td>
<td>0</td>
<td>28,445</td>
<td>0</td>
<td>44,957</td>
</tr>
<tr>
<td>Mustard</td>
<td></td>
<td>3,800</td>
<td>3,648</td>
<td>0</td>
<td>12</td>
<td>7,448</td>
</tr>
<tr>
<td>Tobacco</td>
<td></td>
<td>2,950</td>
<td>0</td>
<td>0</td>
<td>00</td>
<td>2,956</td>
</tr>
<tr>
<td>Pulses</td>
<td></td>
<td>0</td>
<td>1,860</td>
<td>0</td>
<td>0</td>
<td>1,860</td>
</tr>
<tr>
<td>Grapes</td>
<td></td>
<td>0</td>
<td>0</td>
<td>360</td>
<td>0</td>
<td>360</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>941,838</strong></td>
<td><strong>303,604</strong></td>
<td><strong>94,237</strong></td>
<td><strong>10,056</strong></td>
<td><strong>1,349,756</strong></td>
</tr>
<tr>
<td><strong>Percent</strong></td>
<td></td>
<td>69.8</td>
<td>22.5</td>
<td>7.0</td>
<td>0.7</td>
<td>100.0</td>
</tr>
</tbody>
</table>


Some examples of IDM efforts in Ethiopia

This paper is not attempting to review all IDM research results reported in Ethiopia. It rather refers to some examples in order to appreciate the efforts made so far in promoting IDM as a viable approach to plant disease management.

IDM of yellow rust and septoria blotches of wheat

The best way of controlling rust in wheat is to use resistant varieties. Expanded production of these varieties, however, predisposes the varieties to new races of the rusts that break their resistance sooner or later. In wheat rust management in Arsi and Bale, it is usually recommended to use as many varieties as possible in a given area (e.g. in a state farm) since varieties differ in susceptibility to the disease. If a variety becomes susceptible it may be supported with some fungicidal sprays. A study made at Sinana indicates the feasibility of such integrated varietal and fungicidal methods to control yellow rust (Table 6).
Table 6: Economics of yellow rust management with variety and fungicides: Sinana 1995-1997

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Enkoy ET-13A Hollandi Dashen</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F1</td>
</tr>
<tr>
<td>Average yield</td>
<td>4294.8</td>
</tr>
<tr>
<td>Gross benefit</td>
<td>5497.3</td>
</tr>
<tr>
<td>Cost of fungicide</td>
<td>360</td>
</tr>
<tr>
<td>Cost of spray</td>
<td>45</td>
</tr>
<tr>
<td>Total cost that vary</td>
<td>405</td>
</tr>
<tr>
<td>Net benefit (NB)</td>
<td>5092.3</td>
</tr>
<tr>
<td>MRR</td>
<td>1.82</td>
</tr>
</tbody>
</table>

F1 = fungicide sprayed; F0 = unsprayed

In the control of septoria blotches of wheat a study made at Holetta indicated that stubble management, rotation and varietal resistance delayed the onset, progress and severity of the disease and increased wheat yield (Table 7).

Table 7: Main effect of management, nitrogen levels and variety on septoria blotches and yield of wheat: Holetta 2001

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Septoria Blotches Assessments2</th>
<th>KW (g)</th>
<th>Yield (q/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DA</td>
<td>FS</td>
<td>LS</td>
</tr>
<tr>
<td>Management1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>25.2b</td>
<td>34.7a</td>
<td>83.7a</td>
</tr>
<tr>
<td>2</td>
<td>24.2b</td>
<td>33.6ab</td>
<td>84.4a</td>
</tr>
<tr>
<td>3</td>
<td>20.4d</td>
<td>34.4a</td>
<td>83.9a</td>
</tr>
<tr>
<td>4</td>
<td>20.5d</td>
<td>36.9a</td>
<td>84.1a</td>
</tr>
<tr>
<td>5</td>
<td>26.9a</td>
<td>34.8a</td>
<td>81.1b</td>
</tr>
<tr>
<td>6</td>
<td>22.2c</td>
<td>32.2ab</td>
<td>84.4a</td>
</tr>
<tr>
<td>7</td>
<td>22.1c</td>
<td>29.2b</td>
<td>84.1a</td>
</tr>
<tr>
<td>Nitrogen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N1</td>
<td>23.1a</td>
<td>33.7a</td>
<td>83.6a</td>
</tr>
<tr>
<td>N2</td>
<td>23.0a</td>
<td>33.7a</td>
<td>83.7a</td>
</tr>
<tr>
<td>Variety</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HAR604</td>
<td>22.8b</td>
<td>19.5c</td>
<td>77.6b</td>
</tr>
<tr>
<td>HAR1685</td>
<td>24.1a</td>
<td>34.4b</td>
<td>86.3a</td>
</tr>
<tr>
<td>HAR710</td>
<td>22.4b</td>
<td>47.2a</td>
<td>87.1a</td>
</tr>
</tbody>
</table>

1 = wheat - faba bean rotation (2 cycles), 2 = wheat - gomenzer rotation (2cycle), 3 = gomenzer – faba bean - wheat rotation, 4 = faba bean – gomenzer –wheat rotation, 5 = stubble burned, 6 = stubble retained, 7 = stubble partially removed
2 DA = disease appearance (days after planting); FS = first septoria score on 00-99 scale; LS = last septoria score on 00-99 scale; MS = mean septoria score on 00-99 scale; FL = Flag leaf rating on 0-5 scale; KW = 1000 kernel weight.
Source: Eshetu B. (unpublished)

IDM of faba bean and field pea diseases
Growing faba bean and field pea in mixture is often practiced by many farmers in the country. Weed suppression and physical support to the field pea by faba bean were some of the reasons for this mixed cropping. The effect of mixed cropping of faba bean and field pea on Chocolate spot and Ascochyta blight on faba bean and field pea, respectively, has been investigated at Holetta (Table 8). Mixed cropping has significantly reduced disease progress on the respective crop as its proportion progressively decreases in the mixture. As a result, seed yield of the mixed crops was significantly higher than that of a pure stand of both crops.
Table 8: Mean area under the disease progress curve (AUDPC) in percent for Chocolate Spot of faba bean and Ascochyta blight of field pea and yield (1993-1996): Holetta

<table>
<thead>
<tr>
<th>Ratio B:P</th>
<th>AUDPC</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chocolate spot</td>
<td>Ascochyta blight</td>
</tr>
<tr>
<td>42:0</td>
<td>1547a</td>
<td></td>
</tr>
<tr>
<td>34:16</td>
<td>1509a</td>
<td>896c</td>
</tr>
<tr>
<td>31:21</td>
<td>1527a</td>
<td>991c</td>
</tr>
<tr>
<td>28:27</td>
<td>1368b</td>
<td>1024bc</td>
</tr>
<tr>
<td>20:41</td>
<td>1288b</td>
<td>1129b</td>
</tr>
<tr>
<td>0:81</td>
<td>-</td>
<td>1286a</td>
</tr>
</tbody>
</table>

*p plant population per m²; B is faba bean and P is field pea

Source: Dereje G. (1999)

IDM of late blight of potato

Potato production in the main rainy season was abandoned in most highland areas of Ethiopia due to severe attack of late blight (*Phytophthora infestans*). The local potato varieties were so susceptible to late blight and were mainly produced during the small rain or under irrigation in the off seasons during which late blight incidence was low. However, with the development of resistant or tolerant potato varieties it was possible to grow potato in the main season with better yield. Early planting of potato in the main season delays the onset of late blight and increased yield, although the disease development (AUDPC) was higher than the later sowings (Table 9). Varieties and fungicide sprays also have significant effects on late blight.

The economic advantage of integrating varieties with different levels of resistance, early planting and reduced fungicide use has been investigated at Holetta (Table 10). The partial budget analysis showed that when the three management components were fully integrated, the variety Menagesha gave the highest net benefit and marginal rate of return (MRR). If early planting without the use of fungicide was opted for with reduced application of fungicide (Ridomil MZ applied once) growing the variety Tolcha has given the highest net benefit and MRR.

IPM of CBD in coffee

Coffee berry disease (CBD) caused by the fungus *Colletotrichum kahawae* is the major disease threatening coffee production in Ethiopia since 1971, causing 24-30% loss nationally. As an immediate measure of controlling CBD, based on the Kenyan experiences, fungicide spraying was under taken covering the major affected areas. Fungicide screening trials were extensively made and products such as Chlorothalonil, Cuprous oxide, Fluazinam and Prochloraz were recommended and effectively used to control the disease (Eshetu D. *et al.,* 2000).

For a long term and more sustainable management of CBD, however, selection for resistant varieties was taken as a feasible option. Ethiopia being home (origin) of Arabica coffee, the forest coffee in the south, south-west and west of the country, with all the diversities, have given ample opportunities for research to select for resistant varieties. As a result, many resistant selections are continually being developed and released, making also progressive improvement in yield and quality. Currently, fungicidal spraying is practically abandoned due to mostly the availability of such resistant coffee varieties to CBD.
Table 9: Effect of variety, planting date and fungicide application on severity of late blight and tuber yield, Hoetta

<table>
<thead>
<tr>
<th>Treatments</th>
<th>1993</th>
<th></th>
<th></th>
<th>1994</th>
<th></th>
<th></th>
<th>1996</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dis. onset* (days)</td>
<td>AUDPC</td>
<td>Yield (t/ha)</td>
<td>Dis. onset* (Days)</td>
<td>AUDPC</td>
<td>Yield (t/ha)</td>
<td>Dis. onset* (day)</td>
<td>AUDPC</td>
</tr>
<tr>
<td>Variety</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AL-624</td>
<td>27bc</td>
<td>821.5a</td>
<td>8.7c</td>
<td>24b</td>
<td>750.8a</td>
<td>4.6b</td>
<td>22b</td>
<td>1351.4a</td>
</tr>
<tr>
<td>Awash</td>
<td>32ab</td>
<td>291.9b</td>
<td>16.6b</td>
<td>35ab</td>
<td>615.4a</td>
<td>7.1b</td>
<td>29ab</td>
<td>1181.5ab</td>
</tr>
<tr>
<td>Tolcha</td>
<td>41a</td>
<td>142.0b</td>
<td>23.4a</td>
<td>43a</td>
<td>462.8a</td>
<td>11.7a</td>
<td>39a</td>
<td>466.6c</td>
</tr>
<tr>
<td>Planting date</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early June</td>
<td>42ab</td>
<td>652.8a</td>
<td>25.7a</td>
<td>38a</td>
<td>867.4a</td>
<td>13.4a</td>
<td>40a</td>
<td>1567.0a</td>
</tr>
<tr>
<td>Late June</td>
<td>45a</td>
<td>570.0ab</td>
<td>23.0ab</td>
<td>35ab</td>
<td>637.5ab</td>
<td>6.1b</td>
<td>29ab</td>
<td>1260.0ab</td>
</tr>
<tr>
<td>Early July</td>
<td>27c</td>
<td>298.2b</td>
<td>9.2c</td>
<td>26abc</td>
<td>447.3bc</td>
<td>5.5b</td>
<td>23bc</td>
<td>896.4c</td>
</tr>
<tr>
<td>Late July</td>
<td>28c</td>
<td>251.0c</td>
<td>7.2c</td>
<td>21bc</td>
<td>486.6bc</td>
<td>6.3b</td>
<td>19c</td>
<td>276.1d</td>
</tr>
<tr>
<td>Fungicide</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>-</td>
<td>416.1</td>
<td>16.3</td>
<td>-</td>
<td>499.0</td>
<td>7.8</td>
<td>-</td>
<td>998.8</td>
</tr>
<tr>
<td>Yes</td>
<td>-</td>
<td>14.1</td>
<td>23.0</td>
<td>-</td>
<td>55.2</td>
<td>12.5</td>
<td>-</td>
<td>182.9</td>
</tr>
</tbody>
</table>

Source: Bekele K. (unpublished)
* Disease onset is the number of days from planting to the first late blight appearance.
Table 10: Economic analysis of late blight management options in three potato varieties

<table>
<thead>
<tr>
<th>Management Options</th>
<th>Variety</th>
<th>Mean Yield (ton/ha)</th>
<th>Net Benefit (Birr)</th>
<th>MRR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variety + Early Planting + Fungicide</td>
<td>Awash</td>
<td>18.3</td>
<td>17702.24</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Local</td>
<td>32.4</td>
<td>21113.98</td>
<td>428.7</td>
</tr>
<tr>
<td></td>
<td>Tolcha</td>
<td>28.0</td>
<td>28601.62</td>
<td>1113.6</td>
</tr>
<tr>
<td></td>
<td>Menagesha</td>
<td>31.4</td>
<td>32671.62</td>
<td>1535.9</td>
</tr>
<tr>
<td>Variety + Early Planting</td>
<td>Awash</td>
<td>3.4</td>
<td>2529.74</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Local</td>
<td>32.4</td>
<td>21113.98</td>
<td>1155.36</td>
</tr>
<tr>
<td></td>
<td>Tolcha</td>
<td>25.3</td>
<td>25159.12</td>
<td>1826.41</td>
</tr>
<tr>
<td></td>
<td>Menagesha</td>
<td>10.3</td>
<td>5769.12</td>
<td></td>
</tr>
<tr>
<td>Variety + Fungicide</td>
<td>Awash</td>
<td>18.1</td>
<td>17447.24</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Local</td>
<td>32.4</td>
<td>21113.98</td>
<td>460.78</td>
</tr>
<tr>
<td></td>
<td>Tolcha</td>
<td>28.7</td>
<td>29494.12</td>
<td>1246.38</td>
</tr>
<tr>
<td></td>
<td>Menagesha</td>
<td>27.5</td>
<td>27699.12</td>
<td></td>
</tr>
</tbody>
</table>

Source: Bekele K. (unpublished)

Conclusions
Experience and facts suggest that there are ample opportunities in Ethiopia for the successful application of IDM strategy for the management of many plant diseases. The great variability of plant species and their varieties; variability in indigenous biological agents, in cultural practices and farming systems in the country are basic tools for viable IDM approaches. These resources, unlike those in the developed countries, are not yet adversely affected by the extensive uses of chemical pesticides. IDM in Ethiopia should optimize the use of these resources already available in the agriculture system so that yields increase and become more sustainable.

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Yitbarek S. 1991. Pathological research on noog, linseed, gomenzer and rapeseed in Ethiopia. Oil seed research and development in Ethiopia. pp 151-161. IAR. Addis Ababa,
4. **Weed Management Research Experience in Ethiopia**

Fasil Reda  
Weed Scientist, Melkassa Research Center, EARO  
P.O. Box – 436, Nazareth

**Abstract**  
Weeds are among the major production constraints in Ethiopian agriculture. However, unlike other pests, weeds cause damage in a subtle manner and are therefore denied due attention by the farming community. Integrated weed management interventions are required to address the complex weed problems in the diverse ecologies and farming systems of the country. There is a serious challenge of developing appropriate and cost-effective weed control technologies for subsistence farmers with low resource base, and small and fragmented land holdings. Nevertheless, different methods of control were studied as components of integrated weed management systems. Manual control experiments revealed that most crops exhibited significant yield response to one time weeding in the first four weeks of establishment. Some crop species (e.g. groundnut) and crop varieties (e.g. haricot bean var. Mexican 142) required more frequent weeding for optimum performance. It was shown that hand weeding could be effectively combined with mid-season cultivation and use of increased seed rates for enhanced control of weeds. Crop rotation and annual N and P fertilizer application rates had significant effects on the densities of individual weed species and on total weed biomass. Further studies indicated that soil nutrient and fertilizer management, use of competitive and resistant crop varieties, cropping systems, biological control; and integration of two or more of these approaches could provide viable options for combating weeds. Imminent changes in cropping and crop management practices, in the future, will inevitably result in changes in weed flora. Thus, comprehensive containment strategies will have to be developed to effectively deal with the dynamic and complex weed problems.

**Introduction**  
Weeds have a more direct influence on the affairs of humans more than any other pest in developing countries like Ethiopia. Weeds not only cause severe crop losses but also compel farmers and their families to spend a considerable amount of their time weeding, limiting further development in other areas of the rural economy. The weed flora of Ethiopia is highly diverse and it is composed of a wide range of perennial and annual grass and broadleaf weeds, sedges, parasitic and invasive weed species. Table 1 shows a list of the major weed species. Inappropriate cropping practices and deteriorating environmental conditions have contributed to the occurrence of complex weed problems in the country. The cereal belt of the country is infested with perennial weeds, herbicide resistant grass weeds and parasitic weeds such as *Striga*. The lowlands are being invaded by alien invasive species – *Parthenium hysterophorous*, *Prosopis juliflora* and *Lantana camara*. The maize and sorghum growing ecologies are prone to hard-to-control sedge and grass weeds such as *Rottboellia cochinchinensis*. The troublesome perennial grasses vis. *Digitaria abyssinica*,
Table 11: Major weed species in Ethiopian agriculture

<table>
<thead>
<tr>
<th>Grass weeds</th>
<th>Broadleaved weeds</th>
<th>Sedges</th>
<th>Invasive species</th>
<th>Parasitic weeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digitaria spp.</td>
<td>Ageratum conzoides</td>
<td>Cyperus rotundus</td>
<td>Parthenium hystrophorus</td>
<td>Striga spp.</td>
</tr>
<tr>
<td>Cynodon spp.</td>
<td>Amaranthus spp</td>
<td>Cyperus esculentus</td>
<td>Prospis juliflora</td>
<td>Orobanche spp.</td>
</tr>
<tr>
<td>Pennisetum spp.</td>
<td>Argemone mexicana</td>
<td></td>
<td></td>
<td>Cuscuta spp.</td>
</tr>
<tr>
<td>Avena spp.</td>
<td>Bidens pilosa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rottboellia</td>
<td>Celosia argentina</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cochinchinesis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Setaria verticillata</td>
<td></td>
<td>Commelina spp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sorghum arundinacea</td>
<td></td>
<td>Convolvulus arvensis</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Datura stramonium</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flaveria trinervia</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Galinsoga parviflora</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Guizotia scabra</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Cynodon* and *Pennisetum* spp. represent serious challenge in degraded farm and range lands. Loss assessment studies revealed that most crops are highly sensitive to weed competition, especially early in their growth stages. It is documented that uncontrolled weed growth does cause heavy yield losses in the major crops of Ethiopian agriculture (Table 12).

Table 12: Crop yield losses due to uncontrolled weed growth

<table>
<thead>
<tr>
<th>Crop</th>
<th>% loss</th>
<th>Crop</th>
<th>% loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>44</td>
<td>Field pea</td>
<td>15 (up to 67%)</td>
</tr>
<tr>
<td>Sorghum</td>
<td>30</td>
<td>Soybean</td>
<td>50 (up to 75%)</td>
</tr>
<tr>
<td>Wheat</td>
<td>35</td>
<td>Coffee</td>
<td>62</td>
</tr>
<tr>
<td>Barley</td>
<td>18</td>
<td>Cotton</td>
<td>73</td>
</tr>
<tr>
<td>Tef</td>
<td>30</td>
<td>Pepper &amp; tomato</td>
<td>30 (up to 100%)</td>
</tr>
<tr>
<td>Lentil</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chickpea</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fababean</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Haricot bean</td>
<td>36 (up to 90%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Ann Stroud, 1989

The continuing losses due to weeds inequitably distributed across agro-ecosystems, the evolution of herbicide resistance, shifts in weed flora in response to weed management and soil erosion through excessive cultivation all attest to the need to develop systems of weed management that are sustainable. Such sustainability will arise through the development of integrated weed management systems. Integrated weed management (IWM) is a weed
management system designed to be economically, environmentally, and socially acceptable. IWM incorporates various management options i.e. crop rotation practices; soil nutrient and fertilizer management; plant breeding for enhanced competitive ability and resistance; mechanical, biological, and chemical weed control; and tillage and crop residue management, into strategies capable of reducing weed interference while maintaining acceptable yields. For long term and sustainable impact IWM in turn should be integrated into a system’s approach. Adopting a systems approach implies that weed management, as a component of the agricultural system, must be considered in terms of the complex interactions among social, economic and environmental factors. In Ethiopia, considerable effort has been made to study weeds and develop appropriate strategies to reduce their impact on crop production. The weed management research program has shown appreciable growth in recent years, judging by the diversity of weed related issues being addressed. However, constrained by lack of capacity, earlier work was forced to emphasis a limited range of research areas. This paper briefly summarizes weed management experience with particular attention to efforts made to develop integrated management practices for the control of major weeds in the country.

IWM and manual weed control
Low input agriculture is a common feature of food production in the country. Because of their limited resource base, subsistence farmers rely on hand weeding for the control of weeds. However, because of overlap of farm operations farmers either leave their farms un-weeded or perform weed control late in the season. Experience has shown that proper timing of the weeding operation is critical to maximize benefits. According to the findings, crops are particularly sensitive to weed interference in the first four weeks of establishment and early weeding during this period significantly enhances yield performance. However, some crops such as groundnut apparently require more frequent weeding for optimum performance (Tadesse Eshetu and Kassahun Zewdie, 1988). Tenaw Workayehu et al. (1997) reconfirmed the variable response of crops to frequency of weeding taking haricot bean as a test crop and showed that genotype by weeding interaction was significant for grain yield. Mexican 142 required two times weeding to produce significantly higher yield, whereas one early weeding was sufficient for the other two, apparently more competitive varieties, Ex-Rico and Red Wolaita (Table 13). Several workers showed that hand weeding can be effectively combined with mid-season cultivation (shilshaloe) and use of increased seed rates to ensure enhanced control of weeds. The only case where early weeding does not seem to have such an obvious effect is in crops infested by parasitic weeds. The yield gain from early weeding a Striga infected cereal is often insignificant. Although it is difficult to improve yield performance, efficiency could be enhanced and economic advantages gained from late weeding. It was shown that late weeding of Striga (after flowering) requires less than one half of the time needed for early pulling. Furthermore, late pulling is more manageable as one has to remove only flowering Striga plants. It has been established that early weeding could lead to re-sprouting of more shoots and further aggravation of the parasitic weed problem.

Table 13: Weeding and variety interaction effect on grain yield (q/ha)

<table>
<thead>
<tr>
<th>Weeding frequency</th>
<th>Variety</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ex-rico 23</td>
</tr>
<tr>
<td>No weeding</td>
<td>2.6</td>
</tr>
<tr>
<td>Weeding at 25 DAE</td>
<td>9.0</td>
</tr>
<tr>
<td>Weeding at 25 and 55 DAE</td>
<td>10.5</td>
</tr>
<tr>
<td>LSD (5%) Weeding x Variety</td>
<td>3.1</td>
</tr>
</tbody>
</table>

Source: Tenaw Workayehu et al. 1997
Note: DAE – days after emergence
IWM and crop rotation
Crop rotation is an important part of IWM and the more diverse the species included in the rotation, the more likely that the rotation will facilitate control of indigenous weed species. The principles of IWM have been applied to weed control research in wheat. Crop rotation and annual N and P fertilizer application rates had significant effects on the densities of individual weed species and on total weed biomass at Kulumsa and Asasa (Tanner, 1999).

Rotation of infested land into non-susceptible crops or into fallow is theoretically one of the simplest solutions for the control of Striga, but also one that is neither simple nor acceptable (Parker and Riches, 1993). Farmers are usually reluctant to break the cereal production cycle for a long period. Cognizant of this fact, a five-year experiment was initiated to explore the possible benefits of alternate cropping of sorghum and annual legumes over the existing system of cereal monoculture, under Striga infested conditions. The final year results showed that yearly rotation of sorghum with either cowpea or haricot bean resulted in significantly higher cereal yields but failed to lead to concomitant reduction in Striga infestation (Fasil Reda and Wondimu Bayou, 2001). The main lesson that was learned from the exercise was that the time interval between cereal crop cycles has to be sufficiently long for a rotation program to be effective against Striga.

IWM and soil nutrient and fertilizer management
Since the application of plant nutrients to soil, especially fertilizer nitrogen (N), alleviates a common limitation to crop (and weed) growth, many weed species have developed an inherent ability to effectively compete with crops for access to nutrients. Wheat-based on-farm fertilizer trials revealed that the highest rate of phosphorus fertilizer decreased wild oat panicle densities but N markedly increased Avena fatua infestation (Tanner, 1999).

Striga is less damaging and often less severe in fertile soils and the critical element among the nutrients is widely believed to be nitrogen. Investigations indicated that the effect of N could vary across varieties. Nitrogen significantly reduced Striga infestation on Gambella 1107 and N13, but its effect on ICSV-1006 and ICSV-1007 was more consistent (Babiker and Fasil Reda, 1991). Results of an experiment, designed to develop integrated nutrient management strategy, confirmed that the combined use of 41 kg N/ha and 30 t/ha of manure could lead to significant reduction in infestation and considerable increase in sorghum yield (Esilaba et al., 2000). Further experience in dryland environments showed that the outcome from the use of the nitrogen input depends on weather patterns and inherent fertility (Fasil Reda, 2002). The beneficial effect of nitrogen was consistent in the northwestern lowlands of Tigray where there was adequate rainfall and less impoverished soil. On the other hand, mixed results were obtained and no obvious benefit was obtained from the use of the input in the dry highlands in the northeast of the region.

IWM and plant breeding for enhanced competitive ability and resistance
Production of crop species and cultivars that are better competitors with weeds is an important component of IWM. In general, crops that can germinate, root, emerge, and establish a dense canopy earlier and faster are more likely to compete strongly with weeds. In a trial which compared released wheat varieties, the semi-dwarf Dahsen was significantly more susceptible to wild oat competition than the morphologically more vigorous varieties - ET13, Enkoy and Israel (Tanner, 1999). The use of crop cultivars that are not parasitized, or are only lightly parasitized by Striga offers practical control measure. Identification of resistance sources has constituted the major research area of the Striga management program and relatively more
resistant sorghum cultivars including N-13, framida, ICSV-1006, ICSV-1007, SAR-24 and SRN-39 have been identified. These varieties displayed good level of resistance to most of the virulent *Striga hermonthica* populations of northern Ethiopia. Recently, as a result of the successful collaborative work with INTSORMIL resistant sorghum varieties with broad adaptation including P-9401 and P-9403 have been identified and released. Tolerance (capacity to yield well in spite of a high *Striga* infestation) is widely exhibited by local landraces of sorghum.

**IWM and cropping system approaches**

Inter-cropping is a potentially viable, low-cost technology, which would enable to address the two important and interrelated problems of low soil fertility and *Striga* infestation. Identifying the optimal spatial and temporal arrangements of companion crops; and selection of effective, compatible and adapted legume inter-crops, depending on the natural endowments of localities and behavior of existing *Striga* strains, is an important prerequisite. At Sirinka, one row of legume (cowpea and haricot bean) every two rows of sorghum was an optimum arrangement both in terms of reduction in parasitic weed incidence and increase in cereal yield (Fasil Reda et al., 1997). At Adibakel, a dry highland location, the same planting arrangement of sorghum and cowpea was superior in terms of crop productivity and *Striga* control. Intercropping had a rather detrimental effect on yield performance of sorghum and showed no obvious suppressive effect on *Striga*, under non-fertilized conditions, at Sheraro. In another environment, in Tigray, alternate row planting of sorghum and legumes, with staggered planting of the crops (sowing of legume intercrops 3 to 4 weeks after the cereal), was more productive and led to an overall reduction in infestation, over two seasons (Fasil Reda, 2002). Those findings suggested the need for developing site-specific recommendations on inter-cropping.

Relay cropping and improved fallow systems, which involve use of perennial legume shrubs are receiving a growing research attention as a promising method for resource-poor farming communities in Africa (ICRAF, 1992). Improved fallowing requires putting land out of cereal production, which may not be favorably accepted by small farmers. On the other hand, relay cropping could be an attractive option especially in areas affected by natural resource degradation. Experience with *Sesbania sesban* and *Cajanus cajan* in Adibakel and Sheraro, in Tigray, showed that outcome from such an intervention could depend on the environmental factors, rainfall and inherent soil fertility (Fasil Reda, 2002). Transplanting of the legume shrubs into sorghum fields, one month later, led to consistent increase in cereal yield and decline in parasitic weed incidence at Sheraro, the site endowed with conducive weather and edaphic conditions. The system, in some cases, resulted in significantly lower sorghum yield, under moisture stress and non-fertilized conditions at the dry highland location (Adibakel), even though overall yield performance of the cereal crop improved over years.

**IWM and biological control**

Biological control is an obvious tool for inclusion in any integrated management plan. Admittedly, there has been very little effort to exploit this rather promising line of investigation in this country. The first and last, fairly large-scale, attempt was made way back in 1977. Two insect species, *Smicronyx albolariegatus* (weevil) and *Eulocastra argentisparsa* (moth) were introduced from India for the control of *Striga* (IAR, 1977). In 1978, the two biological control agents were reintroduced and released, this time at Kobo (Tadesse G/Medhin and Parker, 1989). The consignments were apparently not in good condition and, one year later, only *S. albolariegatus* was found. It was re-confirmed that none of the insects managed to establish. Preliminary surveys revealed that *Smicronyx umbrinus*, the African
weevil, commonly occurs in many places in the country although not as a serious pest of *Striga*. Two pathogenic fungi species (*Fusarium oxysporium* and *Alternaria alternata*) were also observed causing considerable damage on the weed in northern Ethiopia. Further research is required to investigate the potential of using *Striga* specific, indigenous organisms for biological control.

One area where bio-control exhibits promise is in the management of the rapid spread of invasive species. There is a wealth of international experience that could be tapped in this area of research. Meaningful advances have been made for example in the control of *Parthenium hysterophorus*. Over 144 phytophagous arthropods were found to feed on *Parthenium* in the Neotropics, and 13 of these were considered to be restricted to the sub-tribe Ambrosiinae (McClay *et al.* 1995). As a result of these studies eight insect biological control agents were studied in detail, initially in Mexico and subsequently under quarantine in Australia. In the 1980s, the work was expanded to include pathogens (Cock and Seier, 1999). At least ten pathogenic fungi were recorded to be associated with *Parthenium* in its native range. Work concentrated on the evaluation of a rust fungus, *Puccinia abrupta* var. *partheniicola*, as a potential bio-control agent, which was subsequently introduced into Australia in 1991. The evaluation of a second rust species, *P. melampodiis*, was completed recently. An updated list of the recommended bio-agents for *Parthenium* control is shown in Table 14.

**IWM through crop resistance, tillage, hand weeding and herbicides**

Various combinations of conservation tillage, hand weeding and herbicides were compared for weed management and improvement of lentil seed yield at Debre Zeit (Negussie Tadesse *et al.*, 1993). Generally conservation tillage was more suitable for lentil production compared to conventional tillage. The crop seemed to prefer less disturbed soil conditions. Hand weeding enhanced the beneficial effect of Terbutryn herbicide under conventional tillage system, but this effect was not so apparent under reduced tillage (Table 15). The results further showed that 70% yield increment could be realized through integrated use of minimum tillage and twice weeding; or zero tillage, terbutryn and supplementary hand weeding. The crop is small and fragile and thus was unable to withstand the competitive effect of weeds and hence required adequate protection to realize its potential.
Research results demonstrated that the integrated use of control and crop management practices could enhance productivity and suppress *Striga* (Fasil Reda et al., 1997). At Sirinka, a treatment consisting of row planting, mineral fertilizer (42 kg N/ha) and 2,4-D herbicide (1 l/ha) led to 40% increase in cereal yield and appreciable reduction in *Striga* infestation, compared to the control (broadcast planting, no fertilizer and early weeding; farmer’s practice) (Table 16). Combined use of row planting, fertilizers and hand pulling (during flowering) registered 48% higher grain yield and over 50% reduction in *Striga* shoot counts compared to the farmer’s practice at Adibakel, in Tigray region (Table 17).

**Future Prospects**

The weed problem in the country is worsening due to the growing importance of the aggressive exotic weed species - *Parthenium hysterophorus*, and *Prosopis juliflora*. The infestation of *Striga*, *Orobanche* and *Cuscuta* is increasing in magnitude as evidenced by the rapid spread of the parasitic weeds to new ecologies and crops. The occurrence of herbicide resistant weed biotypes is a source of major concern.
Table 15: Effect of tillage systems and weed control practices on seed yield of lentil

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Seed yield (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT + no weeding</td>
<td>233e</td>
</tr>
<tr>
<td>CT + once hand weeding (30 DAP)</td>
<td>311de</td>
</tr>
<tr>
<td>CT + twice weeding (30 and 60 DAP)</td>
<td>367cde</td>
</tr>
<tr>
<td>CT + terbutryn (2 l/ha) + once weeding (30 DAP)</td>
<td>396cde</td>
</tr>
<tr>
<td>CT + terbutryn (2 l/ha)</td>
<td>437cd</td>
</tr>
<tr>
<td>MT + no weeding</td>
<td>530cde</td>
</tr>
<tr>
<td>MT + once hand weeding (30 DAP)</td>
<td>763a</td>
</tr>
<tr>
<td>MT + twice weeding (30 and 60 DAP)</td>
<td>798a</td>
</tr>
<tr>
<td>MT + terbutryn (2 l/ha) + once weeding (30 DAP)</td>
<td>515bc</td>
</tr>
<tr>
<td>MT + terbutryn (2 l/ha)</td>
<td>528bc</td>
</tr>
<tr>
<td>ZT + no weeding</td>
<td>486bcd</td>
</tr>
<tr>
<td>ZT + once hand weeding (30 DAP)</td>
<td>750a</td>
</tr>
<tr>
<td>ZT + terbutryn (2 l/ha) + once weeding (30 DAP)</td>
<td>797cde</td>
</tr>
<tr>
<td>ZT + terbutryn (2 l/ha)</td>
<td>637ab</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>166</td>
</tr>
</tbody>
</table>

Source: Negussie Tadesse et al., 1993

Note: CT – conventional tillage, MT – minimum tillage, ZT – zero tillage, DAP - days after planting. Yield figures followed by the same letter are not significantly different.

Increased trade and communications will undoubtedly mean that there will be more possibilities for exotic noxious species to enter the country and cause damage. It is, therefore, imperative to adopt a strategy, which integrates training, research and development endeavors for a holistic approach to the problem of weeds. A concerted effort is needed to build the research capacity required to control and manage weeds effectively. Any initiative to increase food production through improvement in current weed management practices must include an investment in having well trained weed scientists and ensuring that there will be funding for research and extension.

The management of weeds is an essential aspect of improving crop productivity within an economically viable agricultural system. However, researchers are confronted with the recurring challenge of developing appropriate and cost effective weed control technologies for subsistence farmers with low resource base, and small and fragmented land holdings. The average farmer has little or no resources and, therefore, can neither afford to take big risks nor go for technologies that require a lot of external inputs. A proper assessment of the prospects for improved weed management in low input farming systems should be pursued more strongly in the future.
### Table 16: Effect of improved management practices on Striga and sorghum at Sirinka

<table>
<thead>
<tr>
<th>Variety (V)</th>
<th>Striga count (Shoots/plot)</th>
<th>Grain yield (Kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degalit (local)</td>
<td>1229</td>
<td>4557</td>
</tr>
<tr>
<td>Birmash</td>
<td>1499</td>
<td>1810</td>
</tr>
<tr>
<td>SRN-39</td>
<td>157</td>
<td>1541</td>
</tr>
<tr>
<td>LSD (0.05) (V)</td>
<td>700</td>
<td>463</td>
</tr>
<tr>
<td>Management (M)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BC-F+HP</td>
<td>1440</td>
<td>2242</td>
</tr>
<tr>
<td>BC+F+HP</td>
<td>1407</td>
<td>2793</td>
</tr>
<tr>
<td>RP+F+HP</td>
<td>426</td>
<td>2210</td>
</tr>
<tr>
<td>RP-F+HP</td>
<td>831</td>
<td>2894</td>
</tr>
<tr>
<td>RP+F+2,4-D</td>
<td>702</td>
<td>3142</td>
</tr>
<tr>
<td>LSD (0.05) (M)</td>
<td>NS</td>
<td>463</td>
</tr>
<tr>
<td>LSD (0.05) (V x M)</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>CV (%)</td>
<td>104</td>
<td>23</td>
</tr>
</tbody>
</table>

Note: BC – broadcasting, RP – row planting, -F – without fertilizer, +F – fertilizer (41/46 N/P₂O₅)

Due emphasis should be given to the wealth of indigenous knowledge and build on those to develop more viable technologies that are within reach to the great majority of farmers. There are indications that many traditional and low input production systems have an ecologically sound basis and built-in risk aversion techniques. Akobundu (1998) stated that in many instances where scientists have had the patience to understand the principles on which smallholder farmers base their practices, these production practices have been seen to provide an important conceptual framework for small-scale production systems.
Table 17: Effect of improved management practices on Striga and sorghum at Adibakel

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Striga count (Shoots/plot)</th>
<th>Grain yield (kg/ha)</th>
<th>Biomass yield (Kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local</td>
<td>262</td>
<td>307</td>
<td>4793</td>
</tr>
<tr>
<td>ICSV-1006</td>
<td>42</td>
<td>621</td>
<td>2440</td>
</tr>
<tr>
<td>ICSV-1007</td>
<td>166</td>
<td>549</td>
<td>2527</td>
</tr>
<tr>
<td>SRN-39</td>
<td>80</td>
<td>453</td>
<td>2840</td>
</tr>
<tr>
<td>LSD (0.05) (V)</td>
<td>105</td>
<td>162</td>
<td>1149</td>
</tr>
<tr>
<td>Management (M)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BC-F+HP</td>
<td>198</td>
<td>381</td>
<td>2767</td>
</tr>
<tr>
<td>BC+F+HP</td>
<td>193</td>
<td>532</td>
<td>3042</td>
</tr>
<tr>
<td>RP+F+HP</td>
<td>92</td>
<td>564</td>
<td>3483</td>
</tr>
<tr>
<td>RP-F+HP</td>
<td>141</td>
<td>393</td>
<td>2642</td>
</tr>
<tr>
<td>RP+F+2,4-D</td>
<td>73</td>
<td>541</td>
<td>3817</td>
</tr>
<tr>
<td>LSD (0.05) (M)</td>
<td>117</td>
<td>181</td>
<td>NS</td>
</tr>
<tr>
<td>LSD (0.05) (V X M)</td>
<td>235</td>
<td>362</td>
<td>2569</td>
</tr>
<tr>
<td>CV (%)</td>
<td>80</td>
<td>35</td>
<td>39</td>
</tr>
</tbody>
</table>

Note: BC – broadcasting, RP – row planting, -F – without fertilizer, +F – fertilizer (41/46 N/P2O5)

The much desired national goal of addressing production shortfalls to ensure food security demands a holistic approach to minimize the impact of abiotic and major biotic factors such as weeds. Limited but valuable research results were obtained on which future endeavors could be based on. Concerted efforts have to be made to select and integrate compatible and effective technologies into packages that would enable to deal with the dynamic changes in weed flora, which will occur in the future due to changes in cropping and crop management practices.

References


5. Farmers Awareness Building on Integrated Pest Management (IPM) Options of Major Vegetable Pests in the Central Rift Valley Region of Ethiopia

Mohammed Y\textsuperscript{1}, Lemma D\textsuperscript{1}, Gashawbeza A\textsuperscript{1}, Aberra D\textsuperscript{1}, Adam B\textsuperscript{1}, Lidet S\textsuperscript{1}, Giref S\textsuperscript{1}, S. Sithanantham\textsuperscript{2}

\textsuperscript{1} Melkassa Agricultural Research Center PO. Box 436, Nazareth, Ethiopia; \textsuperscript{2} International Center of Insect Physiology and Ecology (ICIPE) PO. Box 30772 Nairobi, Kenya

Abstract

Vegetable growers in the central rift valley region of Ethiopia mainly use pesticides to combat pest problems. Irrational use of pesticides has aggravated the problem of pests through resistance development, development of new pests and decimation of natural controlling factors such as parasitoids, among others. Although some non chemical options of pest control are available for use, they have not been used by growers due to poor research, extension and farmers linkage. Experiences have showed that a participatory approach involving end users in technology generation and dissemination is the best way to combat production constraints.

A three years project was conducted between 1999 and 2001 by the Melkassa research centre of EARO in collaboration with the International centre of Insect Physiology and Ecology (ICIPE) to develop IPM options towards sustainable vegetable cultivation by small scale vegetable growers in Wonji area. This paper reports methodologies followed and achievements.

Introduction

Vegetables are important supplements to staple food and provide a regular source of income for small scale farmers living around the central rift valley region of Ethiopia (Lemma et al., 1994). Productivity of the crops is low, even below the world and African averages (FAO, 1989). Several biotic and abiotic factors are responsible for this of which pests (both insect and diseases) are among the most important. Although pesticide usage in crop production is minimal in Ethiopia, vegetable growers use large amount of pesticides to combat pest problems partly because of the commercial nature of vegetable production. However, pesticides are applied without adequate knowledge of the pest and the identity of the pesticide including dosage and frequency. This practice has made pesticidal control ineffective, encouraged development of pest resistance and decimated natural controlling factors such as parasitoids. A case in point is the problem of Diamondback moth, \textit{Plutella xylostella}, in cabbage production in Wonji area.

Some of the reasons for improper use of pesticides by growers include lack of knowledge on pest identification and use of the correct pesticide at the right dosage, among others. Non pesticidal control options such as biological, cultural and varietal control developed in research centers have not reached farmers because of a poor research-extension system. Efforts have been made at the Melkassa Research Center of EARO to develop IPM components for the management of major pests and some promising results have been reported (Tefsay and Habtu, 1985; Tsedeke and gashawbeza, 1994; Tsedeke and Gashawbeza,
1997). However, significant impact has not been made in mitigating the pest problems in farmers' fields. Experiences elsewhere have showed that a participatory approach involving end users in technology generation is the best way to combat vegetable production constraints (Sithanantham, 1998). The farmers' field schools approach has been successfully adopted to develop an IPM strategy by cotton and vegetable farmers in Sudan (Agriforum, 1998). This project was conducted to develop IPM options for sustainable vegetable cultivation by small scale vegetable growers through:

- Improving farmers’ perception of pest problems, knowledge of pest identification and damage caused through group learning.
- Building awareness on the safe and proper use of pesticides
- Identification of suitable options

**Methodologies**

Two farmers’ groups, each consisting of 17 members, were formed in two farmers villages called Melkahida and Kuriftu around Wonji (located at about 12 km west of Melkassa Research Center of the Ethiopian Agricultural Research Organization (EARO). Advisory panel members of different professionals were identified. Panel members included a vegetable breeder, an agronomist, weed scientist, a plant pathologist, an entomologist, an agricultural economist from the research centre and extensionists from the Ministry of Agriculture and a representative of each farmer’s group. Joint problem identification, group learning, and demonstration of pest management technologies and evaluation were made phase by phase during the three year period of the project. The main activities accomplished in each year were the following.

**Year 1**
- Farmers’ group identification/formation
- Survey of farmers’ needs/priorities
- Trainers’ training (For extensionists and farmers group representatives) on group learning methods and awareness building on IPM
- Awareness building of farmers groups through group learning on the need for rational pesticide use and scope for improved pest control

**Year 2**
- Trainers’ training on IPM options selected for testing/demonstration to farmers groups.
- Farmers participatory joint testing of selected IPM options for farmers groups

**Year 3**
- Validation of benefit of selected IPM options by individual farmers and sharing of experiences within the group
- Farmers group facilitation of follow-up for vegetable production
- Model evaluation and impact assessment.

**Survey of production constraints**

After the farmers’ group formation, survey was conducted by involving vegetable farmers and development agents to prioritize vegetable crops widely grown in the area and their major pests in the two locations. Twenty nine farmers were interviewed from the two farmers’ groups using a questionnaire.
**Trainers’ training**

Six farmers, three each from the two farmers groups together with extension agents and two horticulturalists attended the two days training on vegetable IPM both in the first and second years. There were both theoretical (lecture) and practical sessions. The following topics were covered by advisory panel members:

**Year 1**
- Farmers’ group learning and action approaches
- Nursery preparation and management
- Production of vegetables
- Post harvest handling of vegetables
- Marketing of vegetables
- Weed control in vegetable production
- Identification of diseases and insect pests of vegetables
- Pest management options
- Safe use of pesticides

**Year 2**
- Identification of insect pests and their management
- Identification of diseases and their management
- Identification of vegetable weeds and their management
- Improved vegetable varieties and their production techniques
- Seed bed preparation and seedling management
- Farm record keeping
- On-farm trials/demonstration

To assess the impact of the training on trainees’ knowledge and awareness, each of the trainee filled up a questionnaire before the training and the same questionnaire was given and filled up by the trainees at the end of the training.

**Diagnostic study of IPM options**

The criteria applied for assigning ranking scores included adequacy of research results, availability of inputs, potential for adoption by farmers, socioeconomic viability and experience gained elsewhere. Among the major target crops (tomato, cabbage and onion), a total of five insect pests and two disease pests were included for evaluating the different IPM options. The pests and diseases selected were fruit worms (*Phthorimaea operculella* and *Helicoverpa armigera*) and late blight in tomato; Diamondback moth (DBM) (*Plutella xylostella*) and cabbage aphids (*Brevicoryne brassicae*) on cabbage; onion thrips (*Thrips tabaci*) and purple blotch on onion.

**On-farm demonstration/evaluation of IPM options**

Options identified from diagnostic studies were included in the onfarm evaluation of the IPM options against the identified diseases and insect pests.

**Tomato fruit worms** – Fruit worms resistant varieties (Melka salsa and Melka shoal) and the commercial variety “Marglobe” were compared with need based insecticide application (karate 5% EC at 320 ml/ha applied once at early flowering and once at early fruit set) with routine pesticide application (farmers’ practice).
Thrips of onion – In this experiment need based insecticide application was compared with neem products (neem oil and seed extract) along with untreated check. The details of the treatments were the following: untreated check, karate 5% EC applied at 320 ml/ha, neem seed water extract 10% by volume, Neem oil (neemrock 0.03%) at 400 ml / ha.

Diamondback moth of head cabbage – The biological insecticide, Bacillus thuringiensis, neem products (neem seed powder, neem oil, neem seed extract), synthetic insecticides (karate, verat) and untreated check were tested.

Damping-off of tomato – Seed beds were solarized for 30 days using black polythene sheet and compared with non solarized bed for their effect on damping off incidence which is a major seedling disease of tomato and pepper. Seeding was made during the onset of rains (early July) which coincided with a peak period of damping off incidence. A back up on station trial was also conducted for damping off management at the Melkassa Research Center. Treatments were burning of seedbed using maize/sorghum stalks, hot water treatment, Apron star (seed dressing), and untreated check.

Results
Survey for production constraints
Major vegetable crops and pests prioritized are presented in Table 18. The survey result showed that most farmers recognized several pest and disease problems on their vegetables (tomato, onion, brassicas). They use a range of pesticides some of which are either banned or restricted in many countries. In general, they use pesticides as the only option to control disease and insect pests, and control in most cases was reported to be ineffective. They more often get advice from pesticide dealers and neighbours than extensionists. The information needs recognized by the majority of the farmers included:

- Exact identification of pests/ diseases, their symptoms and damage levels
- Exact choice of pesticides, dose and method of application; safe use of pesticides, and use of botanicals (eg. neem).

Table 18: Major vegetable crops and priority diseases and insect pests at Wonji

<table>
<thead>
<tr>
<th>Crops</th>
<th>Diseases</th>
<th>Insects</th>
<th>Weeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomato</td>
<td>Damping-off</td>
<td>Fruitworms</td>
<td>Orobanche spp.</td>
</tr>
<tr>
<td></td>
<td>Late blight</td>
<td>Spider mite</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Powedery mildew</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Onion</td>
<td>purble blotch</td>
<td>Onion thrips</td>
<td></td>
</tr>
<tr>
<td>Cabbage</td>
<td>Black rot</td>
<td>Diamondback moth</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cabbage aphids</td>
<td></td>
</tr>
<tr>
<td>Hot pepper</td>
<td>Wilt complex</td>
<td>_</td>
<td>_</td>
</tr>
<tr>
<td></td>
<td>Viruses</td>
<td>_</td>
<td>_</td>
</tr>
</tbody>
</table>

Trainers’ training
Trainees appreciated the training and expressed its usefulness in the management of pests of their vegetable crops. The impact of the training was good as evidenced by the magnitude of differences in the performance of the trainees in terms of answering the prepared questions before and after the training. Training handouts were prepared in the form of manual/leaf lets and provided to the trainees which will serve as a useful reference.
The participants also brought with them several specimens of pest/disease damage which were used in a practical session for identifying the insect pests and diseases.

**Diagnostic study of IPM options**

Based on the ranking scores (Table 19), the following options that can be tested and/or verified on farmers’ fields and/or on-station as back up trials were identified:

Use of resistant tomato varieties with insecticide application at critical growth stages (early flowering and early fruit set) against fruit worms

- Use of *Bacillus thuringiensis* and neem products against DBM
- Use of neem products against cabbage aphids and onion thrips
- Testing of recommended fungicides against late blight and purple blotch on onion.

In addition to options indicated by asterisks (Table 19), options for the management of damping off disease were included in the demonstration of IPM options based on farmers’ requests.

**Table 19: Diagnostic study results of IPM options of major disease and insect pests of major vegetable crops around Wonji, Ethiopia, 1998**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Pest/disease</th>
<th>Option</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomato</td>
<td>Fruit worms</td>
<td><strong>Chemical</strong></td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2*</td>
</tr>
<tr>
<td></td>
<td></td>
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<td>2</td>
<td>2</td>
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<tr>
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<td>3</td>
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<td>4</td>
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<td>3.25</td>
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<tr>
<td></td>
<td></td>
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<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Onion</td>
<td>Late blight</td>
<td><strong>Chemical</strong></td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
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<tr>
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<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Onion</td>
<td>Late blight</td>
<td><strong>Botanical</strong></td>
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<td>5</td>
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</tbody>
</table>
| On-farm demonstration of IPM options

<table>
<thead>
<tr>
<th>Crop</th>
<th>Pest/disease</th>
<th>Option</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomato</td>
<td>DBM</td>
<td><strong>Chemical</strong></td>
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<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
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<tr>
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<td></td>
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<td>4</td>
<td>3</td>
<td>3</td>
<td>3</td>
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<tr>
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<td></td>
<td><strong>Biological</strong></td>
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<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Botanical</strong></td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2.6*</td>
</tr>
<tr>
<td>Cabbage</td>
<td>Aphid</td>
<td><strong>Chemical</strong></td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2.6*</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Varietal</strong></td>
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<td>5</td>
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<tr>
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<td></td>
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<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2.6*</td>
</tr>
</tbody>
</table>

* = Options to be tested on farm

**Criteria:**
- A = Adequacy of research result,
- B = Input availability,
- C = Potential for impact,
- D = Socioeconomic viability,
- E = External experience

**Score:**
- 1 = Excellent, 2 = Very good, 3 = Good, 4 = Satisfactory, 5 = Not satisfactory
- NA = Not applicable

Tomato fruit worms – Owing to the absence of appreciable difference between routine pesticide application (which is farmers’ practice) and application of lambda cyhalothrin (Karate 5 % EC) at critical stages of fruit worm infestation, farmers realized the benefit of need based application through, the reduction of pesticide costs. Serio had the lowest infestation and provided the highest yield.
Thrips of onion – Neem seed extract reduced the population of onion thrips although its effect in reducing the damage or minimizing yield loss was not as good as the synthetic insecticide, Lambda cyhalothrin (Karate) 5EC.

Diamond back moth of head cabbage – Neem seed kernel insecticide and the microbial insecticide, Bacillus thuringiensis (Bt) significantly reduced damage due to Diamondback moth. On the other hand plots treated with the commonly used pesticide, karate were as heavily damaged as the untreated plots. This could be due to the fact that the pest has developed resistance to the insecticide.

Damping-off of tomato – Seedling establishment percentage was higher and level of weed infestation was lower in solarized bed than non-solarized ones. From the back up on station trial, lower percentage of damping off incidence and higher seedling vigor were recorded from beds burned with maize/sorghum stalks than the rest.

Lessons learnt from the project
As an integral component of crop improvement program, researchers of crop protection have developed technologies that can help mitigate problems of insect and diseases in crop production. However, unlike varietal technologies, which can easily be transferred to farmers, crop protection technologies have not reached farmers to the level required by growers. This is due to poor research extension and farmer linkage. Growers mainly use information from pesticide retailers whose interest is mainly to sell the products available in their store. This has created pesticide abuse and has increased the magnitude of pest problems. This in turn has created a good opportunity to understand farmers’ needs and to implement the project activities through active participation of farmers’ group. The major lessons of the project include:

• Farmers’ groups can be motivated and actively participate if the project is developed based on their needs.
• Farmers’ group members could identify major pest diseases of vegetable crops they are cultivating.
• Farmers are aware of a range of pesticide groups for pest management and their rational use in vegetable pest management.
• Farmers are aware of the existence of natural controlling factors such as parasitoids and the care to be taken in order to use them as a component of IPM.
• Farmers are aware of the availability of non chemical options of pest control and the benefit that can be obtained from the options demonstrated on farm that is:
  - Availability of resistant variety for tomato fruit worm management
  - Use of botanicals and biological products for DBM management on cabbage
  - Use of solarization for damping off management
• The approach employed was found to be time and resource demanding as it required frequent visits of farmers’ groups.
• Unavailability of registered pesticides in the shops of nearby pesticide retailers was the major reason for use of banned or restricted pesticides by most vegetable farmers

Conclusion
The approach followed to develop awareness among vegetable growers on development of IPM options was a regional program designed by ICIPE. Traditionally, researchers in crop protection in Ethiopia report results of on station experiments at conferences and/or publish in
Efforts to transfer crop protection technologies were minimal due to poor research-extension-farmers linkages. This is probably the first experience in developing crop protection technologies, IPM in particular, through a participatory approach in Ethiopia although it is difficult to say that the principles of the approach have been met (Kindu et al. 2002).

Besides demonstrating pest management options and enabling farmers (users of these options), the achievements obtained in empowering farmers to undertake research activity would contribute significantly to explore the indigenous knowledge the farmers have in pest management. The interaction developed among stakeholders, farmers and researchers in particular, would help strengthen close collaboration in future similar work.

It is felt that a participatory research approach be given attention to address pest problems in crop production and the experiences gained from this small project would help to strengthen the participatory research approach in pest management in Ethiopia.

References


6. Status of Forest Diseases in Ethiopia

Alemu Gezahgne
Forestry Research Directorate, EARO

Abstract
Fungal pathogens pose serious damage on trees both in natural forests and plantations. In Ethiopia little information is available on tree diseases. This paper attempts to provide an overview of some fungal pathogens recorded in forests of Ethiopia. Several important fungal pathogens are reported on indigenous tree species. Armillaria root rot is the most common disease, mainly associated with *Acacia abyssinica* and *Juniperus exelsa*. Heart rots and butt necrosis caused by *Antrodia juniperina* are also reported on *Juniperus exelsa*. Several decay fungi including *Hymenochaete ochromarginata* and *Phellinus ferruginosus* affect *Hagenia abyssinica* in natural stands. A number of Corticioid fungi are also isolated from branches and stems of *H. abyssinica*.

A number of diseases are also recorded on several exotic species. Armillaria root rot is found on *Pinus patula*, *Cordia alliodora* and *Cedrela odorata* trees. *Sphaeropsis sapinea* is another major fungal pathogen of *Pinus* spp. in many places. Stem cankers (*Botryosphaeria* spp.) are common on *Eucalyptus globulus*, *E. saligna* and *E. citriodora*. Another stem canker disease associated with a *Coniothyrium* sp. is frequently observed on *E. camalduleensis*. Moreover, cankers (*Cytospora* spp.) and pink disease (*Erythricium salmonicolor*) are also recorded on *Eucalyptus* in some plantations. Leaf blotch (*Mycosphaerella* spp.) is common on *E. globulus* in most areas where this species is grown. This report, therefore, argues that fungal diseases are important in the Ethiopian natural and plantation forests and developing appropriate integrated control measures is essential.

Introduction
In Ethiopia, wood provides 85% of the country’s energy requirements and is used for construction purposes. While the demand for forest products is rapidly increasing, necessitating the establishment of plantations of rapidly growing trees, the natural forest resources are diminishing rapidly (Anonymous 1994). Plantation forests can be developed using either exotic or native tree species. However, there is a growing global trend towards the establishment of exotic tree species especially in tropics and subtropics (Evans 1984, Tunbull 1991, Persson 1995). In Ethiopia, the introduction of fast growing exotic tree species took place about a century ago, with the introduction of *Eucalyptus globulus* Labill in the late 1890’s (Amare *et al.* 1990, Persson 1995).

To meet the increasing demands for wood and wood products, both natural and plantation forests have to be protected. Threats against these wood sources include fire, indiscriminate cutting, encroachment, pests and diseases. The occurrence of pathogens on woody plants is a common phenomenon on trees growing in natural forests, plantations and ornamental trees resulting in serious losses to forestry products worldwide (Manion 1981, Wingfield 1990). Fungal pathogens cause the most diseases of trees; and there are many examples of such diseases world-wide. Chestnut, which is one of the major forest species in North America, has been nearly eliminated by the Chestnut blight fungus, *Cryphonectria parasitica* (Murr.) Barr (Anagnostakis 1987). Dutch elm disease caused by *Ophiostoma ulmi* (Busim.) Nannf. and
Ophiostoma novo-ulmi Brasier have devastated native elm trees in Europe and North America (Brasier 1990). White pine blister rust, caused by Cronartium ribicola Fischer, has greatly affected the production of white pines in America (Ziller 1974). Dothistroma needle blight caused by Dothistroma pini Hulbury (syn. = D. septospora), which was initially identified in the United States of America, occurs in eastern and southern parts of Africa, South Africa, Chile, Australia and New Zealand and devastated exotic P. radiata plantations in these countries (Gibson 1972, 1975). Because of this disease, planting the fast-growing Pinus radiata had been abandoned in several Eastern, Central and Southern African countries (Gibson 1972, Ciesla, Mbugua & Ward 1995). Attempts have been made to substitute P. radiata by slower growing P. patula. However, P. patula has been subsequently affected by the interacting hail damage and Sphaeropsis sapinea (Fr.) Dyko & Sutton in South Africa (Swart et al 1987). Similarly, Cupressus macrocarpa Hartw that showed remarkable growth in Kenya and other East African countries has been abandoned due to cypress stem canker caused by Seiridium cupressi (Guba) Boesew (Gibson 1964, Rudd 1953). As a result, the slow growing C. lusitanica Mill. has been introduced to the region as an alternative species.

Diseases have also negatively affected the planting of Eucalyptus spp. in Africa. For example, the threat from Mycosphaerella leaf blotch on E. globulus, E. nitens (Deane et Maid.) Maid. and E. maidenii F. Muell. has restricted planting these species in many parts of Africa (Lundquist & Purnell 1987). Likewise, E. fastigata Deane et Maid. and E. fraxinoides Deane et Maid., which initially performed well in frost prone areas of South Africa, have been abandoned due to a root disease caused by Phytophthora cinnamomi Rands (Linde et al 1994).

In Ethiopia, little information is available on diseases of forest trees and usually death of trees is ascribed to abiotic agents. The role of biotic factors seem to be underestimated, or poorly understood and has received very little attention. This paper attempts to highlight diseases recorded in some forests of Ethiopia.

**Diseases recorded on some indigenous tree species of Ethiopia**

There are some reports that deal with diseases of native tree species in Ethiopia. The results of one of these studies indicated the occurrence of Antrodia juniperina (Murrill) Niemela & Ryvarden on Juniperus exelsa and J. procera. The pathogen is reported to cause heart rot with intensive brown cubical rot of the wood and necrosis of the butt in J. exelsa (Niemela & Ryvarden 1975). Niemela, et al (1998) recorded several wood decay fungi in natural stands of Hagenia abyssinica (Bruce) J. F Gmel. in the Eastern Africa including Ethiopia. The fungus Hymenochaete ochromarginata Talbot, collected from living trunks and stumps, is considered to be the main decayer of living Hagenia trees. Other wood rot fungi include Phellinus ferruginosus (Schrad. Fr:) Bourdot and Galizin and Trametes socotrana Cooke were identified from fallen branches and stems. Their role in causing diseases to Hagenia sp., is questioned, however, as they are not generally considered to be primary pathogens. A number of Corticioid fungi have also been recorded from H. abyssinica branches and stems. These include Asterostroma medium Bres., Cystidiodontia isabellina (Berk. and Broome) Hjortstam and Dichostereum kenyense Boidin and Lanq (Niemela et al 1998).

Armillaria root rot was found associated with dying Acacia abyssinica trees at Wondo Genet and Bedele. The causal agent was identified as Armillaria fusicpes and its fruiting body was also found on stumps of Juniperous exelsa (Alemu et al. 2003a). Another species, Armillaria mellia, was also reported to cause root rot on a number of hardwoods in Jima area (Otta et al. 2000).
Diseases in plantation forests of Ethiopia

Several root diseases, stem cankers and leaf diseases were recorded in some plantations of Ethiopia (Alemu et al. 2003b). Some of these diseases are summarized below.

**Armillaria Root Rot** – Armillaria root rot was commonly found in association with tree death of *P. patula* in Wondo Genet, Belete and Bedele forests. Armillaria root rot was also found in association with dead and dying trees of *Cordia alliodora* (Ruiz & Pav.) Oken. and *Cedrella odorata* L. in a research plot near Aman (Alemu et al. 2003b). Symptoms were typical of those known for the disease and included death of trees in groups, wilting and yellowing of the crowns, the growth of white mycelial fans between the bark and the wood, as well as the occurrence of rhizomorphs on barks of the infected trees. *Armillaria fusicpes* was the fungus involved in causing Armillaria root rot in these plantations (Alemu 2003, Alemu et al. 2003a). *Armillaria* spp. are known world-wide to cause root rot on a wide range of tree species both exotic and native (Shaw and Kile 1991).

**Stem cankers** – The most common disease observed on *Eucalyptus* spp. in Ethiopia was stem canker caused by *Botryosphaeria* sp. (Alemu 2003, Alemu et al. 2003b). The symptom included bark-cracking, production of copious amounts of kino, stem discoloration, malformation, and the production of kino pockets in the xylem. At Wondo Genet this canker was found on *E. saligna* Sm., *E. grandis* Hill ex Maid., *E. citriodora* Hook and *E. globulus*. At Munessa-Shashemene, it was observed on *E. globulus*, both on coppice and first generation stands, as well as on mature *E. saligna* trees. Stem cracking and kino exudation was observed over the entire length of stems of affected trees at the two sites.

In the Jimma area, similar disease symptoms were observed on *E. citriodora* and *E. saligna*. The damage was most severe on *E. citriodora* and not less than 50% of the trees in the plantation near Jima were symptomatic, but death of trees was not observed. The disease in these areas was characterised by black discoloration and cracking of stems, starting at ground level up to approximately one metre high. When the bark was removed, the cambium was completely discoloured and soaked with kino. Two or three layers of black lines were observed in the wood indicating different seasons of infection. At Menagesha symptoms of stem canker were commonly found on several coppice stems of *E. globulus* that was either wilting or dead.

*Botryosphaeria* spp. are cosmopolitan in distribution and are found on many other different hosts (Barnard et al. 1987, Smith et al 1994). They are considered to be opportunistic wound and stress related pathogens (Pusey 1989, Smith et al 1994). Environmental stress such as drought and frost provide favourable conditions for the disease development. *Botryosphaeria* spp. are also known as endophytes and are found in healthy plant tissues (Smith et al 1999). This pathogen seems to cause poor growth of coppice sprouts of *E. globulus* and most likely contributes to the failure of coppice development. Regenerating *Eucalyptus* spp. by coppicing is widely practised in Ethiopia, and further investigation is needed to determine the association of the stem canker with poor growth and coppice failure.

A recent study showed that a stem canker caused by *Coniothyrium zuluence* seriously affected *E. camaldulensis* in Jiren plantation at Jima and on trees grown between Jima and Woliso, as well as between Wolkite and Sodo (Alemu 2003, Alemu et al. 2003). At least 50% of the trees in a stand were affected. Initial symptoms of the disease include small discrete lesions on young green bark. Patches of large necrotic lesions later developed on stems, branches and twigs. Stems often showed a reddish colour due to the exudation of kino from the cracks and the wood of such affected stems showed the formation of pitted kino pockets. Several of the
infected trees produced epicormic shoots. As a result, the disease produces extensive stem malformations and in severe cases it results in death of trees.

Coniothyrium canker is considered to be one of the most important threats to *Eucalyptus* plantation world-wide. There is a great concern of this disease affecting many *Eucalyptus* spp. in Ethiopia and Eucalyptus clones and hybrids in South Africa, Thailand and Mexico (Wingfield et al. 1996, Van Zyl et al. 2002, Roux et al. 2002). The disease not only complicates debarking, but also affects the quality of sawn timber.

Pink disease is another type of stem canker caused by *Erythricium salmonicolor* (Berk & Broome) Burds (Syn. *Corticium salmonicolor* Berk & Br). Stem canker caused by pink disease was observed on *E. camaldulensis* planted around Pawe in the Benshangul Gumuz region. (Alemu et al. 2003c, Alemu et al. 2003c). Branch die-back, stem cankers, branch and stem girdling, production of epicormic shoots on the stems, death of trees, as well as production of pink mycelial growth on the stems, are characteristic symptoms of pink disease. The fungus produced typical flat/resupinate fruiting structures on the surface of affected stems. Infection by *Erythricium salmonicolor* causes the inner tissue of the bark, mainly the phloem and the cambium, to become brown and eventually die (Sharma et al. 1988).

Pink disease is common in the tropics, affecting a wide range of hosts including *Eucalyptus* spp., coffee, rubber, cacao, tea, *Acacia* and *Podocarpus* spp. (Gibson 1975, Roux et al. 2001). In temperate areas of South Africa, pink disease has been reported on *E. macarthurii* and *E. cloeziana* (Roux et al. 2001). The discovery of pink diseases on *E. camaldulensis* in Ethiopia is a great concern and studies on the distribution and host range of the pathogen are required.

**Leaf disease** – Leaf blotch, spots or blights caused by *Mycosphaerella* spp., is widely distributed and is important on *Eucalyptus* world-wide. It causes defoliation on *E. globulus* and *E. nitens* (Lundquist & Purnell 1987, Park & Keane 1982). Thirty-two *Mycosphaerella* spp. have been described in association with leaf blotch of *Eucalyptus*, of which 12 have been recorded in the African continent (Crous 1998, Carnegie 2000, Milgate et al. 2001, Hunter et al. 2003).

Leaf blotches were commonly observed on *E. globulus*, wherever this species is grown in Ethiopia. The symptoms observed are characteristic of those caused by *Mycosphaerella* spp. and in many cases resulted in defoliation of young trees. Isolation and identification from leaves with blotch symptom consistently yielded three *Mycosphaerella* species namely, *M. nubilosa*, *M. grandis* and *M. marksii* (Alemu 2003).

**Other fungi** – Several other fungi, known to be associated with tree diseases elsewhere in the world, were found in *Pinus* and *Eucalyptus* plantations in Ethiopia, although they appeared to be relatively unimportant. For example, *Sphaeropsis sapinea* was isolated from pine cones collected from Wondo Genet and Munessa-Shashemene forests. *Cytospora spp.*, *Fusarium graminearum* Schwabe and *Cylindrocladium spp.* Morgan were also isolated from *Eucalyptus* branches collected from Wondo Genet, Wolkite and Menagesha. *Phaeophleospora eucalypti* (Cooke & Massee) Crous, F.A Ferreira & B. Sutton was common on *E. camaldulensis* and *E. grandis* leaves, in all areas examined.

**Insect Pests**
In addition to diseases, insect pests are important both in nurseries and in forests. Some insects attack the root system, and cause wilting and death of plants. Others cause defoliation,
shoot die-back, girdling of the stem and attack on seeds. There are insects that are involved in transmitting plant disease that cause considerable damage to trees.

In Ethiopia, only limited research had been conducted in areas of forest insects. Hill (1989) recorded several insect pests on Eucalyptus spp. and Acacia spp. Demelash (1991) reported psyllid attacking E. globulus. Termites are important insect pests in forestry and a study indicated that insecticide treatment has controlled termites and has improved the survival of Eucalyptus species (Amsalu 1991).

Conclusions
This paper presents very little information due to the fact that very limited work has been done on forest pests and diseases in Ethiopia and that not that much information is available on the impact of forest pest on the development of forestry. Even though many problems of disease and insect pests have been observed on tree seeds, in nurseries, in plantations and on wood products little work has been conducted to identify and understand their biology, distribution, and magnitude of damage caused. There is a need for reorganizing and strengthening the forest protection research in the country with the necessary facilities and trained human power. There is also a need for compiling and documenting the existing scanty information on forest tree protection in the country. This helps to devise integrated pest management measures that are urgently needed for the control of some important pests and diseases. Detailed studies should continue however, to better understand major forest pests and diseases and devise more sound management options.

References


7. Major insect pests, diseases and weeds on major crops at the Upper Awash Agro-Industrial Enterprise

Bezawork Mekonnen
Upper Awash agro industry enterprise,
P.O. BOX 12624, Addis Ababa, Ethiopia.

Abstract
Upper Awash Agro industry Enterprise, one of the organizations engaged in the production of horticultural crops, produces quality fruits and vegetables for both local and foreign markets. It occupies a total area of 7497 ha of land of which 6903 ha are cultivated under four farms (Merti jejeu, Nuraera, Tibila & Awara Melka). Even though the enterprise produces a variety of crops, insects pests (citrus leaf miner & thrips, onion thrips, fruit flies, false codling moth), diseases (Phytophthora, powdery mildew, bean rust, nematodes), the parasitic weed Orobanche on tomato and other diseases not yet identified are among the major constraints highly hindering the enterprise from utilizing its full potential. Chemical control is the main method employed to combat pests in the enterprise. However, it is known that over reliance on pesticides may lead to problems sooner or later. Thus, there is a need to implement Integrated Pest Management. However implementing IPM is not possible without proper identifications of the existing problems, evaluation of the current practices and design of new interventions. In this paper the major pest problems of the enterprise which seek solutions and the current practices of pest management are described.

Introduction
Upper Awash Agro-industry Enterprise is one of the suppliers of fresh and processed fruit and vegetable products both to domestic and foreign markets from its four farms and one processing plant. The main objectives of the enterprise are to contribute its share towards the food self-sufficiency national effort and to generate foreign currency. The enterprise is located about 176 km SE of Addis Ababa [8°37’N Lat. & 39°43’E Long.] at an elevation of 1200 m (Merti, Nuraera, Tibila) and 750 m (Awara Melka).

The farms of the enterprise have soil types intergraded between vertisol, xerosol and fluvisol with a pH ranging from 8.1 to 9.1. The majority of the soil has loam texture. The area is characterized with high temperature which is suitable for production of tropical fruits and vegetables. The enterprise owns a total area of 7497 ha out of which 6903 ha is cultivable (Table 20). The amount of rainfall is low and unreliable thus, production is mainly conducted through irrigation. At Tibila there is some rain fed production and the other farms are totally dependent on irrigation. The enterprise produces 25 different crops among which citrus is the most important and occupies 19 % of the total enterprise area and 56 % of the total production area (Table 22).
Table 20: Description of the temperature and rainfall of the Enterprise area

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<th>Air temperature (°c)</th>
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<th>Range</th>
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<tr>
<td>Minimum</td>
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<td>Annual mean</td>
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<td></td>
</tr>
<tr>
<td>Rainfall (mm)</td>
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<td>41.9-1448.1</td>
</tr>
</tbody>
</table>

Table 21: Area (ha) holdings of the enterprise and its use

<table>
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<tr>
<th>Farm</th>
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<td>--------</td>
<td>953</td>
<td>135</td>
</tr>
<tr>
<td>Mertijeju</td>
<td>2010</td>
<td>--------</td>
<td>118</td>
<td>79</td>
</tr>
<tr>
<td>Awara Melka</td>
<td>862</td>
<td>--------</td>
<td>97</td>
<td>271</td>
</tr>
<tr>
<td>Tibila</td>
<td>1334</td>
<td>420</td>
<td>113</td>
<td>3.5</td>
</tr>
<tr>
<td>Total Area</td>
<td>6483</td>
<td>420</td>
<td>1281</td>
<td>488.50</td>
</tr>
</tbody>
</table>

Table 22: Crops grown and factory products of the Upper Awash Enterprise

<table>
<thead>
<tr>
<th>Crops</th>
<th>Fruits: Orange, Lime, Lemon, Grape fruits, Mango, Banana, Guava, Papaya, and Avocado</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vegetables: Processing tomato, Onion, Green chilies, etc</td>
</tr>
<tr>
<td></td>
<td>Export crops: Beans, Melons, Okra, Alliums flower, Passion fruit.</td>
</tr>
<tr>
<td></td>
<td>Industrial crops: Grape vine, Cotton, Maize.</td>
</tr>
<tr>
<td></td>
<td>Seeds: Maize, Onion, Popcorn, etc</td>
</tr>
<tr>
<td></td>
<td>Factory Products: Tomato paste, Tomato juice, Orange marmalade Orange squash, Guava nectar, etc</td>
</tr>
</tbody>
</table>

Major production constraints of Upper Awash
Lack of improved varieties, low onion seed yield, chlorotic phenomenon on citrus, optimum spacing of the perennial tree crops, lack of knowledge on applying optimum amount of water according to the requirement of crops are among the many problems the enterprise is currently facing. However, insect pests, diseases and weeds are major problems causing high economic losses. Pesticides are the main methods of pest control (Table 23). Some chemicals
like Thiodan, Malathion and Diazinon have been used for many years. Spraying of DDT has been stopped for more than a decade. On the other hand, there are several insect pests, diseases and weeds which are not satisfactorily managed.

**Major pest problems and the current practices**

Fruitflies are among the most important insect problems in the enterprise. The only method employed to combat fruit flies is sanitation. Infested fruits are collected and retained in barrels containing water for no less than two weeks. To successfully reduce the population of the fruitflies with sanitation methods, there is a need to weekly collect and destroy infested fruits. However, such complete practice of sanitations is not easy because of large farm sizes. The same method is also used to reduce the damage caused by false codling moth. The annual loss by fruit flies and false codling moth on oranges and mandarin is about 15,000 Quintal which amounts to about 1,868,333 Birr. The damage of fruit flies on Guava is so serious and it is becoming very difficult to harvest undamaged fruits for processing.
Table 23: Economic pests in Upper Awash Agro industry Enterprise and pesticides use

<table>
<thead>
<tr>
<th>Pests</th>
<th>Crops</th>
<th>Pesticides</th>
<th>Past</th>
<th>Present</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scale insects</strong></td>
<td>Citrus &amp; Avocado</td>
<td>Cidil, Ultracide, Diazinon</td>
<td>Suprathion,</td>
<td>Ultracide, Diazinon</td>
</tr>
<tr>
<td><strong>Thrips</strong></td>
<td>Onion, Pepper, Cotton, Mango, Grapevine</td>
<td>Novacron, Thiodan, Dimecron</td>
<td>Karate, Thiodan</td>
<td></td>
</tr>
<tr>
<td><strong>Sucking pests</strong></td>
<td>Beans, Cotton, Tomato, Citrus, Maize, Pepper, Tomato, Pepper, Passion fruit, Melon &amp; Okra</td>
<td>Rogor, Malathion, DDT</td>
<td>Deltanet, Marshall, Mitigan, Mitac</td>
<td></td>
</tr>
<tr>
<td><strong>African boll worm</strong></td>
<td>Cotton, Tomato &amp; Beans</td>
<td>DDT</td>
<td>Karate, Thiodan</td>
<td></td>
</tr>
<tr>
<td><strong>Powdery mildew</strong></td>
<td>Mango, Grape Vine, Pepper, Tomato &amp; Melon</td>
<td>Mancozeb, Bayleton</td>
<td>Bayleton</td>
<td></td>
</tr>
<tr>
<td><strong>Rust</strong></td>
<td>Beans, Maize</td>
<td>Mancozeb, Bayleton</td>
<td>Bayleton</td>
<td></td>
</tr>
<tr>
<td><strong>Blight</strong></td>
<td>Tomato, Beans, Maize</td>
<td>Mancozeb</td>
<td>Ridomil MZ, Kocide 101</td>
<td></td>
</tr>
<tr>
<td><strong>Weeds</strong></td>
<td>Perennials</td>
<td>Roundup &amp; hand weeding</td>
<td>Glyphosate 360SL &amp; hand weeding</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Annuals</td>
<td>Weeding &amp; cultivation</td>
<td>Weeding &amp; cultivation</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pesticides</th>
<th>Past</th>
<th>Present</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cidil</td>
<td>Diazinon</td>
</tr>
<tr>
<td></td>
<td>Novacron</td>
<td>Thiodan</td>
</tr>
<tr>
<td></td>
<td>Rogor</td>
<td>Malathion, DDT</td>
</tr>
<tr>
<td></td>
<td>Deltanet</td>
<td>Marshall, Mitigan, Mitac</td>
</tr>
<tr>
<td></td>
<td>Mancozeb</td>
<td>Bayleton</td>
</tr>
<tr>
<td></td>
<td>Mancozeb, Bayleton</td>
<td>Bayleton</td>
</tr>
<tr>
<td></td>
<td>Ridomil MZ, Kocide 101</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Roundup &amp; hand weeding</td>
<td>Glyphosate 360SL &amp; hand weeding</td>
</tr>
</tbody>
</table>
Table 24: Pest problems without satisfactory management practices

<table>
<thead>
<tr>
<th>Pests</th>
<th>Type of crops</th>
<th>Management methods tried</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruit flies</td>
<td>Citrus &amp; Guava</td>
<td>Sanitation (collect and bury infested fruits)</td>
</tr>
<tr>
<td>False codling moth</td>
<td>Citrus &amp; Guava</td>
<td>Sanitation</td>
</tr>
<tr>
<td>Thrips</td>
<td>Citrus</td>
<td>At experimental stage</td>
</tr>
<tr>
<td>Leaf miner</td>
<td>Citrus</td>
<td>At experimental stage</td>
</tr>
<tr>
<td>Gray mold</td>
<td>Beans</td>
<td>No control method</td>
</tr>
<tr>
<td>Leaf lesion or burn</td>
<td>Onion</td>
<td>No control method</td>
</tr>
<tr>
<td>Phytophtora root rot</td>
<td>Citrus, papaya,</td>
<td>Ridomil SG, Sanatar SM, pruning</td>
</tr>
<tr>
<td>Nematode</td>
<td>Citrus, Melon, Banana</td>
<td>No control method</td>
</tr>
<tr>
<td>Fruit drop/abortion</td>
<td>Citrus</td>
<td>No control method</td>
</tr>
<tr>
<td>Orobanche</td>
<td>Tomato</td>
<td>Cultural practices, Trials</td>
</tr>
<tr>
<td>Parthenium</td>
<td>On fallow land &amp; around the field</td>
<td>Cultural practices</td>
</tr>
</tbody>
</table>

Thrips and leaf miners are other insect problems becoming increasingly important on citrus. Thrips scarify the developing fruits and as the fruit matures the scarified place enlarges, sometimes covering a very large place on the fruit, rendering it unfit for export.

The leaf miner problem is increasing at the enterprise. Assessment conducted on the level of infestation in the year 2000 showed that the insect is prevalent throughout the year and as high as 90% of the citrus trees may show the damage. On each tree, up to 38% of the leaves could be damaged (Table 25).

Onion is among the vegetable bulb crops produced in the enterprise and onion thrips (*Thrips tabaci*) are the major problems on this crop. Preliminary assessments conducted from 2001 to 2003 indicated that the insect is more serious in the month of March compared to December (Table 26). It is known that hot and dry conditions favor the rapid population build up of *Thrips tabaci*. The month of December is relatively cooler than the following months and it could be due to the temperature variations that higher populations of the insects were recorded in the month of March.
Table 25: Extent of infestation of citrus by the citrus leaf miner at upper Awash

<table>
<thead>
<tr>
<th>Month</th>
<th>No of infested trees</th>
<th>% leaves infested*</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 2000</td>
<td>80</td>
<td>17</td>
</tr>
<tr>
<td>Jun. 2000</td>
<td>58</td>
<td>18</td>
</tr>
<tr>
<td>Jul. 2000</td>
<td>58</td>
<td>23</td>
</tr>
<tr>
<td>Aug. 2000</td>
<td>75</td>
<td>30</td>
</tr>
<tr>
<td>Sep. 2000</td>
<td>87</td>
<td>26</td>
</tr>
<tr>
<td>Oct. 2000</td>
<td>42</td>
<td>35</td>
</tr>
<tr>
<td>Nov. 2000</td>
<td>25</td>
<td>16</td>
</tr>
<tr>
<td>Dec. 2000</td>
<td>92</td>
<td>38</td>
</tr>
</tbody>
</table>

* Data presented are average values from 24 trees.

Table 26: Onion thrips level of infestations on onions in the Upper Awash Enterprise

<table>
<thead>
<tr>
<th>Date</th>
<th>% infestation</th>
</tr>
</thead>
<tbody>
<tr>
<td>December 2001</td>
<td>10 – 15</td>
</tr>
<tr>
<td>January 2002</td>
<td>15- 40</td>
</tr>
<tr>
<td>February 2002</td>
<td>55- 75</td>
</tr>
<tr>
<td>March 2002</td>
<td>85</td>
</tr>
</tbody>
</table>

The parasitic weed Orbobanche has become a threat to tomato production in the enterprise. It has invaded 600 ha of the cultivated land and efforts to uproot orobanche by hand cost the enterprise 30000 Birr within three years. The Productivity of Orobanche infested field is as low as 84.21 quintal/ha as compared to yield from normal which reaches 290 Q/ha on average. There are some trials being conducted by researchers of the Ethiopian Agriculture Research Organization. The Enterprise mainly depends on cultural practices like uprooting by hand, crop rotation, irrigation water management, and fertilizer to combat this weed.

The introduced Parthenium is very abundant in the area and in some farms densities of the weed reached > 162 plants/m² (Table 8). Currently more than one thousand hectares of land
are invaded with Parthenium. The Enterprise spent about 50 000 Birr for the management of this weed in three years.

<table>
<thead>
<tr>
<th>Year</th>
<th>Area (ha) invaded</th>
<th>Man days for control</th>
<th>Costs (Birr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>91/92</td>
<td>125.42</td>
<td>266.50</td>
<td>988.00</td>
</tr>
<tr>
<td>92/93</td>
<td>6655.00</td>
<td>9924.00</td>
<td>37,367.50</td>
</tr>
<tr>
<td>93/94</td>
<td>1150.00</td>
<td>3383.00</td>
<td>12,688.00</td>
</tr>
<tr>
<td>Total</td>
<td>7930.42</td>
<td>13,573.50</td>
<td>51,043.50</td>
</tr>
</tbody>
</table>

**Conclusion**

The Enterprise has suitable land and water which enables it to produce a diversity of crops both for domestic and foreign markets. But the expansion of production and profitability is hampered by a range of limiting factors among which insect pests, diseases and weeds are the major ones. Currently, the enterprise is mainly dependent on pesticides and it is known that over reliance on pesticides create many problems. In addition, it will become difficult to export produces protected with the types of pesticides in current use. There are some “disease problems” for which the causative agents are not yet known and for most of the identified pests there are no satisfactory management methods. Therefore, measures have to be taken to critically evaluate the constraints of production and strengthen the research undertakings in the enterprise. The enterprise calls researchers to engage in the above serious pest problems which are threatening the existence of the Enterprise.
8. **Storage Systems and Pest Management Practices in Small-scale Agriculture in Ethiopia**

Teshome Lemma  
Ministry of Agriculture and Rural Development  
PO Box 62347, Addis Ababa, Ethiopia

**Introduction**

Ethiopia is a country with a long history of agriculture. The country endowed with a wide range of climates emanating from it additional variations and hence a diversity of crops have been under cultivation for generations in these varied agricultural zones. Consequently, the rural communities have got a rich heritage of traditional farming practices accumulated over years of experience and that is of indispensable value in the currently existing farming systems.

Among these are the various grain storage methods, which have evolved through the continuous environmental and socio-economic changes that took place in the course of time. The merits of each method are thus closely linked with the present social and environmental factors within the area they are in use.

The great majority of crop harvest in Ethiopia, as in any developing country, is stored on the farm in small quantities. On the other hand, the availability for consumption of farm-stored produce largely depends on the virtue of the traditional storage systems which have got two major aspects: the storage structures and management practices. The nature of the structures mainly varies with respect to the materials they are made from, the type and amount of produce they can accommodate and their location. The management practices, although influenced by the nature of the storage structures, are largely dependent on various environmental factors and the tradition of the society.

This article briefly describes the four most dominant traditional grain storage systems and the pest management practices that are used in small scale agriculture in Ethiopia.

1. "Gota" is an indoor grain storage structure made from a mixture of mud, cowdung and straw. Although this cylindrical container can be moulded in one continuous piece, most frequently it is built up of a series of segments made in the form of rings which are fitted one on top of the other to a required size. The structure can therefore be taken to pieces and reassembled elsewhere. A gota can be made up of as many as 12 or more rings locally called "dengel" and can have a height of up to three meters with holding capacity of up to 20 or more quintals of grain. It is placed in the living house, usually adjacent to the fire place, slightly raised from the ground on a small platform constructed with stone and mud. The placement of the structure close to the heat is believed to facilitate grain drying while the raising from the ground is meant for the protection against moisture migration and termite damage.

Grain is filled progressively as the structure is built up by fitting one ring on top of the other step by step and a lid called "Ifia" is placed on the top. The joints between the rings are then plastered with cow dung and the top sealed with mud. For grain removal the lid is opened and the grain scooped out by standing on an object to easily reach the top. As grain is continually withdrawn and its level in the gota becomes too low to reach, the top
rings are successively removed and kept aside until they are reassembled the following season. Sometimes, instead of separating the rings children are lowered into the structure for grain withdrawal. In some areas, farmers remove the grain through the bottom of the structure. This is made possible by making a small circular opening on the side of the basal ring. This opening called 'mandoldoya' which means a 'pouring vent' is immediately sealed off with mud each time after grain is removed. It can also be plugged with a piece of rug or some other material.

Problems associated with Gota

• **Rapid infestation due to its location:** In most cases gotas are placed in the dwelling hut surrounding the fire place. The heat from the cooking fire favours rapid multiplication of insect pests inside, thus causing significant losses within a short period of time. Farmers themselves do recognize that storage structures kept inside houses with a fire place face a much higher level of losses from insect infestation than those in houses where fire is not used. They also notice variations in the degree of infestation among structures situated at a different proximity to the fire place within the same house.

• **Difficulty in detecting infestation:** Since grain removal is mainly conducted from the top detection of infestation at the lower portion of a large gota requires the dismantling of the structure and at least partial unloading of the grain. As this is cumbersome and often not practiced, farmers suddenly find their grain seriously damaged when the infested portions are exposed in the course of time. This is particularly the case with termite damage which takes place concealed in the lower part of the gota. Termites bore the bottom of the structure directly from the ground and move up through the grain mixing it with the soil and turning it damp, mouldy and caked until the situation is discovered from the top. In some places where termites are very common, farmers place their gota on a flat and solid block of stone which is big enough to accommodate the whole base area of the structure thus making it both termite and moisture proof.

2. "Gotera" is a cylindrical basket-like storage structure made by interweaving vines, splittted bamboo or other plant materials and plastered with mud and cowdung on the inside. It may be kept indoors and is also known by different names such as 'sherfa' or 'kirchat'. It can also be kept outdoors in the homestead usually behind the living hut and it stands on a stone or directly on the ground supported by poles from the sides. It is supplied with a conical thatch roof, which is dismounted at the time of filling the structure and grain withdrawal. The indoor type has got a base of a larger diameter and thus, can rest on the ground or on a slightly raised platform without any support from the sides. Moreover, the latter one is mostly not provided with a lid for it is kept inside the living house. Ordinary goteras can accommodate 10 quintals of grain or more.

Problems associated with Gotera

• **Moisture:** Since the gotera is mainly an outdoor structure, it is vulnerable to the damage caused by water during the rainy season. This is mostly caused by a leaking roof and moisture can also seep into the structure through the bottom which directly lies on the ground.
**Rats:** Both the indoor and outdoor goteras have no protection against rats. Besides, the poor hygienic situation inside the house and its surroundings aggravates the rat damage caused to the structure as well as the stored grain.

**Termite:** The gotera suffers from similar damage caused by termites as the gota.

3. **Maize Crib** is used in many parts of the country for the storage of maize cobs either temporarily for drying purposes before they are shelled or as a permanent means of storage in the season. They are usually constructed from maize or sorghum stalks without plastering and they are normally provided with a thatch roof as a protection against rain. Cribs in some places are so large as to allow maize shelling inside by beating with sticks thus serving as a threshing ground at the end of the drying period.

They in general and the latter types in particular are most vulnerable to rain damage although farmers may store the cobs with the husk on as a means of minimizing the risk. The maize is also exposed to infestation by weevils and grain moths as well as to the attack of termites and rodents for an extended period of time especially where they are used as a permanent means of storage. The problems of crib storage are similar to those of the gotera.

4. "**Gudguad**" (Underground pit) is a traditional underground pit mainly used in the lowland for the storage of sorghum under a reasonably airtight condition. The pits are preferably dug at an elevated sloping ground so as to minimize the danger from the seepage of rain water into their interior. In some areas they are situated inside the living hut for a greater security against moisture and theft. Although the shapes of pits may vary from place to place, the most commonly used ones are flask shaped chambers with the largest diameter at the base and tapering upward into a neck with a circular opening or mouth. The mouth of the pit is situated some depth (usually about 50 cm) below the ground level with a cavity excavated above it to make possible the placement of a flat stone or slabs of wood as a cover. This cover may be plastered with mud and cow dung after which the overlying cavity is filled with earth to the ground level. If the pit is completely filled with grain it can also be closed by simply covering the mouth with a layer of straw before filling the cavity with loose soil. The holding capacity of most pits ranges from 10-20 quintals of grain although they can be made as large as to accommodate much higher quantities. According to a survey conducted at one time, the pits varied from about 1.5 to about 4 m in depth and from about 1.5 to about 3.5m at the base in width, respectively. The mouth of the pits was generally about 60 cm in diameter.

The inside of pits is polished with cow dung and then the floor and the walls are lined with straw or straw-filled sacks before they are filled with grain. Sometimes, a plastic sheet is used as a lining material, but is very limited because of cost. Since newly dug pits are usually damp, some farmers use fire to dry them. If the pit is properly sealed, the grain particularly sorghum can be safely stored for as long as three or more years.

**Problems associated with pit storage**

- **Moisture:** In some areas, water easily seeps into the pits causing considerable damage to the grain through moulds, caking and sprouting. This mainly occurs because of the unsuitability of the location and the soil types for pits and also due to lack of proper lining materials which are impermeable to moisture. Moreover, some farmers do not use any lining materials in their pits regardless of the high level of risk involved. On
the other hand, the danger of mould affected grain is well known to the farmers as they don't even feed it to their animals. They explain that mouldy grain can cause serious harm to their health and also abortions to pregnant animals, particularly cows. Even the smell from a freshly opened pit is known to cause expectant mothers to have a miscarriage and thus such women are not allowed to get close to a pit which has been recently opened after a long period of storage.

- **Insect infestation:** One of the most important advantages of underground storage pits is that insect infestation is eliminated by virtue of their air tightness. This is because insects initially present in the grain are killed as a result of the depletion of oxygen through an enhanced respiration which takes place within the pit early in the storage period. However, sometimes pits are only partly filled with grain, leaving on top a large volume of empty space to be occupied by air which prolongs the survival of insects. The situation is aggravated by frequent opening of the pits for grain removal during which oxygen is replenished and hence accelerating the rate of infestation. Normally, pits must be completely filled with grain and should not be opened for some considerable time (about six weeks) within which the grain inside can be disinfested. Pits in some areas are also infested by termites which can cause tremendous damage to the grain before the situation is discovered.

Other forms of storage more commonly used for small quantities of grain include the use of sacks, pots, tin drums, gourds and others while maize cobs and sorghum heads mainly for seed purpose are kept by suspending them on trees, fences, or rafters over fire places.

**Farmers' Traditional Practices Used to Reduce Storage Losses**

Farmers make sure that the grain is well dried before it is stored and that the storage structures are cleaned before a new harvest is filled in. The gota is dismantled, cleaned and each part separately polished with cow dung. Before filling the grain the structures are smoked with chillies and other plant materials. When infestation by insect pests is detected in a store, the grain is taken out to the open air for sun drying and then winnowed with a fan or allowed to fall from a height so that the wind will blow away the insects and the contaminants. If the infestation is severe, the grain is fire-heated on baking pans. The grain so-treated with fire, however, cannot be used for making "injera" (the local bread), but rather for making "tella" (a local beer).

This being the general storage practice, farmers at different places use one or more of the following methods for the protection of stored grain from various causes of damage or loss.

- **Chilling of grain:** After threshing the grain is allowed to stay on the threshing ground for a few days to expose it to the chill of the nights before it is taken home for storage. This is believed to kill the insects found in the grain as a result of field infestation.

- **Rotation of structures for produce:** A storage structure used to store crops like maize, sorghum, wheat and barley, that are susceptible to infestation in one season, will be used for the storage of crops such as 'tef' and finger millet that are not affected by insect pests in the following season. This eliminates or minimizes the danger from insect pests harboured by the structures during the previous season.

- **Mixing of grains:** Grains susceptible to infestation are mixed with small seeded cereals such as 'tef' and finger millet which will be separated later with the help of
sieves. The seeds of these two crops in addition to being resistant to insect attack themselves can also suppress the infestation of crops mixed with them because of their small seed size. Moreover, they reduce the amount of air trapped between grains of large size and also make it difficult for the movement of pests in the grain.

- **Mixing of grain with ash:** This is used for different crops especially for the protection of pulses against bruchids. In the case of sorghum, the grain is mixed with ash while it is on the threshing ground by sprinkling some water over it so that it is moistened and can easily take up the ash. The grain is then made into a heap and covered with straw and allowed to stay for about a week. This initiates germination of the grain which is later interrupted when it is exposed and spread in the sun for drying. The procedure is locally known as ‘matkor’ (Blackening) because the grain turns darker by the process, which is also believed to improve the baking quality of the grain. The grain so treated is called "tekorto" and it is believed to be less susceptible to infestation by insects. The ash also helps to absorb moisture in the grain and keep it dry.

- **Placement of plant materials in the grain:** Parts of plants locally known as "kinchib", "chome" and others are placed within the grain bulk to protect it from infestation. Most of these plant parts are fleshy and with high moisture content while the rest have got milky latex. According to the farmers, these plants can suppress the infestation because they have got the property to keep the storage environment cooler for a long period of time. The sticky nature of the latex is also believed to trap the insects on the top of the grain where the plant materials are placed. Farmers usually mix pepper powder that has burning sensation with grain to protect it from storage pests. Some plants are also used for fumigating by smoking the empty storage structures before they are filled with grain.

- **Placement of the leaves of Croton at the base of storage structures:** This is used to protect the structures from the damage caused by termites. Wood ash is also placed around the base of the stores for the protection against termite and rats.

**Conclusion**

Since storage is the post-harvest stage where the highest magnitude of loss is taking place, there is an urgent need to address the problem along with the national effort to increase crop production. On the other hand, the diversity in the nature of the storage systems and the traditional pest control practices in the country indicate the presence of a vast opportunity for developing an integrated storage management system for specific areas.

The traditional storage structures served the farmers for centuries with all their deficiencies. There has been little improvement on these structures to reduce losses caused by stored product pests. The traditional storage systems and control methods need to be improved to alleviate the huge losses of stored products.

**References**


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9. Crop Protection Curricula at Agricultural Universities in Ethiopia

Ferdu Azerefegne
Entomologist, Awassa College of Agriculture, Debub University,
PO Box 5, Awassa

Abstract
Crop protection curriculum has been well established in the tertiary agriculture education of Ethiopia. The science of entomology, pathology, weed management, and principles and practices of crop protection are the major components of crop protection courses in all the agriculture colleges of Ethiopia.

Considering the undergraduate plant science program, the courses are adequate to make students grasp the various issues of crop protection. The books used for the basic courses are of international standards. However, the curriculum is deficient in presenting case studies and examples of national experiences owing to the limited research outputs and lack of organized information on the existing results. There are few comprehensive reviews of pest management research and development efforts that can be used as support materials in the agricultural colleges. The involvement of various scientists from other institutions in the education of crop protection is very limited. Similar to the other fields of studies, crop protection teaching suffers from under funding, limited laboratory and laboratory materials and networking.

Graduate programs on crop protection studies are currently being offered at Alemaya and Addis Ababa Universities. Debub University launched graduate studies on crop protection very recently in 2004. Alemaya University has been the main university on graduate studies of agricultural fields. It produced many capable graduates with very good thesis works on national crop protection problems. Currently the plant pathology section has a good staff profile. The other sections are mainly handled by expatriate staff who have little knowledge on Ethiopian agriculture although they are competent scientists. The two universities failed in printing and distributing the thesis work of graduate students that could have been useful teaching materials.

Introduction
Pest is an anthropomorphic word and does not have any ecological meaning without man. Mankind has been fighting the plagues of pests from ancient times and the battle between pest and human beings will continue as long as the human race endures. Although the war waged on pests has been old, mankind could not claim victory and huge amounts of agricultural products are lost due to pests.

Although we currently believe that we have better knowledge and understanding of pests than our predecessors mankind has been creating new pest problems and assisting their development and distribution in various ways. The development of resistance, resurgence and secondary pest problems with the misuse of pesticides are the cases in point. The destructive capacity of pests has been advanced by human civilization. They have efficiently utilized our advancements. Modern agriculture with its genetically uniform plant species cultivated on large areas has made crop production more prone to the attack of pests.
Intercontinental rapid and free movement of pests was achieved as a result of our advancement in transport and exchange of plant species.

Our understanding about our enemies during all these years has been limited and as a result the methods of control we employ have been inadequate. This is very true especially with the advent of the synthetic chemicals where other methods of pest management were neglected. Now, the bad sides of pesticides are understood and the philosophy of combating pest is changing from control to management. New advances are being made and countries are adapting the principles of Integrated Pest Management. This method encompasses the use of multiple techniques in as compatible manner as possible to reduce the damage levels below those causing economic injury. The approach calls for intelligent selection and use of pest control actions that ensure favourable economic, ecological and sociological consequences.

IPM has been defined and understood in various ways showing that all that has been claimed IPM is not real IPM. The concept of IPM is subject to differing interpretations, ranging from simple combination of pesticides with other techniques to ecological habitat management strategies. IPM is a knowledge-intensive approach that emphasizes natural control of pest populations by anticipating pest problems and preventing pests from reaching economically damaging levels. The importance of IPM is reflected in its adoption as a basic tenet of sustainable agriculture. This recent shift from depending on one single method to the integration of several methods and in depth analysis of the farming systems calls for professionals with good scientific background and holistic knowledge of crop protection and crop production.

**Pre College Science Education in Relation to Crop Protection**

Assessments of the science syllabus for elementary, junior and high schools of Ethiopia show that students do not have serious shortcomings in understanding the basic principles of crop protection when they join the tertiary education. In the elementary schools (first to sixth grade) students learn about basic differences between plants and animals, the relationship between organisms and a few examples of crops pests. Plant growth and methods of their dissemination to invade new areas are some parts that may be related to crop protection. In addition, students also learn herbarium techniques. The insect part is well dealt with and includes insect morphology, development (different stages in incomplete and complete metamorphosis), some examples of insect pests and beneficial insects and basic pest control methods. Among the micro-organisms, fungi with their body parts and methods of reproduction are discussed with some examples. Students learn about the use and negative aspects (pollution) of chemicals including pesticides.

In the junior-high classes the subjects in elementary classes are dealt with in more depth. The microbiology part is expanded with coverage of fungi, bacteria, nematodes and viruses. Students are introduced to microscopy. The systems of binomial nomenclature and use of keys in the identification of organisms are discussed.

In high schools ecological concepts like population and methods of sampling, which are a basis in all pest management practices, are introduced. Some examples of economically important crop diseases, insect pests and parasitic weeds, are included in high school science classes. There is a continuation on techniques of microscopy and dissection. The subjects also discuss pesticides including their chemical nature, toxicity and effect on the environment.
It is observed that the basic subject of crop protection is well treated in the books and students joining colleges can follow crop protection classes without any problem. However, it should be noted that the assessment in this paper is limited to reviews made on the teaching books. It is known that there are great variations among the schools in terms of facilities and presence of qualified teachers. Most of the Government schools have inadequate facilities and the situation is exacerbated by a high number of students and few dedicated and qualified teachers to make science teaching more practical. The books need editorial revisions and changes of examples to make it more relevant to Ethiopian situations. Subjects that need emphasis are: the importance of quarantine, the negative aspects of pesticides and the need for adopting IPM as a principle of pest management.

**Crop Protections Studies in Ethiopian Agricultural Colleges and Universities**

Alemaya University, Addis Ababa University, Debub University, Jimma University, Mekelle University and 25 ATEVT Colleges are offering crop protection courses in their respective training schemes. The undergraduate studies of agriculture, specifically the plant sciences departments, offer courses in entomology, plant pathology, weed science and crop protection. The textbooks used in the teaching of these courses have international standards. Basic biology of the pests and principles of control methods including integrated pest management make up the courses. The entomology and plant pathology courses have well worked practical sessions but this practice is weak for the weed science course in most of the colleges. The crop protection classes that are usually offered to senior students deal with specific major pests and their management methods. In addition, students learn about chemical application methods and their safe use.

Graduate studies in crop protection have been offered at Alemaya University since 1978 and 73 students graduated up to 2003. Alemaya University has been the main university of graduate studies in agricultural fields until recently. It produced many capable graduates with very good thesis works on national crop protection problems. An MSc in agricultural entomology is also offered at Addis Ababa University. Debub University started graduate studies on crop protection in 2004. Except for a few course differences, course allocations in the crop protection graduate studies are basically the same at the three universities.

**Shortcomings of the Tertiary Crop Protection Education**

Most of the problems encountered in crop protection education are not unique to the field. Similar to the other fields of studies, crop protection teaching suffers from under funding, limited laboratory and laboratory materials and networking.

**Table 28: Graduate Courses of Agricultural Entomology at Alemaya University**

<table>
<thead>
<tr>
<th>Insect taxonomy</th>
<th>Insect physiology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insect morphology</td>
<td>Integrated pest management</td>
</tr>
<tr>
<td>Agricultural pesticides</td>
<td>Advanced plant pathology</td>
</tr>
<tr>
<td>Insect ecology and population dynamics</td>
<td>Post harvest pest &amp; disease management</td>
</tr>
<tr>
<td>Advanced Biometrics</td>
<td>Computer</td>
</tr>
<tr>
<td>Graduate seminar in crop protection</td>
<td>Breeding for insect pest and disease resistance</td>
</tr>
<tr>
<td>Biochemistry</td>
<td>M. Sc. Thesis</td>
</tr>
</tbody>
</table>
Shortage of qualified Ethiopian instructors is one of the major problems in imparting quality crop protection education. Colleges have tried to build up their staff by training them abroad, however, most of the trainees did not report to duty after completion of their studies. For example, Alemaya University did not have an Ethiopian staff with PhD in entomology for more than 20 years. Currently, Alemaya has a good staff profile in plant pathology and weak in entomology and weed science. Graduate entomology and weed science courses are mainly handled by expatriate staff who do not have adequate experiences of national crop protection problems. There is also a shortage of experienced professionals who could serve as research advisors and the few professionals advise large number of students. Participation of professionals from other institutions in teaching graduate and undergraduate courses, which is very limited currently, could have eased the staff shortage problems.

Table 29: Graduate Courses of Plant Pathology at Alemaya University

<table>
<thead>
<tr>
<th>Agricultural mycology</th>
<th>Agricultural nematology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural pesticides</td>
<td>Advanced plant pathology</td>
</tr>
<tr>
<td>Plant bacteriology and virology</td>
<td>Post harvest pest &amp; disease management</td>
</tr>
<tr>
<td>Diagnosis and techniques in plant pathology</td>
<td>Integrated pest management</td>
</tr>
<tr>
<td>Advanced Biometrics</td>
<td>Computer applications</td>
</tr>
<tr>
<td>Plant microbe interaction</td>
<td>Biochemistry</td>
</tr>
<tr>
<td>Graduate seminar in crop protection</td>
<td>Breeding for insect pest and disease resistance</td>
</tr>
<tr>
<td>M. Sc. Thesis</td>
<td></td>
</tr>
</tbody>
</table>

Compared to Debub, Jimma, and Mekelle universities, Alemaya University has a better library, laboratory facilities and specimen collections of insect pests, disease samples and weeds. Recently Alemaya received very good support through the ARTP project to equip some of its laboratories, purchase books and subscribe to journals. However, they are not adequate.

The crop protection curricula in Ethiopian colleges are weak in presenting case studies and examples of national experiences owing to the limited research outputs and lack of organised information on the existing results. There are few comprehensive reviews of pest management research and development activities in Ethiopia that can be used as support materials to teach crop protection in the agricultural colleges. The Proceeding of the First Ethiopian Crop Protection Symposium published in 1985 was very comprehensive and greatly contributed to crop protection education. The Ethiopian Journal of Agricultural Sciences (EJAS), Proceedings of the Crop Protection Society, and reviews made by various professional societies are used as reference materials. However, such materials lack continuity and some like EJAS were discontinued. Currently, the Pest Management Journal of Ethiopia (PMJOE) has been the main source of information. The journal is being published annually with not more than 12 articles. On the other hand, there is a very limited effort in producing complete lecture notes, teaching materials and laboratory manuals by university staff for their use and for the new colleges like the ATVET. If such types of materials exist, they are not known to the other colleges or to crop protection professionals in the country. Addis Ababa University and Alemaya University failed in prompt printing and distributing the theses of graduate students which could have been useful teaching materials. It is known that many NGOs work
in the area of crop protection and produce several materials on pest management; however, the distribution of these materials is very limited.

<table>
<thead>
<tr>
<th>Table 30: Graduate courses in weed science at Alemaya University</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weed biology &amp; ecology</td>
</tr>
<tr>
<td>Agricultural pesticides</td>
</tr>
<tr>
<td>Principles &amp; practices of weed management</td>
</tr>
<tr>
<td>System analysis &amp; crop modeling</td>
</tr>
<tr>
<td>Advanced Biometrics</td>
</tr>
<tr>
<td>Graduate seminar in crop protection</td>
</tr>
<tr>
<td>Advanced plant pathology</td>
</tr>
</tbody>
</table>

There has been little networking between the agriculture colleges of Ethiopia to collectively review and update their curricula and share experiences. Recently, through the effort of the Ministry of Education all universities and colleges of Ethiopia reviewed their curricula and adjusted the course types and numbers. However, evaluations of the course contents were not made. In designing, reviewing and teaching the agriculture courses there is little involvement of institutions outside the colleges. The Ministry of Agriculture, the main employee institution of the graduates, and the Ethiopian Agriculture Research Organization should have been directly involved in agriculture education.

Crop protection research is mainly conducted in federal and regional centers of EARO and universities. However, there is little long-term thematic research on crop protection. Such kinds of projects could have generated results that can be used for teaching and training students. The absence of such research is especially felt in the graduate studies where students are usually inclined to select MSc research works for the ease of conducting them with small financial outlay and time.

**The way forward**

Currently, universities are urged to take a high number of students in their undergraduate and graduate programs to alleviate the shortage of trained manpower in the country. The following main points need due considerations to improve crop protection education.

- Network among higher learning institutes of agriculture, MoA, EARO, professional societies, NGOs working in the field of agriculture.
- Improve internet access to make use of the huge information on the Web. There is a need to create an Ethiopian Pest Web Site to post and access information on Ethiopian pest problems.
- Conduct a national review on the crop protection curricula of the agricultural colleges with the participation of stakeholders.
- Improve practical training and share experiences among the colleges.
- Publish regularly distribution maps of Ethiopian pests and diseases.
- Publish regularly leaflets on the managements of major pests.
- Improve specimen collections of pests in all agricultural colleges and establish a national reference collections center in EARO or University.
- Sponsor scientists to write reviews, books, identification guides, etc on important pests, diseases and weeds of the country.
Facilitating the Implementation and Adoption of Integrated Pest Management (IPM) in Ethiopia

- Solicit fund to organize specialized courses, training lectures and workshops for crop protection experts in the country,
- Initiate long-term crop protection research and a centre of excellence in specialized areas.

References


**Other Materials**
Course Descriptions and outlines of the Crop protection courses for the undergraduate studies of Alemaya, Debub, Jimma and Mekele University.

Course Descriptions and outlines of Graduate Crop protection course of Alemaya and Debub universities; and graduate program of Addis Ababa University in Entomology.
Facilitating the Implementation and Adoption of Integrated Pest Management (IPM) in Ethiopia

10. The Use of Neem Seed Powder for the Control of Stalk Borers in Sorghum and Maize

Tsedeke Abate\textsuperscript{1}, Manyazewal Ejigu\textsuperscript{2} Selome Tibebu\textsuperscript{3}

\textsuperscript{1}Association for Advancement of IPM, P O Box 359, Nazareth, Ethiopia; \textsuperscript{2}Bureau of Agriculture, Ministry of Agriculture, Dire Dawa; \textsuperscript{3}Ministry of Water Resources Development, Basin Development Department, PO Box 5744, Addis Ababa, Ethiopia

Abstract

An overview of experimental data available on the use of neem for controlling stalk borers in sorghum and maize at Melkassa in central Ethiopia and in the Dire Dawa area in eastern Ethiopia is presented here. At Melkassa, the effects on cereal stalk borer, mainly \textit{Chilo partellus} (Swinhoe) (Lepidoptera: Crambidae) of applications of neem seed powder once 30 days after seedling emergence (30 dae) and twice (30 & 45 dae) were compared with untreated check for two years. Application of neem seed powder in a 1:1 mixture with fine sand (v/v) at about 5 kg per ha provided an effective control of \textit{C. partellus}. In general, two applications were more advantageous than one.

Experiments carried out at two locations in the Dire Dawa area compared the effects of neem seed powder, cow urine, and cypermethrin (Cymbush 1\% G) with an untreated check. It was shown that all treatments gave significantly better control of stalk borers than the check; neem performed better than all the other treatments, but there were no significant differences between the neem, cow urine, and insecticide means. It was concluded that, for all practical purposes, neem would play a significant role in the integrated management of stalk borers in Ethiopia. The need for introducing planting of neem trees to farmers, and devising a simple application device were emphasized.

Introduction

Lepidopterous stalk borers, including the spotted stalk borer, \textit{Chilo partellus} (Swinhoe) (Lepidoptera: Crambidae); the maize stalk borer, \textit{Bussoela fusca} (Fuller) (Lepidoptera: Noontide) and the pink stalk borer, \textit{Sesamia calamistis} (Hampson) (Lepidoptera: Noctuidae) are among the most important pests of sorghum and maize in Ethiopia.

Some information is available on chemical control of stalk borers in Ethiopia (Assefa 1981, 1982, Assefa & Tessema 1982, Adhanom & Abraham 1985, Abraham et al. 1993, Melaku & Gashawbeza 1993, Gashawbeza & Melaku 1995) but chemical control is not sustainable under Ethiopian farmers' conditions, where the bulk of the crops are grown by smallholders (Abate 1993). An integrated pest management (IPM) approach combining two or more of cultural control, biological control, use of botanicals, and host plant resistance is the option for managing stalk borers in sorghum and maize under a smallholder production system.

Even though neem and other botanicals are used as indigenous technologies for pest control in many parts of Ethiopia, their use has been limited to storage pests. Published empirical data on neem and other botanicals against stalk borers or other field crop pests are not available.

In this report we present highlights of results of experiments on the effects of neem seed powder and other non-chemical control measures carried out at the Melkassa Research Centre of EARO (Ethiopian Agricultural Research Organization) and at farmers’ fields in the Dire Dawa area on cereal stalk borers.
Materials and Methods

Melkassa

The experiment was conducted in a split-split plot, randomized complete block design in two replications. Main plot treatments included sowing date, subplot treatments were crops (sorghum, cv. ‘76T1#23’ and maize cv. ‘ACV-3’), and sub-subplot treatments consisted of three levels of neem treatment (applied once at 30 dae, twice at 30 dae and 45 dae, and an untreated check).

A recommended spacing of 75 cm between rows and 10 cm between plants was used for growing sorghum whereas maize was grown at 75 cm between rows and 30 cm between plants. Plots for both crops were 4.5 m long and 3.75 m wide, containing five rows of 225 and 75 seedlings per plot of sorghum and maize, respectively. The two crops were planted monthly, for 24 months, from January 1997 to December 1998. A recommended fertilizer, DAP (di-ammonium phosphate) was applied at the rate of 100 kg per ha, and supplementary irrigation was provided as needed. Stand counts were recorded within 2 weeks of seedling emergence.

Fresh samples of mature seed of neem (Azadirachta indica) were supplied, as needed, by the Dire Dawa Regional Agricultural Bureau; these were dried under diffused light (to avoid deterioration of the active ingredient by direct exposure to sunlight) in the laboratory at the Melkassa Research Center. The dried seed was ground to a fine powder and mixed with pure sand in a ratio of 1:1 by volume. A pinch of the neem-sand mixture was applied in the funnels of the two crops at an application rate of about 5 kg per ha of neem seed powder.

Data on dead heart (due to stalk borers) were recorded weekly, for six weeks, starting at 3 weeks after seedling emergence (wae). Borer density (i.e. number of borers per given number of plants) at 10 wae was determined by using “destructive sampling”. A total of 10 plants were uprooted from each plot by walking along each diagonal and taken to the laboratory, where the number of borers for each plant were recorded separately; counts of larvae and pupae (including pupal cases) were recorded accordingly. At harvest, borer density was determined by taking 20 randomly selected plants per plot. The number of pupating borers (C. partellus) was recorded and their percentages computed at 8 wae, 10 wae and harvest. All data were analyzed by ANOVA, using the statistical package MSTATC.

Dire Dawa area

The experiment in the Dire Dawa area was conducted in a randomized complete block design replicated three times. Treatments included neem seed powder applied in leaf funnels, cow urine (50:50 mixture with water) sprayed using a knapsack sprayer, the insecticide cypermethrin (Cymbush 1% G) applied in leaf funnels, and an untreated check. The experiment was carried out at Aseliso and Awale farmers’ associations around Dire Dawa. The local sorghum variety ‘Muyra’ was used at Aseliso and the improved variety 76T1#23 was used at Awale. Agronomic practices were as described above for Melkassa.

Results

Melkassa experiments

Dead heart-Sowing date, crop type, and the growth stage at which the sample was taken had significant effects on the level of dead heart damage. Neem treatment had significant effects in 1997 but not in 1998. Interaction effects between neem, sowing date and crop type were also significant.
The percent dead heart in sorghum increased progressively with a growth stage of the crop up to 5 wae, and then it leveled off or declined thereafter, both in 1997 and 1998 (Fig. 5). Mean dead heart damage ranged from 3.3 percent to 10.0 percent (avg. 8.0 percent) in 1997 and from 6.0 percent to 13.4 percent (avg. 10.1 percent) in 1998. By contrast, dead heart damage in maize, due to *C. partellus*, was insignificant during both years. It ranged from 0.2 percent and 0.4 percent (avg. 0.3 percent) in 1997 and from 0.1 percent and 1.0 percent (avg. 1.0 percent) in 1998 (Fig. 5). Note that the values shown in the figure are only for sorghum, as dead heart symptoms in maize were very low. Two applications of neem seed powder were superior to one application and to the untreated check.

**Figure 5: Percent dead heart caused by Chilo partellus in sorghum grown with and without neem seed powder treatment at Melkassa during 1997 (after Abate, unpublished)**

**Borer density** – Neem treatments (D) had a highly significant effect on borer density at the plant growth stages sampled. Sowing date (B) and crop type (C) also had significant influence whereas there was no significant difference between years (A). Some of the interactions effects (A x B, B x C and A x B x C) were also highly significant.

Two applications of neem seed powder (30 & 40 dae) resulted in a significant (P<0.05) reduction of stalk borers per plant at 8 wae both in sorghum and maize during both years; mean numbers of borers per 10 plants in one application were not significantly different from the untreated check in sorghum but superior to the check and inferior to two applications in maize during both years (Table 31).

Results at 10 wae showed that both two and one application of neem seed powder were significantly superior to the untreated check (without significant difference between the two) in 1997 for sorghum and both in 1997 and 1998 for maize. Both of the neem treatments showed better performance than the untreated check in sorghum in 1998, but the differences were non-significant.

Furthermore, at harvest, two applications of neem resulted in significantly fewer mean number of borers per 10 plants in sorghum in 1997 and during both years in maize; one treatment was not significantly different from the untreated check. Differences among treatments in sorghum in 1998 were not statistically different (at harvest), even though neem treatments showed a slightly lower number of borers (Table 31).
Table 31: Stalk borers per 10 plants in sorghum and maize grown with and without neem treatment at Melkassa - 1997 and 1998 (after Abate, unpublished)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Sorghum</th>
<th></th>
<th>Maize</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>8 weeks after seedling emergence</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treated (2x)</td>
<td>16.1b</td>
<td>10.9b</td>
<td>5.2c</td>
<td>3.8b</td>
</tr>
<tr>
<td>Treated (1x)</td>
<td>28.1a</td>
<td>16.8a</td>
<td>9.4b</td>
<td>5.5b</td>
</tr>
<tr>
<td>Untreated</td>
<td>24.8a</td>
<td>17.5a</td>
<td>16.5a</td>
<td>10.3a</td>
</tr>
<tr>
<td>10 weeks after seedling emergence</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treated (2x)</td>
<td>27.8b</td>
<td>23.9a</td>
<td>8.8b</td>
<td>7.5b</td>
</tr>
<tr>
<td>Treated (1x)</td>
<td>33.4b</td>
<td>26.8a</td>
<td>11.7b</td>
<td>8.0b</td>
</tr>
<tr>
<td>Untreated</td>
<td>44.1a</td>
<td>29.9a</td>
<td>21.7a</td>
<td>15.1a</td>
</tr>
<tr>
<td>At harvest</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treated (2x)</td>
<td>46.2b</td>
<td>41.0a</td>
<td>11.9b</td>
<td>8.0b</td>
</tr>
<tr>
<td>Treated (1x)</td>
<td>52.6a</td>
<td>41.6a</td>
<td>12.0ab</td>
<td>10.1ab</td>
</tr>
<tr>
<td>Untreated</td>
<td>49.4ab</td>
<td>44.1a</td>
<td>17.5a</td>
<td>13.3a</td>
</tr>
</tbody>
</table>

Means within a column (for each growth stage), followed by the same letter are not significantly different from each other at 5% (DMRT)

It should be noted here that borer density was approximately doubled between 10 wae and harvest, in sorghum, whereas such differences were not observed in maize. This might be attributed to the extended egg laying and re-infestation by overlapping generations of *C. partellus* in sorghum. It is possible that the effects of neem treatments do not last long enough to influence borer numbers at harvest.

**Percent pupation** – Neem treatment had a highly significant influence on percent pupation by *C. partellus* at the three crop growth stages sampled; sowing date (B), crop type (C), and some of their interactions were also significant. There was no significant difference between mean percent pupation between 1997 and 1998. By contrast, the overall average percent pupation in maize (4.1 percent, 16.6 percent and 41.0 percent, respectively, at 8 wae, 10 wae and harvest) was significantly greater than that in sorghum (1.6 percent, 8.4 percent and 24.9 percent, respectively, for 8 wae, 10 wae and harvest).

There were appreciable differences among treatment means for sorghum samples, particularly for 10 wae, both in 1997 and 1998; the highest pupation was in the untreated check whereas the lowest was in plots treated twice with neem (Table 32). However, none of the means were significantly different from each other. Similarly, even though neem treatment applied twice showed the lowest level of pupation compared to the mean for a single treatment and the untreated check at harvest, the differences were not significant.

In maize, the means for the untreated check showed significantly superior percent pupation compared to the means for neem treatments (Table 32). Here, neem treatment applied twice showed the lowest level of pupation at all times of sampling. Means for the one application were also comparable to the two applications at 8 wae and 10 wae. However, at harvest, the means for one application of neem were not significantly different from those of the untreated check (Table 32).
Table 32: Percent pupation in Chilo partellus in sorghum and maize grown with and without neem treatment at Melkassa - 1997 and 1998 (after Abate, unpublished)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Sorghum</th>
<th>Maize</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 weeks after seedling emergence</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treated (2x)</td>
<td>2.1a</td>
<td>0.9a</td>
</tr>
<tr>
<td>Treated (1x)</td>
<td>2.5a</td>
<td>0.4a</td>
</tr>
<tr>
<td>Untreated</td>
<td>2.9a</td>
<td>1.4a</td>
</tr>
<tr>
<td>10 weeks after seedling emergence</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treated (2x)</td>
<td>10.3a</td>
<td>1.1a</td>
</tr>
<tr>
<td>Treated (1x)</td>
<td>12.9a</td>
<td>5.5a</td>
</tr>
<tr>
<td>Untreated</td>
<td>14.6a</td>
<td>9.1a</td>
</tr>
<tr>
<td>At harvest</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treated (2x)</td>
<td>21.8a</td>
<td>24.3a</td>
</tr>
<tr>
<td>Treated (1x)</td>
<td>26.3a</td>
<td>24.8a</td>
</tr>
<tr>
<td>Untreated</td>
<td>27.4a</td>
<td>24.6a</td>
</tr>
</tbody>
</table>

The Dire Dawa area experiments

Infestation by stalk borers – Figure 6 shows percent infestation of sorghum by stalk borers at two locations. Significant differences were observed among the treatments both at Aseliso and Awale farmers’ associations; means of infestations for the two locations were not significantly different from each other. It can be seen from the figure that neem, cow urine, and insecticide treatments were superior to the untreated check; no significant differences were observed among the means of neem, cow urine and cypermethrin treatments.

Borer density – Data for the effects of the various treatments on borer density are shown in figure 7. It can be seen from the figure that the effects on borer numbers followed a similar pattern to the infestations shown above. That is, neem, cow urine, and insecticide treatments were superior to the untreated check; no significant differences were observed among the means of neem, cow urine and cypermethrin treatments.
Figure 6: Percent stalk borer infestation in sorghum at two locations in the Dire Dawa area – 2003 main crop season (after Manyazewal, unpublished)

Figure 7: Numbers of stalk borers per 10 plants for various treatments in sorghum at two locations in the Dire Dawa area – 2003 main crop season (after Manyazewal, unpublished)
References


11. Trees with Insecticidal Properties and Indigenous Knowledge Base with Coping Mechanisms Against Pests

Dechasa Jiru
Forestry Research Center
Ethiopian Agricultural Research Organization

Abstract
This paper presents some examples of plants with pesticide properties and indigenous knowledge of farmers to protect their crops and house from the damage of insects. It is intended to bring local knowledge as an input and for the future generation of appropriate technology. Ethiopia is endowed with many indigenous trees and an appreciable number of exotics which are adapted to local conditions and grow. The most important plants with pesticidal and pesti-repellant properties are discussed in the paper. Neem (Azadirachta indica), chinaberry (Melia azedarach) and pepper tree (Schinus molle) are among the exotic species which grow widely in the country and have both insecticide and insect repellant properties. Leaves of the indigenous Croton macrostachys are used as a bed for crops when the harvest is temporarily stored before threshing. Traditionally Moringa stenopetala has been used for the control of malaria.

The current termite problem on trees and crops can be attributed mainly to the destruction of the vegetation, reduction in the amount of litter and organic matter; and one of its principal natural enemies, Aardvark. This natural predator of termite is becoming extinct in many localities mainly due to human activities.

The dome shaped architecture of traditional houses, which traps fire smoke, has several advantages. One of the merits of this shape is that it protects the poles and the grass making the roof from the attack of insects and fungal decay compared with other shapes. It also provides a safe storage place for farm produce as they are usually stored above the stove and the smoke will keep them dry and free from storage pests.

Chinaberry (Melia azedarach)
Chinaberry (Melia azedarach) is an exotic plant with pesticidal property which is well adapted to Ethiopian conditions. It is grown as a street tree in many towns. M. azedarach is usually confused with its close relative neem (Azadirachta indica). Exact identification of botanicals is very important as plants differ in their pesticidal properties.

M. azedarach is a deciduous ornamental tree usually reaching up to 10m in height with bushy foliage and trusses of lilac-colored flowers. The bark is gray, smooth, becoming browner, rougher and furrowed with age. The branch lets are brown and knobby, dotted with breathing pores or lenticels. The leaves are bright-green at first, later dark-green and shiny, hanging in terminal branches; twice–compound, up to 40 cm long with three pairs of side ribs, each bearing 5 lance-shaped leaflets. The leaflets are up to 8cm in length tapering to base and apex with margins coarsely and irregularly toothed.

The flowers are small, fragrant, pale lilac at first and later turning white, in profuse, rounded clusters. Each flower is about 1.5cm across with a dark purple staminal tube protruding from the center of 5 narrow spreading petals. The fruits are fleshy yellow berries, 1.5cm in diameter, containing single hard seeds, which can be strung as beads. The clusters of berries are conspicuous, and persist well after all the leaves are shed. The berries are extremely poisonous...
and human deaths, as well as losses amongst stock and poultry from eating fallen fruit have been recorded.

**Neem (Azadirachta indica)**

Similar to the chinaberry, Neem (*Azadirachta indica*) is exotic to Ethiopia and grows very well in warmer areas like Dire Dawa, Werer and Gambella. It is a multipurpose tree used for fuel, timber, and shade and increasingly used in agroforestry on exhausted soils.

Neem is a fast growing deciduous tree, which grows well in drier areas and reaches up to 18 m in height with steeply ascending branches. The bark is pale gray–brown and rough. The fresh leaves are glossy green, crowded towards the ends of branches and the leaves are compound with 5 to 8 pairs of leaflets and a size up to 6 cm long. It has smaller terminal leaflets whose apexes are pointed with an asymmetric base and margins coarsely toothed.

The flowers are small and fragrant with white or cream color hanging in long and few flowered axillary sprays. The fruits are first oval-green and turn in to yellow berries as they mature and have a size of about 2 cm in length. Neem fruits contain an aromatic oil, which has medicinal and pesticidal properties and is traditionally used to treat skin diseases such as leprosy. The oil can be used as a paraffin substitute or to make soap. The neem cake residue after extracting the oil is good as cattle feed and fertilizer. The seeds and leaves contain azadirachtin, which is a powerful insecticide. Dried leaves placed amongst clothes will protect them from moths and in stored grains from storage pests. In some areas the green leaves are added to bonfires so that the smoke drives off mosquitoes and sand flies. Sprays made from seed and leaf solutions will protect crops from insect pest attack. Currently, commercial pesticides are available.

Tests of a drug from the leaf extract to treat chloroquin-resistant strains of malaria are at an advanced stage and research also continues into the possible development of an oral contraceptive.

**Pepper tree (Schinus molle)**

The leaves and berries of pepper tree (*Schinus molle*) leaf are used as fly repellents in some houses. They are commonly used in local bars and butcheries to ward off houseflies.

**Moringa stenopetala**

The pod *M. stenopetala* is crushed and applied on a river or ponds bank to kill larvae of mosquitoes in areas where malaria is prevalent.

Farmers in northern Shoa and Wollo use parts of “*sama*”, “*ye hareg resa*” and *Agave persicum* by grinding and spraying the extract to control important sorghum pests.

**Croton macrostachys**

Croton has a wide range of ecological distributions. In Africa the species is found in Guinea, Côte d’Ivoire, Ghana, Nigeria, Cameroon, Central Africa, Zaire, Rwanda, Burundi, Sudan, Ethiopia, Uganda, Kenya, Tanzania, Malawi and Mozambique. In Ethiopia, it is widely distributed in the north western and south eastern highlands (Friis, 1992).

In Ethiopia, the croton flowers profusely from April to July, which is very important for honeybees. Bees collect both its pollen and nectar from different plants (Fichtl & Adi, 1994). Though perennial trees continue to flower when most annual honeybee pollen and nectar
plants ceases to grow and flower, Croton is very important and exceptional among the perennial trees in that it flowers at times when most of the plants are not flowering and pollen and nectar are in short supply. Croton trees are trained and managed on farms in western Gojam, eastern part of Ankober, Arsi Negele, Alaba, Hadyia and Anstokia. On average over 8.3 cubic meters of wood is used by an average family every year (EFAP, 1994). Over 90% of the total energy in rural settings comes from crop residue and animal dung (FAWCDA/FAO, 1982). Traditionally croton wood is not the best fuel wood, but it can be used in cases of scarcity. Croton spp. is one of the 400 species listed on a master list for further fuel wood potential tree screening (National Academy of Sciences, 1980).

The leaves are used as a bed for crops when the harvest is temporarily stored with stalks in a farm. The species is selected due to its characteristic of being repellant to termite attack where the problem is major hindrance in crop production. The bark and buds have several traditional medicinal uses. The sap is used as a common curative for fungal skin disease. Besides fuel, the wood is used for construction purposes and to make farm tools. The first straight pole produced prior to the first pollarding is usually used for pillar in the construction of traditional houses.

Farmers make a distinction between times of the year to harvest timber. For example, they claim that *Cordia africana* timber harvested during full moon is free from insect damage, which may be related to less activity of insects attacking timber. Some plants *Kitkita* (*Dodonia viscose*) are termite resistant.

**Causes of increase in termite incidence**

Termites are becoming serious threats to crop production in Ethiopia and their importance is increasing. In Wollega around Mendi several agricultural and forestland has been cleared. Termites are extremely prevalent in the rift valley and some tree species fail to grow because of termite attack. In Gonder town, on a steep slope near to the airport, *Eucalyptus camaldulensis* establishment was not successful. Afforestation efforts made by World Vision International Ethiopia at Saatusa, Antsokia and other sites faced the same problem. Recently, aggravated problems of termites are being reported from areas like Borana, Metekel and west Tigrai. Some factors have been implicated as major reasons for the increased problem of termites. Aardvark is a wild animal, which is a natural predator of termite and checks the population build up. Currently, man has wiped out this animal from several places. Thus, the termite number extremely increased. Under the natural food chain, termite is the most favorite food for Aardvark. Reduction in the organic matter/lignin in an area forces the termite to change its food habit and start attacking live trees. Currently it is very hard to establish trees in the rift valley and young tree seedlings are under heavy attack.

Increase in the environmental temperature, moisture scarcity due to deforestation and removal of organic rich soil by erosion also influenced the build up of termite populations. Dry condition is conducive for termite population explosion. Some of the traditional methods used to control termites include planting on steep slope (e.g. Gonder), planting on wetland, planting at high density and planting termite resistant species. Planting of seedlings in cut plastic pot has been practiced in “Saatusa” and “Antsokia” area. Digging the mounds and manually removing the queen can control termites.
Facilitating the Implementation and Adoption of Integrated Pest Management (IPM) in Ethiopia

The problem of rats on different tree species
On Yewol mountain (3000m a.s.l) tree species screening trial was conducted. *Olea europeae* sub.sp. *africana* and *Juniperus procera* are the two most dominant and common species found in the area. The exotic species *Acacia decurren, Acacia melanoxylon* and *Eucalyptus viminalis* were also included. Six months after transplanting the exotic species performed better while rats destroyed the local Olea and Juniper. The rats gnawed through the young stem of the indigenous tree seedlings. Farmers in the area explained that this is the result of reduction in the fox population, which is the main predator of rats. Farmers raising sheep hunted the foxes and consequently the rat population increased. Formerly, the rats did not attack indigenous tree seedlings. The stone bund constructed for soil conservation also served the rat as a shelter and breeding place. It seems that the rats are not accustomed to the exotic species or they may have some toxic or repellent chemicals. Areas in Gauwsa (Mehal Meda), Semen and Bale Mountains may face the same problem in the near future as the vegetation dwindles.

Indigenous house construction architecture - Implication for material preservation, insect protection and control
The domes shaped traditional houses of Ethiopia have several advantages. The strength of this structure can be exemplified with the structure of eggs. Thus, this architecture is very much in use to build churches and mosques in Ethiopia and elsewhere including in the modern buildings.

The dome shaped structure of the Ethiopian traditional houses has the advantage of trapping fire smoke in the dome while the lower space near the fire will be smoke free and making it comfortable for human beings to live in without suffocation and with little effect on their health.

A continuous smoking builds tar on the wood and the grass, which makes the dome shaped thatched roof rain proof and avoid leakage. It also preserves the material from any insect damage like beetles, termites and fungal decay.

Smoke in general has a drying effect on any wet object. Farmers usually hang their produce like maize, shallot etc, under the roof above the fire stove for protection from insect damage.

References


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12. The Diversity of Vegetation Types, Agricultural Systems and Their Crops in Ethiopia

Sebsebe Demissew¹ and Sue Edwards²
¹ National Herbarium, Biology Department, Addis Ababa University, Box 3434, Addis Ababa
² Institute for Sustainable Development, Box 171 code 1110, Addis Ababa

Introduction
Most of the natural vegetation of Ethiopia has been greatly influenced by human activities, particularly agriculture, which has been practiced for the past 5000 years or more. The vegetation types most severely affected by agricultural activities are the forests and grasslands of the medium to higher altitudes, i.e. above 1500 m. It is thought that at least the small-seeded agricultural system, which arose in the Fertile Crescent of Western Asia and the Middle East (Iran – Iraq – Syria), was developed in the ecotone between grassland and woodland/forest. And it is this ecotone that the Ethiopian farmer in many parts of the country, where cereal based agriculture is practised continues to exploit. However, the deliberate growing of crops also evolved and adapted to the wide range of climatic conditions found in the country so that the country not only has unique endemic crops, but is also recognized as one of the twelve Vavilov centres of crop diversity in the world.

Agricultural activities have not been uniform throughout the country. Instead they reflect the range of diversity in climate and vegetation types, and several of the most important crops of the country have been developed from the wild relatives in these vegetation types. Ethiopia also shows a full spectrum of agricultural systems from basic hunter/gatherers with some cultivation, and the intensively managed root-crop poly-culture system based on enset (Ensete ventricosum), to the larger-seeded extensive systems of the moister lowlands to the small-seeded cereal-legume-oil crop systems of the intensively cultivated Afro-montane highlands. Extensive and sophisticated pastoralist systems have been developed where moisture is too limiting for crop production. All these systems have impacted on the natural ecosystems, which has also thrown up problems for the farmers in the form of pests and diseases. But these same systems undoubtedly also include the organisms that would normally control these ‘pests’. We have become very good at recognizing our enemies in the natural world. We need to do a lot more to recognize our friends, and what needs to be done to support and develop this friendship.

The identification and promotion of these ‘friends’ is an integral part of developing integrated pest management (IPM) – what we would prefer to call ecological pest management (EPM). The cases in point are the birds.

Using the ten broadly defined vegetation types identified in the Conservation Strategy of Ethiopia, we will explore how these relate to the agricultural systems and their crop complements of the country (See Table 33 as annex). We will also touch on the pests peculiar to the agricultural systems in vegetation types, and an economically and ecologically important group of animals, the birds.

There are two reasons to focus on bird biodiversity. One is ecological and the other economic. Many birds are high up the food chain, particularly the predators and scavengers. They are very good indicators of ecosystem health, particularly the use and abuse of organo-chlorine compounds, now collectively referred to as POPS (persistent organic pollutants).
Drastic reduction in the numbers of birds of prey in America and Europe in the 1950s and 1960s resulting from their inability to breed first identified the negatives impacts of pesticides, particularly DDT on the environment. The challenge of these pesticides was vividly presented in Rachel Carson’s book, “Silent Spring”. DDT is now banned in these countries, but pesticides continue to be a major cause of bird deaths. The annual toll was estimated at 67 million bird deaths on United States farmland in 1992 with ten times that number of birds exposed to pesticides (Pimental et al. 1992).

Economically, birds are the second major tourist attractions, after the country's historic sites. The over 800 species of bird recorded represent 8% of the world's bird fauna. Of these, 16 species are endemic and 31 recognised as globally threatened species. It is, therefore, highly appropriate that intensification of agriculture needed for Ethiopia to feed itself also remembers and takes account of the conservation of the rich bird biodiversity of the country.

The following ten vegetation types (See the following map) are based on those in EWNHS 1996 (Sebsebe Demissew, et al. 1996) and in Volume 1, the Natural Resource Base, of the Conservation Strategy of Ethiopia (Environmental Protection Authority, 1997).

**Desert and semi-desert vegetation**

True desert (zones without plant growth) only occurs in the Dallol/Danakil Depression. Semi-desert vegetation is found in the eastern lowlands and south below 900 m asl where the rainfall is generally erratic and less than 250 mm a year. These areas are found in the Afar Depression, in the eastern parts of the Ogaden (Somali Region), around Lake Chew Bahir and the Omo Delta / Lake Turkana area. Typical plants include distinctive succulents, particularly from the Aloaceae, Euphorbiaceae and Asclepiadaceae, and trees and shrubs of *Acacia*, *Commiphora* and *Boswellia* from which gums, resins, myrrh and incense are obtained. The Somali Region of Ethiopia is the semi-desert area richest in plant biodiversity, with many species having very restricted distributions. Many of these are suffrutescents — shrubs less than 50 cm tall — and small highly drought-resistant trees, including Yehib nut (*Cordeauxia edulis*) that produces a very nutritious fruit and a natural red dye.

Semi-desert vegetation is negatively impacted by a variety of factors including wind and water erosion, overgrazing (particularly around watering holes), human and domestic animal population movements due to drought and war, and agricultural development schemes through irrigation and the regular use of agricultural chemicals - particularly in the Afar region of the Awash Valley, on the Gode-Kelafo Plain along the Wabi Shebelle, and at the north end of Lake Chew Bahir.
Figure 8: Vegetation types in Ethiopia

Map showing vegetation types of Ethiopia after Sebsebe Demissew et al. (1996) and CSE (1997)
The plants of semi-desert areas are adapted to withstand long periods of drought and then grow and flourish when there is moisture. This can provide luxuriant feeding for the desert locust so that it can build up into swarms and come into farmers’ fields at harvest time, as was last seen following the drought of 1983/84.

Very large numbers of migrating birds pass through the Afar, many of them insectivores, particularly at and around the equinoxes in March/April and September. As far as we know, no study has been made of the impact of large-scale irrigated farming on these migrants, or their possible contribution to pest control.

**Acacia-Commiphora, small-leaved / microphyllous deciduous woodland**

*Acacia-Commiphora* woodland is the most extensive vegetation type in central, eastern and southeastern Ethiopia. It occurs at altitudes between 900 m and 1900 m and forms a zone between semi-desert vegetation and the moister montane forest and grassland complex at higher altitudes. The vegetation is usually rich in both incense (*Commiphora*) and acacia (*Acacia*) species, both of which have small leaves that are shed during the dry season. Deciduous woodland is found in the north, in the central Rift Valley, and in the south and south-east in Somali Region (the Ogaden) and Borana. The latter area, delimited to the north by the Bale massif and Chercher highlands, to the south and east by the borders with Kenya and Somalia, is estimated by Gilbert (1986) to contain about 25% of the species in the Ethiopian flora, a clear indication of its high level of plant diversity.

Rainfall within this vegetation type is very localised and unreliable, sometimes none falling for 10 months in a year or for several years in succession, and this is probably the most important factor preventing the expansion of settlements. Traditionally pastoralists and their herds have, therefore, used such vegetation. More recently, however, some areas have been cleared for irrigation schemes, such as near Ziway, and other substantial areas are being cut out, particularly acacias, to supply fuel wood and charcoal for major population centres, including Addis Ababa, Awassa, Arba Minch, Dessie, Mekele etc. (EWNHS 1996).

The Rift Valley was up until the late 1960s largely covered by acacia woodland with only very few *Commiphora* species, but much of this has been cut for making charcoal, and for growing maize and beans. Probably, the major pests are stalk borers in maize and African bollworm in beans.

For bird biodiversity, the Rift Valley is a major corridor for Palaearctic migrants entering and leaving Africa. Many of these are insectivores that can easily catch and consume their own bodyweight insects over a few days. The dry areas are often traversed by rivers or have lakes and these attract very high concentrations of birds, both residents and intra-African migrants, for example Pelicans and Flamingoes, as well as Palaearctic ducks and waders.

**Evergreen bushland**

Evergreen bushland is a natural vegetation type of drier rocky slopes, but it is expanding fast as forested areas are cleared. On the plateau, it is often intermixed with cultivated land as it is all that is left of dry evergreen montane forest and acacia woodland. Evergreen bushland is quite rich in species, particularly of shrubs and small trees including *Balanites aegyptiaca*, *Barbeya oleoides*, *Bersama abyssinica*, *Croton macrostachyus*, *Dodonea angustifolia*, *Euclea* spp., *Rhus* spp., *Tarconanthus camphoratus*; climbers including *Capparis* spp, *Jasminum* spp. and *Pterolobium stellatum*; and succulents, particularly species of *Aloe*, *Cissus*, *Kalanchoe* and *Sansevieria*. Most of these plants have tough leaves, which persist throughout the year.
However, there is usually little herb cover, particularly on the steep rocky slopes in the drier eastern parts of Ethiopia. This is now the most extensive vegetation type above 1500 m on the escarpment between the plateau and the Afar lowlands, and also on the steep slopes of the Abay (Blue Nile) catchment and its tributaries.

The bird fauna of these patches of natural vegetation can be surprisingly rich, and, although it includes species like mouse-birds that can be troublesome, it has many more species that contribute to the natural control of insect populations.

Dry evergreen montane forest and grassland
Friis (1992) describes three sub-types of dry evergreen forest: the dry forest of the eastern escarpment; the dry forest of the north and northeastern highland plateau; and the dry forest of the south in Borana, and Somali (Bale and Hararge). All these forests form mosaics with grassland, acacia woodland and evergreen bushland, the latter particularly found on rocky outcrops. There are a large number of species associated with this vegetation category.

The dry forests of the eastern escarpment
Dry evergreen montane forests occur in patches on the eastern-facing escarpment on rocky ground with unimpeded drainage from Tigray in the north down through Wello and Shewa, and in the Chercher highlands in the east between 1600 and 2400 m or to 3200 m in the mountains.

The low annual rainfall (less than 700 mm) is supplemented by mist as the growth form of *Juniperus procera* with its minute scale leaves and hanging branches is well adapted for catching and condensing moisture from the air. Many of the remaining juniper forests do not appear to be regenerating and they have been seriously damaged by fire outbreaks as well as cutting out of the larger trees and clearing for agriculture. The juniper forest on the escarpment is mixed with evergreen bushland. One of the best remaining examples is the relatively inaccessible Wefwasha forest on the escarpment between Debre Sina and Ankober. *Podocarpus falcatus* is found in the lower and wetter parts of this forest and there are isolated big trees found along the escarpment through Shewa and Wello to the Hugumburda forest in southern Tigray. This shows that the whole escarpment was much better forested and wetter in the past than it is today.

Nearly all of these forests have been cleared for agriculture resulting in much erosion unless the farmers have built up bench terraces and left wide grass bunds in place between the fields. Although these areas do not contribute much bulk to the agricultural production, they are important for contributing to and maintaining the large numbers of farmers’ varieties, each with their own special characteristics, including drought and disease resistance. The small fields keep varieties distinct - they also make it difficult for local insects to build up into economically damaging populations. The notable exception is the sporadic army worm which is a general feeder that spreads from south to north along the escarpment at the start of the rainy season.

The dry evergreen montane forest, grassland and Acacia woodland mosaic of the highland plateau
The mosaic of dry evergreen montane forest associated with acacia woodlands, montane grasslands and rocky outcrops occurs in much of the highlands in the northern and north-western, central and south-eastern parts of the Ethiopia between 1900 and 3400 m, where there is 800-1500 mm of rainfall. The complex is characterised by small to large-sized trees
on the sides of the valleys and extensive grasslands rich in legumes and other herbs in the valley bottoms. The ecotone between forest and grasslands is occupied by acacia woodland. This vegetation mosaic has now been found to include the highest number of endemic plant species, particularly from the three largest families in the Flora: Asteraceae, Fabaceae, and Poaceae. *Juniperus procera*, *Olea europaea* subsp. *cuspidata*, *Prunus africana*, *Celtis africana*, *Euphorbia ampithylla*, *Mimusops kummel* and *Ekebergia capensis* are the most common trees. Typical shrubs include *Dracaena* spp. *Carissa edulis* and *Rosa abyssinica*. In some of the wetter parts some prunus and african podo lao occur in this vegetation type.

These are the typical trees found in the dry evergreen montane forests of the north and north-western highland plateau.

South of Lake Tana, in Gojam and north Shewa where rainfall is higher, the natural forest was probably mixed juniper and African podo. Such mixed coniferous forest forms a transition to the humid forests with conifers in northern Borana and Bale. Menegesha and Chilimo forests, west of Addis Ababa are the best-preserved examples, with African podo re-establishing itself in Menegesha. Trees are taller in the southern part of the plateau with the canopy 20-30 m high. Below the canopy are one or more strata of small to medium sized trees and many climbers, below which are small trees, shrubs and herbs. Some of the common species are listed in Table 33.

The plateau is drained along wide valleys with gentle slopes and impeded drainage. This has resulted in extensive areas covered by heavy black clay soils that support grasslands, but no trees, and more swampy patches. Most of the drier areas of the valleys are heavily grazed with the turf covered by short creeping grasses and many herbs including clovers. The wetter valley bottoms are often covered with tall tussock grasses, sedges and rushes that provide good cover and feeding areas for a wide diversity of birds.

*Acacia* woodland would have been the vegetation type on the sides of the valleys, between the grasslands of the bottomlands, and the forest remnants and evergreen bushland of the upper slopes. Most of the grassland has been ploughed up, but acacia trees persist in fields where their thorny branches provide temporary fencing for fields containing crops.

Kosso, tree heather and tree St John's Wort are found at the upper limit of this vegetation mosaic around and above 2800 m. Sometimes small patches of trees go above 3000m into the afro-alpine zone.

**The dry forests of Borana, Bale and Somali (Hararge)**

The dry juniper forests of Borana, Bale and Hararge occur between 1500 and 2200m. The low rainfall of 400-700 mm is distributed in two rainy seasons, April-May and September-October. In Borana juniper forests are found at Arero, Yabello, Mega and Negele. The dry forest south of Negele is very open, almost juniper woodland with a canopy only 10-15 m high. This forest is often associated with *Acacia-Commiphora* woodland or evergreen bushland, as well as extensive grassland. The undergrowth consists of evergreen bushes with open grassy glades in between. Many of these forests have been severely degraded by logging and damaged by fires, and there is little evidence of natural regeneration.

The richness in plant species, including endemics, is reflected also in the bird diversity of this broad vegetation type through the Afrotropical Highland biome assemblage, which contains 48 species, including 7 of the 16 endemic species. Three of these species, Harwood’s
Francolin, endemic to the Abbay and Jemma river gorge of Northern Shewa, Ankober Serin described from the eastern escarpment, and now also found in Simien, and Ruepell’s Chat are restricted range species, i.e. found within an area of 50,000 km$^2$. These three species define the Central Ethiopian Highlands Endemic Bird Area of the world.

The problems with grain eating birds are a challenge to farmers who build platforms from which children, both boys and girls, chase away birds with sling shot stones. However, farmers also recognize the contribution of birds of prey to controlling rodents and traditionally keep the sides of fields clear of vegetation to make it easier for the birds to catch rodents. Another aid to attracting birds to help in pest control is to place larger stones or piles of stones, sometimes painted white, in a field so the birds can perch on these. The European Stork, a large white and black bird, migrates through Ethiopia from Europe to Southern Africa and can sometimes be seen feeding grasshoppers, particularly when these insects are very numerous. Prince Ruspoli’s Turaco is endemic and found in both the dry (4c) and the moister forests (5a) of southern Ethiopia, particularly Borana.

**Moist (broadleaved) evergreen montane forest**

Moist evergreen or broadleaved montane forests occur in the south, south-western and western parts of the plateau up to 2800 m. Rainfall reaches 1500 mm in the Harenna forest on the south-western slopes of the Bale massif, and in north Borana. In the west in Wellega, Illubabor and Kefa rainfall can be as high as 2400 mm.

This forest type is marked by two species of tall, emergent trees. At drier and higher altitudes this is African podo while in the lower and wetter areas it is a *Pouteria (Aningeria)*, known locally as kerero. These forests are multi-layered with other tall and medium sized trees forming the continuous canopy, and containing epiphytic orchids, ferns and other specialised herbs. There is also a shrub and herb layer. The shrub layer often contains ‘wild’ or ‘forest’ coffee. Plant endemism is not high, although a number of endemic herbs and epiphytes are found.

Three sub-types of moist evergreen forest vegetation have been recognised:

**Humid mixed forest in northern Borana and in Bale**

Harenna forest on the southern flanks of the Bale massif is still one of the most extensive areas of this type of forest although it was badly damaged by fires in 2000, and there has been much uncontrolled logging. The biggest trees are African podo and keraro with olives, crotons and other broad-leaved species in the canopy. Below are smaller trees and large shrubs, lianas, epiphytes and a lush ground cover. The Harenna forest also contains a few species, also found in East African forests, but not in the southwestern forests of Ethiopia. These are found on the southern, drier edge of the forest. Above 2,800m, tree heather, tree St. John's wort and kosso replace the typical species, and the tree line extends to 3,500 m -- well into the afro-alpine zone.

Other forests of this type are those of Anferara-Wadera and Bore-Anferara found in Borana between Agere Selam and Kibre Mengist. The drier areas to the north are dominated by African podo while keraro becomes more important in the wetter southern parts of these forests. The canopy contains a wide variety of species and there are many smaller trees and shrubs making these forests floristically rich in biodiversity.

Patches of highland bamboo are found in both the Harenna forest and those of northern Borana. The bamboo is used extensively in building local houses. These forests are also
fringed by woodland rich in species of small trees and shrubs, several of which produce spicy smelling oils and resins. Areas of limestone in these woodlands are dominated by grassland while waterlogged areas can become overgrown with whistling thorn acacia.

**Humid broad-leaved montane forest in southern Welega, Illubabor and Kefa**
The tall emergent tree is keraro (*Aningeria adolfi-friedericii*). It used to dominate the forests with its crown 20-30 m above the ground. The main canopy around 15-20 m consists of at least 20 species. As well as smaller trees, numerous shrubs, lianas, scrambling shrubs and a wide range of epiphytes, including ferns and orchids, occur and over 100 species of herbaceous plants are known.

A most interesting feature of these forests is their association with wetlands, streams and rivers draining westwards which have become blocked at their outlets inundating the valleys upstream. Many of these near to developing urban centres and roads are now being drained to produce horticultural crops. The effects on the groundwater and the surrounding forests need to be monitored.

**Transitional rain forests of the south-western escarpment**
These are called 'transitional rain forest' because they are found between the lowland forests of the Gambella lowlands, and the humid broadleaved montane forest. They are found between 800 and 1500 m, in the valleys of the Baro river watershed on the south-western escarpment. Species more familiar in the rain forests of Uganda and the Congo basin are found in these forests. Many of these are valuable timber trees and include some on the World List of Endangered Trees. These forests have been and continue to be heavily logged which has led and continues to lead to a substantial reduction in the size and species composition of forests, because selected species are targeted. They have also been and continue to be decimated by commercial coffee and tea growing operations which have included the extensive planting of pure stands of eucalyptus to provide fuel for the tea curing factories.

**Birds** are very important assistants in maintaining forest health. First and foremost is their contribution in controlling insect populations. When breeding and rearing a brood, insectivorous birds collect literally tonnes of insect larvae from leaf-eating caterpillars to wood boring beetle grubs. Birds are also important as pollinators – all red-flowered trees, for example *Erythrina brucei* ‘korch’, are designed for bird pollination – and distributors of seeds in forest regeneration. Any IPM programme for forests has to make sure that a large and healthy bird diversity is encouraged.

Forest bird species, although much more difficult to observe than in more open area or on cliffs, also attract bird watchers and could be used as income earners in forest conservation. Prince Ruspoli’s Turaco has already been mentioned, but there are other forest endemics, for example Yellow-fronted Parrot, Abyssinian Woodpecker and Abyssinian Catbird.

**Lowland semi-evergreen forest**
This semi-deciduous forest is dominated by an endemic leguminous tree, *Baphia*, found along the Baro and Pibor river basins in south-western Ethiopia and adjacent Sudan. In Ethiopia this forest type is only known to occur on the plains just south of Gambela, adjacent to, but outside, Gambela National Park.

The vegetation type is generally poorly known, but one area between Abobo and Gog at 450-600 m is in relatively flat country, on well-drained sandy soils, with ground water not far
below the surface. Mean annual temperatures are very high, between 35-38°C, while most of its annual rainfall of 1300-1800 mm falls between May and September.

This vegetation type is characterised by a 15-20 m tall, more or less continuous canopy of *Baphia abyssinica*, mixed with a few emergents and several other less common species. Below the closed canopy is a further more or less continuous layer of small trees. There is also a shrub layer, which is not dense. Lianas are not prominent, but thorny woody climbers make walking in the forest difficult. There appear to be no epiphytes and generally the forest floor has very few species.

The forest is severely threatened, partly by the rapid expansion of Gambela town and other settlements in the region, and partly by the Abobo dam, which has already flooded a substantial part of the forest (EWNHS 1996). Large scale irrigated agricultural is envisaged in the area in the future.

The **birds** of this forest are little known.

**Combretum-Terminalia, broadleaved / macrophyllous deciduous woodland**

*Combretum-Terminalia* woodland is the most extensive vegetation type in the west. It is found mainly between 500 and 1900 m in the lowlands of western and north-western Ethiopia, the upper and lower Omo valley and in western Eritrea. It is composed of small, fire-resistant trees with fairly large, deciduous leaves and a ground cover of herbs and grasses. There are also large areas of lowland solid-stemmed bamboo in the river valleys of western Ethiopia and on some hillsides. The dominant grasses are mainly tall species, 3 m tall or more. This woodland has been substantially reduced in recent years due to expansion of agricultural activities and the demand for charcoal and fuel wood for major towns.

When the “Important Bird Areas of Ethiopia” was published in 1996, very little detail was known about either the flora or the bird fauna of western Ethiopia, particularly Benshangul-Gumuz. Sixteen species of bird belonging to the Sudan-Guinea Savannah Biome had been recorded from Ethiopia, mostly from the Gambella area. However, now seven years later, we know that Benshangul-Gumuz is much richer in biodiversity of both plant species and birds, than expected. This is thanks to the work of Christof Herrmann, who collected plant species and recorded the birds he saw over two years of work with the Regional Agriculture and Environment Bureau. He recorded around 300 bird species, nearly 40% of the total known for the country. Making sure that adequate representative areas of the different habitats are preserved should be an integral part of the development plan for both the Gambella and Benshangul-Gumuz regions.

**Afroalpine and sub-afroalpine vegetation**

The afroalpine zone is considered to start above 3000 m, though often the more typical vegetation is found above 3200 m. Much of this vegetation occurs on thin soil over basaltic rocks on the slopes and tops of the highest mountains in Ethiopia. Thus, it is found in the Simen Mountains (Ras Dashen, 4620 m), the Lasta Masif (Mount Abuna Yosef, 4194 m), the Guna Massif (Mount Guna, 4281 m), Mount Collo (4300 m), the Choke Mountains (Ras Birhan, 4154 m), the Gurage Massif (Mount Gurage, 3719 m), the Gughe Massif (Mount Tola, 4200 m), the Amaro Mountains, Mount Chilalo (4127 m), Mount Bada (4133 m), Mount Kaka (4200 m) and the Bale Mountains (Mount Batu 4307 m). It is the major vegetation type of the Simen Mountains and Bale Mountains National Parks.
Afroalpine vegetation is characterised by shrubs and shrubby herbs in the form of cushions, particularly many species of everlasting flowers, and at higher altitudes by giant lobelias, small herbs and grasses, many of these closely related to species in the colder and wetter parts of Europe. The plants are adapted to freezing temperatures every night and very intense sunshine with high temperatures during the day.

At lower altitudes, between 2800 and 3200 m, in the sub-afroalpine belt, the most extensive vegetation is of ericaceous bushland and forest with tree heather the dominant species. The poorly drained flatter areas support wet meadows and marsh or aquatic vegetation. The afro-alpine zone is a very important source of dry season water for permanent streams which feed into the rivers of the plateau and lowlands.

This is an extremely fragile environment that is greatly threatened by overgrazing, fire and expansion of barley cultivation, particularly on the steeper slopes, which are being devastated by sheet erosion.

Floristically, the Afro-alpine areas include species with close relatives among the temperate and alpine floras of Europe. Similar closeness is also seen in the bird diversity, with two populations of Red-billed Chough, one in the Simien Mountains and the other in the Bale Mountains. The most spectacular bird of these areas is the Lammergeier or Bearded Vulture with its wingspan of nearly three metres. Although farmers claim that it will take young sheep (lambs) or goats (kids), it is actually designed to eat bones. These high areas are particularly rich in birds of prey, for example eagles, and vultures, whose populations have been severely reduced in most other parts of the world. These birds both help control populations of rodents and attract bird specialist visitors and tourists. It is important that the National Parks already identified in these areas are respected and strengthened.

**Riverine vegetation**

The species found in this vegetation type are very variable, with their composition largely determined by the species found in nearby forests and woodlands. It also varies with altitude, rainfall, geographical location, soil etc. Riverine vegetation is found in the Afar Depression, the Awash River, the Dawa River, the Abay River, and the Baro River in western Ethiopia. It is characterised by large trees, particularly figs and tamarind, palm trees, and a wide variety of small trees, shrubs, and climbers, with associated herbs and grasses. In the moist western river valleys, other tall trees characteristic of riverbanks include albizia (*Albizia* spec.), dokma (*Syzygium guineense*), and crown of thorns. This type of vegetation is also found around the southern shore of Lake Tana and the upper parts of the Abay (Blue Nile) River, and also between Lakes Abaya and Chamo.

The fact that riverine vegetation can be unique or provide specialized habitats for biodiversity is reflected in the third of the Endemic Bird Areas (EBA) found in Ethiopia – this is Juba and Shebeelle Valleys EBA shared with Somalia. Farmers often see bird populations by rivers as threats because many weaver birds make their breeding colonies in trees overhanging water. These birds are particularly troublesome for maize and sorghum. However, the relationship of the other birds in riverine vegetation and their contributions to natural insect pest control has not been studied.

**Wetlands and swamp vegetation**

The main wetland areas include the major rivers, (the Takezze, Abay, Baro, Gilo and Akobo, Omo, Awash, Wabe Shebelle, Genale and Dawa), the large inland lakes (Abaya, Chamo,
Awassa, Abijatta, Shalla, Langano, Ziway and Tana), and inland swamps (at Lake Chew Bahir, along the shores of the Rift Valley lakes, east side of Lake Tana, Lake Afrera, and Lake Abbe in the Awash Valley). The most extensive wetland areas occur, for the highlands, in Fincha, and for the lowlands in the Baro-Gilo-Akobo lowlands of Gambela Region in the west, the end of the Awash river in the east, and the Wabi Shebelle in the southeast. Wetland vegetation also exists along the wide stream valleys and depressions on the plateau.

The dominant species in wetlands and swamps are sedges and rushes, the largest of which is papyrus which still forms quite extensive beds around Lake Tana, and to lesser extent around Lake Ziway. Papyrus is used to build boats on these lakes. Other distinctive species are the bullrushes or cat's tails and the balsa wood tree used to make boats on Lake Abaya. A few grasses are also well adapted to waterlogged conditions. They can grow to over 3 m tall making dense stands, particularly in the Gambella lowlands. At lower altitudes in the drier east, water tends to be saline and the most important species are duum palm, tough tussocky grasses and saltworts.

The **bird fauna** of wetlands includes a number of species which congregate in large numbers, particularly during migrations, and then again at breeding. These species are given special consideration in conservation work. Many agriculturalists and development workers view wetlands as unused or unusable areas that harbour disease, and thus need to be drained. Apart from their ornithological importance, these areas are vital in maintaining the hydrological cycle / balance, i.e. absorbing large amounts of water in the rainy season and releasing this slowly during the dry season. Many of the ‘wet’ valley bottoms become the most important source of grazing during the dry season. However, these areas also harbour ticks and leeches which menace livestock. The feeding habits of the birds in these areas and their possible contribution to helping control these livestock pests have not been studied.

The Sululta valley, northeast of Entoto and Addis Ababa, is an interesting example of an area where the farmers value the natural vegetation over crops, and where one of the rarest birds of the world has been found breeding. This bird is the White-Winged Flufftail, which is a member of the Rail family, related to Rouget’s Rail, YeSatan Doro. The bird lives and breeds in wetlands of Suluta and the farmers of Sululita make a better income out of preserving the rich mix of grasses and legumes and then cutting and selling this as hay to the very large number of small dairy herds in Addis Ababa.
1. Desert and semi-desert vegetation
2. *Acacia-Commiphora*, small-leaved / microphyllous deciduous woodland
3. Evergreen bushland
4. Dry evergreen montane forest and grassland
4a. The dry forests of the eastern escarpment.
4b. The dry evergreen montane forest, grassland and acacia woodland mosaic of the highland plateau.
4c. The dry forests of Borana, Bale and Somali (Hararge)
5. Moist (broadleaved) evergreen montane forest
5a. Humid mixed forest in northern Borana and in Bale
5b. Humid broad-leaved montane forest in southern Welega, Illubabor and Kefa
5c. Transitional rain forests of the south-western escarpment
6. Lowland semi-evergreen forest
7. *Combretum-Terminalia*, broad-leaved / macrophyllous deciduous woodland
8. Afroalpine and sub-afroalpine vegetation
9. Riverine vegetation
10. Wetlands and swamp vegetation

Table 33: Some representative species found in the various vegetation types of Ethiopia

<table>
<thead>
<tr>
<th>Major crops used in Ethiopia</th>
<th>Vegetation type</th>
<th>CEREALS</th>
<th>PULSES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Name</strong></td>
<td><strong>Common name and remarks</strong></td>
<td><strong>Vegetation type</strong></td>
<td><strong>1</strong></td>
</tr>
<tr>
<td>Avena abyssinica Hochst.</td>
<td>sennar or Abyssinian oat – <em>endemic semi-domesticate</em></td>
<td></td>
<td></td>
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<tr>
<td>Avena sativa L.</td>
<td>forage oat, shiferaw - introduced and replacing barley</td>
<td></td>
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<tr>
<td>Eleusine coracana (L.) Gaertn.</td>
<td>finger millet, dagussa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eragrostis tef (Zucc.) Trotter</td>
<td>tef, endemic crop, now grown in other countries to feed the Diaspora, and as a forage crop</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hordeum vulgare L.</td>
<td>barley, very wide diversity of farmers’ varieties</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pennisetum glaucum (L.) R.Br.</td>
<td>pearl or bulrush millet, bultug</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sorghum bicolor (L.) Moench</td>
<td>sorghum, zengada (brewing), mashla (food)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triticum dicoccon Schrank;</td>
<td>emmer, ajar / agar (Amh.), arras (Tig.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triticum aestivum L.</td>
<td>bread wheat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triticum aethiopicum Jakubz.</td>
<td>Ethiopian emmer, *endemic, widely cultivated up to 3000 m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triticum durum Desf.</td>
<td>durum or macaroni wheat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triticum monococcum L.</td>
<td>Einkorn wheat, small spelt, ‘adja’</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triticum polonicum L.</td>
<td>Polish wheat, one of the group of high protein wheats called ‘adja’</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triticum spelta L.</td>
<td>spelt or dinkel wheat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triticum turgidum L.</td>
<td>Rivet wheat, cone wheat, pollard wheat – an ‘adja’ type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zea mays L.</td>
<td>maize, beqolo, yebahr mashla</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>PULSES</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arachis hypogea L.</td>
<td>groundnut, ocholoni, usually grown with irrigation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cicer arietinum L.</td>
<td>chickpea, shimbera, with different farmers' varieties</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lathyrus sativus L.</td>
<td>grass pea, seberi</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 The scientific names are those used in the Flora of Ethiopia and Eritrea
Facilitating the Implementation and Adoption of Integrated Pest Management (IPM) in Ethiopia

<table>
<thead>
<tr>
<th>Major crops used in Ethiopia</th>
<th>Vegetation type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Name</strong></td>
<td><strong>Common name and remarks</strong></td>
</tr>
<tr>
<td>Lens culinaris Medik.</td>
<td>lentil, misser</td>
</tr>
<tr>
<td>Lupinus albus L.</td>
<td>white lupin, gupto</td>
</tr>
<tr>
<td>Phaseolus lunatus L.</td>
<td>lima bean, home garden crop</td>
</tr>
<tr>
<td>Phaseolus vulgaris L.</td>
<td>haricot or common bean, fasolea, adaguare</td>
</tr>
<tr>
<td>Pisum sativum L.</td>
<td>pea, field pea</td>
</tr>
<tr>
<td>Pisum sativum var abyssinicum (A. Br.) Alef.</td>
<td>Abyssinian pea, *endemic</td>
</tr>
<tr>
<td>Trigonella foenum-graecum L.</td>
<td>fenugreek, abish</td>
</tr>
<tr>
<td>Vicia faba L.</td>
<td>faba bean, bakela</td>
</tr>
<tr>
<td>Vigna unguiculata (L.) Walp.</td>
<td>cowpea, adenguare</td>
</tr>
<tr>
<td><strong>OIL CROPS</strong></td>
<td></td>
</tr>
<tr>
<td>Carthamus tinctorius L.</td>
<td>Safflower, suf</td>
</tr>
<tr>
<td>Brassica spp.</td>
<td>oil seed rape, gomen zer</td>
</tr>
<tr>
<td>Gossypium arboreum L. / G. herbaceum L.</td>
<td>perennial cotton, grown in home gardens</td>
</tr>
<tr>
<td>Gossypium arborescens L. / G. herbaceum L.</td>
<td>modern cotton, under irrigation in lowlands</td>
</tr>
<tr>
<td>Guizotia abyssinica (L.f.) Cass.</td>
<td>niger seed, noog</td>
</tr>
<tr>
<td>Linum usitatissimum L.</td>
<td>linseed, telba – most important gene pool in the world</td>
</tr>
<tr>
<td>Ricinus communis L.</td>
<td>castor bean, gulo, mostly home gardens and semi-wild</td>
</tr>
<tr>
<td>Sesamum indicum L.</td>
<td>sesame, selit</td>
</tr>
<tr>
<td><strong>ROOT AND TUBER CROPS</strong></td>
<td></td>
</tr>
<tr>
<td>Amorphophallus abyssinicus (A. Rich.) N.E.Br.</td>
<td>bagana (Konso)</td>
</tr>
<tr>
<td>Cocinea abyssinica (Lam.) Cogniaux</td>
<td>anchote, *endemic, cultivated in home gardens</td>
</tr>
<tr>
<td>Colocasia esculenta (L.) Schott</td>
<td>taro, godere</td>
</tr>
<tr>
<td>Dioscorea spp.</td>
<td>yams</td>
</tr>
<tr>
<td>Ensete ventricosum (Welw.) Cheesman</td>
<td>enset</td>
</tr>
<tr>
<td>Ipomoea batatas (L.) Lam.</td>
<td>sweet potato,</td>
</tr>
<tr>
<td>Plectranthus (Coleus) edulis</td>
<td>Wolaita / Oromo dinich, mostly in home gardens</td>
</tr>
<tr>
<td>Solanum tuberosum L.</td>
<td>potato / Irish potato - introduced since</td>
</tr>
<tr>
<td><strong>STIMULANTS</strong></td>
<td></td>
</tr>
<tr>
<td>Catha edulis Forssk.</td>
<td>chat, mirra, also grows wild in montane forest</td>
</tr>
<tr>
<td>Coffea arabica L.</td>
<td>Arabica coffee, originally as forest coffee, in home gardens</td>
</tr>
</tbody>
</table>
References and Further Reading


Pimentel, David et al., Environmental and Economic Costs of Pesticide Use. Bioscience 42(10): 750-760.


13. Pest Control Technologies in Extension Packages in Ethiopia

Aberra Deressa
EARO, Melkassa Agricultural Research Center
P. O. Box 436, Nazareth, Ethiopia

Abstract
Pests are organisms that interfere with human interest and leading to certain level of losses. Weeds, insects and diseases are considered as pests if they result in 5-10% yield loss. In Ethiopia, the overall yield losses by these pests range from 30-70%. Pests like Striga, Orobanche, Parthenium, stem borers, sorghum chafer, weevils, bruchids, cereal rusts, blights on cereals, and many other pests have been research topics emphasized by the Ethiopian National Agricultural Research and Development System over the last three decades. The research approach on pests has been to develop integrated pest management where emphasis was given to cultural control (sowing date, intercropping, crop residue management, plant density), biological control (mainly conservation of natural enemies), varietal resistance, botanical control (mainly use of neem seed powder) and safe and effective chemical pesticide screening. There have also been basic studies such as weed and insect biology, disease epidemiology, population dynamics, alternative host identification and many others, which would help to design integrated pest management effectively. Only very few of these technologies have been transferred to the user community such as private farmers, state farms and investors. Some of these technologies, which were transferred, made a great impact to the extent of doubling the productivity of some of the commodities. In this paper, research efforts put to control economic pests in Ethiopia will be discussed in depth and examples of case studies for successful pest control which has been considered in an extension package system will be picked up to explicitly demonstrate the need for pest control tactics in the extension package system in Ethiopia.

Dejene Abesha
Ministry of Agriculture and Rural Development, Addis Ababa

Ethiopian agriculture is dominated by smallholder farmers who account for about 95 percent of the food production. The majority of them, due to lack of resources and know-how, do not use improved agricultural technologies. Pre- and post-harvest losses due to various insect pests, diseases, weeds and vertebrate pests are believed to be 30-40%. Because of this, several measures including cultural, biological, and chemical methods are used for the control of these pests.

The bulk of past pest control recommendations in Ethiopia relied heavily on the use of pesticides. Although comprehensive data are lacking incidence of livestock and human poisoning has been reported due to the improper use and storage of pesticides. Recognition of the problems associated with wide spread application of pesticides, the search for alternative pest control strategies such as integrated pest management (IPM) becomes apparent.

It is obvious that the extension programme is open to a wide variety of choices in the use of agricultural technologies. Similarly the extension programme acknowledges alternative strategies to pest control. However, efforts to be made along this line must first of all consider the benefits to be obtained by the farming communities in terms of economy, safety and hazards caused to the natural resources especially land, water, plants and animals.

The majority of small-scale farmers are not aware of the importance of crop pests and the extent of yield loss caused by them in their crops. Very few undertake interventions with pesticides. Those farmers who are able to grow high economic value crops are in the threshold of getting into the "pesticide treadmill", since the investment is more profitable than cereal agriculture.

In the past, chemical approach to pest control was given priority attention. This approach resulted in several disadvantages in terms of cost, loss of foreign exchange, lack of reliability of supply, pest resistance and resurgence, environmental and health hazards, although some of which had worthwhile benefits to food production or to the control of disease vector.

All present development policies and strategies related to rural development, food security and poverty reduction acknowledge the use of environmentally friendly technologies. In spite of this provision, implementation of IPM as one of the options for pest control has been low.
15. Experience with Watershed Management and Moisture Conservation Techniques in Ethiopia

Messele Fisseha
Basin Development Studies and Water Vitalization Control Department
Ministry of Water Resources, Addis Ababa

Abstract
Watershed degradation is a critical issue in Ethiopia. Poor land use practices and deforestation are the major causes of accelerated erosion. As human and livestock population pressures mount, forests are cleared for new farms, grazing space and fuel wood (the main source of energy). Many steep and marginal lands would, formerly when the population pressure was less, have been left protected by trees or bush, but today land and wood shortages force farmers to clear these lands, leaving the soil exposed to erosion. The consequences of watershed degradation result in reduced land productivity, increased vulnerability to droughts, sediment deposition in water resources development structures and habitat damage.

Although the government and non-governmental organizations are putting much effort and money, the progress is slow because of the complexity and magnitude of the problem. Any intervention designed to address watershed management in Ethiopia must be designed to address the root causes of land degradation, soil fertility loss and sedimentation. In view of the multi-sectoral nature of the problem (land degradation, fuel wood demands, population pressures, illiteracy, lack of alternative livelihoods, etc.), a comprehensive and integrated approach is required. However, while the impacts of interventions to address the range of relevant root causes will take a longer timeframe in order to cause lasting change, several site-specific watershed management interventions need to be initiated as soon as possible and in parallel with a broader range of actions. Their urgency of action is brought about by the severity of the problems and the threat from widespread food insecurity.

Watershed development programs aim at improving the income and raise the living standards of the community. This requires a sound integration of technologies for optimal development. Different techniques are possible but the best options, however, are those that are socially acceptable and ecologically viable.

Introduction
Land degradation and deforestation are the two most severe environmental problems affecting Ethiopia. The growing human and livestock population are the basic causes of the accelerating watershed degradation. The results are the serious scarcity of fuel wood, particularly in the highlands and increased use of animal dung and crop residues as domestic fuel, which otherwise could have been used to maintain the level of soil organic matter and enhance crop production.

Deterioration of watersheds causes sedimentation and siltation of downstream reservoirs and irrigation schemes. It also causes flooding and reduction of base flow in rivers and streams. Hurni (1983) asserted that the Ethiopian highlands are one of the largest areas of ecological degradation in Africa.
Organized soil conservation efforts began as a consequence of the severe drought of 1973-74. Two parallel approaches were designed for soil conservation activities. The first utilized a Food for Work Project approach and the second a pure extension approach with no material incentive for adoption. The technical packages were identical for both approaches.

The catchment protection plantations were established using a state forestry development approach with no provision for farmers or their organizations to have a say in their establishment and management. Despite these efforts, planned and implemented by centralized organizations, most of the initial structural advances have been lost. Critical shortcomings in incentive mechanisms; security of tree tenure and applied research support are presently hindering the effort to arrest watershed degradation and expand vegetative cover. Some natural physical constraints also contribute to the problem.

**Climate**

The climate of the Ethiopian highlands is dominated by two factors. These are:

1. The position of Ethiopia near the equator (between 3° 30’ & 18° 12’ north latitudes)
2. The large highland landmass lying in the north and western parts.

The Ethiopian Highlands Reclamation Study (1988) defined the highlands as those areas above 1500 m above sea level and associated valleys. About 44% of the country is highland (FAO 1986b), lying above 1500 m.a.s.l and rising above 4000 m. The main rainy season (kiremt) lasts generally from June to September. About 70 - 90 percent of total annual rainfall occurs during this season. A dry season (bega) lasts from October to January. The minor rainy season (belg) lasts generally from February to May. The timing and duration of these seasons varies in space and time.

Although there are areas of high rainfall with longer wet season, which gives good conditions for vegetative cover, extensive land areas within the low altitude and high altitude get very little or no rain for 6 to 8 consecutive dry months. Further annual variation of rainfall in the wet season is considerable; in some years a real wet season is hardly noticeable (associated with drought years). All these are clear indications of the difficulties of establishing vegetative cover in the actively eroding areas of the uplands. Strongly peaked unimodal profile with peak between July to September and dry from October to May; this pattern covers most parts of the country.

Generally, evaporation depends on both geographical coordinates and on the ground feature such as wind speed, temperature, radiation and altitude above sea level. To cite the example of the Wonji Sugar Estate, for the years 1977 - 1982, the mean annual rainfall is 795 mm, whereas the mean annual Penman Potential Evapotranspiration is 1948 mm.

**Physiography**

The physiography of Ethiopia reflects its geology and geological history. One of the distinguishing features of the highlands is the extremely broken nature of much of the terrain. In general, uplifting of the highland plateau, followed by tilting provided an initial highland altitude range between about 1500 and 3000 m.a.s.l.

Volcanic activity produced upstanding peaks (volcanoes) rising to over 4,000 m, while the associated out pouring of lava left the plateau and mountains covered by a thick basalt cap. The highlands are cut into a number of blocks by the deeply incised gorges of the Abay,
Drylands Coordination Group

Tekeze, Baro-Akobo, Mereb, Awash etc. and their tributaries. The highlands give way to flat and rolling lowlands. Some 60 percent of the central Highland has slopes in excess of 16 percent while about 34% has slopes in excess of 30 percent (FAO 1986a). Increasing slope gradient (steepness) increases the speed of water moving downhill, thereby increasing the erosiveness of the runoff.

Soils
Successful and sustainable cropping depends on effective soil water storage and aggregate stability. The dominant soils in the highlands are Leptosols, which are characterized by a very shallow soil depth of less than 25 cm, resting on hard rock. They also have a rather stony surface. These soils cover 50% of the Tekeze Basin, 21% of the Abay Basin and 20% of the Baro-Akobo Basin.

Water-stable aggregates resist breakdown due to raindrop impact and help maintain favorable infiltration rates whereas unstable aggregates lead to surface sealing and reduced infiltration.

Regosols, Cambisols, Arenosols with 25 - 50 cm depth cover about 20% of the highlands. Soil depths, which are often less than 10 cm, and cultivations that commonly extend into the underlying rock are common occurrence in the highlands.

Runoff is always greater on shallower soils. Shallow soils store little moisture and are less fertile than deep soils because of nutrient depletion under monoculture. Soil fertility is important because it promotes plant growth which in turn protects the soil from erosion. Table 34 shows the soil depth per major landform (% per development zone) of the Tekeze River Basin (MOWR).

Large stable aggregates make a soil difficult to detach and transport. A stable structure results from high organic matter content. Organic matter in the soil can absorb and store water to a greater extent than the inorganic fractions and helps to cement together aggregates and make them more stable. But to our dismay, crop residues and animal dung which are the main sources of organic matter are collected for domestic fuel.

Land Use and Past Experiences in Watershed Management
The amount of soil lost by erosion is dependent on the soil management conditions and degree of soil cover. The way land is used is partly due to what it is capable of growing, and partly due to the individual choice of the farmer. To this must be added the constraints imposed by land suitability.

The soundness of a land use system and their practices in a watershed influences the status and the resulting hydrological behavior of the watershed. A considerable area of woodland and bush land is being cleared annually because of the ever increasing demographic pressure.

The energy sector in Ethiopia is one of the least developed in the world with 90 percent of needs being met from biomass fuels, particularly wood, charcoal and animal dung (Halcrow & Partners 1989).

The rugged nature of the country's terrain, intense cultivation of the steep slopes, together with overgrazing, have all contributed directly to the continued ecological degradation. The way in which the land is used affects erosion basically through its effect on vegetative cover and soil erodibility. Recent studies suggest a critical level of vegetative cover of around 30 to
40% below which soil losses are rapid. The greatest erosion hazard in cropping occurs when soils are exposed prior to planting and during early plant growth. Tillage gives rise to more erosion when it is on slopes as it is traditionally in the highlands while the bottomlands are used mainly for grazing. Two thirds of the 1000 farmers interviewed in the EHRS sociological survey cultivate wholly on hillsides (FAO 1986b). Although the bottomlands have deep fertile soils reflecting the deposition of sediment from the higher slopes, they are not traditionally cultivated because of the problems with traction and strength of the maresha (heavy clay soils) and the valley bottoms tend to become waterlogged during the growing season. This land use pattern is the more damaging the steeper the slope.

The relatively low yielding tef is regarded by some as being highly erosive because its small seeds require a very fine tilth (up to six ploughing required) and it is not normally planted until well after the start of the rains. On the other hand, tef’s dense roots and plant populations close to the ground provide good protection. Perennial crops such as coffee and enset provide continuing protection and soil is not disturbed. Soil losses, therefore, are greatest under cereals.

Overgrazing reduces the carrying capacity of the grasslands resulting in land degradation. The reliance on oxen for animal traction in the highland results in the increasing cattle herd as cultivation expands. The Ethiopian Highland Reclamation Study estimates that 4 hectares of grazing land are needed to maintain the oxen to plough 1 hectare of arable land on average (FAO 1986b).

To combat land degradation, the government has since the early 1970's been involved in reforestation and soil conservation efforts through community participation. About 240,000 ha of denuded hillsides have been reforested, 375,000 ha of land area closed and some 799,000 ha of erosion susceptible croplands bunded (MOWR 1998).

Table 34: Soil depth per major landform (Tekeze Basin)

<table>
<thead>
<tr>
<th>Soil Characteristic</th>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
<th>Zone 4</th>
<th>Zone 5</th>
<th>Zone 6</th>
<th>Zone 7</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil depth &gt;50 cm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level land</td>
<td>10.40</td>
<td>12.13</td>
<td>22.74</td>
<td>17.53</td>
<td>4.25</td>
<td>2.80</td>
<td>3.33</td>
<td>10.45</td>
</tr>
<tr>
<td>Sloping land</td>
<td>7.92</td>
<td>2.96</td>
<td>4.80</td>
<td>3.11</td>
<td>4.55</td>
<td>2.83</td>
<td>2.15</td>
<td>4.05</td>
</tr>
<tr>
<td>Steep land</td>
<td>6.38</td>
<td>5.39</td>
<td>1.68</td>
<td>5.97</td>
<td>12.61</td>
<td>14.55</td>
<td>15.54</td>
<td>9.45</td>
</tr>
<tr>
<td>Composite land</td>
<td>6.40</td>
<td>5.66</td>
<td>9.71</td>
<td>13.59</td>
<td>5.60</td>
<td>2.88</td>
<td>4.30</td>
<td>7.02</td>
</tr>
<tr>
<td>Total</td>
<td>31.09</td>
<td>28.13</td>
<td>41.92</td>
<td>40.20</td>
<td>27.01</td>
<td>23.06</td>
<td>25.32</td>
<td>30.96</td>
</tr>
<tr>
<td>Soil Depth 25-50 cm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level land</td>
<td>2.76</td>
<td>3.42</td>
<td>2.54</td>
<td>3.02</td>
<td>0.66</td>
<td>1.02</td>
<td>0.28</td>
<td>1.96</td>
</tr>
<tr>
<td>Sloping land</td>
<td>6.43</td>
<td>2.82</td>
<td>15.62</td>
<td>3.11</td>
<td>4.55</td>
<td>2.93</td>
<td>2.15</td>
<td>5.37</td>
</tr>
<tr>
<td>Steep land</td>
<td>5.46</td>
<td>5.87</td>
<td>4.64</td>
<td>5.96</td>
<td>12.62</td>
<td>14.56</td>
<td>15.55</td>
<td>9.20</td>
</tr>
<tr>
<td>Composite land</td>
<td>3.83</td>
<td>4.80</td>
<td>4.16</td>
<td>5.19</td>
<td>3.19</td>
<td>1.47</td>
<td>2.29</td>
<td>3.56</td>
</tr>
<tr>
<td>Total</td>
<td>18.48</td>
<td>16.91</td>
<td>16.96</td>
<td>17.28</td>
<td>21.02</td>
<td>19.98</td>
<td>20.27</td>
<td>18.70</td>
</tr>
<tr>
<td>Soil depth &lt;25 cm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level land</td>
<td>1.74</td>
<td>4.68</td>
<td>6.12</td>
<td>4.02</td>
<td>0.81</td>
<td>0.80</td>
<td>0.83</td>
<td>2.71</td>
</tr>
<tr>
<td>Sloping land</td>
<td>7.36</td>
<td>2.52</td>
<td>5.67</td>
<td>4.15</td>
<td>5.98</td>
<td>3.59</td>
<td>2.86</td>
<td>4.59</td>
</tr>
<tr>
<td>Steep land</td>
<td>30.95</td>
<td>4.50</td>
<td>19.78</td>
<td>22.67</td>
<td>40.89</td>
<td>50.47</td>
<td>48.08</td>
<td>36.33</td>
</tr>
<tr>
<td>Composite land</td>
<td>10.37</td>
<td>6.25</td>
<td>9.55</td>
<td>11.68</td>
<td>4.30</td>
<td>2.10</td>
<td>2.64</td>
<td>6.70</td>
</tr>
<tr>
<td>Total</td>
<td>50.43</td>
<td>54.95</td>
<td>41.13</td>
<td>42.51</td>
<td>51.98</td>
<td>56.96</td>
<td>54.41</td>
<td>50.34</td>
</tr>
</tbody>
</table>
The Rehabilitation of Forest, Grazing and Agricultural Lands Project, carried out under the auspices of Community Forest and Soil Conservation Development Department (ex - CFSCDD) which lasted between 1980 and 1990 was the largest Food for Work in Africa in terms of the resources committed. The project’s activities fall within three major categories: On-farm and related soil conservation, afforestation and re-vegetation (including access road construction) and water related activities (Hurni 1983). The long-term objectives of the project were physical transformation of the degraded highland, improvement of the supply of fuel wood and timber, increasing the availability of potable water and irrigation. The project was operational in 44 catchments throughout the country.

The project's activities were mainly streamlined to physical soil conservation measures. There was not, however, a comprehensive assessment of the outputs of the project after it was phased out. It would, therefore, be difficult to present the outputs and effectiveness of the project. It could, however be argued that the project missed the software aspects of watershed management.

Despite all these efforts, however, rate of deforestation has been estimated as between 100,000 - 200,000 ha per annum (MOWR 1998b). The reason for forest destruction is primarily the increasing demand for arable land and wood fuel, and the utilization of forest resources without proper management and a well-balanced reforestation. Other possible explanations for the futile past efforts include failure to recognize basic human needs. The reforested areas and enclosures are subject to destruction if the farmers are not provided with alternative energy sources.

The hydrological behavior of a watershed is modified by land use practices. A pattern of land use should be designed to incorporate production systems, which permit rural families to sustain an acceptable standard of living while protecting the natural environment.

**Magnitude of the Soil Erosion**
Different degradation processes are destroying the natural resources of the Ethiopian highlands. The effect of degradation and its steady annual expansion are not noticed until severe droughts attract top government officials and outside attention. The erosion rate estimate has been made of the soil loss data collected by the Soil Conservation Research Project (SCRP) on its 42 plots at four sites.

Any erosion at the rate faster than soil regeneration i.e. 10 - 15 tones /ha/ year (MOWR 1998b), should be combated to preserve the overall productivity of the land. Representative and quantitative figures on erosion rates are hard to determine. Accelerated erosion is site specific. Hurni in his soil formation rates for Ethiopia estimated that soil formation in the highlands of Ethiopia is of the order of 15/t/ha/yr (Hurni 1983).

In most of the research work and catchment studies the results show that erosion by far exceeds soil formation rates. The results of the Anjeni Research centre near Debre Markos (Abbay Basin) show that actually measured soil loss under the traditional cultivation practices has been 122 to 128 t/ha/yr. On an entirely bare ground, this rate has been found to be 269 to 321 t/ha/yr (8 years results) (MOWR 1999).

Estimates of the total amount of soil lost from the Birr catchment (Abay Basin) show that in the upper plateau, 5 - 60% slope varies between 46 and 425 t/ha/yr. In the interfluvial ridges
Facilitating the Implementation and Adoption of Integrated Pest Management (IPM) in Ethiopia

of 15 - 60% slope, the soil lost varies between 124 and 342 t/ha/yr. The erosion survey of the Tekeze River Basin Integrated Development Master Plan Study \(^8\) over 86,510 km\(^2\) shows that about 80 to 90 percent of the basin is affected by some form of accelerated erosion. Gully and sheet erosion are by far the most frequent erosion features observed.

The Ethiopian Highland Reclamation Study in the mid 1980s estimated that 373,000 km\(^2\) of the Ethiopian highland area will be reduced to bare rock between 1985 and the year 2010. The study also estimated that the affected population losing cropland or grazing land totals 9.6 million in the same 25 years time frame. About 34 percent of them, i.e. 3.3 million people will have to give up any form of agricultural production (FAO 1986 b). A decrease in cultivable land results in a loss of crop production, which is the cost of land degradation.

The Causes of Land Degradation

Some forms of land degradation are the result of normal natural processes of physical shaping of the landscape and high intensity rainfall. The scale of the problem, however, is dramatically increased due to increasing deforestation, overgrazing, over cultivation, inappropriate farming practices, increasing human population.

Removing vegetative cover on steep slopes (with slopes ranging from 15 – 50 percent) for agricultural expansion, firewood and other wood requirements as well as for grazing space has paved the way for massive soil erosion. Forest cover in the Ethiopian highlands as a whole decreased from 16% to 2.7%\(^4\) of the land area between the 1950’s and the late 1980’s. This is compounded by increasing numbers of livestock being forced on to shrinking pastures. Although about 82% of the rural household energy is covered by fuel wood and supplemented by dung (about 9%) and burning of crop residues (about 8%), the land tenure and tree tenure have provided little incentive for protection of forests and tree planting.

The existing farming practices are considered to be the major causes of decline in soil fertility, soil structure, and crop yields. Continuous monocropping of the same fields year after year, ploughing on steep slopes, collection of crop residues and animal dung for household energy are leading to serious reduction of land productivity. Cultivation on steep slopes without protective measures results in a continuous horizontal leaching of the fine soil material (clay) out of the soil mass during the rainy season. The remaining coarse material after the prolonged leaching may not retain moisture and is susceptible for erosion. The leaching of the fine material causes a huge loss of nutrients. The coarse soil left behind will not also retain fertilizer.

Overgrazing is known to reduce the quantity and quality of the renewable natural vegetation. The remaining patches of grazing lands are currently experiencing increase in both human and livestock population and decline in rainfall. Cattle are the main agents of watershed degradation, mainly through overgrazing and trampling. Sheep and goats also play an important role. Trampling on particularly heavy clay soils while they are moist destructs their structure. This causes reduced water infiltration and increased erosion.

Other than the effects of slope and vegetative cover on erosion risk, the soils respond variably to the rainfall erosivity particularly on the highlands. Deep soils formed on the plateau basalts (Mainly Nitisol and Luvisols) have relatively well structured topsoils and are thus able to absorb water and resist rainfall energy. Soils derived from sedimentary rocks, the basement complex and volcanic ash material (Cambisols, Arenosols, Leptosols, Calciisol, Vertisols, etc.) are less stable. Their surface tends to seal, and runoff, as it moves downslope, results in
severe erosion loss of topsoil leads to loss of fertility, organic matter and available nutrients mostly available in large quantity in the topsoil.

**Effects of Watershed Degradation on Water Resource Development**

Soil erosion is damaging onsite for its effect on crop productivity, and also downstream (offsite) because of the sedimentation problem it causes. Sedimentation of reservoirs is a major problem, which is faced in the planning of water resource projects. Sediment sampling data collected at 241 stations in the country show that the sediment yield rates vary from 200 - 2,900 tons/km\(^2\)/year. Estimates of specific sediment yields for the proposed dam sites in the Tekeze River Basin Master Plan Study varied between 1,000 and 1,500 tons/km\(^2\)/year.

A study made on the Koka dam, in the Upper Awash Valley provides a record of siltation from 1959 to 1981. The water storage decreased between 1959 and 1981 from 1850 Mm\(^3\) to 1457 Mm\(^3\), which is a total decrease of 393 Mm\(^3\) in a 22 years period. Surveys of storage loss in existing reservoirs in the Awash Basin\(^{10}\) show that in some cases the whole reservoir area has been silted up. These sites of complete infill include earth dam in the major catchment, Bati earth dam and a reservoir south of Kombolcha along the Borkena River. Almost all the Metehara Sugar Estate night storage reservoirs have been silted up and therefore were replaced by new reservoirs.

Storage reservoirs in some areas need about 15 times larger dead storage capacity and would therefore be much costlier than those built in other countries with less watershed degradation problems. Sediment concentrations of some of the rivers are clearly alarming (Table 35). High sediment load is changing the morphology of the Awash River. The river is changing its course at different location in the lower valley.

The effect on the downstream riparian is also alarming. The Aswan High Dam (in Egypt) was built to accommodate large deposition of sediments in view of the high seasonal sediment loads of the Nile above Aswan. It was initially designed for a dead storage volume to last 400 years. It is now evident that this dead storage volume has been reduced at a much higher rate then expected sediments.

<table>
<thead>
<tr>
<th>River</th>
<th>Locality</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teme</td>
<td>Near Motta</td>
<td>2,527</td>
</tr>
<tr>
<td>Gumera</td>
<td>Near Addis Zemen</td>
<td>1,780</td>
</tr>
<tr>
<td>Ribb</td>
<td>Near Addis Zemen</td>
<td>2,881</td>
</tr>
<tr>
<td>Gebreguracha</td>
<td>Near Jamma</td>
<td>2,779</td>
</tr>
<tr>
<td>Bir</td>
<td>Near Jiga</td>
<td>3,766</td>
</tr>
<tr>
<td>Awash</td>
<td>Awash Town</td>
<td>2,421</td>
</tr>
<tr>
<td>Awash</td>
<td>Tendaho</td>
<td>16,959</td>
</tr>
<tr>
<td>Awash</td>
<td>Adayitu</td>
<td>6,488</td>
</tr>
<tr>
<td>Bilate</td>
<td>Near Alabakulito</td>
<td>3,233</td>
</tr>
<tr>
<td>Wabishebelle</td>
<td>Gode</td>
<td>7,281</td>
</tr>
<tr>
<td>Gilgel Gibe</td>
<td>Near Dam Site</td>
<td>1,320</td>
</tr>
<tr>
<td>Abbay</td>
<td>Near Kessie</td>
<td>7,400</td>
</tr>
</tbody>
</table>

Source: WAPCOS (1990)
Sediments are being deposited in the reservoir at a rate of about 109 Mm$^3$/year. The vast quantities of soils transported by the Abbay and Tekeze rivers from the Ethiopian highlands have accelerated reservoir sedimentation in Sudan. As a consequence, Roseires and Khashm El Giroa reservoirs have lost 40% and 60% of their respective total capacity in less than 30 years. The Roseirs dam was constructed considering a sedimentation rate of 15.3 million m$^3$/year. At present the sedimentation is in the order of 55 million m$^3$/year. As a result, around 13 million m$^3$ of sediment is removed annually from Gezira scheme alone. Hence, the deposition is both in the dam reservoirs and irrigation canals in Sudan.

**Watershed Management Measures**

The various forms of land degradation in Ethiopia are water erosion, wind erosion, salinization, alkalinization as well as chemical, physical, and biological degradation. It takes about 300 to 1000 years of intricate process in nature to produce 1.0 to 2.5 cm of top soil. There is therefore, an urgent need to protect the soil from wrong management. The soil formation rates have been estimated for Ethiopia by Hurni (1983). According to him the rates vary from 2 to 22 tons/ha/year. These figures indicate to what extent the soil loss can be tolerated. The soil loss rates in Ethiopia range between 5 to 300 tons/ha/year. This corresponds to 0.5 to 25 mm depth loss per year. The information regarding the soil loss rates, the soil formation rates, the steepness of the area and soil depth form the basic data necessary for identifying the area needing treatment for the conservation of soil.

Watershed management measures currently practiced in Ethiopia could be categorized under five headings. These are:

1. Management of cultivated land;
2. Grazing land;
3. Forest land;
4. Reclamation and gully control; and
5. Biological control methods.

**Management of Cultivated Land**

The various practices applicable in the agricultural land are stone terraces, earth bunds, Fanya Juu terraces, grass strips, hedgerows trash lines, the main thrust of food for work. It has been observed that so far more emphasis has been laid in Ethiopia for the application of structural measures towards achieving soil conservation. The main thrust of the Food for Work Programme has been the construction of rock walls and earth bunds.

Between the years 1993 and 1995 the following have been implemented in Amhara Region:

<table>
<thead>
<tr>
<th>Practice</th>
<th>Area/Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stone or earth bunds</td>
<td>69,923 ha</td>
</tr>
<tr>
<td>Check dam</td>
<td>1,214 km</td>
</tr>
<tr>
<td>Cut of drains</td>
<td>1,673 km</td>
</tr>
<tr>
<td>Area closure</td>
<td>4,437 ha</td>
</tr>
</tbody>
</table>

In Tigray Region, between 1992 and 1996 the following has been implemented:

<table>
<thead>
<tr>
<th>Practice</th>
<th>Area/Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stone bunds</td>
<td>398,000 ha</td>
</tr>
<tr>
<td>Check dams</td>
<td>3,169 km</td>
</tr>
<tr>
<td>Cut of darins</td>
<td>1,034 km</td>
</tr>
<tr>
<td>Area closure</td>
<td>29,360 ha</td>
</tr>
</tbody>
</table>

In terms of volume, what has been achieved is truly remarkable, but natural waterways are seldom sufficiently stable to handle this increased discharge. But, artificially constructed grassed waterways require careful construction, regular maintenance, and they depend
particularly on the maintenance of a good grass cover which is difficult in conditions of poor soil fertility and long dry periods. In some areas the type of terracing developed in Kenya known as "Fanyu Juu" is being adopted. The main feature of this type of terracing is that the soil is dug from a trench and thrown uphill to form the ridge. There is then a terracing effect as the soil is moved downhill, to some extent by erosion, but mainly by cultivation. The method is effective in deep soils.

A problem unique to Ethiopia occurs as a result of the widespread growing of teff, the staple cereal. The seed is tiny, and so requires an extremely fine and level seed bed. This is accomplished by several cultivations which have an adverse effect on the soil structure. Also, immediately after planting there is a high risk of the fine seed being washed away if there is any surface runoff. The traditional method of preventing this is to form small open drains with a few passes of the ox-drawn plough on a steep gradient, usually at 30 to 45° to the contour, and at a close spacing of from 3 to 6 metres. In many cases, these conventional drains have been put in after the construction of bunds or terraces, thereby making all the effort ineffective.

Management of Grasslands

The different types of soil conservation measures applicable in the grassland areas are controlled grazing, cut and carry system and grassland improvement. The basic problem is the imbalance between numbers of livestock and the sustainable carrying capacity. The possibility of large-scale improvement is not possible because of the irreversible degradation, which has taken place, leaving the reduction of livestock numbers as the only available long-term solution.

Complete exclusion of all stock can give quite remarkable results. Cut-and-carry system should be allowed in the enclosure. In the lowlands nomads and their herds is another factor. It is unlikely that the plans to encourage them into a sedentary lifestyle will be successful, and no solution is in sight to control or mitigate the damage done by the migrant herds.

Management of Forests

Since the forests are commonly situated on steep slopes, they provide maximum protection to the land below, if the canopy is thick. The various methods recommended in these areas are tree planting, wood lots, hillside closures, and hillside terraces. Trials on the effects of different methods of planting trees (e.g. in furrows, pits, micro-catchments, or benches) on the survival rate and on runoff are essential.

Reclamation and Gully Control

The commonly accepted approach is that to concentrate efforts on the preservation of good land rather than reclamation of degraded land and gullies. The benefit cost ratio of reclamation is low. There are, however, special circumstances, where the reclamation and gully control are required, where a few badly degraded areas are contributing very large amounts of sediment in the water development structures.

In such circumstances, reclamation programs may be justified, but to be effective, they have to be intensive and expensive. The starting point always has to be complete exclusion of livestock. Physical treatment includes bank sloping, and construction of check dams. Vegetative measures include planting of grass, trees, and shrubs on the sides and in the bottom of gullies.
Biological Control Methods

The reports of the Ethiopian Highlands Reclamation Study (EHRS) have pointed out that very little biological control was implemented during the previous efforts. As a result, the concept of "Conservation based farming" has been widely accepted and much quoted, but there has been little progress in putting this into operation (FAO 1986b).

The preferred techniques include improved varieties, better supply of seed and fertilizer, improved cultivation methods and residue management. Surface residue cover greatly reduces soil erosion. As residue cover approaches 100%, soil erosion approaches zero percent.

Moisture Management Techniques of Field Soils

Successful and sustainable rainfed agriculture in semi-arid (kolla) regions depends on effective soil water storage, which is influenced by evaporation. Controls devised to reduce the rate of evaporation directly from the soil surface depend primarily on 1) reducing the potential rate of evaporation at the surface or 2) reducing the amount of water retained near the surface when water is added to soil. If the evaporation rate can be reduced in either of these ways, plants will be able to make use of the water before it is lost.

Control by Mulches

Any material used on the surface to prevent the loss of moisture by evaporation may be designated as mulch. Straw, leaves, and other litter may be used successfully. Such mulches are practical for high value crops, including fruit trees. Paper and plastic can also be used as mulch. Stubble mulch is stubble of trash mulch used for larger areas. Mulching materials have been grown in places that consist of refuse of the previous crops. The use of such a mulch not only conserves moisture, but also helps to control wind erosion.

Control of weeds is an effective and practicable means of reducing the loss of moisture from soils. Weeding ensures greater amount of water available for crop transpiration. Soil aggregate size distribution and stability affect soil water storage. Many factors affect aggregate size distribution and stability.

These include tillage methods and cropping systems. Use of no-till or reduced tillage often results in larger and water stable aggregates than more intensive tillage methods. Crop rotation effects on water-stable aggregation ranges from slight to large. Aggregate size and stability in water generally increases with increased organic matter. Residue cover is a major factor affecting aggregate breakdown.

Conservation tillage systems to conserve soil moisture include no till, ridge till and mulch.

No-till

No-till is a conservation tillage system to minimize soil moisture loss. In this system the soil is left undisturbed from planting to harvest. Planting or drilling is done in a narrow seed bed or slot created by coulters, row cleaners, disk openers, or in row-chisels. Crop cultivation may be used as part of the weed control strategy.

No-till reduces costs while producing yields equal to or greater than other tillage methods. Eliminating tillage obviously eliminates the time needed for each tillage operation.

No till makes double cropping easier and more practical by eliminating time consuming tillage steps and by conserving valuable moisture. A farmer can plant crops the day he
harvests grains. No till can reduce the labour needed by 50 to 60 percent. That allows farmers to diversify their operations and better manage their farm. No till farming is the most effective practice for reducing erosion.

**Ridge till**
With this system, the crop is planted in a seed bed on ridges. The ridges are re-shaped and maintained with cultivation as the crop grows. Crop residue covers the soil between the ridges from planting to harvest. The crop residue protects the soil from erosion and preserves soil moisture. The ridges allow the soil to worm earlier. These benefits make ridge tillage an appropriate choice for soils that normally remain too wet.

**Mulch till**
Mulch till is referred as full width tillage. It is a system that uses such implements as a disk plow and chisel plow to till the entire land area of the crop field. It is the most common of type of conservation tillage.

The challenge with this technique is to use the proper equipment and settings (depth and time of operation) to achieve the desired residue level after planting. Planning to maintain more than 30 percent coverage.

Most potential problems with any of the aforementioned tillage types can be eliminated with careful planning, experience and knowledge and plant verities. Adapting some of the basic principles to the Ethiopian situation could be very helpful to arrest the moisture stress from the recurring drougs. The benefits will be the following.

**Conserving moisture**
Crops are under stress from lack of moisture in most parts of the lowlands in Ethiopia. Conservation tillage systems conserve moisture significantly for three major reasons:

- Evaporation is much less because the soil is not turned over and exposed to the sun's radiation. Plant residue shades the soil, causing lower soil temperature and less evaporation.
- Conservation tillage soils, after a period of time hold more moisture at saturation than conventionally tilled soils because of increase organic matter.
- Crop residue in a conservation tillage field serves to trap water during a rain, giving it more time to soak in.

**Reducing Soil Compaction**
Soil compaction is caused by pressure applied to the soil when it was wet and soft. The incidence is greater after wet seasons, particularly when rain coincides with either seed bed preparation or crop harvest. Soil compaction is, therefore, largely a man-made problem.

As the soil is compacted plant roots are restricted in their ability to grow horizontally and vertically. As a result, the plant is stunted and never reaches its full yield potential. Reducing tillage helps reduce soil compaction.

**Key Watershed Management Issues**
The challenge of watershed management in Ethiopia is extremely complex, if traditional sectoral approaches and activities are employed. The current situation has been caused by excessive erosion, sedimentation, low crop productivity, high population pressures, continued
need for agricultural expansion, and a drive for fuel wood. The following constraints have been identified.

**Low watershed management technologies**
- Absence of improved methods to promote conservation based agricultural activity. Prolonged leaching of the soils in the sloping grounds selectively moves out the fine soil material with which soil nutrients are also moved out. The fine soil and the nutrients are partly deposited in the interfluves basins and valley floors. These wet soils of heavy texture are rich in soil nutrients. There is no sufficient technology to properly manage the wetlands and the coarse textured soils left behind.
- The research is skewed to physical soil and water conservation measures.

**No alternative fuel sources**
- Decrease in usage of fuelwood, dung and agricultural residues as sources of household energy.
- Dissemination of version wick stove and introduce biogas technology to reduce rate of deforestation.
- Support to improved stove dissemination.

**Population pressures accelerate land degradation**
- Delivering family planning service.
- Attracting farmers away to non-agrarian activities.
- Controlled resettlement programmes and Malaria control to encourage settlement in the lowland.
- Alternative livelihood options.

**Overgrazing causes erosion**
- Improved forage development and seed multiplication centres.
- Agroforestry development.

**Poor watershed management planning and implementation**
- Absence of an in-built monitoring and evaluation mechanism.
- Unsustainability of projects and programmes when foreign assistance is withdrawn.

**Insecure land and tree tenure**
- Farmer's individual land holdings are not secure.
- Lack of use right clarity on community forest.

**Conclusion and Recommendations**
Soil erosion degrades our soils. Besides selective leaching of fine soil material leaving behind coarse material susceptible to erosion rain storms on sloping lands truncate and remove topsoil high in organic matter and nutrients. The result is surface soil depleted of plant available nutrients, high in bulk density, low in porosity and capacity for water intake.

Conservation tillage is one of the most important agricultural advances in the past decades over a large area of the world. It is important to introduce the concept of conservation tillage and promote the implementation in food insecure areas to conserve moisture and improve land productivity.
Creation of strong institutional coordination is important for the successful execution of watershed management projects and programmes. The relevant institutions are the Ministry of Water Resources, Ministry of Agriculture, Environmental Protection Authority, Energy Agency, Ethiopian Electric Power Corporation, and Ministry of Mines.

Much effort and money is often put into protective rather than development activities. Watershed Management Programs must as their ultimate objective promote sustainable use of natural resources to improve the farmers' income and living conditions. The Government should take watershed management as a highest priority development programme for funding.

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16. Towards Food Security via Improvement in Small-Scale Irrigation: What are the priorities and what needs to be done?

Getachew Alem
Private-Consultant
P.O.Box 3036. Addis Ababa, Ethiopia.

Historical Overview of Irrigation
The history of irrigated agriculture in Ethiopia is very much unknown, and it is not documented properly. However, reports made in association with archeological findings have revealed traces of information on water resource development activities including irrigation practices in antiquity. According to Fattovich’s (1990) archeological findings, irrigated agriculture is to exist as early as 850 and 500 B.C in the northern part of Ethiopia. Excavation work revealed the remains of a dam and household utensils that have similarity to the utensils with that of the southern Arabian Peninsula suggesting the presence of migrants in the area, and it is presumed that these immigrants could have developed the water resources and possibly practiced irrigation schemes at the time.

The Geez inscriptions of the riparian doctrine in the Fetha Negest indicated that irrigation had been practiced in Ethiopia in the fifteen century (Tzeadwa, 1968). In late 1800 and early 1900, there were traditional small-scale irrigation schemes in the central highlands largely owned by the landlords and local administrators (Tahel, 1988). The production of fruits and vegetables under irrigation was a well-documented fact in Harar Zuria mainly due to the influence of Arab migrants and the availability of export outlets to the neighboring Arab countries (Kloos, 1991). It is believed that the production of fruits and vegetables was later spread over to other parts of the eastern Hararghe.

During the Italian occupation of Ethiopia in the 1930s, a study on large scale irrigated agriculture started in the upper Awash River Basin. Plans of large-scale irrigation schemes were finalized and while the equipments for the project were shipped and on their way to Ethiopia, the Second World War started and Italy (ally of Germany and Japan) lost the war. The Dutch company, Handles-Vereeniging Amsterdam (HVA) won the international bid to take over the equipment that was off-shore Djibouti at the time (Bigo, 1986). HVA took land first in the present Wonji Shewa Sugar Estate in the 1950s and second in Metehara in 1969 under concession from the Ethiopian Government and started the first modern large scale irrigation agriculture in Ethiopia (AVA, 1971).

In 1960, a multi-use dam was constructed in Koka by Italy as war indemnity, and this has opened up a new and vast opportunity for the development of irrigated agriculture in the downstream areas of the Awash Valley. This is presently the most developed river basin in the country and constitutes about 60 percent of the irrigated area in the country.

As large and medium scale irrigation schemes showed declining performance in the 1970 and 80s, emphasis was on small-scale peasant based irrigation farms. Small-scale irrigated agriculture development showed encouraging growth over the last 40 years. Kloos (1991) reported small-scale irrigation in the country estimated to cover a total of 75,000 ha. In 2000, MoA reported the total small-scale irrigation coverage to be about 186,000 ha, which shows an increase of 40 percent over the last 15 years and with annual growth rate of a little less than
3 percent. Currently, there is no accurate information on the status of the medium and large-scale irrigation schemes in the country.

**Irrigation Potential: Land and water resources**

Ethiopia has an estimated annual surface run-off of approximately 110 billion m$^3$ of water and 2.6 billion m$^3$ of ground water. The major river basins with high runoff include Abay (48%), Omo-Gibe (16%), Baro-Akobo (11%), Genale-Dawa (5%) and Awash (4%). These river basins constitute a large track of land suitable for irrigated agriculture, mostly located in the lowlands. Ethiopia presently requires 57 Billion m$^3$ of water (nearly 50% of the existing surface water resource potential of the country) to produce sufficient food to meet the food needs of its 65 million people with adequate per capita calorie requirement of 2200 kcal. This may be more of an agronomic view where an average estimate of water productivity for a crop protection is considered. It is quite evident that the available water resources in the country are sufficient to support the country's food need and beyond.

Ethiopia is endowed with relatively large and suitable land for agriculture. According to the Master Land Use Plan (MoA/UNDP/FAO, 1988), the land use classes are given as follows.

(i) The arable land is 34 million ha (27% of the total) which includes areas with dependable length of growing period (LPG) more than 90 days, soils more than 250 mm depth, less than 50 % stone cover, slopes with less than 30%, and excluding vertisols.

(ii) The vertisols are also another land use class and constitute 6% of the total area. Vertisols are quite a substantial portion of this soil and exist in irrigated low lands with serious limitations in water management practices.

(iii) Other arable land with slopes of greater than 30 percent also constitute about 5% (estimated to reach about 6 million ha).

(iv) Approximately 16 million ha (13%) is marginal land which is characterized by significant moisture limitations (less than 90 days of LGP but more than 60 days on the average).

(v) The remaining 49% (61 million ha) of the country is classified as non-arable with severe moisture limitation, soils with less than 250 mm depth and surface stoniness greater than 50%.

As per this land use classification, approximately 35 to 38 % of the land in the country is expected to be cultivated under rain fed, irrigation or both. Areas under criteria (i) and (ii) above and areas with less than 8% slope represent the potential for irrigation with some degrees of management constraints such as water logging, and salinity.

According to the Ethiopian Highland Reclamation study (Hewett,1984), the principal characteristics of the highlands from the viewpoint of suitability for irrigation are summarized as follows.

1. Wide range of land forms, with large catchments that offer potential for water diversion and storage
2. Most of the area has high, but variable rainfall with a marked dry season
3. High surface water flows, but a limited number of perennial rivers,
4. Three quarters of the area has a mean length of growing period (LGP) of over 180 days, and all but 2% has an LGP of over 90 days
5. Farming systems, although traditional, are well established and productive in subsistence terms, and husbandry skills are good.

The geomorphology, land suitability and available climatic and water resources offer the country much more advantage than its neighboring African countries in producing diversified crops throughout the year.

The water resource base, irrigation potential, developed small-scale irrigation and associated poverty index at regional level are shown in table 36.

Table 36: Basic Regional water and land resources, and socio economic indicators

<table>
<thead>
<tr>
<th>Region</th>
<th>Population ('000)</th>
<th>Food Production in '000 (MT) (2000)</th>
<th>Food Aid Cereal (MT) **</th>
<th>Poverty Index in % in 1999/00 ***</th>
<th>Water Resourse Potential (BM³)</th>
<th>% Of Water resources utilized</th>
<th>Irrigation Potential ('000 ha) *</th>
<th>Developed SSI (Ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oromiya</td>
<td>23,600</td>
<td>4,371.976</td>
<td>367,933</td>
<td>39.9</td>
<td>58.0</td>
<td>5%</td>
<td>1,350.00</td>
<td>74,497</td>
</tr>
<tr>
<td>Amhara</td>
<td>16,300</td>
<td>2,880.711</td>
<td>342,100</td>
<td>41.8</td>
<td>35.0</td>
<td>8%</td>
<td>500.00</td>
<td>69,787</td>
</tr>
<tr>
<td>SNNPR</td>
<td>13,200</td>
<td>738,757</td>
<td>105,722</td>
<td>50.9</td>
<td>13.8</td>
<td>5%</td>
<td>700.00</td>
<td>13,577</td>
</tr>
<tr>
<td>Tigray</td>
<td>3,900</td>
<td>622,728</td>
<td>204,348</td>
<td>61.4</td>
<td>3.8</td>
<td>16%</td>
<td>300.00</td>
<td>12,607</td>
</tr>
<tr>
<td>Afar</td>
<td>1,220</td>
<td>24.593</td>
<td>117,930</td>
<td>56.0</td>
<td>?</td>
<td>0.016</td>
<td>163.55</td>
<td>2,440</td>
</tr>
<tr>
<td>Somali</td>
<td>3,690</td>
<td>22,521</td>
<td>118,313</td>
<td>37.9</td>
<td>?</td>
<td>0.015</td>
<td>500.00</td>
<td>10,000</td>
</tr>
<tr>
<td>Gambella</td>
<td>211</td>
<td>24.907</td>
<td>7,235</td>
<td>50.5</td>
<td>?</td>
<td>0.017</td>
<td>600.00</td>
<td>46.0</td>
</tr>
<tr>
<td>BSGRS</td>
<td>537</td>
<td>184,551</td>
<td>-</td>
<td>54.0</td>
<td>?</td>
<td>0.123</td>
<td>121.18</td>
<td>400.0</td>
</tr>
<tr>
<td>Harari</td>
<td>160</td>
<td>5,815</td>
<td>2,003</td>
<td>25.8</td>
<td>?</td>
<td>0.004</td>
<td>19.20</td>
<td>437.0</td>
</tr>
<tr>
<td>DD</td>
<td>318</td>
<td>6.135</td>
<td>11,025</td>
<td>33.1</td>
<td>?</td>
<td>0.004</td>
<td>2.00</td>
<td>1,500</td>
</tr>
<tr>
<td>AA</td>
<td>2,495</td>
<td>8.300</td>
<td>36.1</td>
<td>?</td>
<td>0.005</td>
<td>0.526</td>
<td>352.00</td>
<td>66.90</td>
</tr>
<tr>
<td>TOTAL</td>
<td>8,890.994</td>
<td>1,276.60</td>
<td>110.0</td>
<td>0.184</td>
<td>4,256,457.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


**Source: DPPC. 2002/2003 Annual Reports


Population growth and food production trend

Agriculture is the basis of the Ethiopian economy, providing employment for approximately 85% of the country’s population, and contributing about 45% to the country’s economy, and accounting for about 85% of the export earnings. Crop production accounts for about 40 to 50 % of the GDP, and it is predominantly rainfed. Smallholder peasant farms dominate the sub sector. Modern irrigation in Ethiopia started about four decades ago and small-scale traditional irrigation schemes are still widespread.

Food production growth trend over the last thirty years has been unsatisfactory and disappointing. There was no significant growth; rather it was a period of stagnation. The trend in food production oscillates up and down with no significant jump, or steady growth, but clearly influenced by the rainfall of the season, when drought depresses food production for instance in 1984/85 and 1994/95 (Fig 1). The following recorded statistics explains this situation well. According to Robinson and Yamazaki (1986), the annual growth rate for the agricultural sector declined from 3.3% between 1953 and 1959 to 0.3% growth between 1974 to1980. Others reported that the average per capita production declined from 225 kg/yr in 1961 to 130 kg/yr in 1990 (Solomon, 1990). FAO (1985) reported the per capita production declining at 6% between 1974 and 1985. In general, the agriculture sector and food
production in particular showed unhealthy performance over the last three to four decades. Population growth in the same years showed a steady upward trend creating a period with a very high food deficit. This unfavorable trend in food production and population growth has remained a big challenge for the people and government of Ethiopia in trying to feed the mouth of the ever-bourgeoning population. The food deficit in 2002/2003 is expected to be the highest of all since the population affected by food shortage during this year was about 14 million, the highest of all the periods recorded.

Institutions, Policies and Strategies

Institutions

There have been several institutions established over the last forty years to support irrigation and water resources development projects. In 1956 the Water Resources Department was established under the Ministry of Public Works and Communication. In 1962 the Awash Valley Authority (AVA) was established and administered by a Board of Directors. Under proclamation 118, Valley’s Agricultural Development Authority (VADA) was established in 1977 and was responsible for the development of all valleys’. In 1981, the National Water Resources Commission (NWRC) was established under proclamation 217. Water Resources Development Authority (WRDA) and Ethiopian Water Works Construction Authority (EWWCA) were important agencies under this commission to develop medium and large-scale irrigation development in the country. The Water Conservation Department of the Ministry of Agriculture was responsible for planning, construction and rehabilitation of small-scale irrigation until 1983. The Irrigation Development Department (IDD) replaced the water Conservation Department of the MoA in 1983, and IDD became responsible for the study, design and implementation of small-scale irrigation and rehabilitation of traditional irrigation schemes. In 1993, IDD was dissolved and all small-scale irrigation development projects were given to Regional Water Bureaus.

The Ministry of Water resources provides technical support and monitors project progress, while the extension part is the responsibility of the Regional Bureaus of Agriculture. A small unit under Crop Production and Protection Department of the Ministry of Agriculture oversees the extension services of irrigation developments in the regions. Recently the Ministry of Water Resources opened a new department for irrigation and is at its infant stage.
Figure 9: Population growth and food production trend in Ethiopia between 1981 and 2000

Irrigation policy

The main elements of the irrigation policy of the Federal Democratic Republic of Ethiopia are the following (FDRE, 2000):

A. General Policies

- Ensuring the full integration of the irrigation with the framework of the country’s socio-economic development plans, and more particularly with the ADLI strategy.
- Promotion of development of irrigation on two-pronged approaches of:
  - Strategic planning for achieving socio economic goals and
  - Participatory-driven approach for promoting efficiency and sustainability.
- Recognizing that irrigation is an integral part of the water sector and consequently developing irrigation within the domain and framework of overall water resource management
- Earmarking a reasonable percentage of the GDP as a committed resource towards the development of irrigated agriculture, especially in capacity building and infrastructures
- Promoting decentralization and user-based irrigation systems management taking into account the special needs of the economy and requirements of raw materials and other needs
Developing a hierarchy of priority schemes based on food requirements, needs of the national economy and requirements of raw materials and other needs

Support and enhance traditional irrigation schemes by improving water abstraction, transport systems, and water use efficiency

Ensure the prevention and mitigation of degradation of irrigated water and maintain acceptable water quality standards for irrigation.

Establish water allocation and priority setting criteria based on harmonization of social equity, economic efficiency and environmental sustainability requirements

Integrate the provision of appropriate drainage facilities in all irrigated agriculture schemes

Enhance greater participation by Regional and Federal Governments in the development of large-scale irrigated farms in high water potential basins but with low population density.

**B. Stakeholders**

Promote full and meaningful participation of individual farmers, cooperatives and all other stakeholders in all phases of the planning, studies, implementation and operation and maintenance of small, medium and large-scale irrigation farms

Promote the involvement of the Government at different levels and NGOs, in the provision of support for bulk water storage and transfer schemes and other relevant structures

Promote fairness and transparency in the management of irrigated agriculture

Develop systems for the harmonization of the co-existence of indigenous peoples and irrigation projects.

**C. Economic and Finance**

Establish norms and procedures for financial sustainability and viability of irrigated schemes

Promote credit facilities and bank loans for the development of irrigation schemes

Develop the appropriate cost recovery systems and mechanisms for all irrigation schemes.

**Food Security Strategy**

The Food Security Strategy broadly aims at supporting small-scale irrigation farmers to increase food production and achieve food self-sufficiency. This is to support farmers with the resources needed to increase the utilization of available land and water resources and increase the potential to produce and to intensify crop production through double or multiple cropping and through assuring partially and year-round availability of water for supplemental or full irrigation thus raising resource productivity and production at household level.

**Stabilizing food production using irrigation**

Water and food security are strongly connected as shown in table 36 above. Many of the poor people live in water scarce regions of the world. Limited access to or availability of water often plays a major constraint to improving food production. It is interesting to note that the most populace countries in the world are food secured and have the highest irrigation coverage in the world. China, India and USA are the leading nations in the world with the highest irrigation coverage, having a total irrigation area of approximately 77, 39 and 21.4
Facilitating the Implementation and Adoption of Integrated Pest Management (IPM) in Ethiopia

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million hectares, and the ratio of irrigated to cultivated area for these countries is 68.9%, 16.7% and 8.2%, respectively. These countries are surplus producer countries in the world today. There is no secret for this fact, they have simply developed and utilized their land and water resources effectively and efficiently through good will and commitment to water resources and irrigation development.

The crop production in Ethiopia is a predominantly traditional and rain-fed farming system. Generally, all production activities are confined to no more than 6 to 8 months based on rainfall seasonal pattern. As mentioned earlier in this report, food production in Ethiopia fluctuates remarkably from year to year, and it is subject to seasonal rainfall fluctuations. When drought occurs, rain fed crops fail and financial risk of using fertilizer and seed inputs increases, and in such years food production is significantly reduced creating enormous food deficit balance and bringing economic crisis and instability in the country.

The use of irrigation, particularly at small-scale farm level, reduces the risk of crop failure even at drought periods, reducing the financial risk of farmers for using improved inputs. Data collected from Amhara Region and used as a case to show the significant differences between rain-fed and irrigated crop production per unit area is presented in Table 37. In fact there are gross assumptions in this analysis that it is not crop specific at both rain fed and irrigated conditions.

<table>
<thead>
<tr>
<th>Zones</th>
<th>Productivity (q/ha)</th>
<th>Rain fed</th>
<th>Irrigated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Traditional</td>
<td>Modern</td>
</tr>
<tr>
<td>North Gondar</td>
<td>10.94</td>
<td>23.21</td>
<td>47.65</td>
</tr>
<tr>
<td>South Gondar</td>
<td>7.6</td>
<td>89.21</td>
<td>63.31</td>
</tr>
<tr>
<td>North Wollo</td>
<td>7.88</td>
<td>12.31</td>
<td>37.21</td>
</tr>
<tr>
<td>Wag Himra</td>
<td>2.75</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>South Wollo</td>
<td>6.85</td>
<td>121.5</td>
<td>63.89</td>
</tr>
<tr>
<td>Oromia</td>
<td>8.48</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>North Shoa</td>
<td>10.22</td>
<td>51.59</td>
<td>20.51</td>
</tr>
<tr>
<td>East Gojjam</td>
<td>14.42</td>
<td>90.22</td>
<td>94.66</td>
</tr>
<tr>
<td>Awi</td>
<td>13.38</td>
<td>69.85</td>
<td>63.19</td>
</tr>
<tr>
<td>West Gojjam</td>
<td>17.99</td>
<td>84.92</td>
<td>62.55</td>
</tr>
</tbody>
</table>

The rain fed production varies between 3 and 18 quintals per hectare while the irrigation production varies between 12 and 90 quintals and between 20 and 95 quintals per hectare in traditional and modern irrigation schemes, respectively. The significant variation among zones perhaps depends on the resource base of the areas. Awi Zone, West Gojjam, South Gondar and South Wollo are high producers under irrigation, while the highly degraded North Gondar, North Wolo and Wag Hamra zones showed low productivity.
Constraints to small scale irrigation development

**Social Problems:**
The social problems are more pronounced than the technical problems in peasant based small-scale irrigation schemes. According to several assessments made on small-scale irrigation in the country, the social resentments caused by land reallocation, conflicts caused on irrigation water use, gender inequality, etc. contribute most to the failures of several irrigation schemes. Farmers are reluctant to work with the government and NGOs on the development of small-scale irrigation because of the fear of being uprooted from their land as a result of the development work in their area. Adequate preparation and awareness creation work on the part of the project implementers could have alleviated this problem. The process to make farmers aware of the benefits of irrigation projects takes a long time and a lot of effort.

**Design problem**
Small-scale irrigation often experience design problems particularly in diversion and conveyance structures. This may be due to unavailability of [long-term] hydrological data for most of the rivers and streams planned for development; lack of information on the sediment discharge of the river/stream; and not taking into consideration the morphology of the river/stream system. The result is, as evidenced in some diversions structures and pumping sites in different regions, irrigation water abstraction and use is becoming a major limitation. For example, the diversion weir in Gambella, Benshangul, and pumping site in Jole, Meskan Wereda, Gurage Zone in SNNP regions. The problem was manifested by flooding of the structures, sedimentation of pump house sites, change of rivers/stream courses, etc. Under such condition the schemes often were reported to fail before they even start their first year of irrigation or in a year or two.

**Low capacity of farmers**
Farmers tend to avoid risks, cannot realize their potential and lack the means to accomplish the initiatives because of the prevalence of a high level of poverty. As a result, farmers’ knowledge and interest in adapting new technologies is often weak. Financial constraints (prevalence of irregular income and unavailability of credit services), access to market, etc. are problems. Even if there are markets like Addis Ababa, a large part of the benefit goes to the middle men. Delayed input supply is also a common experience in many areas.

**Environmental Degradation**
Soil erosion and rapid land degradation in the upstream part of the catchments where irrigation projects exist threatens the scheme with increased sediment load in river water. Low water retention capacity of watersheds due to erosion and land degradation and deterioration of farmland due to improper replenishment of the nutrients depleted are some of the environmental concerns.

**Prevalence of water born diseases in the low land and arid areas such as malaria and schistosomiasis**

**Low development incentives**

**Institutional Constraints**
- Low capacity Water User Association (WUA)
- Government institutions do not have the capacity
**Policy constraints on**
- Land tenure
- Market
- Introduction of improved land use
- Input supplies and delivery (It should not be centralized)

**Recommendations**

1. Ethiopia still has enormous potential in rain-fed agriculture and it could benefit a lot if a conjunctive use of rain-fed and supplementary irrigation from harvested water is administered. This still requires adequate training of farmers in water harvesting and practicing supplementary irrigation, and using this as a transition to a full-scale irrigation practice, which could be a more realistic approach to adopt irrigation practices in the farming system.

2. Good political will from the government side is expected in supporting smallholder farmers practicing irrigation through improved policies that are instrumental to promoting small-scale irrigation. Institutions responsible for irrigation development should be stable and sustainable even with the change in government. Improving the land tenure issues, timely delivery of inputs and enhancing the capacity of farmers through their WUA are some of the issues the government has to consider.

3. Government support in technical services should be fully decentralized, better organized and strengthened. This responsibility is now at wereda level and it is encouraging, but not yet well organized to become fully functional in all woredas.

4. Access to finance/credit and marketing is crucial to the success of small scale peasant based irrigation schemes

5. There is a need to improve infrastructure in order to increase the productivity of irrigated agriculture.

6. Irrigation requires capital and donors should increase their assistance in finance for farmers participating in irrigation schemes

7. Giving more priorities and assistance to women interested in small scale irrigation development.

**References**


Minutes of the General Discussion

The discussions were preceded by an introductory remark of Dr. Tsedeke. He indicated that there are two types of IPM technologies – technologies that are available for pest control on cotton, coffee and citrus, which require some fine-tuning and technologies that are ready for use. The latter include technologies developed on stalk borers, *Striga*, tomatoes and beans. It was stated that attempts made to properly document indigenous knowledge were insufficient. As regards to past experiences in application of IPM technologies, greater emphasis was given to high value crops in large scale farms and the implementation of such practices in small scale farms was inadequate. Inadequate awareness, lack of policy support, poor linkage amongst stakeholders are constraints limiting wide scale adoption of IPM technologies. Initiatives were carried out on ad-hoc bases and the fact that they were not institutionalized homegrown initiatives impaired sustainability. Having said that, Dr. Tsedeke introduced two major topics as agenda for the general discussion. The salient points of the discussion are summarized below.

Agendum I: Lessons learned

- Participants highly appreciated the effort made by ASAI to bring together prominent scientists to deliberate on timely and pressing issues related to IPM.

- The presented lead papers were fairly well organized and covered the major IPM issues. However, comprehensive reviews are required to document current knowledge. Such massive work would require collaborative engagement among stakeholders such as ASAI, the Crop Protection Society of Ethiopia and others. ASAI will take the initiative and organize a meeting with concerned institutions. In the reviewing process, available technologies will have to be carefully assessed for relevance.

- A lot of knowledge on IPM and components of IPM exist in the country. Further efforts may be needed to integrate compatible technologies and formulate packages. IPM based initiatives should involve a wide range of disciplines (socio-economic, gender etc.)

- Participants stressed that ASAI should establish a strong working relationship with others (professional societies, associations and NGOs), which have similar goals and objectives.

- The main issue is on how to pass on the knowledge to the public. Means should be sought to include IPM in school curricula to facilitate improved awareness of the youth on the subject. The practical aspects of IPM should receive due emphasis. New innovations and developments in research should be conveyed regularly to keep students up to date.

- Large-scale farms need all the support they could muster from research centers in dealing with an increasing number of complex production constraints. But the linkage is unfortunately growing rather weaker. It is thus within the interest of associations like ASAI to offer technical backstopping and advisory services to strengthen the capacity of the farm enterprises to deal with their own problems.

- All professionals, associations and societies should contribute their share for the realization of a favorable policy environment on IPM. Therefore, it is up to us to
provide the necessary advice and guiding ideas that would lead to the formulation of appropriate policies.

- The issue of coordination was discussed at length as a critical element for success. A joint effort of various actors is imperative to facilitate proper implementation of the broad and diverse activities/programs in IPM. However, the participants acknowledged that the challenge is on how to bring together associations (ASAI), societies (CPSE), GOs (EARO, Regional Bureaus of Agriculture) and NGOs dealing with IPM to operate in a synergistic manner.

Agendum II: Future directions

- On behalf of ASAI, Dr. Tsedeke outlined certain ideas that require due consideration in the future. Thorough inventory and review of developed technologies should be made in order to identify the knowledge gaps that do exist. Through a participatory approach, involving different partners, ASAI will focus on selecting an appropriate blend of tools; promotion of the generation and implementation of IPM technologies; local production and marketing of control agents; employing training, publications and other awareness creating mechanisms and finally on impact assessment of the technologies.

- The audience dwelt more on how best inventory work of existing technologies could be accomplished. Following extended discussions consensus was reached that the task will require the contribution of many experienced individuals and a wide range of organizations and, to this end, ASAI and EARO will take the initiative and call the first meeting. Participants stressed that IPM is a broad subject and thus should involve people and organizations outside the plant protection discipline. It was also stressed that competence and not representation should be the guiding principle in selecting people for the task.

- It was also suggested to have in place a networking system that is based on modern technology i.e. electronic media to enhance partnerships. The possibilities of using regular communication media such as List Serve have to be explored. Networking with the production sector, stakeholders and research institutions (CGIAR centers) is essential to facilitate free flow of information. The mass media could be exploited to reach the wider public within the country. It was noted that the first step in such endeavor is developing a roster of potential partners.

- In reality IPM cannot stand on its own. There are a variety of social and economic issues that are closely associated with IPM and they need to be taken into consideration in the process of implementation and adoption. Identifying the right mix and determining an appropriate blend of technologies for a given system demands participatory approaches.

- Several participants shared their experience and emphasized that there are some ripe technologies on the production of bio-control agents that could be taken up by small agri-businesses. It was stressed that this is one area, which the country can exploit to international markets. Many countries are benefiting from the business by establishing small facilities that produce and sell microbial-pesticides. Efforts have to be made to learn from the experiences of other countries such as Israel and international
agricultural research organizations such as IITA. All the current initiatives on the different aspects of bio-control will have to be encouraged and assisted.

- A draft National IPM policy was developed some years back. Follow up is needed to bring the subject to the attention of the government for its implementation.
List of Participants

Abdella Shafi
Head, Crop Protection
Upper Awash Agro-Industry Enterprise (UAAIE)
Tibila Farm

Abebe Deriba
Head, Crop Protection Department
Oromia Agricultural Development Bureau
PO Box 1877, Addis Ababa
Telephone: 251-1-158829/528617

Abera Teklemariam
Deputy Head, Amhara Region
Bureau of Rural Development
PO Box 1031, Bahr Dar
Telephone: 251-8-205583/202769/200357
Fax: 251-8-207819
E-mail: aberath@yahoo.com, rural-dh@telecom.net.et

Aberra Deressa,
Center Manager
Melkassa Research Center, EARO
PO Box 436, Nazareth
Telephone: 251-2-112186
Fax: 251-2-114623
E-mail: nrc@telecom.net.et

Adam Bekele
Head, Socio-Economics Dept.
Melkassa Research Center, EARO
PO Box 436, Nazareth
Telephone: 251-2-112186
Fax: 251-2-114623
E-mail: adamb@freemail.et

Alemayehu Refera
Entomologist
Forestry Research Center, EARO
PO Box 2003, Addis Ababa
Telephone: 251-1-460444
E-mail: alemayehu_refera@yahoo.com

Aleku Gezahegn
Forest Pathologist
Forestry Research Center, EARO
PO Box 2003, Addis Ababa

Ashebir W. Yoannes
Division Head
Areka Agric. Research Centre
PO Box 79, Areka
Telephone/fax: 251-6-552143
E-mail: Ark.arc@telecom.net.et

Bekele Azmera

Biological Control Expert
MoARD
PO Box 62347, Addis Ababa
Telephone: 251-1-460187

Betre Tadesse
Entomologist
Melkassa Research Center, EARO
PO Box 436, Nazareth
Telephone: 251-2-112186
Fax: 251-2-114623

Bezawork Mekonnen
Entomologist
UAAIE
PO Box 12624, Merti
Telephone: 251-2-122701
Fax: 251-2-122703
E-mail: uaaie@telecom.net.et

Bisrat Retu
Tech Asst. & Admin
SG2000
PO Box 12771, Addis Ababa
Telephone: 251-1-528511
Fax: 251-1-528507

Brhane Gebrekidan
Chief of Party, AMAREW Project
PO Box 61, Bahr Dar
Telephone: 251-8-201430/201470
Fax: 251-8-202555
E-mail: amarew@telecom.net.et

Dagnew Wogary
Coordinator, National Maize Project
PO Box 3, Bako
E-mail: dwgrissa@yahoo.com

Daniel Dauro
Director, SARI
PO Box 6, Awassa
Telephone: 251-6-204000
E-mail: ARC@telecom.net.et

Dawit Alemu
Policy Research Specialist
Melkassa Research Centre, EARO
PO Box 436, Nazareth
Telephone: 251-2-112186
Fax: 251-2-114623
E-mail: dawit96@yahoo.com

Dawit Amare
Sales Officer
Adami-Tulu Pesticide Processing Share Company
Addis Ababa
Telephone: 251-1-633298
Drylands Coordination Group

Geremew Gebeyehu
Head, Sorghum Program
Melkassa Research Center, EARO
PO Box 436, Nazareth
Telephone: 251-2-127023/112186
Fax: 251-2-114623
sormil@telecom.net.et

Getachew Alem
Engineer/Private Consultant
PO Box 30361, Addis Ababa
E-mail: getachew.alem@telecom.net.et

Getachew Alemayhu
Director, Crop Research
ARAI
PO Box 527, Bahr Dar
Telephone: 251-8-206626
Fax: 251-8-205174
E-mail: getachewalemayehu@hotmail.com

Girma Abebe
Agronomist
Melkassa Research Center, EARO
PO Box 436, Nazareth
Telephone: 251-2-112186
Fax: 251-2-114623
E-mail: narc@telecom.net.et

Girma Demissie
Entomologist & Department Head
Addis Ababa Agriculture Office
PO Box 16905, Addis Ababa
Telephone: 251-1-150695/516691

Gure Kumsa
Project Officer
Catholic Relief Services (CRS)
PO Box 6592, Addis Ababa
Fax: 251-1-654450
E-mail: gureku@crsethiopia.org

Hadera G. Medhin
Entomologist/Senior Pest Management Expert
Safe Environment Group (SEG)
PO Box 41190, Addis Ababa
Telephone: 251-1-537533

Hadush Tsehay
Entomologist
Mekele Agricultural Research Center
PO Box 492, Mekele
Telephone: 251-8-407900
Fax: 251-8-408031
E-mail: hado31@yahoo.com; marc@telecom.net.et

Hussien Harran
Agronomist
Melkassa Research Center, EARO
PO Box 436, Nazareth
Telephone: 251-2-112186
Fax: 251-2-114623
E-mail: narc@telecom.net.et; harruni@yahoo.com

Jemal Abdurehaman,
National Maize Project, EARO
PO Box 6, Awassa
Telephone: 251-6-202035/205309
E-mail: anmr@telecom.net.et; jemalabdu2000@yahoo.com

Girma Demissie
Entomologist & Department Head
Addis Ababa Agriculture Office
PO Box 16905, Addis Ababa
Telephone: 251-1-150695/516691

Gure Kumsa
Project Officer
Catholic Relief Services (CRS)
PO Box 6592, Addis Ababa
Fax: 251-1-654450
E-mail: gureku@crsethiopia.org

Hadera G. Medhin
Entomologist/Senior Pest Management Expert
Safe Environment Group (SEG)
PO Box 41190, Addis Ababa
Telephone: 251-1-537533

Hadush Tsehay
Entomologist
Mekele Agricultural Research Center
PO Box 492, Mekele
Telephone: 251-8-407900
Fax: 251-8-408031
E-mail: hado31@yahoo.com; marc@telecom.net.et

Hussien Harran
Agronomist
Melkassa Research Center, EARO
PO Box 436, Nazareth
Telephone: 251-2-112186
Fax: 251-2-114623
E-mail: narc@telecom.net.et; harruni@yahoo.com

Jemal Abdurehaman,
National Maize Project, EARO
PO Box 6, Awassa
Telephone: 251-6-202035/205309
E-mail: anmr@telecom.net.et; jemalabdu2000@yahoo.com

Lidetu Sitotaw
Entomologist
Melkassa Research Center, EARO
PO Box 436, Nazareth
Telephone: 251-2-112186
Fax: 251-2-114623
E-mail: narc@telecom.net.et

Manyazewal Ejigu
Team Leader, Crop Protection
Dire Dawa Agricultural Office
PO Box 2088, Dire Dawa
Telephone: 251-5-112098/112695
Fax: 251-5-110537
E-mail: manyazewalejigu@yahoo.com

Mesfin Tessera
Plant Pathologist
Holetta Research Center, EARO
PO Box 2003, Addis Ababa
Telephone: 251-1-370300

Mesele Fisseha
Ministry of Water Resources
Addis Ababa

Million Abebe
Entomologist/Centre Manager
Jimma Research Center, EARO
PO Box 192, Jimma
Telephone: 251-7-110367
Fax: 251-7-111999
E-mail: jarc@telecom.net.et

Mohammed Dawd
Entomologist
Plant Protection Research Center, EARO
PO Box 37, Ambo
Telephone: 251-1-362036
Facilitating the Implementation and Adoption of Integrated Pest Management (IPM) in Ethiopia

Mulatu Wakgari
Entomologist
Ethiopian Science & Technology Commission
PO Box 19917, Addis Ababa
Telephone: 251-1-516770
E-mail: Wakmul@yahoo.com

Ousmael Oumer
Extension Expert
Mekassa Research Center, EARO
PO Box 436, Nazareth
Telephone: 251-2-112186
Fax: 251-2-114623
E-mail: narc@telecom.net.et

Rebecca Desta
Plant Pathologist
Forestry Research Center, EARO
PO Box 30708, Addis Ababa
Telephone: 251-1-460444
E-mail: frc-dbs@telecom.net.et

Samuel Halala
General Manager, Adami-Tulu Pesticides Processing Share Co.
Telephone: 251-1-624656
Fax: 251-1-611764

Sebsebe Demissew
Professor and Leader, Ethiopian Flora Project
Addis Ababa University
PO Box 3434, Addis Ababa
Telephone: 251-1-573374
Fax: 251-1-552350
E-mail: nat.deb@telecom.net.et

Seifu Bantiwalu, Head
Plant Protection, UAAIE
PO Box 12624, Merti Jeju
Telephone: 251-2-122688

Seifu Gebre-Mariam
Head, Fruits Program
Mekassa Research Center, EARO
PO Box 436, Nazareth
Telephone: 251-2-112186
Fax: 251-2-114623

Seme Debela
Agronomist/Plant Breeder
PO Box 17253, Addis Ababa
Telephone: 251-9-407344
E-mail: semealem@telecom.net.et

Seyoum Mekonen
Agronomist

Fax: 251-1-362325
E-mail: mdawd2000@yahoo.com

Sue Edwards
Science Editor/Botanist
Institute for Sustainable Development
PO Box 171, Addis Ababa
Telephone: 251-1-167406
Fax: 251-1-669466
E-mail: sustain@telecom.net.et, sustainet@yahoo.com, sed@bio.aau.edu.et

Tadesse Gebremedhin
Advisor to Director General, EARO
PO Box 2003, Addis Ababa
Telephone: 251-1-456891
Fax: 251-1-461294
E-mail: advisor-dg@earo.org.et

Taye Tessema
Biological Control Expert
Plant Protection Research Center, EARO
PO Box 254, Ambo
Telephone: 251-1-362036
Fax: 251-1-362325
E-mail: tayetessema@yahoo.com

Tamiru Geno
Expert, Quality & Standards Authority
PO Box 2310, Addis Ababa
Telephone: 251-1-460111
Fax: 251-1-460880
E-mail: qsa@telecom.net.et

Tebkew Damte
Entomologist
Debre Zeit Research Center
PO Box 32, Debre Zeit
Telephone: 251-1-338555
Fax: 251-1-338061
E-mail: dzarc@telecom.net.et

Tekeste G. Kidan
Plant Protection, UAAIE
PO Box 12624, Merti Jeju
Telephone: 251-2-122685

Tekola Melisse
Member, SEG
PO Box 3025, Addis Ababa
Temesgen Belayneh  
Plant Pathologist  
Plant Protection Research Center, EARO  
PO Box 37, Ambo  
Telephone: 251-1-3622204  
Fax: 251-1-362036  
E-mail: Temu@yahoo.com

Tesfahun Fenta  
Team Leader  
Ethiopian Science & Technology Commission  
PO Box 2490, Addis Ababa  
E-mail: tfenta@yahoo.com

Tesfaye Alemu  
Plant Pathologist  
Coffee and Tea Authority  
PO Box 3222, Addis Ababa  
Telephone: 251-1-152141  
Fax: 251-517293  
E-mail: talemu2000@yahoo.com

Tesfaye Tessema  
Senior Agronomist  
SG2000  
PO Box 12771, Addis Ababa  
Telephone: 251-1-528500/09-04  
Fax: 251-1-528507  
E-mail: sgeth@telecom.net.et

Tesfaye Wudye  
Technical Assistant  
Pawe Research Center, EARO  
PO Box 25, Pawe  
Telephone: 251-8-202525

Tesfaye Zenebe  
Forester  
Melkassa Research Center, EARO  
PO Box 436, Nazareth  
Telephone: 251-2-112186  
Fax: 251-2-114623

Teshale Assefa  
Leader, Lowland Pulse Program  
Melkassa Research Center, EARO  
PO Box 436, Nazareth  
Telephone: 251-2-127020/112186  
E-mail: narc@telecom.net.et

Teshome Lemma  
Senior Expert, Post-harvest  
MoARD  
PO Box 62347, Addis ababa  
Telephone: 251-1-410187  
Fax: 251-1-626505

Tessena Megena  
Chief Research Officer  
Desert Locust Control Organization for Eastern Africa  
PO Box 4255, Addis Ababa  
Telephone: 251-1-461477  
E-mail: dlcoea@telecom.net.et

Tibebe Getaneh  
Head, Plant Protection, UAAIE  
PO Box 12624, Merti Jeju  
Telephone: 251-2-122701  
Fax: 251-2-122703

Tsesaye Abate  
Managing Director  
Association for Advancement of IPM (ASAI)  
PO Box 359, Nazareth  
Telephone: 251-2-128098  
Fax: 251-2-114409  
E-mail: asai@telecom.net.et,  
geremush@yahoo.com

Wasihun Legesse  
Sorghum Breeder/Center Manager  
Pawe Research Center, EARO  
PO Box 25, Pawe  
Telephone: 251-1-8-202525  
Fax: 251-1-202535

Wondirad Mande  
Nematologist/Centre Manager  
Plant Protection Research Center, EARO  
PO Box 37, Ambo  
Telephone: 251-1-3622204  
Fax: 251-1-362325  
E-mail: Wondish@hotmail.com

Workineh Abebe  
Coordinator, Agricultural Mechanization Project  
Melkassa Research Center, EARO  
PO Box 436, Nazareth  
Telephone: 251-1-112186  
Fax: 251-2-114623
Woubit Dawit
Plant Pathologist
Debre Zeit Research Center, EARO
PO Box 32, Debre Zeit
Telephone: 251-1-338555
Fax: 251-1-338061
E-mail: dzarc@telecom.net.et

Yalemtehay Mekonnen
Member, SEG
PO Box 31010, Addis Ababa
Telephone: 251-1-763091
E-mail: yalemtehay@yahoo.com

Yaynu Hiskias
Plant Pathologist
Institute of Biodiversity & Research
PO Box 30726, Addis Ababa
Telephone: 251-1-634958/766015
E-mail: yhiskias@hotmail.com

Zegeye Tadesse
Ag. Machinery Technician
Melkassa Research Center, EARO
PO Box 436, Nazareth
Telephone: 251-2-112186
Fax: 251-2-114623

Zemedu Worku
Horticulturist
Private (Freelance)
PO Box 25992/1000, Addis Ababa
Telephone: 251-1-716970

Zinash Sileshi
Director, Livestock Research
EARO
PO Box 2003, Addis Ababa
Telephone: 251-1-454432
E-mail: livestock@earo.org.et
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Proceedings:


Drylands Coordination Group Addresses in Norway:

**Secretariat of the Drylands Coordination Group**
Grensen 9b, 0159 Oslo, Norway  
Tel: +47 23 10 94 90, Fax: + 47 23 10 94 94  
E-mail: dcg@drylands-group.org

**ADRA Norge**  
Postboks 124, 3529 Røyse, Norway  
Tel.: +47 32 16 16 90, Fax: +47 32 16 16 71  
E-mail: 102555.2157@compuserve.com

**CARE Norge**  
Universitetsg. 12, 0164 Oslo, Norway  
Tel: +47 22 20 39 30, Fax: +47 22 20 39 36  
E-mail: care.norge@online.no

**Development Fund**  
Grensen 9b, 0159 Oslo, Norway  
Tel: +47 23 10 96 00, Fax: +47 23 10 96 01  
E-mail: u-fondet@u-fondet.no

**Norwegian Church Aid**  
Postboks 7100, St. Olavs plass, 0130 Oslo, Norway  
Tel: + 47 22 09 27 00, Fax: + 47 22 09 27 20  
E-mail: nca-oslo@sn.no

**Norwegian People’s Aid**  
P.O. Box 8844 Youngstorget, 0028 Oslo, Norway  
Tel: + 47 22 03 77 00, Fax: + 47 22 17 70 82  
E-mail: norsk.folkehjelp@npaid.no

**Noragric, Department for International Environment and Development Studies**  
University of Life Sciences, P.O. Box 5003, 1432 Ås, Norway  
Tel: +47 64 94 99 50, Fax: +47 64 94 07 60  
E-mail: noragric@noragric.umb.no