Recommended Research Results for Improving Crop, Livestock and Natural Resources Productivity in Western Oromia: Users' Manual

Edited by
Firdissa Eticha, Gemeda Duguma, Shimelis Dejene, Abebe Yadessa, Gebregziabher Gebreyohannis and Tolessa Debele.

Oromia Agricultural Research Institute (OARI)
Bako Agricultural Research Center
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Editorial

The majority of the population of Ethiopia consists of farmers and their families who have limited access to education and health services. Food security is also one of the most important problems for the rural population whose life is almost entirely dependent on agricultural products, suggesting that agriculture is the mainstay of the major proportion of human population of the country. The challenging task to the development of this sector is at the forefront of agricultural researchers in which case the generation of agricultural technologies is imperative. Bako Agricultural Research Center is mandated to generate crop-livestock and natural resources management technologies for varying agro-ecologies extending from lowland to highland areas of western zones of Oromia Regional State. So far, the center has developed various technologies that could be important for the improvement of agricultural production to this region. However, all the endeavors made were not put together in a clear and in a useable form. But research recommendations are found in different manuscripts in a fragmentary manner. This resulted in an inefficient utilization of the agricultural technologies by the immediate users. Having this issue in mind, the management and the research staff of the center formed a committee that compiled the findings of the work of different research disciplines. Following, you will find a package of production technologies developed by Bako and other agricultural research centers in the country. Relevant findings that would help improve the quantum yield of crop-livestock sectors and/or the systems as a whole were reviewed. Utmost efforts will also be made to update this document following developments made in research. In addition, it should be recognized that these recommendations are not static. It means, though basic recommended practices will be similar from season to season; they should be adjusted to reflect latest research findings and environmental dynamics.

The members of the editorial committee would like to thank the center management and all the authors, who in one way or another have contributed for the betterment of this document. The Agricultural Research and Training Project (ARTP) office of the Ethiopian Agricultural Research Organization (EARO) is acknowledged for sponsoring the publication of this production guideline. We are also highly indebted to the Research-Extension-Farmer Linkage Department of EARO for its encouragement and facilitating the procurement of the required budget to publish this document.

The opinions expressed in this volume are the sole responsibility of the authors.

Bako, August 2002
Foreword

It is undeniably true that generation of an ecologically adapted and economically viable agricultural technology is an essential condition for success in achieving the sustained growth in agricultural productivity. One has to note, however, that technological innovation is not a sufficient factor for a small holder agricultural development, and can not contribute effectively, without other essential and complementary conditions.

One of the factors that contribute to a wider technological gap is the absence of technological information in a form that can be easily utilized by the intended clientele – farmers and the frontline development workers. Cognizant of this fact, the center decided to review and document the results of the research activities conducted thus far in its mandate areas so that users could easily get access to it. I hope the information contained in the document will contribute much to the development of agricultural sector in the region or in the nation. On behalf of the center and myself I would like to acknowledge the steering committee members who compiled and edited the draft documents.

Diriba Geleti, Center manager
Bako Agricultural Research Center
1. Introduction

Maize is originated in Central America and was introduced to West Africa and then to Ethiopia during the 1600s and 1700s. Although the introduction of maize to our country is late, today, maize is one of the most important food crops all over the country. It is the first in total production and yield per hectare and next to tef in area coverage. Due to this it has been selected as one of the national commodity to satisfy the food self-sufficiency program of the country as well as to feed the alarmingly increasing population of the country.

Though maize has high yield potential, the local varieties that our farmers have been used for the last many years were low yielders, and have been subjected to many biotic and abiotic stresses. Therefore, in order to upgrade maize production and productivity in the country, in general, and western region, in particular, the following guidelines for maize production have to be further exercised appropriately.

2. Types of maize varieties

Maize variety is defined as individual plants or group of plants that are distinct from other groups and identifiable from generation to generation.

2.1. Open pollinated variety

A sub-division of species that is different (distinguishable from other varieties), uniform (its identifying characteristics are well defined), and stable (its identifying characteristics are constant in time and space). An open pollinated variety (OPV) could be traditional farmers' variety, synthetic (OPV formed from inbred lines) and composite (OPV developed from germplasm complexes). An OPV is also formed from selected families during recurrent selection. Kuleni, Abo-Bako, UCB, Alemaya composite, Gutto, Gibe-1 and Gambella comp-1 are some of the open pollinated varieties. The importance of OPVs is that a farmer can use seeds of OPVs for 3-5 years without any yield reduction.

2.2. Hybrids

Hybrid is an F1 generation resulting from crossing two maize parents identified as genetically different. Hybrids fall in to two broad categories:

1. Conventional hybrid
2. Non-conventional hybrid

2.2.1. Conventional hybrids: - they are resulted from crossing two or more inbred lines that have high combining ability. Inbred lines are developed through a process of self-fertilization (inbreeding).
Single cross: - The first generation resulting from controlled crossing of two inbred lines. Example, BH-540, BH-541...etc.

Three way cross: - The first generation resulting from controlled crossing of a single cross and an inbred line. It involves the union of an inbred line, serving as the male, and a highly productive (in seed yield) single cross hybrid, serving as female. Examples: BH-660, BH-670 and BHQP-542.

Double cross: - It involves the union of two single cross hybrids themselves, each of the single cross is the product of two inbred lines. The National Maize Research Program has not yet released double cross hybrids.

2.2.2. Non-conventional hybrids: - They are formed through crosses in which at least one parent is not an inbred line.

Variety-cross hybrid: - It is a cross between two open-pollinated varieties that are sufficiently different genetically to show hybrid vigor.

Family-cross hybrid: - It is formed through the union of two elite fractions that have been extracted from improved varieties that have high combining ability.

Top-cross hybrid: - It is a cross between a variety (generally used as the female) and inbred line (serving as the male parent). E.g. BH-140, BH-530.

Generally, hybrid varieties are high yielder than opvs. However, using the seeds of hybrid varieties for further production causes a significant yield reduction.

Table 1. General comparison of hybrids, synthetics and composites varieties

<table>
<thead>
<tr>
<th>No</th>
<th>Parameters</th>
<th>Hybrids variety</th>
<th>Synthetic variety</th>
<th>Composite variety</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yield</td>
<td>***</td>
<td>**</td>
<td>*</td>
</tr>
<tr>
<td>2</td>
<td>Cost of seed production</td>
<td>***</td>
<td>**</td>
<td>*</td>
</tr>
<tr>
<td>3</td>
<td>Genetic variability</td>
<td>*</td>
<td>**</td>
<td>***</td>
</tr>
<tr>
<td>4</td>
<td>Adaptation</td>
<td>*</td>
<td>**</td>
<td>***</td>
</tr>
<tr>
<td>5</td>
<td>Management requirements</td>
<td>***</td>
<td>**</td>
<td>*</td>
</tr>
<tr>
<td>6</td>
<td>Price to buy seeds of</td>
<td>***</td>
<td>**</td>
<td>*</td>
</tr>
<tr>
<td>7</td>
<td>Seed replacement</td>
<td>Every year</td>
<td>3-5 years</td>
<td>-5 years</td>
</tr>
</tbody>
</table>

Remark: >>>>>>>

3. Varietal characterization

Descriptions of morphological traits are important as a guide for maintenance and multiplication of varieties. They are essential for rouging and field inspections operations. Characteristics that may be included in a variety description are plant height, ear height, plant architecture, and resistance to insect and disease pests.

Quantitative descriptors are generally used in the maintenance of the genotype and production of breeder seed, whereas the qualitative descriptors are generally used for subsequent seed
multiplication and for certification standards. In general, qualitative descriptors are preferred because they are more easily measured and tend to show fewer interactions with the environment. The purple (reddish) tassel color of BH-660 could be a good example. Plants with white tassel color in the BH-660 field are off-types (plants with traits that do not fit the variety description). Thus quality seeds that fulfill the quality standards should be supplied to the farmers to get high yield and to increase food production.

4. Recommended maize varieties and areas of adaptation

Environment is a general term that covers conditions under which plants grow and may involve locations, years, management practices, or a combination of these factors. Every factor that is part of the environment of a plant has the potential to cause differential performance that is associated with genotype by environment interaction. Genotype by environment interaction will occur when the contributions (or level of expression) of the genes regulating the trait differ among environments.

Environmental variables are classified as unpredictable and predictable factors.

Unpredictable variations: - These include the fluctuation features of the environment such as rainfall, relative humidity, temperature etc.

Predictable variations: - These include those factors that are under human control. Example planting date, row spacing, plant population, and rates of nutrient application.

The national maize research program has classified the maize agro-ecologies into four broad agro-ecological environments. These are mid-altitude sub-humid zone, mid-altitude moisture stress zone, high altitude sub-humid zone and low altitude sub-humid zone. Improved varieties have been recommended for each agro-ecology (Table 3). Improved varieties give high yield whenever they are planted in their areas of adaptation. Thus, development agents are advised to plant them in their areas of adaptation to exploit the high yield potential of these varieties (hybrids, opvs). Improved varieties also express their genetic potential whenever they are planted under the recommended management practices.
<table>
<thead>
<tr>
<th>Crop</th>
<th>Variety</th>
<th>Year of release</th>
<th>Altitude (m)</th>
<th>Rain fall (mm)</th>
<th>Plant height (cm)</th>
<th>Ear placement</th>
<th>Days to maturity</th>
<th>Seed color</th>
<th>Yield (q/h)</th>
<th>Lodging</th>
<th>Disease Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize Hybrids</td>
<td>BH-660</td>
<td>1993</td>
<td>1600-2200(2400)</td>
<td>1000-1500</td>
<td>255-290</td>
<td>145-165</td>
<td>160</td>
<td>White</td>
<td>90-120</td>
<td>60-80</td>
<td>F T T T</td>
</tr>
<tr>
<td></td>
<td>BH-140</td>
<td>1988</td>
<td>1000-1800</td>
<td>1000-1200</td>
<td>240-255</td>
<td>105-120</td>
<td>145</td>
<td>&quot;</td>
<td>80-90</td>
<td>47-60</td>
<td>T MT MT MT</td>
</tr>
<tr>
<td></td>
<td>BH-530</td>
<td>1996</td>
<td>1000-1300</td>
<td>1000-1500</td>
<td>200-230</td>
<td>110-120</td>
<td>140</td>
<td>&quot;</td>
<td>80-90</td>
<td>50-60</td>
<td>T MT MT MT</td>
</tr>
<tr>
<td></td>
<td>BH-541</td>
<td>2001</td>
<td>1000-1800</td>
<td>1000-1200</td>
<td>245-260</td>
<td>130-140</td>
<td>150</td>
<td>&quot;</td>
<td>80.5-110</td>
<td>60.5-70.5</td>
<td>T MT T T</td>
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<tr>
<td></td>
<td>BH-670</td>
<td>2001</td>
<td>1700-2400</td>
<td>1000-1500</td>
<td>260-295</td>
<td>150-160</td>
<td>165</td>
<td>White</td>
<td>90.5-120</td>
<td>60.5-80.5</td>
<td>MT T R R</td>
</tr>
<tr>
<td></td>
<td>BHQP-542</td>
<td>2001</td>
<td>1000-1800</td>
<td>1000-1200</td>
<td>220-250</td>
<td>100-120</td>
<td>145</td>
<td>White</td>
<td>80-90</td>
<td>50-60</td>
<td>MT T T T</td>
</tr>
<tr>
<td>Maize OPVS</td>
<td>Kulem</td>
<td>1995</td>
<td>1700-2200(2400)</td>
<td>1000-1200</td>
<td>240-265</td>
<td>130-145</td>
<td>150</td>
<td>&quot;</td>
<td>60-70</td>
<td>40-45</td>
<td>T T T T</td>
</tr>
<tr>
<td></td>
<td>Abo-Bako</td>
<td>1986</td>
<td>500-1000</td>
<td>1000-1200</td>
<td>240-260</td>
<td>130-145</td>
<td>150</td>
<td>&quot;</td>
<td>50-70</td>
<td>35-45</td>
<td>T MT MT MT</td>
</tr>
<tr>
<td></td>
<td>Gutto</td>
<td>1988</td>
<td>1000-1700</td>
<td>800-1200</td>
<td>165-190</td>
<td>90-110</td>
<td>126</td>
<td>&quot;</td>
<td>30-50</td>
<td>25-30</td>
<td>R MT MT MT</td>
</tr>
<tr>
<td></td>
<td>Al-Comp.</td>
<td>1997</td>
<td>1600-2200</td>
<td>1000-1200</td>
<td>280-300</td>
<td>170-190</td>
<td>163</td>
<td>&quot;</td>
<td>50-70</td>
<td>38-42</td>
<td>MS T T T</td>
</tr>
<tr>
<td></td>
<td>Rare-1</td>
<td>1997</td>
<td>1600-2200</td>
<td>900-1200</td>
<td>250-270</td>
<td>130-150</td>
<td>163</td>
<td>&quot;</td>
<td>60-80</td>
<td>40-45</td>
<td>MT T T T</td>
</tr>
<tr>
<td></td>
<td>Katumani</td>
<td>1974</td>
<td>Mid alt.moit.stres</td>
<td>600-1000</td>
<td>160-180</td>
<td>90-100</td>
<td>105</td>
<td>&quot;</td>
<td>25-45</td>
<td>20-25</td>
<td>T _ T T</td>
</tr>
<tr>
<td></td>
<td>ACV-3</td>
<td>1996</td>
<td>Mid alt.moit.stres</td>
<td>600-1000</td>
<td>160-180</td>
<td>90-100</td>
<td>105</td>
<td>&quot;</td>
<td>30-50</td>
<td>20-30</td>
<td>T _ T T</td>
</tr>
<tr>
<td></td>
<td>ACV-6</td>
<td>1996</td>
<td>Mid alt.moit.stres</td>
<td>600-1000</td>
<td>160-180</td>
<td>90-100</td>
<td>105</td>
<td>&quot;</td>
<td>30-50</td>
<td>20-30</td>
<td>T _ T T</td>
</tr>
<tr>
<td></td>
<td>Melkasa-1</td>
<td>1999</td>
<td>Mid alt.moit.stres</td>
<td>600-1000</td>
<td>160-180</td>
<td>90-100</td>
<td>105</td>
<td>&quot;</td>
<td>30-50</td>
<td>20-30</td>
<td>T _ T T</td>
</tr>
<tr>
<td></td>
<td>Gibe Comp.-1</td>
<td>2000</td>
<td>Low alt.-Mid alt.</td>
<td>1000-1700</td>
<td>240-260</td>
<td>130-140</td>
<td>145</td>
<td>60-70</td>
<td>40-45</td>
<td>T MT T T</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gambela Comp.-1</td>
<td>2001</td>
<td>500-1000</td>
<td>1000-1200</td>
<td>210-230</td>
<td>120-140</td>
<td>110</td>
<td>White</td>
<td>60-70.5</td>
<td>40-50</td>
<td>MT R R R</td>
</tr>
</tbody>
</table>

F=Fair; T = tolerant; R = resistant; MR = moderately resistant; MT = moderately tolerant; MS = moderately susceptible
Maize Management Factors:

1. Land preparation
2. Planting time
3. Planting methods
4. Plant Density
5. Nutrient Requirements
6. Weed control
7. Cropping systems
8. Soil and water conservation

1. Land preparation

Selecting a site: Maize grows best in deep and well-drained loamy soils but can be cultivated nearly anywhere in Oromia. Sandy, gravelly and shallow soils should be avoided whenever possible, as they are more affected by drought. Avoid planting maize in shady areas, yield will decrease with reduction in the amount of sunlight that reaches the plant.

The primary purposes of land preparation prior to planting are to create a soil structure favorable for crop growth, to incorporate residues and to control weeds and diseases. Maize crop requires 2-3 times plowing depending on the previous cropping history of land. Avoid burning because the decaying weeds and crop residues act as mulch for maize crop. The mulch will keep the soil cooler, conserve moisture, increase water infiltration and reduce soil erosion. To reduce erosion on sloppy land, plowing should be done across the slope rather than up and down.

There are three types of problems at planting:

a) The land may not be plowed properly clods or crusts prevent planting at a uniform depth and even germination.

b) Land preparation is too long before planting & weeds have an advantage over the crop.

c) The seeds are placed at the wrong depth.

2. Planting Time

Choosing a Variety: Plant an improved variety for highest yield. The full season variety (150 days to maturity, eg. BH-660, BH-670 and Kuleni) normally gives the highest yield, followed by the medium (120-130 days to maturity, eg. BH-540, BH-140, BH-541, BHQP-542, Gibe-1 and Melkassa-1) and early maturing varieties (90-110 days to maturity, eg. Gutto, Acv-3, Acv-6 and Katumeni).

Maize farmers are frequently concerned about the response of maize to planting date. Early planting of maize is recommended because full-season hybrids utilize the entire growing season and achieving physiological maturity before killing moisture comes. The recommended planting calendar varies from place to place based on the on set of rainfall. Hence, planting dates are based on the establishment of the rains in each agro-ecological zone. However, the farmers’ experience in their area is the best guide. Experience over the years indicated that planting as early as possible after the rains have been established is likely to give the highest yield. Another reasons that early-planted maize yields better is the lower incidence of insects and diseases. Early planting benefits more from the higher soil fertility present at the beginning of the rainy season. As the season progress, nutrients leach below the root zone and are, therefore, no longer available for uptake.
**Planting method:** A good planting method is one that allows seed to be placed at the correct depth and provides good contact between seed and soil. The correct depth of planting is **deep enough** to allow seed to take up water, to protect the seed from desiccation or birds and to prevent the seed from germinating with light rains. But **shallow enough** to allow the seedling to reach the surface before depleting its food reserves or being attacked by soil insects or diseases. Thus, the suitable planting depth for maize is 5-7cm.

The advantage of row planting in maize production is very high, as compared to broadcasting. Thus, row planting is advisable.

**Plant Density:** The optimum plant density under non-limiting condition will be different for different varieties. The optimum density could be related to plant height and maturity. The medium and early maturing varieties must be planted at higher densities if their full yield potential is to be realized.

**Seed rate:** 25 – 30 kg/ha.

**Spacing:**
- Full season varieties: 75 cm x 30 cm one seed/hill (44,444 plants/ha) or 80cm x 50cm two seeds/hill (50,000 plants/ha)
- Medium maturing varieties: 75 cm x 25 cm (53,333 plants/ha)
- Early maturing varieties: 75 cm x 20 cm (66,666 plants/ha)

<table>
<thead>
<tr>
<th>Causes of low plant Density</th>
<th>Possible solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor seedbed preparation</td>
<td>Improve land preparation or cultivation practices</td>
</tr>
<tr>
<td>Seed planted not viable</td>
<td>Plant quality seed</td>
</tr>
<tr>
<td>Farmer plants too few seeds</td>
<td>Do germination test before planting and adjust the seeding rate accordingly</td>
</tr>
<tr>
<td>Plants lost after planting (during germination and afterwards)</td>
<td>Increase seeding rate</td>
</tr>
<tr>
<td>Farmer destroy some plants while cultivating/shilshalo</td>
<td>Insecticide treatment of seed to reduce insect losses</td>
</tr>
<tr>
<td></td>
<td>Crop rotation to reduce insect/disease losses</td>
</tr>
<tr>
<td></td>
<td>Avoid late 'shilshalo'</td>
</tr>
</tbody>
</table>

**Nutrient Requirements of Maize:** Maize crop needs certain mineral elements in adequate quantities for good growth. These nutrients are generally supplied from the soil and from the added fertilizers. Soils of Oromia are deficient in nitrogen and phosphorus content. **Why?**

**Causes of nutrient deficiencies**

- Not enough fertilizer was applied in the previous years of harvest and caused nutrient depletion in the soil.
- Fertilizer applied is lost to leaching, run-off, volatilization, or fixation
- Fertilizer is applied when the crop can not use it well
- Excessive competition with weeds or intercrop combination for nutrients
- Soil pH makes certain nutrients unavailable
- Water logging results in nitrogen deficiency

**Nitrogen Management in Maize**

Nitrogen requirement of maize is important from emergence to grain filling stage. Nitrogen is the one nutrient element required in the highest dose by maize. It is also the most element with most pronounced response by maize. Nitrogen removed by the crop (seed) is lost
permanently from the fields. Therefore that much of nutrient has to be replenished to sustain maize production.

**Addition of nitrogen to the soils:**

a) Organic manure (farmyard manure, green manure and compost, etc.)
b) Chemical fertilizers (urea).
c) Fixation of atmospheric N by legumes.

**Nitrogen losses from soils**

a. **Denitrification:** Waterlogged fields, warm, very wet and poor aeration favors denitrification

b. **Volatilization:** Urea (NH\(_2\)-CO-NH\(_2\)) is a volatile source of nitrogen.

c. **Crop removal:** Nitrogen removed by seed is a permanent loss from the soil.

d. **Leaching:** Nitrate is much more susceptible to leaching than ammonium. Leaching proceeds much faster in sandy soils than in clay soils

e. **Erosion/run-off**

How can we achieve high nitrogen use efficiency? By appropriate time, method, rate and source of applications.

**Time of application:** Split application (half of at planting time and the remaining half at 35 days after sowing)

**Rate:** 200 kg/ha of urea for Bako area and 150 kg/ha of urea for Jimma, Gudar, Mutulu, Toke, Babichi, Gimbi, Guliso, Jarso and similar areas.

**Method of application:** Urea must be incorporated into the soil after side dressing. Urea does not store well. Do not attempt to store opened bags from one year to the next.

**Phosphorus Management in maize**

Phosphorus requirement of maize is important from germination to about R\(_5\) (Dent) stage. The need for phosphorus in maize is particularly critical during the establishment stages.

**Phosphorus problem is three-fold**

1. The amount of inherent phosphorus is very low in most soils
2. Most of phosphorus present in the soil is in unavailable form
3. Added soluble forms of phosphorus are quickly "fixed" by many soils

**Rate:** 100 kg/ha of DAP for Bako, Gudar, Mutulu, Toke, Babichi, and Jimma areas and 150 kg/ha DAP for Gimbi, Guliso, Jarso and similar areas.

**Time of application:** All at planting

**Method of application:** Band placement.
Organic Fertilizers

Organic sources of fertility play a major role in maize production. Every attempt should be made to use locally available organic sources of fertility. When well decomposed, the organic materials should be spread uniformly over the land prior to planting. The possible organic sources of fertility in Oromia are farmyard manure, crop residues, compost and green manure.

- To supply 100 kg/ha of urea it is necessary to apply 50 qt/ha of well-decomposed manure to maize crop.
- 50qt/ha compost along with 50kg/ha of DAP (applied at planting) and 35kg UREA (top dressed at 'Shilshalo') is also recommended.
- Use of Dolichos lablab and Mucuna as improved fallow along with 50% of the recommended fertilizer found to be promising.
- 200kg/ha bon meal (or rock phosphate) or 100kg bon meal along with 50kg DAP can also be used for maize production.

If these all organic sources of nitrogen are not available in sufficient quantities, chemical fertilizers should be used in addition to whatever manure or compost is applied.

© Weed control

Maize is very sensitive to weed competition during the critical period between emergence to flowering stages. Weeds are very effective competitors for nutrient, water, light and space than maize. Good land preparation helps in controlling weeds and gives maize a starting growth advantage over the weeds. Ideally, maize fields should be kept weed free. For practical and economic considerations, however, twice hand weeding is recommended, the first one at 25-30 days after sowing and the second at 55-60 days after sowing. Slashing may also be necessary to control late weeds. Slashed weeds should not be removed from the field but should be used as mulch around the plants.

<table>
<thead>
<tr>
<th>Causes of high weed competition</th>
<th>Possible solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>▶ Poor manual weed control</td>
<td>▶ timeliness of weed control (Recommended)</td>
</tr>
<tr>
<td>▶ Weeding to late</td>
<td>▶ early weeding</td>
</tr>
<tr>
<td>▶ Inefficient herbicide application</td>
<td>▶ apply herbicides to wet soil (early in the morning or late in the afternoon)</td>
</tr>
<tr>
<td>▶ planting of maize delayed after land preparation</td>
<td>▶ plant maize immediately after land preparation</td>
</tr>
<tr>
<td>▶ maize monocropping (build up of weeds)</td>
<td>▶ crop rotation</td>
</tr>
</tbody>
</table>

Herbicidal weeding

Needless to say, herbicide use should not be obviating the need for supplementary hand weeding. Primagram is 83% efficient in controlling weed in maize when applied at the recommended rate of 4-5 Lt/ha. Similarly, gesaprim is 71 % efficient at 4-5 Lt/ha.

© Cropping systems

Cropping system is the pattern in which crops are grown in a given area over a period of time, and includes the technical and managerial resources that are utilized. Continuous cropping is the cultivation of the same piece of land year after year. Continuous cropping is usually associated with a higher level of technology and management.
Monoculture is the practice of continuous cropping, growing the same crop on the same land season after season.

Maize yield decline in monoculture. Why?
- Increase in incidence of diseases, pests and weeds.
- Deterioration in soil structure (soil tended to become compacted and to drain with more difficulty).
- Associated loss of topsoil by erosion.
- Depletion of plant food by continuous cropping to maize year after year.

Crop Rotation

Crop rotation is the growing of different crops, one at a time, in a definite sequence on the same piece of land. Maize crop benefits considerably when rotated with a legume crop (haricot bean, soybean, and noug) because legumes supply part of their own nitrogen. Some of this nitrogen remains in the roots, stems and leaves of the crop after harvest. Because of this, residues from legume crops should not be burnt, but rather left on the field for the benefit of following crop. That is why maize planted after noug and beans will yield better than maize planted after maize, sorghum or teff.

Intercropping

The practice of growing one crop variety alone in pure stands on a field is referred to as sole cropping. The alternative practice of growing two or more crops simultaneously on the same field is called intercropping. Recent experimental evidence indicated that without affecting maize yield, extra yield (bonus yield) of haricot bean, soybean, and sweet potato could be obtained by intercropping.

Maize haricot bean intercropping

Intercropping had higher over all benefits than sole cropping of either maize or haricot bean. Hence, intercropping 75% plant density of haricot bean into 100% plant density of maize during oxen cultivation 'Shilshalo' at about 35 days after planting maize is recommended.

Maize soybean intercropping: Soybean can successfully be intercropped with maize. Maize/soybean intercropping had an advantage of 22% over sole cropping of maize.

Maize horticultural crops intercropping: Horticultural crops like sweet potato can successfully be intercropped with maize.

Maize forage crops intercropping: This practice is important in crop livestock mixed farming systems, especially where animal feed is limiting. Forage crops like Desmodium uncinatum and Chloris gayana can be well established if under sown in the maize after about 60 days of planting maize without affecting maize yield. Doing it at second maize weeding saves labour compared to any other time.
Relay Cropping

Relay cropping refers to growing two or more crops simultaneously during part of the life cycle of each. A second crop is planted after the first crop has reached its reproductive stage of growth but before it is ready for harvest.

Maize haricot bean or sweet potato relay cropping

Food crops such as haricot bean and sweet potato can successfully be relayed into maize without any effect on maize. Maize can be harvested either for green ears or for grain. The advantage of relay cropping was 72% when maize harvested green and 46% when maize harvested grain. Harvesting maize for green ears and relaying sweet potato into maize at flowering are economically attractive. The appropriate time of relay planting sweet potato is at 50% flowering of maize. However, for those farmers wishing to spread the labour demand, relay planting haricot bean starting from 50% to 15 days after flowering of maize is also an attractive alternative for maize farmers.

Soil and water conservation

Soil is a non-renewable natural resource. The time span required for the formation and development of 2.5 cm of surface soil is between 100 and 600 years depending on the factors of soil formation. However, that 2.5 cm of fertile surface soil could easily be lost over a 24 hour period by run-off erosion if it is not conserved and managed properly. Extremely high top soil loss of 750 qt/ha and water loss of 524 m³/ha annually were eroded from bare land with 9% slope. While 0.8 t/ha soil loss and 185 m³/ha water loss were recorded from grass covered land. Buffer strip-cropping maize with grass also showed good control with 3.7 t/ha soil loss and 298 m³/ha water loss. For practical purposes, it is concluded that buffer strip cropping of grass with haricot bean intercropped between maize rows would be the best practice for farming on sloping lands.

Summary

Ten Steps to Increase Maize Production
1. Select a good site
2. Prepare the land well
3. Plant an improved variety such as BH-660, BH-540, BH-140, kuleni, Gibe-1, etc.
4. Use good seed
5. Plant as early as possible after the rains have come to stay
6. Plant in rows at the recommended spacing
7. Sow the seed (5 - 7cm) deep and cover well
8. Apply fertilizers at the recommended rate, method and time of application
9. Control pests on time
10. Harvest at agronomic maturity and treat/dry grain for storage

Major Insect Pests of Maize and their management in Western Ethiopia

A) Stem borers
Lepidopterous stem borers are very important pests of maize in Ethiopia. The maize stalk borer (MSB) (*Busseola fusca*) is the major stem borer in western region while the spotted stalk borer (SSB) (*Chilopartellus*) is the major species only in Gambella area. The pink Stalk...
borer (PSB) was recorded in small numbers from Mendi area. MSB is dominant at higher altitudes (1160-2500 masl) and cooler areas, whereas SSB is dominant at lower altitudes (510-1700 masl) and in warmer areas, but PSB is intermediate between the two (Assefa, 1985). Damage occurs from seedling to maturity and larvae pupate within the stem.

Management practices

1. Cultural Methods

1.1 Manipulation of Sowing dates

Appropriate time of planting has long been recommended for various pest and disease problems. For the control of Maize Stalk borer, maize should be planted as early as possible following the rainfall in order to escape infestation by the second-generation larvae. Late sown maize escapes attack of the first generation but they are much more susceptible to damage by the second generation whose influence on plant growth, cob production and grain yield is much greater compared with damage by first generation larvae. Reports indicate that early sowing had a yield advantage of more than 58.2% (Tsedeke and Elias, 1998).

1.2 Destruction of wild host plants and crop residues

The most destructive pests of maize in Africa are originated in this continent and evolved with the native grasses (e.g. stem borers and cicadulina leafhoppers) and only recently adapted to feed on maize. Therefore, any attempt to control these pests must talk into consideration the close association between their ecology and that of the native grasses. The major wild host species of maize stem borer in Ethiopia are *Pennisetum purpureum*, *sorghum verticilflorum* and sorghum tillers grown from ratoons (Assefa, 1988).

1.3 Intercropping

Maize/bean intercropping experiments showed that sole maize had significantly higher incidence of stalk borer and cob worms as compared to intercropped treatments. However, it is not advisable to plant maize and bean in the same row for the reason that incidence of stalk borers was higher when both crops were planted in the same row (Negussie and Reddy, 1996).

1.4 Cutting maize stalks at soil level

Longer stalks left in the field would mean larger populations of stalk borer. Thus, when stalks of maize or sorghum are removed they should be cut at soil level so that most larvae will be removed from the field (Assefa, 1988).

1.5 Horizontal placement of infected stalks

The conventional method of storing stalks (up right position) after harvest constituted a major source of carry over population of maize stalk borer. Horizontal placement of infested stalks for four weeks in the sun resulted in substantial reduction in survival of the insect. The stalks should be thinly spread so that all stalks get direct sun light (Assefa, 1988).
1.6 Natural enemies

Biological control through natural enemies should be emphasized because it is one of the most important components of integrated pest management program. Survey results (Mulugeta, 2001) revealed that the major parasitoids of stem borers attacking maize and sorghum are Apanteles sesamiae (cameron) (=cotesia); Bracon hebetor (say); Bracon sesamiae (cameron), Procerochasmias nigromaculatus (cameron) and a sarchophaga spp.(Diptera). Out of these parasitoids, cotesia sesamiae (cam.) was found to be widely spread in all surveyed areas. Hence, having identified the type of parasitoids found in our vicinity, we have to be able to conserve and utilize them.

1.7 Botanicals (plant materials)

A preliminary field test showed that application of extracts of dried fruits of china berry (Melia azedarach L.), endod (Phytolocca dodecandra L.) and pepper tree (Schinus molle L.) in the rate of 60, 32 and 40 kg/ha, respectively, significantly reduced leaf infestation, dead heart injury and tunneled stalks. This, in turn, resulted in yield increment. Besides, more than two applications of the extracts would be necessary to reduce pest numbers (Assefa and Ferdu, 1999). On the other hand, application of extracts of Neem berries (seed) (A. indica) and pyrethrum flowers (chrysanthemum spp.) at 8% concentration resulted in 90 and 100% mortality to I to II instare of B. fusca within three days, respectively (EARO, 1998/99). Basing this fact, indigenous knowledge of using such plant extracts should further be assessed in order to solve specific pest problems of a specific area.

1.8 Chemical control

Cypermethrin G, Endosulfan, carbofuran, diazinon, trichlorofon granule and carbaryl were found to be effective against maize stalk borer. Application of most of these chemicals at 4-6 weeks after crop emergence was significantly better than other periods; However, two to three applications per season of the chemicals were adequate and economically profitable to control the pest (Assefa, 1982).

B) Leaf feeders

Several species of grasshoppers and army worms (spidoptera spp.) feed on the leaves of seedling maize. Grasshoppers are not serious pests of maize. Army worms occur sporadically; however, once they occurred they are so devastating that appropriate forecasting system has to be developed to predict their out breaks for timely spray.

C) Soil Pests

Several insect pests are known to attack maize from under ground. These include chaffer grubs (Scarabaeidea), ground beetles (Gonocephallum spp.), cut worms and termites. However, only termites are the most common pests occurring every year causing several damages to maize in Western Ethiopia.

Management practices

Termite control: Termites have been regarded as serious pests of agricultural crops, forest trees, and buildings in west wellega, Ethiopia, contributing to severe soil degradation
problems by reducing vegetation and leaving the soil surface barren and exposed to the elements of erosion.

Nevertheless, care should be taken while designing any termite control measures because not all stand losses by termites lead to significant yield reduction. The occurrence of losses in yield by termites depends up on the magnitude of stand reduced and the stage at which the crop is attacked. Moderate stand losses caused by macrotermes at earlier stage of crop development can be compensated by increased growth of the remaining plants, and thus yield losses are prevented. Simulated damage trials showed that up to 30% stand losses at the 6 leaf stage and 9 leaf-stage had no effect on maize grain yield, where as 45% stand loss at all the crop stages tested did reduced yield (Abdurahman, 1990).

The termite problem is as complex as it is interrelated with ecological disturbance. Therefore, interventions should follow a holistic management approach (Integrated termite control measures) incorporating stakeholders' priorities and needs. To minimize the termite situation, recommendations are thus made to strengthen farmers' participation in research, develop and establish a working group of relevant stakeholders (farmers, extension agents, researchers, NGOs, etc.), and systematically co-ordinate research and development activities (Devendra et al., 1998). It should not also be forgotten that termites have beneficial effects for the soil.

D) Storage pests

Numerous Coleopterous and Lepidopterous pests attack maize in storage. *Sitophilus* weevils and the Angoumois grain moth are the most important primary pests of stored maize and are responsible for heavy losses every year. Infestations by storage pests start in the field making their management more difficult.

Management practices

1) Cultural methods: Timely harvesting, use of varieties with hard endosperm, tight and long husk cover will minimize field infestation. Grain should be stored after proper drying (at low moisture content) and should not be mixed with old grain in storage. Wood ash, tobacco dust, sand and saw dust applied at the rate of 20, 30, and 40 per cent, respectively gave good control of *Sitotroga cereallela* (Emana and Assefa, 1998). Slight roasting of maize grain (heat 70-80ºc for 4 hrs), maize/teff mixture, exposure to the sun (every two weeks), hanging maize in smoke over fire and mixture of chemically treated maize with untreated maize were also gave good control against maize weevils.

2) Botanical control: The use of insecticidal plants such as neem seed powder and *chenopodium* plant powder (1-2% each) gave good control of *sitophilus* weevils. Other botanicals that gave good result in controlling storage insect pests include, *Croton macrostachyus, Ricinus communis, Datura stramonium, Capsicum frutescens* at the rate of 10% weight/weight (Emana, 1999). However, recommendation of botanicals for protection of grain for human consumption requires further residual analysis tests and determination of side effects on human beings. Hence, farmers can only use them to store their seed for next season.

3) Natural enemies: The common ones are parasitic Hymenopterans such as *Anisopteromalus calandrae* and *Theocolax elegans*. Although information on the natural enemy complex of important field & storage insect pests of maize is available, little or no work has been done to quantify their contribution and promotion in the farming community
for the control of insect pests. Hence, it is important that an initiative be taken to address the knowledge gap in this area.

4) Chemical control: In addition to the previously recommended insecticides such as malathion 1%, permethrin 1%, deltamethrin 0.25% and 2.5%, metacrifos 2 DP, and primiphos-methyl 2%D (Abraham, 1995), malathion 5%D in the rate of 75g/qt was found effective against the maize weevil.

Rodent control

Improved storage structures with rat baffles fixed on the supporting legs of the crib, biological control (using cats) and effective chemicals (rodenticides) are the only alternative control methods we have at hand.

Major Maize Diseases and Control Methods in Western Ethiopia

Grey leaf spot (GLS), (*Cercospora zeae-maydis*): GLS is a disease caused by the fungus *Cercospora zeae-maydis*. It was observed on maize very recently (Dagne et al, 1999). But now, it is becoming the most important disease that occurs widely and causes severe yield losses to maize production in the country. Total loss may occur if GLS infection occurs early and favourable environmental conditions exist following infection. At first, lesions on maturing maize leaves are pale brown or small tan spots are typically observed on the lower leaves and later rectangular to irregular in shape. Lesions run parallel to the leaf veins and this can easily distinguish GLS from any other foliar diseases of maize. Extensive leaf blighting may occur until all the leaves are killed, finally resulting in stalk breakage and lodging.

Control methods

Cultural: Management of crop residue (avoid infected plant debris), wider spacing between and within rows, deep ploughing help to bury crop debris and early sowing (late April and early May) showed lower incidence of GLS (Assefa, 1997).

Varietal: Use varieties with relatively better resistance/tolerance to the disease. Eg. BH-670, BH-660, Kuleni, and others.

Chemical: Fungicide spraying of benomyl at the rate of 0.5 kg/ha can also be another alternative, if fungicide usage is economically justified especially in hybrid seed production.

Turcicum leaf blight (TLB) (*Exserohilum turcicum*): Turcicum leaf blight caused by *Exserohilum turcicum* is one of the first maize diseases to be identified in early days in the country. It is widely distributed and economically important disease of mid and high altitude major maize growing areas of the country (Assefa, 1997). The disease becomes severe at cooler and higher elevations and during the rainy season in the low lands, provided that there is ample moisture. Early symptoms are easily recognised by the slightly oval, water-soaked, small spots produced on the leaves. These grow in to elongate spindle-shaped necrotic lesions. They appear first on the lower leaves and continue increasing in size and number as the plant develops, until a complete "burning" of the foliage is conspicuous.
Control methods

Cultural: Use of appropriate/adequate inorganic fertilizers in combination with farm yard manure or alone can make maize plants more vigorous and thus tolerate the disease infection (Assefa, 1998). Inter cropping of maize with sweet potato at planting or haricot bean at 'shelshallo' reduces the disease incidence. In addition, use of optimum seeding rate, spacing and early planting of maize showed lower TLB severity (Assefa, 1997).

Varietal: using varieties relatively resistant/tolerant to the disease. E.g. BH-670, BH-660, BH-540, Kuleni and others.

Chemical: Applying fungicide combination of mancozeb and propoconazole at the rate of 2 kg active ingredient per ha of maize (2-3 times of application at ten days interval) can help to control TBL (Assefa and Tewabech, 1993; Assefa et al., 1996).

Common leaf rust (CR) (Puccinia sorghi): Leaf rust caused by Puccinia sorghi is widely distributed in mid and low land maize producing areas of the country. It is most conspicuous when plants approach tasselling. It may be recognised by small, powdery pustules over both surfaces of the leaves. Pustules are brown in early stage of infection; later, the epidermis is ruptured and the lesions turn black as the plant matures. Plants of the alternate host (oxalis spp.) are frequently infected with light orange coloured pustules. This is simply another stage of the same fungus. Common leaf rust does not cause heavy damage to early sown maize, but late sown maize may be severely damaged.

Control methods:

Cultural: Timely planting, inter cropping of maize with sweet potato and crop rotation help in reducing rust incidence. Furthermore, intercropping maize with haricot bean at the time of 'shilshalo' reduces the level of infestation (Assefa, 1997).

Varietal: use varieties with relative resistance/tolerance such as BH-670, BH-660, BH-540, Kuleni and others.

Chemical: Applying fungicide combination of mancozeb and propoconazole at the rate of 2 kg active ingredient per ha (2-3 times of application at ten days interval) can help to control common rust (Assefa and Tewabech, 1993).

Maize streak Virus (MSV): Maize streak virus is very sporadic disease, but it can cause heavy yield reduction if conditions are favourable. The disease is more severe in the lowland areas. Most of the released varieties are not resistant to this disease (Assefa, 1999). The virus is transmitted by Cicadulina spp.known as C. mbila. Early disease symptom consists of very small, round, scattered spots in the youngest leaves. Number of spots increase with plant growth; they enlarge parallel to the leaf veins.

Control methods:

Cultural: Early planting of maize reduces the incidence of streak virus (Assefa and Twabech, 1993).
Varietal: Use varieties Abo-Bako and Gambella comp-1, which is relatively resistant and better adapted to low land especially at Gambella region.

Chemical: Controlling the disease vector that transmits the disease using insecticide.

Ear and Kernel rot disease (*Diplodia zeae, Fusarium monoliforme* and *Gibberela*): Ear rot caused by *Diplodia zeae, Fusarium monoliforme*, and *Gibberela zeae* is a common disease in humid areas of western Oromia. The disease is associated with seed rot and seedling blight. It is observed in the highland to mid altitude areas. During warm season, the effect of kernel rot disease is serious after three months of storage of grains (Assefa 1999). The spores are wind-borne and are trapped between the husks of ear. When moisture conditions are favourable, they penetrate in to the developing ear, on which a greyish-white mould develops. The husks of early-infected ears appear bleached or straw-coloured of infection within two weeks after silking, the entire ear turns greyish brown, shrunken, very light weight, and completely rotted. The rot starts at the base of the ear and progress towards the tip.

Control methods

Chemical: Seed dressing with Fungicide Luxan TMTD is effective in controlling kernel rot disease in the rate of 200-500gm/qt of seed. (Assefa unpublished report).

General recommendation for insect pest and disease management

The present tendency of farmers to solely depend on agro-chemicals (pesticides) for the control of insect pests should be discourage and the concept of IPM (integrated pest management) should be promoted. This in turn calls for the active involvement of farmers themselves in the planing and implementation of research so that their indigenous pest management practices will be explored.
Recommended Research Results for Cereal Production

Daba Feyissa, Girma W/Tsadik, Tesfaye G/Giorgis, Fekede Abebe, Che meda Daba, Abdena Dheressa, Firdissa Eticha, Aschalew Sisay and Teshome Bogale

Oromia Agricultural Research Institute, Bako Research Center
P.O.Box 03, Bako

Introduction

Cereals are among the widely grown crops in the western part of Oromiya. The most limiting factors for cereal production are attributed to several major constraints. Among these are poor cultivation method, inappropriate planting time, low soil fertility, poor weed management, high erodibility, diseases and insect pests, low yielding local varieties, etc.

It is paramount importance to review and document the readily available technologies to the end users. This paper covers on-center and on-farm crop improvement, agronomic and crop protection research results of long experience on cereal crops. The agronomic experimental results include most of the center research results since 1968. It covers seedbed preparation, sowing date, seed rate, fertilizer rate and type, weed control measures, and other cultural practices on teff, sorghum, wheat, barley and finger millet.

Even though the yield of these major crops at a regional level is higher than the national average, a large gap still exists between yield obtained at experimental center and those realized by farmers and state farms. To overcome the crop production constraints and to develop improved packages cultural practices, which are appropriate for the region, were investigated. Cultural practices include all activities to be carried out by the users in the process of cereal crops production.

Crop production and productivity depend on various factors among which diseases play the most significant role. Pre and post harvest losses due to diseases are estimated to be over 30% of the total production. To tackle the problem incurred by these pests, crop protection division has made many attempts on control methods since the establishment of the center.

I. TEFF

It is a well-known fact that teff is the major cereal crop grown in our country at present and has great preference in the national diet. It is cultivated at an altitude of 1700-2800 meters above sea level. Best yields are raised on uplands of 1900-2000 meters above sea level. This crop grows well on any type of soil, including those with very heavy textured. Depending on the altitude of its cultivation, soil fertility and cultivation techniques the teff yield fluctuates between 3-30 qt ha⁻¹.

Improved varieties

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Altitude</th>
<th>Rain (mm)</th>
<th>Fall</th>
<th>Days to maturity</th>
<th>Yield (Qt/ha)</th>
<th>Seed color</th>
</tr>
</thead>
<tbody>
<tr>
<td>DZ-01-99</td>
<td>1400-2400</td>
<td>300-700</td>
<td>85-130</td>
<td>17-22</td>
<td>Red</td>
<td></td>
</tr>
<tr>
<td>DZ-01-974</td>
<td>mid to high altitude areas</td>
<td>300-700</td>
<td>75-137</td>
<td>-17-24</td>
<td>White</td>
<td></td>
</tr>
</tbody>
</table>
Agronomic Practices

Seedbed preparation
- Under current farmers' practices teff field is plowed two to five times depending on the soil type and some specific problems of the farm such as weed condition and water logging.
- Heavy clay-soils need plowing more frequently than loam or sand soils. Farm fields with more weed populations need repeated plowings than those with less weed population.
- At Bako research center 3-4 times plowing gave the highest yield.

Seedbed packing
- Packing the seedbed at 2\textsuperscript{nd} and 4\textsuperscript{th} day after last plowing increased teff grain and straw yields by an average of 132.4\% and 130.8\% respectively.
- Packing the seedbed from 1\textsuperscript{st} - 9\textsuperscript{th} day after last plowing gave up to 30\% and 32\% straw and grain yields and are recommended for teff production.

Sowing date
- For most cultivars 300-500 mm rainfall for a growing season is required.
- At Bako the highest yield was obtained from the July sowing date and delay in sowing after this month resulted in progressive yield depression.

Seed rate: 25-30 kg ha\textsuperscript{-1} seeds are recommended for broadcasting

Fertilizer rate
- 25 kg ha\textsuperscript{-1} urea and 100 kg ha\textsuperscript{-1} DAP is recommended for East Wellega and West Shoa regions.
- For Arjo, Digga and Shambo areas 50 kg ha\textsuperscript{-1} DAP is agronomically recommended.
- At Bako and Sire, cross-37 and DZ-01-787 both under low (farmers) management levels (low fertilizer rate, less ploughing frequency, low seed rate, low weed management, etc.) and at Shambo, local cultivar and DZ-01-787 under high (research) management level (optimum fertilizer rate, optimum ploughing frequency, optimum seed rates, etc.) gave better grain yield than the other cultivars.
- At Arjo, under both management practices, cross-82 followed by cross-37 were agronomically optimum and economically profitable and are recommended for early maturing improved teff varieties.

Weed management

Hand weeding
- It is best to start with a weed free and cleaned field during the time of planting. The teff seeds should be free from weed seeds.
- Hand weeding once at early tillering stage (25-30 days after planting) is ideal and adequate if weed population is low. However, if the weed infestation level is high, a second weeding should be done at the stem elongation stage (55-60 days after planting).

b) Chemical
- Pre sowing herbicides should be applied 1 - 2 weeks before planting whereas the post emergence herbicides should be applied at early tillering stage.
- Pre-sowing herbicide, Gesaten 500 fw should be applied at a dosage of 1.2 kg a.i ha\(^{-1}\) and post-emergence herbicides, 2,4-D and MCPA should be applied at a dosage of 1.0 kg a.i. ha\(^{-1}\) at 5-leaf stage (i.e. about 5-6 weeks after sowing).
- The weed called *Gommane* (*Raphanus raphanistrum* L.) found around Shambo area in teff, herbicides such as Brittox, 2,4-D (Dicopur 720 SL), Mecoprop (Dicopur PP 600 SL) and the ready tank mixture of 2,4-D and Mecoprop, all at their respective factory recommendation rate were recommended for effective control.

- To control weeds and to get the highest yield three times ploughing with one time hand weeding gave the highest net benefit.
- At Shambo area one hand weeding, 10 kg ha\(^{-1}\) urea and 65 kg ha\(^{-1}\) DAP is agronomically optimum and economically profitable for tef production.

### Disease Control Practices

**a) Head smudge** caused by *Helminthosporium miyakis* shows dense mat of dark brown spores covering the spikelet in which the spikelet is filled with black dust spores rather than the normal seeds.
- Culturally using seed rate of 25 kg ha\(^{-1}\), planting date of 2\(^{nd}\) to 3\(^{rd}\) week of July and using resistant/tolerant variety can reduce damage due to the disease.

**b) Rust** (*Uromyces eragrostidis*) is characterized by small pustules on most of the green parts of the plant sheath culms, rachis of the spicklets, and especially on the upper surfaces of the leaves.
- Cultural method: Early sowing reduces incidence of rust while it increases damping off disease.
- Chemical: Spraying with fungicide tridemorph has decreased both head smudge and rust.

### II. SORGHUM

Sorghum is one of the most drought-resistant plants due to its specific root system. It responds best to fertile, well-drained structural soils of medium-texture and neutral composition.

#### Improved varieties

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Altitude (masl)</th>
<th>Rainfall (mm)</th>
<th>Days to maturity</th>
<th>Yield (qt ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birmash</td>
<td>1600-1900</td>
<td>&gt;900</td>
<td>147-181</td>
<td>30-39</td>
</tr>
<tr>
<td>Baji</td>
<td>1600-1900</td>
<td>&gt;900</td>
<td>162-175</td>
<td>40-60</td>
</tr>
<tr>
<td>Jimma (SAR-2)</td>
<td>1600-1900</td>
<td>&gt;900</td>
<td>162-175</td>
<td>-</td>
</tr>
</tbody>
</table>

#### Agronomic Practices

**Sowing date:** Sowing date for sorghum varies depending on the altitude of the area. May 1-30 is thought to be the optimum sowing period for sorghum varieties.

**Seed rate:** When sowing in rows seed rate of 8-10 kg ha\(^{-1}\) with spacing of 75 cm between rows and 15 cm between plants, i.e., a plant population of 88,888 plants ha\(^{-1}\) is recommended.
Fertilization: The recommended N and P fertilizer rates for sorghum around Bako, Dhidhessa, Wamma and Anger-dheidhessa areas are 165 kg ha\(^{-1}\) DAP and 100 kg ha\(^{-1}\) urea.

Time and method of application: The recommended amount of P should be applied as basal dressing during planting whereas N is applied as top dressing when the plants reach knee height and as basal placement and the basal placement of both fertilizers should at least be 5 cm away from the rows of the plant.

Weed control measures

a) Hand weeding: It is important to destroy weeds at early stages of crop development. Two times hand weeding, first at 25-30 and the second at 55-60 days after planting is optimum.

b) Herbicides: Grain yields obtained by applying Atrazine and Atrazine/metolachlor mixtures were superior to hand weeding and as these mixed herbicides dosage increases from 1.75 to 2.0 kg a.i. ha\(^{-1}\) yield also increased.

Disease Control Practices

a) Anthracnose (*Colletotrichum graminicola*) is locally called baala gubaa (Kolera) and is characterized by circular to elliptical spots formed on the leaves. It attacks leaves, stem, peduncle and seeds; it is seed borne disease.

Control methods

Cultural: Use disease free seeds and avoid planting of susceptible varieties

Varietal: Bir-mash, IS 9302, Bako mash, and Jambo are resistant/tolerant to anthracnose and many other foliar diseases.

b) Leaf rust (*Puccinia sorghi*) is observed during cool and humid weather conditions towards crop maturity.

Control methods: Using Birmash, Bako mash and IS 9302.

c) Covered and loose smut is locally called Aramamo in Amharic and Awaro in Afaan Oromoo. It develops inside the seed and replaces the seed by the black powder.

Control methods:

Cultural: Late sowing from 5-20 June, rouging and burring infected plants to avoid seed contamination reduces inoculum levels for the next cropping season.

Botanical: Abbeyyi (*Maesa lanceolata,*) leaf extract at the rate of 20 ml/200kg seed can effectively control the disease. Seed dressing with goat urine at the rate of 1:1 water to urine ratio and Thriam 3 gm kg\(^{-1}\) of seed were recommended.

Chemical: A systemic fungicide vitavax (carboxin) at the rate of 3 gm kg\(^{-1}\) seed, Pomarsol forte (TMTD), Fernason D' (TMTD/lindane), Benlate 50% WP (benomyl) at the rate of 3 gm,
3.6 gm. and 2.5 gm kg⁻¹ seed respectively can also be used alternatively to control loose and covered smut at Bako.

d) Grain Mold is designated as pink, orange-white, or black mycelium on the grain surface. It's more severe in early maturing sorghum genotypes where they flower and fill grain during period of high rainfall and high relative humidity.

Control methods

Cultural: Adjusting planting date where crop maturity should not coincide with rainy season and use disease free seed.

Varietal: Sorghum variety 84 MW 4138 is resistant to grain mold.

III. WHEAT

Wheat is produced exclusively under rain fed condition. Durum and bread wheat are the two most important wheat cultivars growing in the country, occupying about 60% and 40% of the total wheat area respectively.

Improved varieties

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Altitude (masl)</th>
<th>Rainfall (mm)</th>
<th>Days to maturity</th>
<th>Soil type</th>
<th>Yield (qt ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAR-604 (Galama)</td>
<td>1850-2800</td>
<td>600-2000</td>
<td>138-142</td>
<td>red light, heavy black soil</td>
<td>45-65</td>
</tr>
<tr>
<td>HAR-1709 (Mitike)</td>
<td>1850-2800</td>
<td>600-2000</td>
<td>125-135</td>
<td>&quot;</td>
<td>30-70</td>
</tr>
<tr>
<td>ET-13</td>
<td>1850-2800</td>
<td>600-2000</td>
<td>107-149</td>
<td>&quot;</td>
<td>30-70</td>
</tr>
<tr>
<td>HAR-1522 (Abola)</td>
<td>2200-2700</td>
<td>600-2000</td>
<td>128-131</td>
<td>&quot;</td>
<td>38-63</td>
</tr>
<tr>
<td>HAR-1685 (Kubsa)</td>
<td>2200-2700</td>
<td>600-2000</td>
<td>120-140</td>
<td>&quot;</td>
<td>50-70</td>
</tr>
<tr>
<td>HAR-1775</td>
<td>2200-2700</td>
<td>600-2000</td>
<td>120-149</td>
<td>&quot;</td>
<td>37-50</td>
</tr>
<tr>
<td>HAR-1889 (Sofumer)</td>
<td>2200-2600</td>
<td>400-950</td>
<td>134</td>
<td>&quot;</td>
<td>37-95</td>
</tr>
</tbody>
</table>

Agronomic Practices

For both improved and local wheat varieties better grain yield even in the absence of chemical fertilizers, better agronomic performance and better response to management levels were observed on "eker land" than on "non-eker land". Therefore, for sustainable production of wheat the use of legumes as precursor crop with improved management practices was recommended to attain high grain yield of wheat even with low production inputs.

[eker land = land planted to legumes, non-eker land = land planted to cereals]

Seedbed preparation: At Holeta, 4 times oxen plowing gave the highest grain yield of wheat on both red and black soils.

Sowing time: The optimum dates of sowing for bread wheat production is mid-June to mid-July for the highlands of Arjo and Shambo areas.
Seed rate: Seed rate of 150 kg ha\(^{-1}\) is recommended for broadcast and maresha incorporated method, whereas drilling requires a seed rate of 125 kg ha\(^{-1}\). Bread wheat varieties with poor tillering ability require 160 kg ha\(^{-1}\) seed while semi-dwarf varieties require seed rate of more than 175 kg ha\(^{-1}\) for broadcast and Maresha incorporated method.

- At Shambo for both farmer and research management levels HAR-1685 was found superior, but at Arjo HAR-1685 under farmers management level was found the best.

Weed management

a) Hand weeding: The combination of two times hand weeding and 90/65 kg ha\(^{-1}\) DAP/urea fertilizers has resulted in higher wheat grain yield at Shambo. However, at Arjo, the highest grain yield was obtained from once hand weeding and 90/65 kg ha\(^{-1}\) DAP/urea fertilizers.

b) Chemical: Best control of *Gommane (Raphanus raphanistrum* L.) has been detected from Mecoprop (Dicopur PP 600 SL), 2,4-D (Dicoput 720 SL), Brittox and the ready tank mixture of Mecoprop and 2,4-D, all at their respective manufacturer recommendation rates.

Disease Control Practices

a) Stripe/Yellow rust (*Puccina striiformis*) is locally called wagi and shows bright orange-yellow pustules arranged in lines; pale green or brown stripes on leaf blade. Yellow rust also affects leaf sheath and the ears and it is a common disease of wheat at Shambo and Arjo.

Control methods

Cultural: Destroying volunteer plants before main season wheat plant emerge; use optimum sowing date for crop yield and avoid early planting of susceptible varieties. Use appropriate rotation. At Ambo sowing date between June 1 and 15 exhibited low level of rust infection, while July to August increased rust incidence with lower yield.

Varietal: wheat varieties HAR 1709 (Mitike), HAR 604 (Galema), Pavon-76 and K-6295-4A are resistant to rust and yielded better than the standard check (ET-13) and are recommended for Arjo, while HAR 604 Galema, Pavon-76, 6290 Bulk and K-6295-4A recommended for Shambu.

Chemical: Fungicide Tilt 250 EC, Bayleton and Mistral (1 lt ha\(^{-1}\)) revealed promising results.

b) Leaf / Brown rust (*Puccina recondatta*) of wheat affects leaves, showing brown pustules scattered at random on the leaf. It is a common disease of wheat in Shambu and Arjo areas.

Control methods

Cultural: Similar control measures taken to yellow rust can be applied for leaf rust.

Varietal: Similar varieties used for yellow rust can be taken for leaf rust.

Chemical methods: applying fungicides such as Tilt 250 EC, Bayleton and Mistral (1 lt ha\(^{-1}\)) gave promising results.
c) Stem/Black rust (*Puccinia graminis*) is the major disease of wheat in the east and west Wellega zones. The disease affects sheath and stem by showing orange brown (later black) pustules mainly on sheath and stem of the plant.

Control methods

Cultural: Similar control measures taken to yellow rust can be applied for stem rust.

Varietal: Similar varieties used for yellow rust can be taken for stem rust.

Chemical methods: At Ambo effective and profitable control of rust and other foliar diseases of wheat were achieved by applying fungicides Tilt (propiconazole) and Impact (flutriafol). Two applications at half rate (0.5 lt ha⁻¹) or one application at the full rate gave high net return.

d) Leaf spot (*Septoria tritici Rob.*) is the most damaging foliar fungal disease of wheat in east Wellega especially at Shambu and Arjo. Symptoms are pale brown isolated oval spots, later larger irregular areas, or small brown spots on upper leaves and sheath.

Control methods

Cultural: Field sanitation, crop rotation and ploughing to bury crop residues are recommended for the reason that the fungi survive best on the surface debris of both wheat and barley.

Varietal: Susceptible varieties should be avoided in areas prone to the disease, use of resistant varieties such as HAR 604 (Galema).

Chemicals: Application of fungicides like Tilt, Baylton, Benelate (0.03%), Brestan (0.01%) (at heading stage) Topsin and Sportax, at the rate of 1 lt ha⁻¹ for each and mancozeb at the rate of 1.3-2 kg ha⁻¹ are recommended.

e) Glume blotch (*Septoria nodorum [Berk.]*.) is an ear disease of wheat. Symptoms can be seen on the green ears when dark purple-brown spots on the glumes, often beginning at the tips.

Control methods

Cultural: Field sanitation, crop rotation, and ploughing to bury crop residue to avoid initial inoculum are important to reduce disease infection.

Varietal: Use of resistant or tolerant cultivars such as HAR 604 (Galema).

Chemicals: Seed treatment with fungicides such as vitavax (carboxin), vincit 200, pancitin 200 and vitaflo 200, prochloraz and sportak delta reduces infection level.
IV. BARLEY

In Ethiopia, barley grows under rain-fed conditions predominantly on the highlands, it is better adapted than other cereals in poor soil fertility, frost and soil acidity. It is produced both in the main rainy season and short rainy season.

Improved varieties

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Altitude (masl)</th>
<th>Rainfall (mm)</th>
<th>Days to maturity</th>
<th>Yield (qt ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HB-42</td>
<td>2200-3000</td>
<td>1000-2000</td>
<td>129-134</td>
<td>32-63</td>
</tr>
<tr>
<td>Shage</td>
<td>2200-3000</td>
<td>1000-2000</td>
<td>122-130</td>
<td>32-55</td>
</tr>
<tr>
<td>HB-120 (Malting barley)</td>
<td>2200-3000</td>
<td>1000-2000</td>
<td>124-133</td>
<td>24-53</td>
</tr>
</tbody>
</table>

Agronomic Practices

Sowing date: Early July is optimum for sowing early maturing varieties, early to mid-July for medium duration varieties.

Seed rate: For medium duration varieties, broadcasting of 125 kg ha⁻¹ on red soil and drilling of 75 kg ha⁻¹ on black soils were optimum seed rates for barley growing areas.

Weeding Control

a) Hand weeding: First hand weeding 25-30 days after planting and the second at 55-60 days after planting. Barley gave the highest yield when weeded early compared to mid and late season weeding.

b) Herbicides: 2,4-D and Linuron pre-emergence (both at the rate of 1 lt prod. ha⁻¹) were effective in broadleaf weeds and Dichlofop methyl (3.5 lt prod. ha⁻¹) was similarly effective on important grass weeds. Applying the post emergence herbicides like the ready tank mixture of 2,4-D and Mecoprop, Mecoprop, Brittox and 2,4-D respectively effectively controlled Gommane (Raphanus raphanistrum L.).

Disease Control Practices

a) Leaf blotch, Scald (Rhynchosporium secalis) is a major disease of barley in east Wellega and infects leaf blade, leaf sheath, floret bracts, and glumes coleoptiles and awns. Symptom of the disease is first large pale green oval lesions on the leaf blade (1 cm or more). This enlarged with age becoming pale brown with a dark brown or purple-brown wavy margin.

b) Net blotch (Pyrenophora teres): as the name indicates, net-like lesions are typically formed on the leaves that can occur at any growth stage from seedling to crop maturity. Chlorotic areas usually surround the lesions. The fungus survives from one growing season to the next on plant debris.

c) Spot blotch (Cochliobolus sativum Syn Helminthosporium sativum) is the fungus that attacks all parts of the plant. It can attack the leaves from seedlings to the adult stages. The fungus can also attack the kernels and causes symptoms called Black point, which appears as
numerous dark-brown spots on the germ end. The organism is seed born and over winters as mycelium in plant residues, seedlings and leaves of winter.

Control methods

Cultural: Crop rotation, avoiding use of very susceptible varieties, eradicating volunteer plants and plowing aimed to bury crop residue, provide optimum-planting time.

Varietal: barely varieties such as HB-42 from food barely and HB-52 and HB-120 from malting barely were resistant/tolerant and are recommended for Western Oromiya.

Chemicals: Seed treatment with fungicide maneb and spraying with tilt reduced the incidence of scald and net blotch.

d) Barely leaf rust: (Brown rust) \textit{(puccinia hordei)} is circular in shape and generally confined to the leaves and sheaths.

Control methods

Varietal: HB-42, HB-52 and HB-120 were found tolerant to the disease.

Chemicals: Tilt 250 E.C., Bayleton and Sportax, at the rate of 1 lt ha$^{-1}$ each and mancozeb at the rate of 1.3-2 kg ha$^{-1}$; propiconazole (Tilt), Triadimenol (Bayfidan) at the rate of 0.5 lt ha$^{-1}$ were recommended. Seed treatment with Baytan protects the seedlings against early season infection by the leaf rust. Bayleton applied at the first sign of infection will give excellent control but should be re-applied if re infection occurs.

V. FINGER MILLET

It is cultivated in areas where there is more rainfall (900 mm annually) because it is less drought-resistant. It is grown in valleys and mountainous regions of the tropics (up to 2500 meters above sea level).

Improved varieties

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Altitude (masl)</th>
<th>Rainfall (mm)</th>
<th>Days to maturity</th>
<th>Yield (qt ha$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KNE#411 (Boneya)</td>
<td>1400-1900</td>
<td>1200-1300</td>
<td>145</td>
<td>20-30</td>
</tr>
<tr>
<td>KNE # 1098 (Tadesse)</td>
<td>1600-1900</td>
<td>about 700</td>
<td>-</td>
<td>25</td>
</tr>
</tbody>
</table>

Agronomic Practices

Sowing date: Mid July was found the optimum planting date. Delays in sowing reduce yield.

Seed rate: 30 kg ha$^{-1}$ appeared to be the optimum seed rate.

Spacing: 20 cm between rows and drilling the seeds in rows gave the highest yield.
Fertilization: 110 kg ha\(^{-1}\) DAP and 65 kg ha\(^{-1}\) urea for Bako and similar areas is economically profitable and recommended for improved Finger millet varieties. For Nedjo and similar environments, 18 kg ha\(^{-1}\) urea and 150 kg ha\(^{-1}\) DAP is recommended.

Weed control measures

Once hand weeding after planting or using post-emergence herbicides such as 2,4-D at a dosage of 3.0 lt product ha\(^{-1}\) and MCPA at a dosage of 4.0 lt product ha\(^{-1}\) each after 30 days of planting were found to be the best in controlling both broad-leaved and grass weeds.

Crop Protection Practices

a) Head blast (*Pyricularia grisea*) affects leaf, stem, and panicle. At early stage the panicle shows light yellow and later changes to dark brown with shriveled or no seed inside. Infected plants resemble chaffy unfertile head.

Control methods

No control method has so far been identified.
Introduction

In most cases, pulse crops are grown by subsistence farmers. Pulses rank second in area, production, and yield next to cereals. These crops occupy about 13% of cultivated land and 12% of the total production of major crops in Ethiopia. Major pulse crops include faba bean (*Vicia faba* L) and field pea (*Pisum sativum* L.) which are adapted to cool highland areas and haricot bean (*Phaseolus vulgaris*) and soybean (*Glycine max* L.) that are grown at lowland and mid-altitude areas. Faba bean ranks first in area, production and yield followed by field pea. Haricot beans are important components of the human diet in Ethiopia, grown as food crop and export commodity. Mixed beans of various seed size, seed color and growth habits are grown in two main cropping systems (sole cropping and intercropping with other staple food crops like maize). Introduction of the soybean crop into the western part of Ethiopia dates back only to three decades, probably with the inception of the then Ethio-German Bako Agricultural Research Station. Since then, efforts were made to improve the adoption and productivity of this crop. This document gives the research recommendations for these four major pulse crops whereby the efforts of various disciplines were put together in a package form so that producers can have an easy access to modern crop production technologies.

I. FABA BEAN

Faba bean grows well at highland and mid-altitude areas ranging between 1800 to 3000 m asl. It grows well in areas receiving a rainfall of 700 to 1000 mm in highland altitudes and 600-800 mm of rainfall in the mid altitudes. Faba bean requires a well-drained and deep fertile soil or clay loam with pH between 6.0 and 7.0.

**Recommended varieties:** Recommended faba bean varieties that are adapted to western highlands and their yield potential are presented in the following Table.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Altitude</th>
<th>Rainfall (mm)</th>
<th>DM**</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS20DK</td>
<td>2200-2800</td>
<td>&gt;1000mm</td>
<td>130-160</td>
<td>30-40</td>
</tr>
<tr>
<td>Bulga 70</td>
<td>2200-2800</td>
<td>&gt;1000mm</td>
<td>125-165</td>
<td>30-40</td>
</tr>
<tr>
<td>Shaaloo</td>
<td>2300-2600</td>
<td>750-1000</td>
<td>141</td>
<td>31-46</td>
</tr>
</tbody>
</table>

**Days to maturity**

**Land preparation:** The recommended land preparation is that starts early to encourage weed seeds to germinate and be destroyed in the subsequent cultivation of 2-3 sowings with the local plow.

**Seed rate:** The seed rates recommended for faba beans are 175 kg/ha for small seeded cultivars while 200 kg/ha for large seeded cultivars. For row planting, the recommended spacing is 40 cm between rows and 5 cm between plants.
**Sowing method:** Broadcasting is the traditional practice while row planting has a substantial yield advantage of row planting and proper weeding.

**Planting depth:** The local maresha depth puts seeds at the depth of about 10-15 cm. Several research results showed that the best planting depth for Faba bean is 5 cm.

**Sowing time:** Date of sowing is determined by the on-set of rains however sowing between 22 June to 7 July is recommended.

**Fertilizer rate:** If the soil is extremely poor, 100kg/ha DAP is required for good crop stand and better production.

**Weeding:** One to two times hand weeding is recommended depending on the severity within three to six weeks after planting.

**Crop rotation:** Faba bean improves soil biological properties. It also encourages the development of deeper and more extensive root system, enabling crops that come after them to take more water and nutrients.

**Cropping systems:** Faba bean could be grown in mixed forms with field pea. The best combination of faba bean and field pea mixture is 75% seeding rate of faba bean and 25% the seeding rate of field pea.

**Diseases:** Diseases such as rust (*Uromyces fabae*), chocolate spot (*Botrytis fabae*) and black root rot (*Fusariem solani*) cause substantial yield loss of this crop but it is believed that the recommended varieties are tolerant to these diseases.

<table>
<thead>
<tr>
<th>Disease</th>
<th>Description</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chocolate spot</td>
<td>Survives between two seasons on crop residues as mycelia, conidia or sclerotia</td>
<td>Reduction of inoculum (burning and crop rotation), fungicides (chlorothalonil, benomyl)</td>
</tr>
<tr>
<td>Rust</td>
<td>-</td>
<td>Fungicides (Plantavax / Oxycarboxin)</td>
</tr>
</tbody>
</table>

**II. FIELD PEA**

Field pea grows at an altitude range of 1800 - 3000 m asl. Annual rainfall of 700 - 1000 mm and frost-free growing period is required for field pea production. Field pea grows on a wide range of soil types with moderate fertility levels, well drained and with a pH range of 5.3 - 6.5.

**Recommended field pea varieties with their agronomic characters and area of adaptation.**

<table>
<thead>
<tr>
<th>Variety</th>
<th>Altitude</th>
<th>Rainfall (mm)</th>
<th>DM**</th>
<th>Yield (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tegenyech</td>
<td>2200-2800</td>
<td>&gt;1000</td>
<td>133-135</td>
<td>33-38</td>
</tr>
<tr>
<td>Adi</td>
<td>2300-3000</td>
<td>2200-2800</td>
<td>128</td>
<td>30-35</td>
</tr>
<tr>
<td>Dadimos</td>
<td>2300-2800</td>
<td>700-1100</td>
<td>130</td>
<td>35-40</td>
</tr>
<tr>
<td>Tulu Dimtu</td>
<td>2300-2600</td>
<td>750-1000</td>
<td>129</td>
<td>40-53</td>
</tr>
<tr>
<td>Hursa</td>
<td>2300-2600</td>
<td>750-1000</td>
<td>130</td>
<td>25-30</td>
</tr>
<tr>
<td>Tulu Shanan</td>
<td>2300-2800</td>
<td>750-1000</td>
<td>128</td>
<td>30-40</td>
</tr>
</tbody>
</table>

**Days to maturity**
Land preparation: 1-3 times plowing is recommended.

Fertilizer rate: Like faba bean, field peas have ability to increase soil fertility levels, if the soil is extremely poor, however, 100 kg/ha DAP is required for good stand and better establishment.

Weeding: Once hand weeding (25-30 days after planting) is an optimum to control weeds in field pea.

Seed rate and spacing: For row planting, 40 cm between rows and 5 cm spacing between plants is recommended. However, for broadcasting, 150-180 kg/ha seed rate is recommended.

Sowing time: Late June to early July

Crop rotation: Crop rotation with cereals every 3 to four years is advisable.

Cropping systems: Mixed cropping with field pea at the ratio of 25 % field pea and 75% faba bean (1:3 ratio)

Diseases and disease control options

<table>
<thead>
<tr>
<th>Disease</th>
<th>Description</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Powdery mildew</td>
<td>Severe in dry weather in the day and cool night</td>
<td>Use resistant varieties, use fungicides (Topsin-M and Thiophanate-methyl)</td>
</tr>
<tr>
<td>Ascochyta blight</td>
<td>Starts as small, dark, irregular flecks on leaves, stems and pods</td>
<td>Use resistant varieties</td>
</tr>
</tbody>
</table>

III. HARICOT BEAN

Haricot bean grows between 1000 - 2200 m asl but it grows well in altitude range of 1400 and 2000 m. Areas with medium rainfall (350 - 700 mm) and well-defined rainy season are preferable so that the harvest can be done in dry weather. The soils should be well drained because beans are sensitive to water logging; the pH should be above 5.0.

Recommended varieties

Recommended bean varieties adapted to Bako area

<table>
<thead>
<tr>
<th>Variety</th>
<th>Altitude</th>
<th>Rainfall (mm)</th>
<th>DM**</th>
<th>Yield (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roba 1</td>
<td>1400-2000</td>
<td>350-550</td>
<td>80-100</td>
<td>20-24</td>
</tr>
</tbody>
</table>

**Days to maturity

Land preparation: Haricot bean does not need fine seedbeds. However, the land has to be free of weeds, soil clods, and other undesirable materials. One to two times plowing is required for haricot bean. First plowing should be done just after the harvest of the previous crop and before the soil becomes too hard. This operation will help to turn down the vegetation and the remains of the previous crop. A second plowing can be made one month later. A third plowing can follow just sowing.

Sowing method: Haricot bean should be sown in rows for easier weeding. The row sowing can be done by hand or by a seed drill. It is also possible to sow by making a furrow with the
local plow maresha. The seeds are then sown in the furrow and covered with soil from the next furrow and covered with soil from the next furrow. If broadcasting is used the seed can be covered by plowing with an ox plow or by disk harrowing.

**Seed rate and spacing:** The seed rate should be chosen to give 400,000 - 500,000 plants per hectare. To get this much plant population a seed rate of 90 - 100 kg/ha is required for row planting and 120 - 130 kg/ha for broadcasting. Note that the smaller the seed size the smaller the amount of seed rate. In row planting the spacing for haricot bean is 40 cm between rows and 10 cm between plants.

**Planting depth:** The recommended seeding depth for haricot bean is 4 - 8 cm.

**Sowing time:** The sowing date chosen as suitable for maturity in the dry season. In most cases beans mature between 85 - 95 days. Eighty days before the end of the rain at mid altitude and 100 days before the end of the rain at high altitude or late June to early July is the recommended sowing date for beans.

**Fertilizer rate:** For optimum production of haricot bean in the Bako area the recommended N and P fertilizers are 50 kg nitrogen and 50 kg P$_2$O$_5$ per hectare, which is equivalent to 110 kg DAP and 65 kg urea per hectare, respectively can be applied.

**Crop rotation:** Growing of beans year after year on the same piece of land will result in the build up of pests and diseases. Beans should preferably be not growing more often than every third or fourth year on the same land.

Weeding: Beans do not compete well with weeds, especially at an early stage. Therefore, weeding is important. Weeding of beans can start at 2-3 weeks after sowing and it can continue up to 5 weeks after sowing. To minimize the weed problem and increase the yield of beans weeding of at least once in 30 - 35 days after emergence is important. Weeding should be finished before flowering in order to avoid flower drop.

**Haricot bean in different cropping systems:** Haricot bean can be intercropped with maize or with sorghum by simply broadcasting beans in between two rows of these crops. The intercropping system improves productivity by 20%. It also reduces weed incidence and improves soil fertility. At Bako 75% haricot bean plant density can successfully be intercropped to 100% maize.

**Diseases and disease control options:**

<table>
<thead>
<tr>
<th>Disease</th>
<th>Description</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacterial blight</td>
<td>Spread by infected seeds, infected trash in the soil</td>
<td>Healthy seeds, rotation, sanitation and use resistant varieties</td>
</tr>
<tr>
<td>Bean rust, Anthracnose</td>
<td>Spread by infected seeds, infected trash in the soil</td>
<td>Healthy seeds, rotation, sanitation and use resistant varieties, treatments of seeds with benomyl and mancozeb</td>
</tr>
</tbody>
</table>

**IV. SOYBEAN**

Soybean is a crop of great economic importance. It has a wide range of utilization. It can grow successfully in all places where cotton and maize are grown. It is highly susceptible to drought during crop establishment and pod filling. The recommended soybean varieties
commonly grow at altitudes ranging between 700 - 1700 m asl. A rainfall ranging from 400 - 1000 mm is required for soybean production.

**Recommended varieties:**

Recommended soybean varieties for Bako area

<table>
<thead>
<tr>
<th>Variety</th>
<th>Altitude m asl</th>
<th>Rainfall (mm)</th>
<th>DM**</th>
<th>Yield (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coker 240</td>
<td>700 - 1700</td>
<td>700-1000</td>
<td>121-140</td>
<td>15-25</td>
</tr>
<tr>
<td>Davis</td>
<td>1000 -1700</td>
<td>400-500</td>
<td>90-120</td>
<td>10-15</td>
</tr>
<tr>
<td>Williams</td>
<td>700 - 1700</td>
<td>400-500</td>
<td>90-120</td>
<td>10-15</td>
</tr>
<tr>
<td>Clark 63K</td>
<td>1000 - 1700</td>
<td>400-500</td>
<td>90-120</td>
<td>20-30</td>
</tr>
</tbody>
</table>

**Days to maturity**

**Land preparation:** First ploughing is done just after harvest of the previous crop and before the soil becomes too hard. A second ploughing can be made one month later. Before sowing the field must be completely clean of shrubs, stumps, weeds and all other undesirable materials.

**Seed rate and spacing:** The spacing of soybean is 60 cm between rows and 10 cm within a row for late and medium maturity groups; while 40 cm between rows and 5 cm between plants for early maturity groups. The amount of seed necessary is 60 kg per hectare.

**Sowing time:** The best time for sowing in the Bako area is between second week of June and last week of June.

**Fertilizer rate:** The yield per unit area can be increased with fertilizer application. Fertilizers help soybean to a faster start. The rate and type of the recommended fertilizer is 100 kg per hectare of DAP (18 kg N and 20 kg P) applied at planting.

**Weeding:** In small farms three hand weedings are essential, the first one when the plant is 2 - 4 leaf stage, the second one 2 to 3 weeks later and the third and last one at flowering. In mechanical farms using rotary hoe the first weeding be made at 2 - 4-leaf stage, second weeding takes 25 days after planting and the third at the flowering stage.

**Diseases, pests and their control options**

<table>
<thead>
<tr>
<th>Disease</th>
<th>Description</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacterial blight and postule</td>
<td>Small, angular or raised spots on the leaves; at first chlorotic, later brown</td>
<td>Use disease-free seed; rotate with non-susceptible crops</td>
</tr>
<tr>
<td>Bean aphid (Aphis fabae)</td>
<td>Cluster of small, black, soft-bodied insects on young shoots and the under side of leaves. Large clean holes eaten in pods where seeds forming</td>
<td>Spray with 1 lit. of 40 dimethoate emalritable EC 100 lit/ha of water.</td>
</tr>
<tr>
<td>African bollworm</td>
<td>Large clean holes eaten in pods where seeds are forming</td>
<td>Spray with a mixture of 2 lit 30% endosulfan EC in 80-11 lit/ha of water.</td>
</tr>
</tbody>
</table>
References


Oil Crops Production Technologies for Western Oromia

Fekede Abebe, Aschalew Sisay, Teshome Bogale, Kedir Wako, Firdissa Eticha, Dhiba Feyissa, Girma
W/Tsadik, Tesfaye G/giorgis and Abdena Dheressa
Bako Research Center, P.O.Box 3, western Oromia, Ethiopia

Introduction

There are eight economically important oil seed crops grown in Ethiopia. They are noug, gomenzer/rape seed, sesame, sunflower, ground nut, cotton and castor. Of these, noug and linseed occupy most of the area allotted to oil crops seeds production. The lowland oil crops that grow in some parts of western and eastern Wellega particularly at Dedessa, Loko, Nedjo, Mendi and Dembi Dollo area are sesame and ground nut. Noug and rapeseed are among the oil crops widely grown in the highlands of western Ethiopia.

The most limiting constraints of oil crops production in the western parts of the country include lack of improved varieties, disease, insect pests, weeds and lack of agronomic recommendations. To tackle these production constraints Bako Research Center has conducted various research activities since many years’ back. It is thus imperative to review and document the available research findings in such a way that agricultural development practitioners and farmers can easily use them. This paper, therefore, summarises the varietal, agronomic and pest management recommendations that can directly be used by farmers.

Highland oilseed crops

I. NOUG

Noug is first ranked oil crop in Ethiopia accounting for about 50% to 60% of the total oil crops production area. It is not widely distributed in the world. In Ethiopia it is grown in cooler parts of the country. It can survive heavy water logging during mid growing season. With its unique adaptability to such unfavorable growing environments it grows well on these potentially rich but problematic soils, which otherwise would not be put into use by the capital limited small farmers. The crop is less responsive to management practices.

Sowing date: The optimum sowing date of Noug varies with location mainly influenced by the rainfall of the particular location. Generally, around Bako area early to mid-July was found optimum time of sowing. Delayed sowing reduced yield.

Seed rate: If sowing is accomplished at the optimum date, a seed rate of 5-10 kg/ha is good enough. A seed rate of above 10 kg/ha is a waste of seed.

Spacing: 30 cm between rows and then drilling is recommended.

Fertilizer: Noug is proved to be less responsive to fertilizer. However, application of fertilizer hastened flowering and maturity. At Bako research center application of fertilizer gave less yield than unfertilized plots.

Weed control: Weed controls in farmers’ field entirely depend on hand operations. In most cases noug is not weeded at all. Noug is believed to be competent since it is fast growing and when fully established it is a good smothering crop.
Ploughing and harvesting stage: Agronomic results indicated that noug yield increased with frequency of ploughing. Two times ploughing and harvesting four weeks after 50% petal drop gave the highest oil content (36.2%).

Diseases

Shot-hole/ Leaf spot: The disease caused by Septoria guizotiae is one of the important diseases in this area. It is characterized by black spots surrounding white spot in the center and resembles oval leaf spot.

Leaf and stem blight: This is the second most important disease of noug caused by Alternaria spp. It affects primarily the leaves, stem, flower and fruits.

Control methods

Chemicals: Seed-dressing fungicides against major diseases of noug was studied at Bako, but none of the fungicides were effective in the controlling the diseases. But fungicides polyram DF (metiram) and Tilt 250EC (propiconazol) at Holetta reduced the incidence and severity of the shot hole and none of the fungicides gave significantly higher yield than the check.

Powdery mildew: Powdery mildew caused by Oidium sp. is characterized by the appearance of spots or patches of a white to grayish, powdery, mildew growth on young plant tissue or entire leaves. This disease is common in warm and humid regions of western Oromia.

Control: No control methods have been reported.

II. RAPESEED/GOMENZER

Rapeseed (Brassica napus L.) and gomenzer (Brassica carinata A. Braun) are the most adapted oilseed brassica species in the high land of Ethiopia. Gomenzer and rapeseed are adapted to altitude between 2000m and 2800m, a temperature range of 14 °C to 18 °C, and a rainfall range of 600mm - 900 mm during the growth season.

Recommended varieties: Cultivars S-67 and Yellow Dodolla are resistant to these diseases

Downy mildew (Prenospora parastica)

Downy mildew of rapeseed is caused by Prenospora parastica. Mycelium intercellular hyaline coenocytes haustoria's large elongated club shape often branched. Abundant conidial sporulation on the lower surface of cotyledon and upper surface which showing pale spotting necrotic of the seedling and result spotting on the leaves, stems and inflorescence. In mature cabbage infection causes sever gray to black lesion, which spread to large areas of the lamina and successively from the outer to inner leaves.

Control methods

Varietal: Cultivars S-67 and Yellow Dodolla are resistant to these diseases

Chemicals: The fungicides Bordeux, Bayleton and Mitral reduced the disease severity in both species.
III. SUNFLOWER

Sunflower (*Helianthus annus*) is second, next only to soybeans, most important source of vegetable oil in the world. In Ethiopia it is widely grown in the southern, western and northern state farms. Before privatization Wellega state farms were major producers of this crop. The availability of sunflower seed as a row material for government as well as private oil factories is indispensable. But due to low attention given for diseases the production areas have been reduced to the minimum. Soils suitable for maize have usually been identified as equally suitable for sunflower. The crop is drought tolerant and can produce a seed yield on only 300-mm rain.

**Sowing date:** The sowing time depends on mainly on temperature conditions and the seasonal pattern of the rainfall. Sowing date trial conducted at Bako showed that generally high seed yield was recorded when sowing in June. Early sowing resulted in higher lodging percentage while later sowing dates inflicted moisture stress conditions that resulted in low seed yield.

**Seed rate:** Seeding rates vary depending on the seed size, the optimum being 80-100kg/ha.

**Spacing and plant population:** Studies conducted at Bako showed that a spacing of 75 cm between rows and 25 cm between plants with a plant population of 53,333 plants/ha gave a high seed yield.

**Fertilizer:** Sunflower is one of the oil crops grown in western Oromia. Sunflower responds well to nitrogen and phosphorus fertilization. Based on research result conducted at Bako, Didessa and Ambo the recommended amount of nitrogen and phosphorus fertilizers for these areas are 50 kg nitrogen and 50 kg P$_2$O$_5$ per hectare. These are equivalent to 65-kg urea and 110 kg DAP.

**Time and method of application:** DAP is basally applied or incorporated at sowing by broad casting. Urea is top-dressed when the plants reach knee height.

**Weed control:** Weeding in sunflower is needed in the early growth stages, until the plants shade out weeds. The yield loss from weed competition was estimated to be 58%. The critical stages of weeding were 25-30 and 55-60 days after planting. At Bako the effect of pre-emergence herbicide, lasso was tested along with hand weeding. The best yield was obtained at the rate of 4.5 lits/ha and hand weeding resulted in the second highest yield.

**Diseases**

**Downy mildew:** Downy mildew of sunflower is a fungal disease caused by *Plasmopora halstedii* (Farl.). The disease mainly attacks leaves. The disease is prevalent in most sunflower growing areas of Ethiopia in general and western Oromiya in particular. It causes serious seed yield reduction when conditions favour disease development.

**Control methods**

**Cultural:** Early planting (June 7) of sunflower can suppress the incidence of downy mildew

**Chemical:** Polyram M as a foliar application against downy mildew is effective and gives higher yield. Preliminary results of seed dressing studies conducted to control downy mildew

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indicated that metalaxyl at the rate of 210 g a.i./100kg seed gave complete control of downy mildew.

**Rust:** Rust (*Puccinia helianthii* Schw.) is also one of the major foliar diseases of sunflower and it is more severe in the higher altitude areas.

**Control methods**

**Variatel:** Sungro 380A and Sunhi 301A showed the lowest score for rust, whereas Russian Black, Eliodoro, Argentario, LCI and Novisad 21 showed tolerance and gave high yield.

**Stem and head-rot:** *Sclerotinia sclerotium* (Lib.) de Bary) is a major pathogen of sunflower that infect roots, stems, and flower head to cause root rot, wilt and stock and head rot. Sclerotia can survive in the soil for several years under cool moist condition.

**Control methods**

**Cultural:** Use of crop rotation (with cereals, legumes and Vegetables) for about 4 years including fallow period and non-susceptible host. And it is advisable to use shallow cultivation that accelerates the reduction of inoculum. Removal of infected plants also reduces the build up of sclerotia in the soil. Wider plant spacing decreases the chances of contact between root of diseased plant with adjacent plant and reduces the incidence of wilt. It is also advisable to use disease free seed and timely weeding.

**Septoria leaf spot:** Septoria leaf spot is one of the major diseases of sunflower caused by *Septoria helianthii* Ell. & Kell. The disease mostly affects the leaves that contribute to the low seed yield of sunflower.

**Control methods**

**Cultural:** Avoid mono cropping. Early sowing (June) of the crop at Awassa showed better result.

**Lowland oil crops**

**IV. SESAME**

Sesame (*Sesamum indicum* L.) is one of the oldest cultivated oil seed crops originated in Ethiopia. Its production accounts for 6% of the total production in all oil crops. In terms of foreign exchange earning, it accounted for about 70% of the export value of all oil crops. It is drought tolerant, and can mature on as little as 400-mm rain on light soils

**Sowing date:** The optimum date for sowing sesame at Didessa is in mid-June.

**Seed rate:** 5 kg/ha is the optimum seed rate for sesame.

**Spacing and plant population:** 10 cm spacing between plants and 50 cm between rows was recommended to obtain a theoretical population of 250, 000 Plants/ha.

**Weed control:** The most important activity in sesame cultivation is to keep the soil under this plant always free from weed and well loosened. Sesame is highly sensitive to infestations,
particularly during the early stage of its development. Weeds on sesame have adverse effect like reducing yield, increasing pest and disease incidence, interfering with fertilization, and harvesting. Yield loss owing to weeds on sesame can reach as high as 77%. Hand weeding twice at 20-25 and 50-55 days after emergence is recommended in order to get high yield.

**Seed rate x weeding x harvesting stage:** 5 kg/ha seed rate, twice hand weeding (25-30 and 55-60 days after emergence) and harvesting when 1/3 of the leaves, stems and pods turned yellowish brown or at 90 - 100 days after emergence increased grain yield and minimized shattering around Loko and similar areas.

**Diseases**

**Bacterial blight**

Bacterial blight of groundnut is caused by *Xanthomonas sesami* Sabet and Bowson and *Pseudomonas sesami*. Dark gray to black spots appears on the leaves and later become concentric ridges. These lesions develop mostly on the leaf and extensive blight and premature defoliation occur under sever attack. Flower infection can lead to stem end rot and is favored by humid and high rainfall. The disease is seed-borne and prevalent in Dedessa, Loko, Uke and Anger Gutin of eastern Wellega zone. Disease transmission is through infected seeds.

**Control methods**

**Cultural:** The use of disease free seed material is the best control method. Hot water treatment is one of the oldest and the cheapest methods to control bacterial blight. Treating the seed in hot water for at least 10-14 minutes at 52 °C and dry it with blotter paper in the sun. Removal of infected plants and residues, destroying alternative hosts and weeds, and crop rotation are few among the cultural controlling methods. The disease is mainly transmitted through the vector Jassid (*Orosius albicinctus*) and control of Jassid vectors there by controls the disease.

**Chemical:** Treating seeds with 250-PPM streptomycin solution (bactericide) for 30 minutes at Loko showed that seed treatment effectively controls bacterial blight.

**V. GROUNDNUT**

Groundnut (*Arachis hypogea*) is crop of medium to low altitude warmer areas of Ethiopia. It is grown mostly for domestic use. In Ethiopia individual small farms produce this crop. Losses in yield and quality on the crop caused by fungi, bacteria, virus, and mycoplasma diseases are high in Ethiopia. The most suitable soils for groundnut are light sandy loams. It is often grown on low fertility soils, which are unsuitable for other crops.

**Sowing date:** According to study conducted at Didessa Mid-July is the optimum planting time. A consistent decline in pod yield was recorded when planting was delayed from this time.

**Seed rate:** Depending on the seed size 80-100 kg/ha is the optimum seed rate for groundnut.
Spacing and plant population: Trials at Didessa showed that planting on 50 cm row spacing with 10 cm within plants gave higher yield. Ridging was not beneficial for variety Shulamith. A plant population of 200,000 plants/ha is also recommended.

Weed control: Weed competition is more severe on groundnut at early stage. Therefore, when weeds grow aggressively controlling at proper time is critical. An experiment conducted on weed competition indicated that weeding groundnut not later than four weeks after planting was found the critical period of weed competition. During weeding, the plants may be earthed to encourage penetration of the pegs into the soil.

Weeding x ridging x spacing: The frequency of hand weeding, ridging, and row spacing on the yield of groundnut at Dedessa state farm suggests that weeding once at four weeks after emergence was found to be essential. Repeated weeding then after was not economical. Ridging was found to be not important for groundnut production at Dedessa state farm. Further widening of rows has no significant effect. Rather there is a room for narrowing the space between rows below 50 cm.

Diseases

Cercospora leaf spot: Cercospora leaf spot is serious disease of groundnut. The disease is caused by *Cercospora orachaidicola* / *C. personate*. It attacks leaves, petioles and stems by causing chlorotic leaf spots, enlarging, and becoming brown to black. Loss assessment trials carried out at Dedessa showed that mean yield loss was about 65%.

Control methods

Cultural: crop rotation (with cereals, pulses, and vegetables), removal of volunteer plants and infected crop residues can reduce the primary sources of inoculums.

Chemical: Fungicide as a seed treatment with agrosan at the rate of 5 g/kg seed gave effective control against seed and soil-borne pathogens. In spraying trials carried out at Dedessa fungicides Benomyl, Copper oxychloride and bordeaux mixture showed good control of the disease.

Rust: Rust caused by *Puccinia arachidis* is a destructive disease in all groundnut-growing areas. First it is recorded in Melka Werer and Bale. Later the disease spread to other parts of the country. It is also recorded in Bako.

Control methods

Cultural: Removal of volunteer plants, strict quarantine, and removal of crop debris.

Chemicals: Application of fungicides such as Daconil, Mancozeb, Bordeaux mixture, Copper oxychloride and Chlorothalonil are effective.

Mold/Storage disease (*Rhizopus sp.; Aspergillus niger; Aspergillus flavus*): Mold of groundnut is caused by different species of fungi. The disease is important in storage seed and its contamination is high in the humid high rainfall areas of western Oromia. The severity of the disease differs with pathogens. *Aspergillus flavus* 14.5%, A. *niger* 10.5% and *Rhizopus sp.*
reaches 34% on pods and seeds 59%. This fungus grows best in humid conditions. The fungus produces aflatoxin that is poison to human and animals.

Control methods

Cultural: The seeds should be kept as dry as possible
Chemicals: Fungicides such as Agrosan and Difolatan reduced the damage and increased germination percentage in the laboratory and in the field 29 to 89% and 67.7 to 93.5%, respectively.

References

Stewart B. Robert and Dagnatchew Yirgu. 1967. Index of Plant diseases in Ethiopia. College of Agriculture Haile Selassie I University, Bull No. 32.


Research achievements and recommended technologies for horticultural crops production in west Oromia

Girma Abera, Daniel Mekonnen, Fekede Abebe and Aschalew Sisay
Oromia Agricultural Research Institute, Bako Agricultural Research center, P.o. Box 03

Introduction

Food production and security in Ethiopia merely focus on the adequacy of cereal supplies. The economic and nutritional importance of horticultural crops are underrated. However, they are as important as cereals and they could use for domestic consumption, raw material for local industries, and play great role in earning foreign currency. They also provide employment opportunities provided that intensive management is given as compared to other food crops.

Horticultural crops include fruits, root and tubers, spices and vegetables. They are good sources of vitamins, minerals, carbohydrates and proteins. Some nutrient deficiencies like vitamin A and C, calcium and iron can be corrected by use of selected species/varieties of fruit, vegetable and root and tuber crops.

Ethiopia is a country with a great variety of climate and soil types, which can grow huge diversity of rain fed horticultural crops for home consumption and foreign markets. On top of this, there are plenty of rivers and small streams; there are considerable large bodies of fresh water; there is a vast store of underground water, which could be used to irrigate horticultural farms. Therefore, these crops are the principal crops, which need to be integrated in to developing countries agriculture, as they are so diverse and immense in number, which could ensure ecological balance stimulated by diverse agro-ecologies of the country.

Despite their enormous merits and potential, the average area of horticultural crops production is quite limited. More over, the existing crop productivity has been low and variable under farmers' local condition. This is presumably due to lack of improved crop varieties, lack of appropriate agronomic packages, disease, and insect pest pressure and poor extension promotion activities.

In line with this, more than two decades have been elapsed since germplasm and agronomic studies started with the objectives to alleviate production constraints of horticultural crops of the region and thereby increase their production and productivity. Currently, intensive research work is underway on hot pepper, tomato sweet potato, potato, and anchote. Hence, this paper is intended to provide summaries of directly usable technologies and information, along this future research direction and government policy intervention is indicated.

Root and tuber crops: Potato, sweet potato, yam, anchote, taro and Dinnicha Oromo are the most important root and tuber crops produced in the Western parts of Oromia region. Research efforts made on root and tuber crops in the past decades have developed some technological packages appropriate for both commercial and small-scale sectors. However, there are only very limited number of improved root and tuber crops varieties at the farmers disposal and even the existing varieties and /local cultivars are variable in yield and quality or susceptible to various disease and pests over the production areas.
Of these priority root and tuber crops, it is important to signify that, at present potato production is rejuvenating under both rain fed and irrigated agriculture in western Oromia region. This was mainly because of the farmers have got easy access to improved potato technology via CIP/ASARECA potato technology transfer project implementation in the area. Moreover, through a concentrated research effort the following improved technologies are recommended.

**Sweet potato:** Sweet potato is versatile because of its agronomic characteristics as well as short growth period and high productivity per unit of time and area. It can be used together with cereals in intensive diversified land use patterns. It is inexpensive to produce and is highly adaptable to stress condition. Sweet potato is an excellent food sources, providing high energy and protein production along with important vitamins and minerals.

**Variety improvement:** Crop production could be improved either through improving the genetic resource or through improved agronomic management application and or both. Several sweet potato variety improvement studies have been undertaken to come up with superior and high yielding genotypes. As a result, the varieties white star, koka-12 and Cemsa (Bako) are recommended for their high yield, root colour and good taste. Very recently, based on concentrated research findings, varieties Koka-18 and Cemsa (Awassa) from early maturing group and 375 and AJAC-1 from medium maturing groups are found to be the best overall location under study. Hence, they can be widely produced in Western Oromia region.

Early sweet potato varieties should be harvested at 120 days after planting whereas medium materials require 150 days to reach physiological maturity.

Table 1. Recommended vegetables, and root and tuber crops in different production areas (1963-2001)

<table>
<thead>
<tr>
<th>Crop type</th>
<th>Variety</th>
<th>Yield (q/ha)</th>
<th>Altitude (masl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onion</td>
<td>Adama Red</td>
<td>162.01</td>
<td>500-3200</td>
</tr>
<tr>
<td></td>
<td>Red Creole</td>
<td>142.39</td>
<td>1701-3000</td>
</tr>
<tr>
<td>Tomato</td>
<td>Roma VF</td>
<td>314.4</td>
<td>500-2200</td>
</tr>
<tr>
<td></td>
<td>Marglobe</td>
<td>203.34</td>
<td>500-2200</td>
</tr>
<tr>
<td></td>
<td>Money maker</td>
<td>284.28</td>
<td>1701-2200</td>
</tr>
<tr>
<td>Pepper</td>
<td>Marekofana</td>
<td>20</td>
<td>1400-2200</td>
</tr>
<tr>
<td></td>
<td>Bako Local</td>
<td>30</td>
<td>1400-1900</td>
</tr>
<tr>
<td>Potato</td>
<td>Menagesha</td>
<td>250-350</td>
<td>1550-2800</td>
</tr>
<tr>
<td></td>
<td>Tolcha</td>
<td>200-240</td>
<td>1550-2800</td>
</tr>
<tr>
<td></td>
<td>Wechecha</td>
<td>160-200</td>
<td>1550-2800</td>
</tr>
<tr>
<td>Sweet potato</td>
<td>Koka-12</td>
<td>139.50</td>
<td>1500-1800</td>
</tr>
<tr>
<td></td>
<td>White star</td>
<td>133.9</td>
<td>1400-1800</td>
</tr>
<tr>
<td></td>
<td>Cemsa(Bako)</td>
<td>221.6</td>
<td>1400-1800</td>
</tr>
<tr>
<td></td>
<td>Cemsa(Awassa)</td>
<td>243.2</td>
<td>1400-1800</td>
</tr>
<tr>
<td></td>
<td>Koka-18</td>
<td>287</td>
<td>1400-1800</td>
</tr>
<tr>
<td></td>
<td>375</td>
<td>249.6</td>
<td>1400-1800</td>
</tr>
<tr>
<td></td>
<td>AJAC-1</td>
<td>232.7</td>
<td>1400-1800</td>
</tr>
<tr>
<td></td>
<td>TIS-1499</td>
<td>219.80</td>
<td>1400-1800</td>
</tr>
</tbody>
</table>
Agronomy/Physiology

Land preparation: Mounds, ridges and planting on the flat are all commonplace. Plantings on the flat yield lower than the others and are more difficult to harvest. Planting on the flat is also particularly unsuitable for soils with high water table. Ridge making can be mechanized, because of this it is progressively replacing mound making as the most common land preparation for sweet potato production.

Spacing: Spacing can vary based on soil condition and crop variety. The optimum spacing for sweet potato production is 100 cm between rows and 30 cm between plants for Bako and similar agro ecologies. This spacing is identified as the best in providing optimum root yield, soil root coverage and for easy of applying agronomic management practices.

Planting date: Actually, planting date is site specific based on the on set of rainfall, altitude variation and disease pressure. Planting sweet potato the whole month's of June was recommended for Bako and other similar agro ecologies as the optimum planting date, if reliable rainfall exists during and after planting.

Vine cutting length: Traditionally farmers use various size cuttings from different parts of sweet potato vine. Some use the tip delicate/young tissue; others use the basal vine, which might be old and difficult to root. Vine cuttings have the ability to re-grow in to full plant. The portion and size of cuttings however are found to vary in their rooting ability. Hence, research come up with a length of 30-36 cm middle portion vine cuttings as an optimum and better quality planting material for sweet potato production. Other parts of the vine may also be used if there is shortage of the middle portion vine. In general, the cuttings preferred with few leaves intact.

Clipping stage: The best clipping stage identified was 3.5-4 months age of the plant after planting, with reasonably optimum vine harvest and minimum impact on root yield. Moreover, the local varieties can be grown for its high fresh top part yield than the root yield but white star gave reasonable fresh top part yield at all clipping stage with less effect on its root yield. Therefore, white star is recommended for production of food for human being and feed for livestock.

Nitrogen and phosphorous rate: Soil fertility decline is noted as the principal cause for crop yield reduction in western Oromia. This aspect may assume serious dimension in sweet potato production as the crop is known to be a heavy feeder of nutrients. This is because of sweet potato bulks high yield in a relatively short season. Hence, the affordable and profitable rate of 100/100 kg ha^{-1} Urea/DAP is identified as an optimum for sweet potato production in Western Oromia. Nitrogen fertilizer applied to sweet potatoes should normally split in to two doses. The first dose is applied at planting. The second dose is applied at one and half month after planting. But excessive nitrogen fertilizer should be avoided since it delays tuber formation and promotes shoot growth at the expense of tuber growth.

The application of fertilizer helps to:
- Improve sweet potato root yield;
- Improve sweet potato root quality and
- Provide early establishment/ early ground cover of sweet potato, there by reduce the hazards of erosion and smoother weeds.
Harvesting time: Harvesting time has significant effect on root yield and quality. Early harvest resulted in immature, undersize, watery and less sweet and poor quality roots. To the contrary, too late harvested roots become oversized, cracked and susceptible to weevil attack. To this end, the optimum harvesting time was found to be 5th month after planting to harvest reasonably high root yield and good root quality.

Potato

Variety Improvement

A collaborative research has been undertaken for development of improved high yielding and wide adaptable disease resistant potato genotype(s).

Three potato varieties namely Menagesha, Tolcha and Wechecha found to be superior in tuber yield, quality and disease reaction in Western Oromia. Therefore, they are recommended for wider area production in the western parts of Oromia region. Menagesha is relatively late in maturity. Hence, planting is advisable at the onset of rain. It also needs wider spacing because of vigorous vegetative growth as compared to others.

True potato seed (TPS)

Elsewhere, potato normally produced by use of tuber seed. In some tropical countries including Ethiopia potato production suffers from lack of adequate quantity and quality tuber seed. In such condition, CIP scientists have identified the use of TPS as an alternative technology. To this end, in our condition parental lines of TPS tuber yielding potential were identified. These genotypes are Tolcha, CIP38137.15 and CIP387894.2. They give uniform tuber in color, size and shape and as well as high tuber yield, which are relatively comparable with tuber seed. However, the TPS production is viable during off-season using irrigation to overcome fruit drop due to heavy rain.

Agronomy/Physiology

Land preparation (Ridging): Ridging refers to hilling or earthing up of the soil around the potato plant. It is a normal practice in potato production. Tuber should be covered with sufficient layer of soil. As compared to non-ridging, ridging of the crop at least twice during its production time increase yield by 10-15%. It also helps in reducing soil erosion particularly on step slopes. The first round ridging should be given 10-15 days after emergence, which can be synchronized with the first nitrogen application. At a fortnight interval, the second and the third ridging can be done. Ridging the crop after complete flowering may damage the stolons and developing tubers. Hence, at a later stage only light cultivation can be applied just to control weeds. This practice reduces damage by potato tuber moth. It also reduces soil erosion.

Seed and ware spacing: Spacing in potato depends on the intended end use. If the deliberation is for seed, narrow spacing is advisable to harvest more number of seed size tubers. To the contrary, if marketable or large size tuber (ware) is envisaged wider spacing between plants is recommendable. To this effect, appropriate spacing for seed and ware potato production are 75 x 20 cm and 75 x 50 cm, respectively. These spacing are found to be the best spacing under Bako and similar agro-ecologies in providing sufficient soil cover and
space for any management application. Accordingly, the amount of seed tubers required to plant a hectare of land varies from 12-22 quintals depending on seed size and spacing.

**Potato tuber seed storage:** Potato tuber seeds are living organs with high moisture content as compared to seeds of other crops. Hence, there should be a proper storage system, which can keep storage losses at minimum and carry products over months.

Proper storage facilities are lacking in Ethiopia. As a result, farmers are forced to sell their entire harvest at lower prices during and for few weeks after harvesting. On the contrary farmers purchase seed tubers at a very high price at planting. Some farmers store seed potatoes in burlap sacks or in dark rooms or simply spreading the tubers over floors. Others store the inferior quality and smaller size tubers just by simply leaving in the soil. In addition to high risk of rotting and tuber attack by the potato tuber moth, potatoes stored under such conditions significantly lose their weight.

Cold store is generally considered best, however, it is costly for small-scale producers. Hence, a low cost storage structure has been developed by CIP for developing countries. This structure, the Diffused Light Store (DLS), has been tested at Alemya as well as Holetta potato research programs and recommended for wide uses in the country. At Bako Research Center also the DLS has proved to be efficient in tuber seed storage. Thanks to ASARECA/CIP financial assistance for potato technology transfer project, DLS has been demonstrated to host farmers of the project area, west Oromia. As a result, some potato farmers have successfully adopted the DLS structure technology for potato storage. It is possible to store seed tubers for about 8 months in the DLS, depending on the variety. The structure can be constructed from locally available materials such as trees or mesh wire for wall and grasses or sheets for roof. The size of the store to be constructed is, however, determined by the amount of tubers intended to be stored.

**Vegetable Crops:** Hot pepper, tomatoes, and onion are important vegetable crops produced in the western Oromia region. These crops are important cash sources for farm household. Very recently tomato production is rapidly flourishing under both traditional and modern small scale irrigated agriculture in the west Oromia region.

**HOT PEPPER**

The crop is produced under rain fed as well as irrigated condition. About 500 to 700 g of seeds should be raised in the nursery bed and transplanted to the field after 45 to 65 days. Proper watering, shading manuring/fertilizing and weeding should be followed as a routine hot pepper nursery management and production practices. Hot pepper is susceptible to various diseases, therefore, affected plants should not be used to produce seeds. In addition, rotation and proper sanitation is required for healthy hot pepper production.

**Variety improvement:** Hot pepper variety improvement study has been elapsd more than two decades in the country. According to the research results so far made Bako local and Marekofana were found to be good yielder and recommended for large scale as well as small-scale production along with full production packages. They give an average dry pod yield of 20 quintals ha\(^{-1}\). Bako local produces light red pod, which are relatively thin and long. Whereas, Marakofana produce dark red, thick and big sized pod. Both are mild in pungency, however, Marekofana is less pungent.
Direct sowing vs. transplanting: Commonly transplanting and to a lesser extent direct sowing were practiced as pepper production methods in the Bako and other areas of the country. However, research has come up transplanting as the best method over direct sowing.

- Transplant seedlings of 15 - 25 cm height or 40 - 63 days old and
- Sow seeds on a seedbed at early to mid April based up on the agroecological condition and nursery management to be provided.

Nitrogen and phosphorous rate: Apply 137/207 kg ha\(^{-1}\) Urea/DAP for hot pepper production at commercial as well as small-scale level.

Improving efficiency of nitrogen use: The effect of N on environment and its escalating purchase price has received considerable attention. Hence, improving efficiency of N use by the crop based up on soil condition of the area, plant growth stage, varietal difference and other environmental factors is of paramount important. To this effect, the trial was carried out at Bako to observe the effect of split application of fertilizer on nitrogen use efficiency. Based on the result 25%, 50% and 25% at transplanting, 4 and 8 weeks after transplanting respectively were found the best amount and time of application.

Spacing: Spacing varies based up on soil condition and crop variety. To this end, produce Bako local variety by spacing of

- 70 x 30 cm for Bako area and similar condition and
- 60 x 20 cm for Didessa area.

Whereas, Marckofana could be produced at spacing of

- 60 x 30 cm at Bako area and
- 60 x 20 cm for Didessa area.

Harvesting time: Harvesting time is one of the most determinant agronomic factors, which affects yield and quality of hot pepper. To this effect, delayed harvesting when pods partially withered or when the pods at red ripen (leathery stage), i.e., when the fruit color is well developed and no breakage of the pod at bending takes place were recommended as the best time to harvest reasonable high yield and good quality pod. The pods can be harvested through several hand pickings as flowering and fruit set takes place over long period.

ONION

Variety improvement: The varieties Adama Red, Red Cerole and Bombay red were recommended for Bako and other areas of similar agro-ecological zones.
Agronomy/Physiology

Sowing date: Onion sowing date trial was conducted in the dry season using irrigation. Based on the result, August sowing gave the highest marketable and total bulb yields followed by October to December sowing time at Bako and other similar agro ecologies.

Methods of Seed production:

The two common methods of seed production of onion are described below:

Bulb to seed method: The method has the advantage of maintaining seed quality. It allows rouing of off colour, misshapen, splits, rotten and sprout bulbs. Several stalks are formed per bulb. It takes 10 to 12 months to produce seeds using this method.

Seed to seed Method: This method misses the above advantages, but it could be used alternately (every other year) with the other method to speed up the production practices without affecting the varietal quality. It takes about 7 to 8 months to produce seeds. These both methods mentioned are also used for bulb production.

Planting date (bulb): The optimum mother bulb planting time is between August and October. August, September and October bulb planting can give high number of flower stalks and seed yield due to worm temperatures, low rainfall and low disease pressure during flowering, fruit set and harvesting.

Seed rate and spacing: About 3.5 to 4.0 kg ha⁻¹ with a potential of 92 to 95% germinating seed should be raised on a seed bed and transplanted to the field after 45 days at 40 x 20 x10 cm spacing (i.e. 40 cm bed including furrow, 20 cm between rows on the bed and 10 cm between plants). The bulbs will be ready for harvest after four and a half months after transplanting. Large or medium mother bulbs (5 to 6 cm), uniform, typical size and colour, free from diseases, insects and other injuries should be selected and stored for about two months and planted. Double row plantings of 50 x 30 x 20 cm with 125, 000 bulb per hectare (80 to 90 q ha⁻¹) could also be used for onion production.

TOMATO

Variety improvement: Evaluation of different varieties was carried out during dry season using irrigation. Based on the result Marglobe, Roma VF and Money maker gave high yield. Therefore, they were recommended for Bako and other similar agro ecologies.

Agronomy/Physiology

Sowing date: Sowing date trial at monthly interval was evaluated under irrigation. The result indicated that October sowing was the highest in both marketable and total fruit yields followed by November sowing at Bako and other similar agro ecologies.

Seed rate and Spacing: The field culture of tomatoes for seed production is identical whether they are grown for fresh market or processing. It is grown under irrigation in the dry season. Rain fed production is not preferred due to heavy disease incidence and poor seed set. About 250-300 g of seed is raised on nursery bed and good once be transplanted to the field at 3 to 4
true leaf stages, i.e., 28 to 35 days after emerging at a spacing of 100 cm between rows and 30 cm between plants.

Tomatoes should be grown on the same field ones every 2 to 3 years. Related crops such as potatoes and hot pepper should not be used in the year's rotations to avoid diseases build up. Frequent watering, weeding, frequent cultivation, disease and pest control are essential for good seed yield.

**Potato diseases and their control mechanism**

1. Late blight (*Phytophthora infestans*)

Late blight caused by *Phytophthora infestans* is one of the major diseases of potato in the major production areas of the country. Potato leaves, which are infected with late blight, have a water soaked appearance at first. In wet weather white fungus growth or "mildew" will develop on the water soaked areas, particularly on the under side of the leaves. In dry weather the water soaked areas turn brown and dry up, resulting in death of infected leaves.

**Control methods**

**Cultural:** Planting healthy varieties. Do not plant susceptible varieties. Destroy crop residues from main and neighboring fields of potato, tobacco and other crops from the same family (Solanaceae). Use crop rotation and avoid volunteer plants. Early planting, destroying dump piles and killing potato tops before harvest or spraying them with fungicides to prevent tuber infection during harvest and controlling other diseases to reduce susceptibility of tubers to late blight infection.

**Varietal:** Menagesha and Tolcha are the latest tolerant varieties in western Oromia highlands

**Chemicals:** Spraying of the systematic fungicides Ridomil MZ63.5 WP (metalaxyl mancozeb) at the rate of 3 kg ha⁻¹ at an interval of 8 days, beginning from the onset of the disease gave the best control. Captafol 0.4% also gave reasonable blight control. Among protective fungicide Bresthan 10 (Chlorothalonil), Dithane M-45 (mancozeb) and Polyrm M (maneb) performed better in controlling the disease and resulted higher yield.

**Insect pests**

**Potato tuber moth (PTM):** It is the larvae of the PTM that cause a serious damage by mining the foliage and the stem. The larvae pupate in the leaf already mined and gradually reach the soil. Through the soil cracks the larvae find a way to the tubers. The larvae bores into the tuber and creates tunnels on the tuber. PTM incurs a serious crop loss by moving into the store with produce.

**Control Measures**

**Cultural measures:**
- Cover the seed tubers completely with soil after planting
- Clean seed stores from all possible source of PTM.
- Avoid any remains of the past season, which could be the potential source of PTM.
Harvest the crop at the right time

Chemical control: Different insecticides have been recommended to control PTM both in the field and in the store. Dizinon 60% EC 20 ml in 10 litters of water should be applied to protect seed potato in the store. Fenitrothion 50% EC (Sumathion), Malathion and Cypermethrin 50% EC (Symbush) could be in the fields up until location specific recommendations are available.

Vegetables Diseases and their control mechanism

HOT PEPPER

1. Fusarium wilt (*Fusarium oxyporum*)

The first visible symptom is dropping of the lower leaves. At this stage, decay has advanced at the base of the stem, which resulted in raped wilting of the plant. Younger shoots later die and turn brown. Infection usually begins at the point where the side roots are attached causing dark-brown sunken cankers that gradually girdle the plant at the base of the stem. Roots also are invaded, become soft and develop a water soaked appearance.

Control methods

Cultural: Use raised seed bed, avoid water logging, and use well-decomposed farmyard manure at the recommended rate.

Varietal: There is no recently recommend variety but variety Bako local better tolerate diseases than Marekofana.

2. Frog eye spot (*Cercospora capsici Heald & Wolf*): The leaf spot caused by Cercospora capsici is a common pepper disease. The leaf spot are brown small roughly circular with reddish purple borders with shape of frogeye.

Control Methods

Cultural: Use disease free seeds or seeds at least 3 years older. Crop rotation with hosts not affected by cercospora.

Chemical: Fungicides such as benomyl, chlorochalonil, bordeaux mixture, mancozeb and maneb.

3. Stem blight/ Wilt (*Phythophthora sp.*): The disease appears on leaves, stems as blight and on pods as dry and soft lesions. The first indication of this disease on the pods is small water soaked dull green spot. The disease is new and specific only to sweet pepper production.

Control methods

Chemical: Fungicide Metalaxyl- mancozeb at 3.5kg/ha product was the best in reducing the disease incidence.

4. Bacterial leaf spot (*Xanthomones campestris pv. vesicatoris*): Bacterial leaf spot caused by *X. campestris* is a widespread disease in most of hot pepper growing area of the country. Symptoms appear on the leaves as circular to irregular, water soaked spots later turned to
purple or brown. It is a seed born disease and can limit the production of pepper in the medium to high altitude areas of the region.

**Control methods**

**Cultural methods:** When weeding or thinning of pepper carried out in dry the disease infection level reduces much. Crop rotation and sanitation help in controlling of the disease. The disease can easily be transmitted through farm machinery, insect and planting material thus care should be taken in avoiding contamination.

**Chemical:** Treatment with common bleaching agent (clorox) is the last option to control the disease. Fifty milliliter of chlorox dissolved in 250-ml of water was found enough to disinfect 100 grams pepper seeds in the cheesecloth and the seed should be in the solution for 30 minutes with constant sterrings. Then the seed washed with tap water for 1 hr and dried in the sun. Spraying with cupravit 45% (copper oxychloride 0.5%) three times at 14 day interval proved to be effective in reducing the infection of bacterial leaf spots at Bako.

5. Anthracnose (*Glomerella cingulata* or *Colletotrichum capsici*): Anthracnose on pepper plants include pre and post emergence damping off, die back of shoots leaf spots and fruit rots. Shoots symptoms, most prevalent on hot pepper varieties, usually began at the growing point or on flower buds, but they can begin at stem wounds, the top of affected branches wither and turn brown, elongated infected stem areas becomes white with scattered black bristles minute locations are sharply demarcated from the health green tissue by black line.

**Control methods**

**Cultural:** Use disease free seed, crop rotation, removal and burning of infected plant parts

**Chemicals:** Fungicides commonly used are bordeaux mixture, mancozeb, benomyl.

6. Powdery mildew (*Leveillula taurica*): Powdery mildew is very severe in pepper plantation during dry season or irrigated field. Heavy infestation during early stage of plant growth causes leaf defoliation that result in considerable yield and quality losses.

**Control methods:**

**Chemical:** Fungicides Triadimefon 25% WP at 0.2 kg/ha and Denmeat 10% EC at the rate of 0.5 L/ha.

**ONION/SALLLOT**

1. Purple blotch or scald disease (*Alternaria porri*): Purple blotch caused by *Alternaria porri* is a major disease of onion. It attacks all parts of onion plants. First symptoms are small, whitish, sunken spot, which appear on leaves and flower. These spot enlarge, becomes zonate and girdle the leaf or the stem in wet condition. The spots turn purple and surrounded by chlorotic areas.

**Control methods:**

**Cultural:** Crop rotation (legume, cereals and vegetable), use of clean seed since it is the seed born disease and burning of the crop residues are recommended.
Chemical: spray Mancozeb 3.5-kg ha\(^{-1}\) checks the disease.

2. Downy mildew (*Peronospora destructor*): *P. destructor* is the causal agent of downy mildew which start with the appearance of long yellowish lesions on the leaves. When sporulation occurs these lesions become covered with characteristic grayish violate mildew. Lesion also occurs on the seed stalk especially on the upper parts, and often cause twisted or uneven stalk growth and cause stalk to break.

**Control methods:**

Chemical: Earlier studies at Bako revealed that captanol (80% WP) at 0.3% concentration applied at 7 days interval gave better control of purple blotch and downy mildew.

3. Rust (*Puccinia allii*): *P. allii* attacks the leaves and stem of the onion plants. Elongate, chlorosis spots appear first and develop into orange pustules. Leaves may die if the infection is severe. Lower leaves may yellow; wilt and bulbs may be reduced in size.

**Control methods:** Use resistant/tolerant varieties and captifol (80%) at 0.3% concentration applied at 7 days intervals gave better control.

**Onion Thrips (*Thrips tabaci*):** Onion thrips is the most severe pest during dry worm weather. Cypermethrin 100 g a.i. ha\(^{-1}\) or 500 ml ha\(^{-1}\) and Decamethrine 12.5 g a.i/ha check the pest successfully.

**TOMATO**

1. Early blight (*Alternaria solani*): The early blight caused by Alternaria solani is the major disease of tomato. It affects leaf, stem, flower and fruit of tomato. The disease appears as leaf spot and blight on tomato. Alternaria attack fruits when it reaches maturity.

**Control methods**

**Cultural:** Crop rotation (root crops, legumes, vegetable, cereals etc), removal of plant debris, eradication of weeds and host plant help reduce the inoculums for subsequent planting of susceptible crops. Use disease free planting materials. Generally applying adequate amount of nitrogen fertilizer reduce the rate of infection by alternaria.

Chemical: Seed treatment with fungicides such as maneb, captanol, or maneb-zinc combination. Spraying with captanol and ridomil at on set of the disease

2. Leaf spot (*Septoria lycopersici* Speg): Leaf spot is one of the most important diseases of tomato caused by *Septoria lycopersici*. This disease mostly causes leaf spots and blights on tomato.

**Control methods**

Chemical: Captanol 80% WP at 0.3% concentration and Ridomil (R) MZ 63.5% WP 0.27% separately or in combined form significantly reduced the incidence of late blight and septoria leaf spot at Awassa and Melkassa.
3. Late blight (*Phytophthora infestans* (Mont.)): Late blight caused by *Phytophthora infestans* is a major disease of tomato. It affects leaves, stem, and fruits. Tomato leaves, which are infected with late blight, have a water soaked appearance at first. In wet weather white fungus growth or "mildew" will develop on the water soaked areas, particularly on the under side of the leaves.

**Control methods:**

**Cultural:** Destroy crops residue from main and neighboring fields of potato, tobacco, and other crops from the same family (Solanaceae). Use crop rotation and avoid volunteer plants.

**Chemical:** Captafol 80% wp at 0.3% concentration and Ridomil MZ 63.5% wp 0.27% separately or in combined form significantly reduced the incidence of late blight and septoria leaf spot at Awassa and Melkassa.

**Summary and Conclusion**

Ethiopia is a country where traditional and subsistence agriculture is still widely practicing. The people of the country suffer from shortage and fluctuation of food production mainly due to an erratic climatic behavior. At present, although food production is surplus/sufficient in some areas, poor agricultural market stabilization policy also emerged as a factor for shortage and fluctuation of food production in Ethiopia. In over all, it is necessary to note that the majority of Ethiopian people live below/under poverty line. This was attributed to less productivity of the agricultural sector, poor transport and market infrastructure facilities, poor agricultural policy, and political instability in the country.

More over, in Ethiopia, where there is recurrent drought, accelerated population growth rate, and high soil fertility degradation; if not changed/reversed the current extension program, which is mainly cereals, based high input agriculture put serous risk on the future agriculture. Mono-crop cultivation and extensive specialization instead of diversification, are also the type of agriculture practiced in the country.

On the other hand, there exists a great biodiversity in Ethiopia related to differences of climate, altitude, hydrological characteristics, and relief. This is manifested in the wide variety and number of animal and plant species survival. Hence, diversification spread of produce and income over space and time is a remedy for small-scale agriculture. In fact diversification is more than this-it also provides conservation based sustainable agriculture.

To this end, the importance of horticultural crops as a tool for diversification, poverty alleviation and nutrition security should be appreciated and taken as interface. At the same time, diversification of agriculture by inclusion of horticultural crops could also help risk aversion by reducing the vagaries of climate and other catastrophes.
Reference

Introduction

Trees are a fundamental element of life. They play a vital role to our lives. Food and fruits we eat, medicines extracted from leaves and barks, many industrial products, energy we use, shade from heavy sun heat, nutrient cycling and recycling, etc., comes from forest. For thousands of years, men and trees cohabited quite peacefully. But in the recent centuries and decades, mankind has become a conquering predator, and the balances between man and nature have been broken. Currently, trying to heal this destructive relationship between men and trees is becoming the priority agenda in forestry research. Agroforestry is one of the means of healing such relationships. Agroforestry involves a close association of trees or shrubs with crops, animals and/or pasture. The success of agroforestry/forestry system depends on the quality of their components. Therefore, developing appropriate forest and agroforestry management practices through research which can serve as guidelines for users is very important to conserve and utilize the country's forest resources and scattered multipurpose tree species over different rural landscapes in a sustainable way. Research alone however, can't be an end in itself and it may not suffice. The research component should therefore be supported by strong extension system. In this paper, guideline for agroforestry research recommendations obtained from nursery management, species and provenance selection, alley cropping, scattered tree species, biomass transfer and taungya plantation system are presented. The objective of the paper is therefore to gather agroforestry research findings and make available for the users in brief and usable way to assist the dissemination of these findings.

Nursery management

Nursery is the place where seedlings are raised under intensive management for later transplanting to the field. It provides the means to control moisture, light, and physical and chemical soil constituents in such a way as to produce healthy and uniform seedlings of the required species and quantity necessary for planting activity. The most important goal of nursery management is to produce quality trees. However, many factors can affect seedling growth in the nursery, such as the genetic potential, the environmental characteristics of the site and the level of amendment of the soil. These factors need to be optimal to produce a healthy and vigorous seedling.

Soil mixture and Pot size

Nursery soils should be fertile, and containers should be of appropriate size. Because they are very indispensable for the success of nursery operations. Seedlings are baby trees. Like all infants, they are delicate, sensitive and need tender loving care. Nursery soil is the most important factor that influence seedling growth from the nursery environment. This is because, first, it is basically a plant's first home; secondly, it physically supports a growing seedling, and thirdly, it both stores and supplies nutrients, water and air to the root system.
Different nursery soil mixtures are required for different tree species. Equally important is the use of suitable pot size that can fit with the potting soil and root system of the seedling.

- **Calliandra calothyrsus**
  
  *C. calothyrsus* was introduced from Guatemala, and it is now planted in different African countries including Ethiopia. The species is performing well in western Oromia, notably in Bako area. The growth performance of *Calliandra* seedlings is higher when grown in the larger pots (10 cm and 12 cm) than in that of the smaller (8 cm). Moreover, seedling growth is higher in potting mixture with higher farmyard manure (3 part local soil:1 part sand:2 part farmyard manure) than in those without farmyard manure (3 part local soil:2 part sand:1 part forest soil), but seedling survival was higher for the latter (98%) than for the former (76%). Therefore, for practical purpose it is advisable to use the **10 cm pot size** and potting substrate with more forest soil together with some sand - **3 part local soil:1 part sand:2 part forest soil** - for growing *Calliandra* seedlings in the nursery.

- **Leucaena pallida**

  *L. pallida* is native to central Mexico, and it grows well in mid-altitude areas, to which Bako area belongs. It shows tolerance to low temperatures and *Leucaena psyllid*, which is currently devastating the popular *Leucaena* species (*Leucaena leucocephala*) in different countries. The performance of *L. pallida* seedlings is better in the larger pots (10 cm and 12 cm) than in that of the smaller (8 cm). Moreover, seedling growth is better for soil mixtures containing farmyard manure than in those with no farmyard manure, but seedling survival is higher in the latter than in the former. Therefore, it is advisable to use the medium sized pot - **10 cm pot size** and soil mixture without farmyard manure but with more sand and some forest soil - **3 part local soil:2 part sand:1 part forest soil**.

- **Acacia mearnsii**

  *A. mearnsii* is native to Australia. It is often cultivated for tannin in New Zealand, southern, central and east Africa, India, Sri Lanka, parts of Central America, southern Europe and Indonesia. Large plantations have been established in different countries including Ethiopia. It is therefore advisable to carry out nursery propagation study for this important species. And it is recommendable to use the **10 cm pot size** for *Acacia mearnsii* and a potting mixture with more sand and some farmyard manure - **3 part local soil:2 part sand:1 part farmyard manure**. This may be due to the biological nitrogen fixing capacity of *A. mearnsii* and hence its ability to compensate for N in soils with less farmyard manure. The fibrous root nature of *A. mearnsii* also might have necessitated the need for sandy growing media.

- **Eucalyptus camaldulensis**

  *E. camaldulensis* is one of the most widely distributed Eucalyptus species and is probably the world’s most widely planted tree in arid and semi-arid lands. It is planted in many tropical and subtropical countries like in Ethiopia. Research finding has shown that it is recommendable to use the **8 cm pot size** for *E. camaldulensis* and a potting mixture with more farmyard manure - **3 part local soil:1 part sand:2 part farmyard manure**. Increasing the farmyard manure in potting mixture favors the growth of *Eucalyptus* seedlings.

- **Cordia africana**

  The species occurs at medium to low altitudes. It is an early colonizer in forest regrowth. It is often left when forests are cleared for cultivation. In western Oromia, it is the priority species grown for timber and shade tree for crops. Since *Cordia* tree is a colonizer species, its seedlings don’t respond as such to the different soil mixture, but respond well to the pot size...
and they need larger pot size. Therefore, it is advisable to use local soil and the 12 cm pot size for raising Cordia seedlings in the nursery. Cordia seedlings don't show considerable response to farmyard manure.

- **Grevillea robusta**
  G. robusta occurs naturally in Australia and it has been introduced into warm, temperate, subtropical highland regions around the world and is widely planted in India, Sri Lanka and many countries in Africa. Generally, it is also showing good performance in Ethiopia and in western Oromia in particular. Research work at Bako on nursery management of this species indicated that it is advisable to use the medium sized pot - 10 cm and soil mixture with 3 parts local soil: 2 parts sand: 1 part forest soil.

- **Melia azedarach**
  This tree species, well known as Persian lilac, is native to India but is now grown in all the warmer parts of the world, and in many of these places it is naturalized. For instance, it is widely planted in western Oromia, Ethiopia. For better propagation, it is advisable to use the medium sized polyethylene tube - 10 cm and soil mixture containing 3 parts local soil: 2 parts sand: 1 part forest soil for Melia seedlings.

In summary, different tree species respond differently to the different soil mixture and pot in the nursery. And accordingly different recommendations should be given for different tree species as indicated in Table below. Generally, increasing the forest soil in potting mixture more favors leguminous seedlings, while increasing the farmyard manure content more favors the non-legumes; and for most species, pots with 10 cm diameter are optimum to use. Therefore, growing media without farmyard manure are suitable and are recommended for leguminous tree seedlings, whereas those containing farmyard manure are suited for non-leguminous tree species in nurseries. Using farmyard manure for raising leguminous tree seedlings is simply incurring an opportunity cost, as it is needed for other different uses (soil fertility, fuel, etc.).

Table 1. Optimum soil mixture and pot size for growing different tree seedlings at Bako.

<table>
<thead>
<tr>
<th>Botanic name</th>
<th>Local name</th>
<th>Pot size</th>
<th>Soil mixture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calliandra calothyrsus</td>
<td>Kallandraa</td>
<td>10cm</td>
<td>3 Local soil : 1 Sand: 2 Forest soil</td>
</tr>
<tr>
<td>Leucaena pallida</td>
<td>Luukinaa</td>
<td>10cm</td>
<td>3 Local soil : 2 Sand: 1 Forest soil</td>
</tr>
<tr>
<td>Acacia mearnsi</td>
<td>Laaftoo Farnjii</td>
<td>10cm</td>
<td>3 Local soil : 2 Sand: 1 FYM</td>
</tr>
<tr>
<td>Eucalyptus camaldulensis</td>
<td>Bargamoo Diima</td>
<td>8cm</td>
<td>3 Local soil : 1 Sand: 2 FYM</td>
</tr>
<tr>
<td>Cordia africana</td>
<td>Waddeessa</td>
<td>12cm</td>
<td>Local soil</td>
</tr>
<tr>
<td>Grevillea robusta</td>
<td>Muka Qawwe</td>
<td>10cm</td>
<td>3 Local soil : 2 Sand: 1 Forest soil</td>
</tr>
<tr>
<td>Melia azedarach</td>
<td>Miliyaa</td>
<td>10cm</td>
<td>3 Local soil : 2 Sand: 1 Forest soil</td>
</tr>
</tbody>
</table>

FYM = Farm yard manure

**Seedling root deformity**

A good root system is very essential for healthy growth of seedlings. Because it determines the future life of the seedling. But a good root system doesn't occur by chance - it results from good management during early life of a seedling. Thus, the nursery stage is critical for good root quality. Variation in the production techniques results in the variation in the performance of the seedlings. In addition, seedling root deformity can vary due to the difference the soil
mixture and method of sowing the seeds. It also varies from species to species. Seedling root deformity problem in tree nurseries around Bako ranged from 50% in *Cordia africana* to 99% in *Mangifera indica*. And the overall average of about 86% root deformity was recorded, only about 14% had normal roots. This shows how the problem of root deformity, which determines the future life of the seedling, is serious in the area and this calls for special attention to improve the scenario.

The problem was more serious for seedlings that are transplanted from germination bed than those directly sown into pots. This may be one of the reasons for poor survival of the seedlings in the field. Thus, it is recommended if possible to sow seeds directly to polyethylene tube rather than transplanting from germination bed.

**Seedling quality**

A nursery manager's most important goal is to produce quality trees. In nursery management, seedling quality is more important than its quantity.

Seedling quality has two main aspects:

- The genetic quality or the source of the seed
- The physical quality or condition when it leaves the nursery

Improving genetic quality of seedlings requires a long-term strategy of seed selection, while improving the physical quality can be accomplished in just one or two seasons.

Good plant quality is the basis for tree planting success.

- A poor quality seedling will always be a poor quality tree even if planted on a well-prepared, good site. In the field, each poor quality tree wastes space and resources leading to low site productivity.
- High quality seedlings have a higher survival rate and faster growth in the field than poor quality seedlings. Fast growth allows a tree to out compete weeds and reduces the initial labor costs of establishment.

Concentrating on the total number of trees/seedlings produced and neglecting their physical and genetic quality is a common practice in many nurseries. Therefore, it is better to produce a few good trees than many poor ones. Equally important is to select only the best, superior and healthy parent trees that have desirable characteristics depending on whether the trees are for wood, fruit, for fodder or medicine

- For *timber* trees, a long, straight trunk with few branches.
- For *fodder* trees, palatability and digestibility of foliage (leaves that animals like to eat and are easily converted to energy)
- For *fruit* trees, low branching is desirable for easier fruit harvest.
- For *fuel wood*, fast growth and high biomass but trunk straightness not important
- Collect seeds from at least 30 parent trees that are at least 100 meters apart.
- Pre-treat the seeds if they take longer time to germinate.

Seedling quality is a combination of several traits (height, diameter, root size, shape etc.) and these traits act together and influence one another. Select seedlings which

- Are healthy, vigorously growing and free of diseases.
- Have a robust and woody single stem free of deformities.
- Have sturdy stem and large root collar diameter.
- Have symmetrical and dense crown.
- Have a dense root system with many fine, fibrous hairs with white root tips.
- Have a 'balance' between shoot and root mass
- Have healthy and dark green leaves.
As soon as detected, discard poor quality seedlings/ sacrifice a few plants to improve the quality of total nursery production.

**Watering**

Water is life, and regular supply of water is essential to plant growth depending on seedling age, amount of sun light and soil type.
- Check the leaves and the soil to determine if the plant needs water.
- Water in the early morning or late afternoon, when the sun is cooler.
- Don't over water, it weakens plants and causes many diseases.
- Don't water the leaves but the substrates.
- Water seedlings with proportional amount of their sizes, small seedlings with small amount and large ones with large amount of water.

**Shade**

Nursery plants need to be protected from extreme edaphic factors until they are strong enough to withstand them.
- During germination, use 40-50% shade, reduce the shade with increasing plant age and expose to full sun before the plants are taken to the field.
- Regulate the amount of shade and water together, plants in heavy shade require less water and those in full sun require more water.
- Pollard the branches of natural shade to allow light to enter.
- Adjust the height of the shade with the sun's movement through out the day.

**Pricking out**

For some species having very small seeds and seedlings which need special attention, pricking out (planting seedlings from the germination bed in to pot) should be done as early as possible after germination, before roots grow so long that they could be damaged in the process.

**Root pruning**

In order to strengthen root development, lignification and to balance root and shoot growth root pruning (cutting roots grown out of the bottom of the pots) should be done.

**Shoot pruning**

Cutting of shoots is also another nursery activity needed to control excessive shoot growth, stimulate root growth and harden the stems.

**Hardening-off**

Adapting seedlings to field conditions by gradually reducing the frequency and quantity of watering and exposing the seedlings to full sun light by gradual removing of shades is important before planting in the field.
Stay in the nursery

Different species grow at different lengths of time to reach planting size. In most cases, the pricking and plantable size of most of the seedlings is when they reach about 3-5 and 25-30 cm. height respectively. Growth time required from sowing to germination, pricking and planting size for seedlings of different species are indicated below.

<table>
<thead>
<tr>
<th>Species name</th>
<th>local name</th>
<th>Number of days from date of sowing to:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Germination</td>
</tr>
<tr>
<td>Acacia mearnsii</td>
<td>Lafkaa Faranjii</td>
<td>5</td>
</tr>
<tr>
<td>Grevillea robusta</td>
<td>Muka qawwe</td>
<td>17</td>
</tr>
<tr>
<td>Casuarina equisetifolia</td>
<td>Shuushuwwe</td>
<td>7</td>
</tr>
<tr>
<td>Croton macrostachyus</td>
<td>Bakkanisaa</td>
<td>14</td>
</tr>
<tr>
<td>Calliandra calothyrsus</td>
<td>Kalandraa</td>
<td>5</td>
</tr>
<tr>
<td>Cordia africana</td>
<td>Waddleessaa</td>
<td>16</td>
</tr>
<tr>
<td>Acacia abyssinica</td>
<td>Garbii</td>
<td>7</td>
</tr>
<tr>
<td>Melia azedarach</td>
<td>Meliyaa</td>
<td>23</td>
</tr>
<tr>
<td>Leucaena diversifolia</td>
<td>Lukina</td>
<td>7</td>
</tr>
</tbody>
</table>

Planting

Nursery success is not just a matter of producing healthy and vigorous trees in the nursery. Over all success must include how those trees grow and survive in the field.

- Plant seedlings immediately after they leave nurseries.
- Store in the shade until they are planted.
- Trees should be well watered when they leave the nursery and if store at the outplanting site, they should be watered again before planting.
- Trees should be carefully loaded for transport.
- Throw away damaged trees to reduce the effort to maintain them.
- Remove bags and coiled roots before planting.
- Decide number of plants to be planted per given area.
- Holes should be deep to reduce root exposure above the soil line.
- Plant at the beginnings of the rainy season whenever possible.

Species and provenance selection - what to plant?

- Species

Multipurpose trees and shrubs screening is a sort of matching the species with the site quality, and this is the primary requirement to solve the problems of land degradation, food shortage, fodder, poles/construction materials, fuelwood and other wood products. Be it exotic or indigenous, any tree/shrub species has its own range of biotic and abiotic factors in which it performs with its maximum capacity. Thus, whenever one plans to plant a tree/shrub species in any form, he has to match the site quality with the requirement of the species.

Similarly, a multipurpose trees screening study, *Acacia mearnsii* is the most vigorous and promising under Bako conditions, followed by *Calliandra calothyrsus*. Thus, for the immediate use it is possible to recommend *Acacia mearnsii* and *Calliandra calothyrsus* species for Bako area and for sites with similar agro-ecological conditions with Bako. It is advisable to use *Acacia mearnsii* for boundary planting and woodland establishment as a
source of fuelwood, poles, and stakes, and *Calliandra calothyrsus* for fodder bank, green manure and live fence.

- **Provenance**
  Many tree species grow naturally over a range of sites and locations, and are widely distributed. This wide separation and often isolation of stands may lead to genetically different populations within one species (provenances). These different varieties/provenances often perform differently when tested together on one site. Thus, choosing the right species is not an end in itself. After selecting a species for planting purpose, it is equally important to select the best provenance in order to exploit the diversity that could exist within that species.

Similarly, a provenance study conducted on ten different provenances of *Calliandra calothyrsus* Meissn. from Oxford Forestry Institute (OFI) at Bako revealed significant difference in between the provenances. Generally, performance of provenances from Nicaragua (San Ramon) and Mexico (Ixtapa) were found to be superior to those from other sites/countries, whereas those from Hondurans (La Ceiba), Guatemala (Santa Maria de Jusus) and Mexico (Bombana) were inferior. For Bako area, it is advisable to use seeds from San Ramon and Ixtapa as *Calliandra* seed source.
### Biophysical limits for different tree species

<table>
<thead>
<tr>
<th>Species</th>
<th>Altitude (m)</th>
<th>Temperature (°C)</th>
<th>Rain fall (mm)</th>
<th>Soil type</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Calliandra calothyrsus</em></td>
<td>250-1800 m</td>
<td>20 (22-28)</td>
<td>700-4000</td>
<td>Prefers light textured, slightly acidic soils; it can tolerate infertile and compacted but does not tolerate waterlogged and alkaline soils.</td>
</tr>
<tr>
<td><em>Acacia mearnsii</em></td>
<td>300-2440 m</td>
<td>9-20</td>
<td>500-2050</td>
<td>Flourishes in deep, well-drained, light-textured and moist soils. It thrives in well-aerated, neutral to acid soils, loamy soils, and is highly intolerant of alkaline and calcareous soils. Soils with lateritic pan close to the surface are most unsuitable.</td>
</tr>
<tr>
<td><em>Eucalyptus camaldulensis</em></td>
<td>0-1500 m</td>
<td>3-22 to 21-40</td>
<td>250-2500</td>
<td>Grows best on deep, silty or loamy soils with a clay base and accessible water table. Tolerates waterlogging and periodic flooding. Establishes well in riverine habitats, on alluvial soils that are free of waterlogging and mildly acid to neutral. Loam soil is preferred. It also occurs on clay loam and sand.</td>
</tr>
<tr>
<td><em>Grevillea robusta</em></td>
<td>0-2300</td>
<td>14-23 to 25-31</td>
<td>600-1700</td>
<td>Deep, fertile, sandy loam soils support the best growth</td>
</tr>
<tr>
<td><em>Cordia africana</em></td>
<td>550-2600</td>
<td>-</td>
<td>700-2000</td>
<td></td>
</tr>
</tbody>
</table>
Biomass transfer/green manuring

Biomass transfer is an agroforestry practice that involves using the foliage of selected trees, shrubs and other plants as organic fertilizers or green manure on agricultural fields. Plants that are to be used for biomass transfer (green manuring) should have the following special features:

- Large biomass,
- Capacity to assimilate nutrients and
- Supply additional benefits (fodder, firewood, food, etc.).

*Cajanus cajan* is one of such important leguminous shrub species commonly used as soil ameliorant. In green manuring study maize grain yield is affected by application of *Cajanus* biomass. Applying 4 t/ha *Cajanus* biomass can give a yield advantage of about 87 and 67% over the control plot (without both organic and inorganic fertilizers), but less only by 17 and 3% from the standard plot (plot that received recommended fertilizer rate) for BH-660 and Kulani maize varieties, respectively.

Application of 4 t/ha *Cajanus cajan* biomass is a promising alternative for maize production. Incorporating *Cajanus* foliar biomass into the acidic Nitosols increases maize grain yield both in quantity and quality. This organic fertilizer can give a yield comparable to that of inorganic fertilizer and hence it can serve as substitute for inorganic fertilizer.

**Other advantages of *cajanus* biomass**

- **Cost advantage**

  Unlike inorganic fertilizers, farmers can produce many tones of organic fertilizer like plant biomass. Even for farmers that can afford the costs, inorganic fertilizers may not be available on time due to different reasons and it is economical to use organic fertilizers. In light of the increasing price for inorganic fertilizers but decreasing purchasing power of our farmers and decreasing price for maize grain, using organic fertilizers is becoming inevitable for our condition in the near future.

- **Nutrition advantage**

  Apart from its cost, organic fertilizer is one means of getting organic maize, this was evidenced by higher maize grain obtained in this study due to the application of *Cajanus* biomass as opposed to that of inorganic fertilizer where no considerable effect was noticed on grain quality. Unlike the inorganic fertilizers, another good opportunity with organic fertilizers (tree biomass) is that they also supply additional nutrients that may limit maize production such as potassium and micronutrient. Using tree biomass is thus balanced fertilization as opposed to that of partial fertilization in case of inorganic fertilizers (N and P in Ethiopia).

- **Disease management advantage**

  Grey leaf spot is the most important maize disease in western Oromia. Biomass transfer is one remedy for this problem. Application of *Cajanus* biomass significantly reduces the severity of GLS. The disease severity is lower when *Cajanus* biomass alone was used as compared to when inorganic fertilizer alone was used or when *Cajanus* biomass was used along with inorganic fertilizers, suggesting the potential of *Cajanus* biomass transfer in disease control. Thus the present finding indicates that green manuring by *Cajanus* biomass is one control method for GLS besides increasing maize yield.
Procedures of biomass application
- The *Cajanus* stand will be established on degraded or waste land one year before biomass application.
- The stand will be cut after 9 months when it reached 50% flowering stage.
- The woody and foliar biomass will be partitioned.
- The foliar biomass is dried and kept in sacks up to the day of application, and the woody part will be used as firewood or for construction purpose (e.g. dagalee).
- The biomass is cut from *Cajanus* stand and carried to maize fields and hence its name biomass transfer.
- The biomass is applied into the soil two weeks before maize planting.
- Maize will be planted at the recommended time of planting.

Alley cropping
Alley cropping is an intercropping system that involves managing rows of woody plants with annual crops planted in alleys. Its primary purpose is to maintain or increase crop yields by improving the soil and microclimate and weed control.

- **Maize variety and tree species**
  There is differential response of varieties under different situations; that is, different maize varieties respond differently when alley cropped with different multipurpose tree species. Accordingly, BH-660 outsmarted other varieties in grain yield under *Cajanus* and no-hedge conditions; BH-140 under *Leucaena diversifolia*; and BH-540 under *Calliandra calothyrsus*; but *Kulani* yielded lowest in all cases.

  Generally, however, lower maize grain yield was recorded under plots with hedgerows (alley cropping) than under plots with no trees (monocropping), which might be due to the fact that trees take some space out of crop production.

  Besides, the hybrid varieties (BH-660, BH-540, BH-140) could not yield more than the open pollinated one (*Kulani*) under alley cropping system. This shows that the hybrids are less feasible as intercrops in alley cropping as compared with open pollinated one. This is because the seed cost is considerably higher and also not recycled for the hybrids as opposed to the open pollinated *Kulani*. Though all varieties are similar in biological yield, it is better to use the open pollinated variety (*Kulani*) for alley cropping than the hybrids from the economic point of view.

- **Intra-row spacing and Cutting height**
  At Bako maize grain yield was affected by intra-row spacing of *Calliandra* plants, but not affected by cutting height. Higher intra-spacing (75 cm) gave higher maize yield than the lower ones (25 and 50 cm). But there is no considerable difference in maize yield whether the hedge is cut at the 25, 50 75 or 100 cm height, and any of them can be used as convenient. This may be because once planted, the influence of spacing can’t be changed and difficult to manage as opposed to that of the cutting height, which can be managed by systematic pruning cycle. The closely spaced plants have competed for resources with maize than those widely spaced ones even though closely spaced plants usually give relatively higher biomass for soil amelioration.
Taungya system

Taungya refers to the practice of growing agricultural crops along with trees during the early stage of plantation establishment. It allows farmers to grow annual crops between the newly established trees until the trees shade the crops out, usually for 2 to 3 years. During the first year of tree establishment, there is no difference in grain yield among intercropped maize and different tree species. However, yield of maize is affected by the associated trees (Markhamia lutea, Calliandra calothyrsus, Chamacytisus palmensis, Erythrina brucei, Eucalyptus abyssinica, Acacia cyanophila, Acacia mearnsii, Moringa oleifera and Acacia melanoxylon) during the second year. Competition between trees and maize is not noticed during the first year of tree establishment in taungya system at Bako. The effect of tree species on maize yield becomes apparent later when the trees grow taller starting from the second year, this may be because at the age of one year the trees are at seedling/sapling stage (shorter) and hence pose relatively little shading problem on the intercropped maize. Under Bako site condition, maize can be intercropped safely with trees in a sort of taungya system during the first year without considerable reduction in grain yield so that the idle growing space can be utilized to the maximum, and this can be one way of ensuring food security in the area.

Scattered tree system

The practice of growing scattered trees on cropland is usually based on the protection and management of selected mature trees already on the site. Farmers do have several reasons for growing trees scattered on cropland. Some of the most common are:

- To increase the total yield of mixed products from cropland
- To diversify the range of products
- To increase crop production
- To produce a particularly valuable product in a secure site protected from animals.

The influence of Cordia trees on maize yield may be noticed up to 3 m distance and there may be little, if any, influence up to 6 m and almost no influence at 9 and 12 m distances, but this may not noticed on grain size. Maize grain under the tree canopy is not shriveled. There is differential response of direction to tree management on maize yield; pollarding branches seriously affects maize yield on the western side, whereas not pollarding highly favors maize yield on the same direction. Maize grain yield is lower under the tree canopy as compared to the adjacent open area, even though a horizontal soil gradient study shows relatively higher concentrations in some soil chemical properties under the tree canopy (organic carbon by 13%, total nitrogen by 17%, available phosphorus by 42%) and improvement of soil pH from 5.68 in the open area to 5.93 under the canopy.

Therefore, to minimize yield reduction by Cordia trees systematically pollard the tree (every 2 years) to reduce shading on the crop especially on the eastern orientation, leaving the branches on western side may be possible to increase the tree products without adversely affecting maize yield.
Further reading


Diriba Bekere and Abebe Yadessa (in press). Root deformity problems of widely grown tree seedlings in nurseries around Bako Agricultural Research Center. *In: Forestry and...*


Recommended Soil Fertility Management and Soil Conservation Technologies for Sustainable Agricultural Productivity in Western Oromia

Wakene Negassa, Nega Emiru and Abdenna Deressa
Bako Research Center, P.O. Box 3, West Shoa, Ethiopia

Introduction

The well being of present and future generations depends on the fertility status of soils in agricultural countries like ours. The natural phenomena and interference of man activities are aggravating soil degradation that needs immediate remedies to sustain crop and livestock production and productivity. Many of the soil management technologies are not transferred to the farming communities, although, promising soil management technologies have been generated since 1964 at Bako Research Center. The soil fertility management research has focused on using locally available organic materials such as farmyard manure, green manure, compost, crop residue management, crop rotations, and bone meal along with inorganic fertilizers whereas soil conservation measures dealt with the biological, and physical structures. Soil fertility management and soil conservation practices are the same coin of different phases that one supports the other. The primary objectives of this paper is to assist the subject matter specialists and the development agents to disseminate the existing soil management technologies for the farming communities of western Oromia and similar agro-ecology of the region.

Soil Fertility Management

Currently, due to the ever-increasing price of inorganic fertilizers and its long-term effects on environment, research is focusing on locally available organic fertilizers that are economically feasible, and environmentally friendly. Hence, the methods of using locally available organic fertilizers with inorganic fertilizers were elaborated.

Farmyard Manures

Importance of manures in soil system is:

I. An additional supply of NH₄⁻N
II. Greater movement and availability of P and micronutrients due to complexation
III. Increased moisture retention
IV. Improved soil structure, increase infiltration rate and decrease soil bulk density
V. Higher levels of CO₂ in the plant canopy
VI. Increased pH and base cations
VII. Complexation of Al³⁺ in acid soils
VIII. Increased soil organic matter

The amount of manure that safely added to soil without causing pollution dependent upon

I. Nitrogen content of the manure
II. Climatic condition of the area
III. Amount of residual manure left from a previous additions
IV. Storage and application methods
V. Nitrogen requirement of the crop to be grown
Methods for Field Application

I. Spreading of solid materials when weather, soil, and crop permits.
II. Injecting the slurry of water and manure into the soil or spraying it on the surface.
III. Injecting the slurry into a sprinkler irrigation system.

If the objective is to build soil fertility:
I. Uniformly distributed on the surface and immediately incorporated to the soil and the same is true for crops grown in broadcasting.

If the objective is to feed the crops:
II. Spot application will be adopted for row planted crops such as maize and for most of horticultural crops.
III. Rate of farmyard manure: whatever applied will benefit crops and soils: up to 50 t ha\(^{-1}\) has no harm both on soils and crops.

To conserve the plant nutrients and increase the efficiency of farmyard manure:
IV. Collect fresh farmyard manure under shade for well decomposition.
V. The well-decomposed farmyard manure could be applied at planting.

Recommendation:

I. Four tons per hectare farmyard manure with 100 kg DAP per hectare for maize.
II. Ten tons per hectare farmyard manure with 70 kg urea and 100 kg DAP per hectare for hot pepper. When the lack of inorganic fertilizers encountered, the sole use of well decomposed farmyard manure at the rate of 4 to 12 t ha\(^{-1}\) are economical for both vegetables and cereals crops.

Time and method of application: the well-decomposed farmyard manures and DAP applied in spot for maize at planting and for hot pepper at transplanting. Urea applied at 'babbaqaa' for maize and after one and half months of transplanting to hot pepper.

Compost

Although compost technology is new to Ethiopian farmers in general and to Oromia in particular, it is old soil fertility management system in Asian and European countries. As considerable amounts of decomposable materials are available in western Oromia, the use of compost technology to soil fertility management could contribute much in sustaining soil productivity.

Uses of compost are:
I. Manuring (as fertilizers)
II. Erosion prevention
III. Potting soil
IV. Mushroom growing
V. Fish feed
The following five points should be taken into consideration in compost preparation.

i. **Transportation:** The heap should be situated as close as possible to the source of organic materials and where the compost to be used to save times and labor in transport of organic materials and compost.

ii. **Space around the heap:** There should be enough space around the heap to enable the compost to be turned or examined; a space about 2 to 3 times that of the heap itself is the most practical.

iii. **Air:** Remember that the materials in the heap must be able to get enough air. Therefore, do not put the compost heap right up against a wall or dike so that it could be possible to walk around the heap easily.

iv. **Vermin:** A compost heap should always be outside, and not too close to living accommodation or stables.

v. **Moisture:** The heap must be protected against drying out
   - A shade place out of the wind is ideal
   - A water source near the heap is convenient for sprinkling if too dry weather
   - Under wet conditions the heap will have to be protected against excess water
   - A compost heap under a shade tree will be well protected against excess water
   - Both dry and wet weather conditions are likely to play an important role in determining a suitable place for making a compost heap

**Size and setting up of the heap**

**Size:** The heap has to conform to a certain size; if too broad or too high, aeration is poor.
   - A good basic size is 2 to 2.5 meters wide and 1.5 to 2 meters in height
   - The length depends on the quantity of organic materials but it is better to make a shorter heap quickly than a longer heap slowly
   - It is strongly advised to start with a heap greater than one cubic meter, otherwise, the temperature in the heap remains low and decomposition is too slow and incomplete

**Setting up:** start the heap by the foundation of coarse plant materials so that;
   - The outside air can easily flow in and any excess water flows away more quickly
   - Decomposition is easier if the materials put on in layers
   - Layers of easily decomposable material alternated with material difficult to decompose
   - The individual layers should be preferably not be thicker than 10 cm for plant materials and 2 cm for manure

**Composting Methods**

There are many ways of making compost. The Indore and Bangalore methods are the common ones. The essential differences between the methods will be elaborated below taking into account the factors mentioned before, such as available material and weather conditions. However, the most suitable will depend on individual experience. In the long run, every one must work out a method to suit oneself.
Indore Method of Composting

The indore method is much used for compost in layers. The basis of the heap should consist of branches. The following successive layers are piled on top of this:

I. a layer of about 10 cm material which is difficult to decompose
II. a layer of about 10 cm material which decomposes easily
III. a layer of 2 cm animal manure, if at hand
IV. a thin layer of soil which should come from the top layer of arable land to bring the right microorganisms to the heap.
V. On top of these prepared layers, again 10 cm of difficult to decomposable and 10 cm of easily decomposable material, 2 cm manure and a thin layer of soil is added.

This has to be repeated until the heap has reached a final height of 1.5 to 2 meters. During decomposition, the heap has to be turned over regularly, so that it remains well aerated and all the material is converted into compost.

The first turning over process of the heap:

I. Should be done after 2 to 3 weeks
II. The heap is broken down and built up again next to the old heap
III. The layers are mixed and the heap is as it were, turned upside down and inside out
IV. Again, a foundation of coarse plant material is made first
V. Then the drier and outer, less decomposed part of the old heap is placed in the central part of the new heap
VI. The drier material will have to be watered before the heap can be built up further

The second turning over takes place after 3 weeks of the first turning over and it may even be necessary to turn the heap over again for a third time. Decomposition is complete if the plant material has changed into unrecognizable crumbly, dark masses. Under favorable conditions, the decomposition process in the Indore method takes three month, but under adverse conditions it may take longer than 6 months.

Bangalore Method

The heap is constructed in a similar way to the Indore method. Here too, a compost heap of several layers is set up in a week’s time. It differs from the Indore method as follows: A few days after completion of the heap, it is completely covered with mud or grass sods, thus closing it off from outside air. Decomposition of organic material continues, but now other types of microorganisms keep the processing going. These microorganisms decompose the materials much more slowly. Therefore, it takes longer before compost is formed than in the Indore Method, although the quality of the compost is about the same. Compost should be used as quickly as possible; otherwise it will lose its fertility. To keep compost quality:

I. The compost should be covered against rain and sun
II. The rain-washes out the nutrients and the sun can cause burning
III. Some useful covers are: banana leaves, or a sheet of plastic
IV. If the compost is left too long, it may also become a breeding place for unwanted insects
Compared to fertilizers, compost contains considerably less nutrients, which are also much more gradually released to the plants. So, if compost is to be used for fertilizing, 2 to 5 tons per hectare are needed. However, compost has obvious advantages over chemical fertilizers:

I. It contains an abundance of essential microelements
II. The nutrients are made available for plant growth more slowly
III. It improves the soil structure

**Recommendation:** For maize and hot pepper, 5 t ha\(^{-1}\) compost with 35 kg urea ha\(^{-1}\) and 50 kg DAP ha\(^{-1}\)

**Time and method of application:** The compost and DAP applied at planting for maize and at transplanting for hot pepper. Urea is applied at ‘babbaqaa’ for maize, and one and half months of transplanting for hot pepper. If the shortage of inorganic fertilizers is encountered, sole application of compost at the rate of 5-tons ha\(^{-1}\) is economical. The same recommendation could be used for the other cereals and vegetables production.

**Green Manure**

Green manuring is an arable farming practice in which undecomposed green plant material is incorporated into the soil in order to increase its immediate productivity. This material may be either obtained from quick growing green manure crops grown in situ or harvested elsewhere.

**Benefits of Green Manure**

There are four major benefits from the use of green manures in a crop rotation.

I. Organic matter addition
II. Nitrogen addition (if the green manure is legume)
III. Nutrient conservation
IV. Ground cover during erosion prone periods of the year

**Forms of Green Manuring**

Green manure crops can be planted in different combinations and configurations.

**Improved fallow:** Replacing natural fallow vegetation with green manure crops to speed up regeneration of soil fertility and permit permanent cultivation. These green manures may be left to grow for one or several years, or during the dry seasons.

**Alley cropping:** A form of simultaneous fallow in which quickly growing trees, shrubs, (usually legumes) or grasses are planted in rows and are regularly cut back; the pruning are used as much or worked into the soil in the alleys between the rows.

**Integration of trees into cropland:** as found in traditional farming system. For instance in Ethiopia *Acacia spp* (Laaftoo), *Erythrina poeppigiana* (Waleensuu), *Cordia africana* (Waddeessa), *Faidherbia albida* (gosa laaftoo) etc growing among the crops are regularly cut for mulch material to maintain soil fertility.

**Relay fallowing by sowing bush legumes among the food crops:** After they have established and in the dry season, using the cut green biomass as mulch or working into the
soil as examples, live mulch, shaded green manures, azola, and blue green algae. Green manuring is particularly important for humid areas.

Desirable plant characteristics suitable for green manure

I. A crop is economically not feasible for green manure when it requires the entire cropping season for its growth
II. The most desirable green manure crops occupy for the part of the season without interference with the regular crops in the rotation
III. The green manure crop should be easily established and should grow quickly
IV. It should produce an abundant growth of succulent tops and roots in a short time
V. Its growth habit should encourage ground cover soon after its establishment
VI. Green manure crops should have ability to grow on poor soils because these are the ones where the beneficial effects are most needed
VII. When other conditions are equal, it is better to make use of a leguminous green manure in preference to a non-leguminous one because of the nitrogen gained by the soil and the organic activities it promotes.

Suitable Plants as green manure

<table>
<thead>
<tr>
<th>Leguminous</th>
<th>Non-leguminous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crimson clover</td>
<td>Australia Winter pea Cowpea</td>
</tr>
<tr>
<td>Bur clover</td>
<td>Alfalfa</td>
</tr>
<tr>
<td>Les pedeza</td>
<td>Red clover</td>
</tr>
<tr>
<td>Crotalaria</td>
<td>Soybean</td>
</tr>
<tr>
<td>Vetch</td>
<td>Canadian field pea</td>
</tr>
<tr>
<td></td>
<td><strong>Non-leguminous</strong></td>
</tr>
<tr>
<td>Rye</td>
<td>Mustard</td>
</tr>
<tr>
<td>Sudan grass</td>
<td>Barley</td>
</tr>
<tr>
<td>Oats</td>
<td>Rape</td>
</tr>
<tr>
<td>Noug</td>
<td>Sunflower</td>
</tr>
</tbody>
</table>

Practical Utilization of Green Manure

The place of green manures in practical cropping systems will vary according to:

I. Climatic conditions
II. The nature of the cropping
III. Fertilizing systems

In regions where nitrogen fertilizers are still quite costly and inaccessible, leguminous green manures are clearly beneficial. Green manures as soil-and-nutrient-conserving crops have application under most humid climatic conditions. Even in countries where fertilizer nutrient supplies are plentiful and cheap, the use of cover crops to regulate the flow of nutrients from agricultural lands into streams and lakes is important. Green manure crops can contribute 30-60 kg N ha\(^{-1}\) annually to the subsequent crops. The cumulative effects of continued use of green manure are important, not only in terms of nitrogen supply but also with regard to soil organic matter and other elements such as phosphate and micro-elements which are mobilized, concentrated in the top soil and made available for plant growth. Deep-rooted green manure crops in rotation can help to recover nutrients leached to the subsoil. Under high rainfall conditions, especially at the start of wet season, permanent deep-rooted systems
as some trees are needed for recycling. Most food crops have shallow roots, which develop too slowly to intercept the mineralisation flush when the soil is first wetted. Some leguminous cover crops also appear to be able to develop deep-root systems on acid soils in the humid tropics.

Recommendation

*Dolichos lab lab* as improved fallow along with 100 kg urea and 50 kg DAP per hectare and *Mucuna* as improved fallow along with 67 kg urea and 33 kg DAP per hectare could be used for maize production. If the shortage of chemical fertilizers exists, *Dolichos lab lab* and *Mucuna* will be used as precursors for crop production.

Crop Rotation

Crop rotation is generally defined as a more or less regularly recurrent succession of different crops on a single piece of land. The crops used are commonly cultivated crops: small grain, grass, legume, or legume-grass mixture. Of these, the cultivated crop exposes the soil to the maximum erosion; the small grain allows less erosion; and grass or legume-grass crop effectively controls erosion during the period of its life.

Purpose and Advantages

Crops are rotated in order that:

I. Soil productivity may be preserved  
II. Crop yield is maintained

These objectives are gained because the practice of crop rotation systematizes farming:

I. Saves labor  
II. Helps to control weeds, insects, and plant diseases  
III. Aids in maintaining soil organic matter and nitrogen  
IV. Lessens soil loss through erosion

Recommendations

Noug, sunflower, haricot bean, field pea, rapeseed and faba bean, are important precursor crops for cereals production. Reasonable yield could be obtained even without supplementing with chemical fertilizers.

Crop Residues Management

Removing or burning of crop residues is depleting the fertility status of a given land. To maintain and improve soil fertility status, the nutrients removed through grain, crop residues, and erosion should be replaced, other wise the soil fertility status will be depleted.

Recommendation

The traditional crop residues management systems should be avoided. Any crop residues should be incorporated into the soil directly or indirectly. As crop residues decompose
gradually, may not give immediate benefit for the following crop. To alleviate the incidence of pests and diseases, crop rotation is playing significant role. Rotating cereals with legumes and vice versa is fundamental.

Bone Meal and Rock Phosphate

Bone meal and rock phosphate are the only phosphate fertilizers that fit to acid soils. Because DAP and TSP are aggravating soil acidity when used on acid soils.

Recommendation

The integrated use of 100 kg bone meal per hectare or 100 kg rock phosphate along with 50 kg DAP per hectare could be used for maize production. In the absence of DAP, the sole application of 200 kg bone meal or 200 kg rock phosphate is promising for maize production. The recommended rate of urea for maize was kept constant in both cases i.e. 200 kg urea per hectare.

Method and time of application: the bone meal, rock phosphate and the DAP will be applied at planting in spot along with 100 kg urea per hectare. The remaining 100 kg urea per hectare will be applied at ‘Babbaqaa’.

SOIL AND WATER CONSERVATION

Soil erosion by water is the most important land degradation problem in the humid tropics, which is aggravated by the natural phenomena and interference of human activities. For instance, in western Oromia, intensive tillage practices, cultivation of sloppy land, deforestation, and overgrazing are accelerating soil degradation. To alleviate the problems, biological and physical soil and water conservation measures are forwarded.

Conservation Practices for Different Land Use

Cropland

Different soil and water conservation measures are applied for the management of croplands so that its productivity could be sustained. These conservation measures are enumerated below:

i. Reduced (minimum) tillage

I. Conservation tillage has been more extensively tested and adopted for maize than for any other crop in the world.

II. Land preparation

This conservation tillage practice involves a single plowing event (one traditional maresha pass), which is made for breaking apart the bonded soil mass into small pieces.

III. Planting

Planting is made in rows at the first plowing with 5-10 cm depth from early to mid May. The spacing will be 50 and 80 cm between plants and rows, respectively.

IV. Fertilizer and seed rate

Optimal fertilizer rates was 200 kg urea and 100 kg DAP with 25-30 kg seed rate per hectare

V. Use of Herbicide
Round up is a non-selective herbicide used as pre-planting herbicide at 3 liter per hectare to kill the actively growing weeds while matured weeds need to be removed by hand. It should be sprayed 7-10 days prior to the time of planting. A mixture of 100-liter of water with 3 liter of the herbicide should be made to spray one hectare of land. In practical terms, using Jackto Brazilian type, 16-liter capacity and finely pored nozzle manual sprayer, i.e. 480 ml of round up is required to form the solution with 16-liters water.

Lasso atrazine, a selective herbicide for post-emergence weed control and should be applied at 5 liter per hectare. A mixture of 5 liters Lasso atrazine and 100 liters water should be sprayed to one hectare. This herbicide should be applied within 3 days after planting, securing the availability of sufficient moisture within the soil system.

VI. No disturbance of the already sprayed land by human and livestock until two months to secure sheath formation of the herbicide on the soil surface that protect the emergence of weeds.

VII. Well calibration of the volume of the liquid to be used to cover one hectare of land should be done based on walking speed of the sprayer.

ii. Contour strip cropping

I. This practice is appropriate on slopes subject to sheet and rill erosion where narrow strips of cultivated land, hay, and grain crops check the rate of runoff.

II. The fields are arranged in narrow strips on the contour across the slope, or at right angles to the slope of the land alternating the tilled crops.

III. A one-meter wide grass strip can be used every 10 rows of maize crop (7.5 meter).

IV. In contour strip cropping, as in other types of stripping, the growth of the crops should be in such away that it develops maximum foliage so as to withstand the attack of heavy rain. In order to get good foliage, the seed rate of legume and pulse crops may be doubled or tripled according to requirements.

V. On longer slopes, strips nearer the lower part of the slopes should be narrower than those at the top, because of the accumulated runoff.

iii. Buffer or spreader strips

I. It is a more or less permanent contour strip of variable width, planted to grass or other erosion resistant vegetation, which is not a part of the regular farm rotation that may or may not be harvested.

II. The area planted to erosion-resistant crops under buffer-strip system is smaller than under contour strip-cropping system.

III. The buffer strips usually vary between three and seven meters in width depending on the slope length; wider for higher slope and narrower for lesser sloppy lands.

IV. These strips can be used on farms where land is valuable and erosion resistant crops have no sale value.

V. In rotated cultivated fields, buffer system has little practical value. However, where erosion-resisting crops do not occupy a sufficient part of the field to allow strip cropping, buffer stripping offers the next best method of vegetative erosion control.

VI. The most effective use of buffer strips is on critical slopes and other vulnerable parts of cultivated fields, which cannot be controlled by annual crops or by ordinary strip cropping methods.
iv. Mixed cropping

I. It is a practice of planting a crop into another crop prior to harvest and is a method that helps in buffering for family income, providing multiple products and integrates farming system in concrete terms diversification.

II. The associate crop should have better land coverage than the major crop to protect the attack of the farm field by heavy rain.

III. Maize as a major crop can be planted either with haricot bean, soya bean or forage legumes. Haricot bean and soybean are planted 35 days after the planting of maize. Forage grasses such as *Chlorus guyana* can be planted after the maize plant has passed slashing stage (60 days after its sowing).

IV. The population of the associate crop in this cropping system is 75 per cent of the normally recommended seeding rate in its mono-cropping system. For instance, 75 per cent of the normally recommended sowing rate, 60-100 kg ha⁻¹ of improved haricot bean is recommended in this cropping system if haricot bean is used as an associate crop.

v. Contouring (*dalga qotuu*)

I. Contouring is tillage practice in which plowing, planting and cultivation is carried out on the contour rather than up-and-down the slope.

II. It is practiced on fields with only modest slopes. In this tillage practice, the traditional plowing equipment *maresha* is expected to form ridges along the contour thus interrupting the fast moving runoff.

III. Even though, its effectiveness varies with slope steepness and slope length, it can be used as a sole conservation measure for lengths less than 180 m at 1° steepness.

IV. The technique is only effective during storms of low rainfall intensity. Protection against more extreme storms is improved by supplementing contour farming with strip cropping.

vi. Cutoff drain (*boraatii*)

I. It is a channel used to collect runoff from the land above and divert and dispose it safely to a waterway or river, thus protecting the land below from excessive soil erosion.

II. The channel bed must be planted with erosion resistant grasses and should follow minimal slope gradients across its length to minimize the running speed of the runoff.

III. The grasses can be utilized in cut and carry system for extra uses.

IV. All farmers that have land on and below the cutoff drain outlets are responsible for maintenance and repair.

V. Grass species such as *Chloris guyana* ("*masaabaa*”) and Vetiver grass are recommended for channel bed stabilization and plantation should be done at early onset of the rainy season to protect the grass seeds washed away by runoff.

VI. If overflow occurs, the dimensions must be increased to secure free boarder

VII. Assuming 70 mm hr⁻¹ storm intensity, poorly grassed cutoff drain, a hilly pasture above the drain, clay loam soil, and a free boarder of 20 cm in the drain, the dimensions of the cutoff drain, given for different sizes of the catchments above the drain are as follows:
vii. Contour soil bunds (daagaa)

I. Contour bunds are earth banks, 1.5 to 2m wide, thrown across the slope to act as a barrier to runoff, to form a water storage area on their up slope side and to break up a slope into segments, shorter in length than is required to generate overland flow.

II. They are suitable for slopes of $1^\circ$ to $7^\circ$ and are frequently used on small-holdings where they form permanent buffers in a strip-cropping system being planted with grasses or trees.

III. The banks spaced at 10 to 20 m intervals are generally hand-constructed.

IV. There are no precise specifications for their design and deviations in their alignment up to 10 percent from the contour are permissible.

V. The effectiveness of contour bunds to control erosion varies with slope and they would only reduce soil loss sufficiently on the lowest of the slopes. The contour line making process can be made by line level or locally workable instrument: A-Frame.

Marking Contour Lines with the Line Level

Water level, thin plastic rope of 11 m long, 2 wooden poles with 2 m long marked at every 10 cm interval, meter-band or meter-stick and pegs for marking the ground are required.

Preparation

Fix the thin rope with each end to one wooden pole so that exactly 10 m of rope are between the poles. Mark the middle of the rope at 5 m with knod. Hang the small water level in the middle of the rope. Three to four people are needed to survey a level line and to mark it on the ground. Two of them are adjusting the poles when one looking at the water level and the other marks the located contour lines with pegs.

Marking the Contour Lines

Before any operation cut tall grasses and remove other obstructions so that you could move easily. Begin near the highest points and drive the right pole at the boundary of the area. Adjust the other pole until the water level become level. Remove the right pole and transfer it to front side and repeat the first step until you get the water level leveled. In this way, proceed across the slope and survey 10 m at a time, in difficult topography only 5 m (half the rope). Continue marking contour lines until you reach the other side of the field and come to the next contour line. Repeat all these processes until you reach the bottom of the hill. The vertical distance/interval depends on the degree of slope and soil type, shorter for more sloppy topography and less stable soils.
Grazing Land

High population pressure is extending agricultural activity to marginal land and is shrinking grazing lands. High cattle population is also currently contributing for land degradation that paves the way for desertification. Therefore, the following soil conservation measures are recommended for grazing land.

i. Cut and carry system

It is a conservation based management practice of using forage species for stall-feeding.
I. This practice is applied only after the grass has recovered or if certain types of grass, legumes or bushes have to be removed.
II. Higher productivity will result due to the protection of livestock trampling and extreme grazing down to the roots.
III. The cutting frequency depends on the regenerating capacity of the grass species, faster for rapidly growing species and lower for slowly growing.
IV. This practice could be good for private pastures and farm sides where random grazing is difficult.

ii. Rotational grazing: Rotational grazing is land management for periodic recovery of the grassland.

iii. Continuous grazing

Continuous grazing needs careful decision on the number and type of livestock taking into account the regenerating capacity of the grass species. In both rotational and continuous grazing, the carrying capacity of the land should be considered.

Abandoned Land

Because of natural phenomena and human activities, considerable hectares of lands are yearly abandoned. Unless gradually recovered, the live and livelihood of every living creatures could be challenged. As a result, the recovery of abandoned land is urgently required with the following methodologies.

i. Area closure

I. It is a conservation technique by which livestock is not allowed to graze, and no human interference tolerated for 3-5 years, until 80% natural grass cover is obtained.
II. Utilization of these areas has to be planned and initiated as soon as a satisfactory state of recovery has been reached.
III. The fate of this land after rehabilitation is determined based on the conservation status and community’s local need. It can be used as grassland or developed into forestland or any further uses that ensures its sustainable use.
IV. Live fencing with *Dovyalis abyssinica* (“Komshoo”), *Pterolobium stallatum* (“Qonxiir”) or *Agave sisalana* (“Quacca”) is possible to demarcate its boundary and exclude livestock from grazing and people from interference.
ii. Tree planting

I. It is an activity to improve the vegetative cover of the ground thereby reducing runoff and soil erosion and producing wood. The tree roots stabilize the soil, and the tree canopy protects the ground from raindrop impact.

II. Proper nursery and field management practices should also be provided to the plant.

III. It is suggested that any multipurpose tree species with wider canopy such as *Mangifera indica*, *Cordia africana* etc. are typical plant species for soil and water conservation purposes.

Conservation Approaches

Local level participatory planning approach

I. In this approach, farmers get considerable amounts of participation from problem identification through planning to implementation thereby develop a sense of ownership.

II. The technical staff from the Woreda Natural Resources Management and Environmental Protection Bureau along with the local farmers clearly identifies and set about the various conservation needs of their area.

III. The government body, which already has the information about needs of conservation in different Peasant associations, then call the local farmers for a general meeting for final decision, and decides where and how much conservation work should be carried out within a specified period of time.

IV. The soil and water conservation activities usually carried out in off-season when farmers are relatively free from burden of farming activities.

Socio-economic and Institutional Issues

There are many socio-economics and institutional problems that hindered the adoption of soil and water conservation technologies by the farming communities. Recommendation was forwarded to alleviate some of the problems.

Incentives

V. It should be appreciated that farmers receive incentives that encourage them to participate in soil and water conservation activities such as provision of seeds, seedlings, herbicides, pesticides, and hand tools and credit.

Participation of farmers

VI. Enhancement of the voluntary and active participation of farmers from problem identification to implementation is crucial.

VII. Farmers should have active role in identifying, and planning where and how much conservation work should be carried out

VIII. The Woreda Natural Resources Conservation Officials should play significant roles in identifying knowledgeable persons from the farming community and in facilitating of communities to produce action plans.

IX. The active involvement of religious organizations in influencing farmers’ attitudes towards natural resource management also should not be neglected.
Unit of intervention

X. It is highly recommended that taking watersheds as a unit of intervention makes it planning, implementation, monitoring and evaluation levels of conservation activities simpler. Since it incorporates up and down streamers within given watersheds in which action of the up-streamer affects down streamers. Even it is a convenient conservation unit in monitoring, evaluation and impact assessment duties of conservation related activities.

XI. Therefore this makes it watershed approach useful to take watersheds as whole and implement conservation practices over the whole area rather than piecemeal.

Local institutions

XII. The local community should be enhanced to establish their own local rules and regulations that promote the sustainable use and management of natural resources.

XIII. Institutions such as producers/growers cooperatives, peasant associations, credit associations, etc are strong institutions to bring the farmers together for a common goal. Through these rules and regulations the responsibilities of individuals and group of individuals is determined. The Woreda administrative bureau should support in facilitating for people to respect the rules and regulations of the institution. Such institutions can assist in mobilizing and organizing land users in managing equipments, provide support for conservation activities and approve who do not respect locally established rules and regulations for communal resource management.

XIV. Re-afforestation and soil and water conservation are among activities that could easily be coordinated by such institutions.

For Further Reading


Recommended Research Results for Forage Production in Western Oromia

Diriba Geleti
Animal Feeds and Nutrition Division
Bako Agricultural Research Center, P.O.Box 3, Western Shoa, Ethiopia

Introduction

The Western part of Oromia is diverse in its agro-ecology and endowed with a wealth of indigenous livestock and pasture species. The different parts of the region experience warm-dry and warm-wet tropical, and cool temperate climates. Almost in all agro-ecologies livestock are the integral parts of the production systems. Except in hot humid environment where trypanosomiasis pose a serious problem feed shortage both in quality and yield is the number one problem of improved livestock production in the region.

Natural pastures and crop residues are the traditional feed resources, with the former gradually shrinking in size as a result of increase in human population and subsequent need for cultivable land. Future potential for livestock feed rests on crop residues and cultivated forages and to some extent on agro-industrial by products. Feed resource research has an age of more than 30 years at Bako Research Centre. Over this period, many aspects of natural and improved forages, agricultural and agro-industrial by products have been studied and a lot of technologies were developed. As the aim of this document is to raise the awareness of the farming community about the recommended technologies capable of addressing their pressing problems, only research findings assumed to fulfil this purpose are summarized and compiled in a usable form in this paper.

Natural pasture: Potential Opportunities for Improvement

- Despite the steady expansion of cropping into virgin lands that exclusively used in the past for grazing, natural pastures still remain the major contributors of feeds for ruminant livestock in the region.

- Wider variability in topography, climate and soil types have great influence on pasture productivity and species composition. This has a great implication on the improvement interventions to be taken to enhance their productivity.

- The dominant pasture species found in different ecological zones of the western region are given in Table 1 below.
Table 1. Dominant natural pasture species of natural grasslands in Western Oromia.

<table>
<thead>
<tr>
<th>Study site</th>
<th>Altitude (masl)</th>
<th>Dominant pasture species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bako</td>
<td>1600-1800</td>
<td>Hyperrhenia anamesa, Sporobolus pyramidalis, and Neotonia weightii</td>
</tr>
<tr>
<td>Assosa</td>
<td>1600</td>
<td>H.filipendula, H.pilgerana, Arthraxan mican, and Crotalaria microcarpa</td>
</tr>
<tr>
<td>Bandira</td>
<td>1700-1800</td>
<td>Hyperrhenia, Exotheca abyssinica, and Aricestida adoens</td>
</tr>
<tr>
<td>Nekemte/Arjo</td>
<td>&gt;2000</td>
<td>Pennisetem adoens, P.schimperi, Andropogon abyssinicus, Trifolium spp., Digitaria spp., Eragrostis spp., Exotheca abyssinica, H.tuberculata and Festuca abyssinica</td>
</tr>
</tbody>
</table>

- The most abundant pasture species in the highland grasslands, *Pennisetum adoens* and *Andropogon abyssinicus*, are good for grazing and hay making and the farmer should be advised to make use of these species.

- The fairly good proportion of *Trifolium* species in these pastures further enhances their feeding value and botanical composition.

- The problem associated with highland pastures is thus of management than species composition. Here overgrazing and soil nutrient depletion are the causes of poor pasture productivity. Efforts should be made to reduce the degradation risks associated with these two factors in these areas.

- Most of the predominant species in the grasslands of the mid altitudes listed in Table 1 are of poor grazing value. Rapid physiological maturity and low indigenous legume proportion further undermines their potential to supply sufficient nutrient for grazing animals. This implies that early harvesting and incorporation of improved legumes in to the pasture system is very important.

Agronomic management practices for natural pasture

- A number of agronomic possibilities exist to improve the quality and DM yield of natural pastures.

- Much of the natural pasture improvement research undertaken so far at Bako Research center centred around mineral fertilization, manuring and incorporation of improved pasture species.

- In the highlands the use of 23 kg nitrogen per ha and 46 kg phosphorous per ha on natural pastures increased DM yield and crude protein content and is recommended for natural pasture improvement.

- Urea and TSP (triple super phosphate) each applied at 100 kg/ha or barnyard manure at the rate of 12 kg/ha is recommended for the mid altitude pasture.
• With the intention of improving the proportion of valuable pasture species and productivity of natural pastures in the mid altitude, so many improved pasture species and pasture introduction strategies have been recommended.

• Using a cultivated strip of $1.25m^2$ (0.5*2.5m) and a between strip distance of 1.5m, *Stylosanthes*, *Macroptilium*, *Desmodium*, and *Cajanuss cajan* lines can successfully established in *Hyperrhenia* dominated natural pasture.

• Preparing a seed bed by burning a pasture land at about the start of the main rainy season and incorporating the sown legumes into the soil by animal trapling improves DM yield and vegetation composition of natural pasture and the introduced legume species, like *Stylosanthes*.

• Proper pasture management practices like optimum stocking rate, bush control, appropriate rest period, etc, should precede the above improvement interventions.

• Adjusting the livestock number in accordance with the available herbage is crucial for the well being of the pasture and grazing animals.

• In the highland, a well managed pasture could to sustain two to three TLU (tropical livestock unit)/ha (July-Dec.) or 10 to 15 sheep/ha, on a year round basis.

• In the mid altitude, a stocking rate of two TLU was recommended but there is a strict need of supplementation in the dry season.

**Improved pasture and fodder crops recommended for western Oromia**

Table 2. Promising improved forage crops, their areas of adaptation and possible production strategies.

<table>
<thead>
<tr>
<th>Major zone</th>
<th>Pasture/fodder crop species</th>
<th>Production strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-medium altitude (1000-1800 masl)</td>
<td>Browses: <em>Leucaena leucocephala</em>&lt;br&gt;<em>L.pallida</em>&lt;br&gt;<em>L.diversifolia</em>&lt;br&gt;<em>Gliricidia sepium</em>&lt;br&gt;<em>Sesbania sesban</em>&lt;br&gt;<em>Calliandra calothyrsus</em>&lt;br&gt;<em>Cajanuss cajan</em>&lt;br&gt;Perennial forage legumes: <em>Stylosanthes guianensis</em>&lt;br&gt;<em>S.hamata</em>&lt;br&gt;<em>S.scabra</em>&lt;br&gt;<em>D.unicenatum</em>&lt;br&gt;<em>D.intortum</em>&lt;br&gt;<em>M.atropurpureum</em>&lt;br&gt;<em>M.axillare</em>&lt;br&gt;Annual forage legumes: <em>Lablab purpureus</em>&lt;br&gt;<em>Vicia atropurpurea</em>&lt;br&gt;<em>V.dasycarpa</em>&lt;br&gt;Herbaceous grass species:</td>
<td>SF, AC, RD, GM, LF&lt;br&gt; SF,US,RD,ONP&lt;br&gt; SF;GM</td>
</tr>
</tbody>
</table>

84
<table>
<thead>
<tr>
<th>High altitude (&gt;1800 masl)</th>
<th>Chloris gayana</th>
<th>SF,US</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Panicum coloratum</td>
<td>SF,US</td>
</tr>
<tr>
<td></td>
<td>Pennisetum purpureum</td>
<td>SF,BU,RD</td>
</tr>
<tr>
<td></td>
<td>Setaria secalata</td>
<td>SF,BS</td>
</tr>
<tr>
<td></td>
<td>Melinis minutiflora</td>
<td>SF</td>
</tr>
<tr>
<td></td>
<td>Sorghum sudaness</td>
<td>SF</td>
</tr>
<tr>
<td></td>
<td>Sorghum alumni</td>
<td>SF</td>
</tr>
<tr>
<td>Browses:</td>
<td>S.sesban</td>
<td>SF,AC,RD,GM,LM</td>
</tr>
<tr>
<td></td>
<td>Chamaecytisus palmensis</td>
<td>SF</td>
</tr>
<tr>
<td>Herbaceous forages</td>
<td>Avena sativa</td>
<td>SF</td>
</tr>
<tr>
<td></td>
<td>Vicia dasycarpa</td>
<td>SF,GM</td>
</tr>
<tr>
<td></td>
<td>V.atropurpurea</td>
<td>SF,GM</td>
</tr>
<tr>
<td></td>
<td>Native Trifolium spp.</td>
<td>SF,US,GM</td>
</tr>
<tr>
<td></td>
<td>Beta vulgaris</td>
<td>SF</td>
</tr>
</tbody>
</table>

'SF- Sole forage, BS- Bund stabilizer, US- undersowing in cereals, AC - Alley cropping, RD- Rehabilitating denuded sites, GM - Green manuring, ONP - Oversowing in natural pasture, LF - Live fence

Recommended Agronomic Practices

Seed bed

- Seedbeds meant for herbage production should be clean, firm and fine. Three times plowing when oxen are used was observed to give good result.

Fertilizer use

- The use of fertilizers on forages under smallholder farmers situation is conditional. In home gardens where the soil fertility is often high due to frequent disposal of household leftovers and manures, no need to worry about fertilizers.

- But in depleted fields judicial use of fertilizers or manures is important. Under such circumstances farmers can apply whatever amount of fertilizer/manure they can afford; but for best effect one should apply 100 kg DAP (diammonium phosphate)/ha at planting of all forage crops and an additional 50-100 kg urea/ha for perennial grasses annually.

- In the highlands, the DM yield of indigenous clovers was reported to increase sixfold with application of 30 kg P/ha and hence this rate is recommended.

- In mid altitudes, the persistence of herbaceous legumes was extended by annual top dressing of phosphorous above 18 kg/ha. But responses of tree legumes to phosphorous fertilizer was either minimum or inconclusive.

- In heavy rainfall areas, split application of urea gives good result.

Seed scarification

Seed coat dormancy (hard seededness) is common in legumes and can be overcome by:

- **Scarifying** - Seeds can be scarified by abrasion using sand paper (e.g. Clovers, *Stylos*, *Desmodium*, etc.)
• **Hot water treatment** - The seeds can be immersed in boiling water for not more than two minutes (e.g. *Leucaena*).

**Seed rates**

- The quality and size of the seed, the fertility status of the soil, the purpose of the crop (herbage or seed), pattern of planting all influence seed rate.

- For more practical purpose herbaceous forages can be planted in the following densities: small seeded (e.g. *Stylo*): 10 kg/ha

- Medium seeded (e.g. *Vetch* and *Macrotyloma*): 15-25 kg/ha.

- Large seeded (e.g. *Dolichos*): 35-40 kg/ha.

- For browsers, 1 x 0.5 and 1.5 x 1.0 inter- and intra row spacing can be utilized for narrow and wider canopy groups, respectively.

**Time of sowing**

- Always start planting at a time when the rainfall stabilizes. Early planting will enable the crop to take the full advantage of the main rainy season.

**Mode of planting**

- Broadcasting and row planting are the two modes of plantings used in forage crops. Mode of planting is largely the function of the architecture of the crop.

- Browsers, vigorously sprawling herbaceous legumes (e.g. *Stylo*) and tussock forming grasses (e.g. *Panicum*) are more suited for row planting.

- Broadcast planting on the other hand, must be employed for twining legumes (e.g. *Siratro*), less competitive forages (e.g. fine stem stylo) and stoloniferous forage grasses (e.g. *Lotononis* and *Rhodes*).

**Depth of sowing**

- As a thumb rule a seed should not be covered by a soil more than its diameter. It is always safer to plant shallow than deep.

- Packing by animal, trampling and rolling following sowing improves the seed and soil contact and increases percent germination.

**Utilization**

- Cultivated forages can be grazed in the field, utilized as a green feed or conserved in the form of hay or silage for later use in lean period.
• Fodder crops with thicker stems like maize, sorghum and napier grass can more appropriately be utilized as green feed or silage.

• Study that compared the quality of hand viz machine chopped; small viz big silo of the above fodder crops and *Hyperrhenia* pasture have underlined the importance of machine (fine) chopping and the use of silos larger than 17m³ capacity

• In few forage legumes, the quantity at offer and the developmental stage during feeding may pose some health problems to animals.

• But such problems could hardly be encountered if the legumes are made to constitute not more than 30% of the daily diet (DM bases) of the animal.

• However, if availability is not limiting, most improved forages can be fed to appetite.

• The most practical way of improved forage legume utilization is to use them sparingly as a supplement to poor quality forages, say up to 30% inclusion.

**Aspects of cutting management**

• Cutting too low kills *Panicum* and Cook stylo. One always has to take care not to cut below the growing point.

• Some species are tolerant to close defoliation. In seed crops, severe cutting affects the days of emergence and number of heads/m² as compared to lenient cutting.

• The time of clear cutting must be based on the rainfall distribution. For grasses, after cutting, N should be applied to increase the number of forth coming tillers.

• Above ground height of 10-15 cm for erect or semi-erect and 5-10 cm for prostrate species can be taken as a reference. For tree legumes, however, cutting should be made 0.75 m from the ground.

**Provision of supporting structures for seed production**

• Growing of twining legumes such as *Centrosema pubescens*, *vetches*, *Siratro*, etc. on trellises leads to increased seed production.

**Harvesting time for forage**

• Harvest when 50 to 75 percent of the plants flower.

**Optimum time for seed harvest**

• Observe the colour change or squeeze with your fingers or bite it with your teeth.

• Harvesting could be done by sickle, plucking and shaking. Seeds have to be harvested as soon as they are ready for harvest. Any further delay causes shattering loss and insect and disease damage.
Seed drying

• After harvest, seeds have to be sweat to complete maturity and facilitate easy dropping of seeds. Seed drying can be natural or artificial.

• The seed drying temperature should not exceed 35-40°C and the moisture lost in 24 hours should not be above 5%.

• As the temperature in open air exceeds 40°C, direct sun drying is dangerous because it causes seed cracking.

• Shade drying is preferable but use raised drying containers so as to allow free air movement underneath.

• Care must also be taken not to dry seeds on metal sheets for seed on such materials could quickly be damaged by heat.

Seed storage

Ideal seed stores should fulfill the following conditions:
• Cool, low humidity
• Insulated with reflective buildings
• Long axis of the building should face N-S direction and air conditioned.

Forage production strategies

• Improved forage crops are high in essential nutrients and DM production potential.

• On-farm forage development programs at farm level requires, a number of inputs such as: land, labor, fertilizer, etc. whose relative abundance vary from household to household.

• There are, however, quite a number of options available for farmers of different resource endowment. Few are given below.

Pure (mixed) stand

• If resources are not limiting improved forage crops can more successfully be grown in pure stand or in a mixture of one or more forage species.

• For Bako and other areas with similar environmental conditions, Rhodes/Cook stylo, Rhodes/Siratro and Molasses/Cook stylo are the most promising grass-legume mixtures.

Strip planting/over sowing in natural pasture

• Establishing forage legumes on cultivated strips and on burnt pasture land demands comparatively less input and is appropriate for resource poor farmers. This could be done in the immediate vicinity of the house and/or stock exclusion areas.
• *Stylosanthes*, *Macroptilium*, Desmodium, Macrotyloma and Cajanus cajan lines were found to be suitable for the improvement of natural pasture of Bako area.

• Similarly, oversowing of Cook stylo on burnt natural pasture, dramatically improved pasture DM yield and average daily gain of cattle.

**Undersowing**

*D. uniceanatum* and *S. guianensis* and the mixture of these legumes with Rhodes grass are capable of establishing when undersown in maize.

• These legumes have desirable characteristics such as deep rooting, persistency, high herbage yield and improving soil fertility and negligible or no negative effect on the grain yield of maize.

**Alley cropping/live fence/shelter belt**

• Forage trees or shrubs can be established in alternated strips with food crops or single/double lines around homestead and field boundaries to fulfill farmers’ need for fodder, fuel wood, erosion control and improvement of the associated crop yield. *Leucaena* and *Sesbania* are the most ideal candidate species identified for these purposes.

**Establishment**

• Most of the species in Table 2, are propagated by seed but *Leucaena leucocephala* and *Gliricidia sepium* can be grown from stem cuttings.

• *Pennisetum purpureum* (Napier grass) establishes exclusively from root splits and stem cuttings.

**Weeding management**

• Owing to variation in climate and weed flora, uniform weed management practice can’t be suggested for the whole part of Western Ethiopia.

• But at early stage of growth, improved forage crops are less aggressive and weed growth have to be avoided altogether.

**Stage of harvest**

• Forage crops should be cut at a growth stage where both DM yield and nutritive value are optimized. This time could differ among the different forage genotypes but safer practical guidelines can be suggested for forage species of broader category.

• Harvesting stage study on *L. leucocephala* shows that cutting the crop at 100% flowering is recommended.

• This time of cutting may equally apply for most browse species that meant for herbage production.
• For reasonable DM yield and digestible nutrient concentration, herbaceous legumes can be harvested at 15-50% flowering and grasses at 50-75% heading.

• Browses and herbaceous forages were observed to deteriorate very fast when cut at a height shorter than 15 and 75 cm from the ground, respectively and care should therefore be taken.

**Crop management for seed production**

• Despite the many desirable characteristics of selected and cultivated forages, they have not been disseminated to farmers largely because of seed scarcity.

• Most of the adaptable pasture species are capable of flowering and producing healthy seeds.

• As the field husbandry critical to herbage seed production is little studied, current seed quality and yield levels for most of them are unsatisfactory.

• In the mid altitude, seed yield of *vicia atropurpurea* was shown to increase by more than 318 and 570% over the control (unsupported) when the seed crop was supported by a wooden structure constructed in the form of A-frame and a fence, respectively.

**Crop residues and agro-industrial by products**

• In Western Ethiopia, quite a number of crop species are grown but the largest share of cultivable land goes to maize, sorghum, tef, barley and wheat.

• Traditionally immediately following grain harvest, animals are allowed to graze maize and sorghum stovers directly on the field whereas the straws of tef, barley and wheat are stacked around the homestead for feeding the most preferred animals.

• In situ grazed crop residues are utilized inefficiently due to the fact that much is wasted by trampling, and exposure to sunlight and rainfall.

• Timely collection and storage under shade undoubtedly minimizes wastage and further drops in quality.

**Improving crop residue feeding value**

• Crop residues are high in structural carbohydrates, and low in CP and soluble minerals; factors that seriously limit voluntary intake, and animal production and reproduction.

• Higher DM intake and livestock productivity from crop residue based diets largely depend on physical or chemical treatments and/or supplementation of deficient nutrients.

• Intake and animal performance data from alkali treated crop residues are impressive but had limited application under smallholder farmers' conditions.

• Physical treatments such as reducing particle size by chopping improve voluntary intake of crop residues.
• Wetting also slightly improved tef straw DM intake by sheep. Sprinkling one kg of tef straw with 18 g fertilizer grade urea dissolved in water dramatically increases tef straw intake of Horro sheep.

• Supplementing crop residues with high value protein and energy concentrates or leguminous forage legumes appears to be a prudent practice. Supplementation of \textit{D.intortum} and \textit{S.guianensis} at a respective 530 and 250 g/head/day is recommended for sheep feeding maize stover.

• Tef straw voluntary intake and growth rate of sheep were improved as a result of \textit{L.leucocephala, G.sepium, M.atropurpureum, Lablab purpureus, V.atropurpurea, D.unicenatum, S.guianensis,} noug seed cake and urea supplementation.

Conclusion

As opposed to the grasslands of the highland, pastures in the low and mid altitudes are predominated by fast growing and less nutritious species. Profitable animal production from these pastures thus depends on strategic forage legumes incorporation and/or concentrate supplements. Fertilizing / manuring and legume reinforcement invariably were shown to increase crude protein values, DM yields and animal outputs of natural pastures of medium and high altitudes; while proper stocking eliminated or lessened heavy weight losses that normally grazing animals experience in the dry season. Though fertilizers and manures were proved to increase DM yield and animal output, their present use for this purpose is very unlikely. In small holder farmers' context improving the feed situation through integrating improved forages in pasture and cropping systems have a far reaching effect. The scope of cultivated forages to improve the feeding value of crop residues is also remarkably high. Until we start to grow herbage seeds locally, shortages will continue to drag the progress of forage development programmes. For some of promising forages agronomic practices Important for good seed yield have already been generated.

Opportunities do exist for those who want to go into the business of intensive fattening or dairy programmes. Milk yields of F1 crossbred cows and the finishing performance of indigenous livestock that dwell on rations composed of roughages and concentrates are quite high.
Introduction

Small ruminant production is an essential economic activity in most smallholders farming systems in our country. They are mainly bred for monetary return, which usually comes from phenotypic products such as size and body condition. Small ruminants occupy an important niche in the smallholder production systems mainly due to low initial capital requirement, ability to produce food and fibre at relatively low cost from feed materials and on land that often cannot be used in any other way, production of meat in readily usable quantities, high rate of reproduction (early puberty, short gestation period and high prolificacy), potential marketability in a period as short as one season (less than six-month) and ease of being cared for by most family members (women, old men and children).

Western Oromia (Wollega, Jimma, Ilu-Abbabora and part of Western Shoa) accounts for about 17% of the sheep population of the country. In this region, small ruminants are raised under traditional husbandry systems, where livestock graze and breed under uncontrolled or unrestricted environments. Overall productivity indicators such as mortality and utilization (sales and home slaughters) rates reveal low levels of productivity in the small ruminant industry. Nevertheless, to maintain self-sufficiency in meat consumption for the increasing human population, to increase export earnings and to improve the standard of living of the large number of poor farmers in rural areas, the current level of on-farm productivity of small ruminants should be increased. Moreover, poor people in rural areas, with little land available and limited access to capital, have few opportunities to increase their income.

The increase in livestock production has to be mainly achieved through enhanced productivity per animal. Poor management practices and dry season feed shortage are the two major production constraints in Western Oromia. In addition to the genetic potential of a given breed or type, management practices play an important role in improving flock productivity by reducing maintenance and feeding costs. For the past three decades, the Small Ruminant Research Unit of Bako Agricultural Research Center has been studying the performance of Horro sheep, which are used solely for meat production, using different management practices. This paper summarises recommended research results made by this unit on lamb survival rates, sheep fattening technology, selection of male and female lambs for breeding purposes and finishing of old ewes prior to marketing in the context of a smallholder agriculture.

Lamb survival rate

The number of lambs born and surviving to marketing is very critical to sheep production. The causes of lamb mortality are largely linked to management since they are mainly related to low birth weights. To improve lamb survival the constraints imposed by genetics, nutrition, husbandry, disease and weather should be addressed.
To improve lamb survival rate:
- Improve nutrition of ewes during the last trimester of pregnancy (300g/head/day concentrate supplements). The composition of concentrate mixture is 49% ground maize or wheat bran, 49% noug cake, 1% salt and 1% blood and bone meal. Better nutrition of pregnant ewes will reduce pre- and postnatal losses and increase lamb growth rates.
- The choice of particular lambing season. Relatively favourable, compared to unfavourable seasons for rearing of lambs, should be taken into consideration. This could be based on agro ecological condition of the area. For instance, under Bako condition lambs born during early July to late August have the highest weight gain and survival rate than those lambs born at other seasons of the year. They may take advantage of better grazing conditions directly or through maternal milk yield favoured by good grazing conditions.
- Protect the new born lambs from chilly, windy, wet and harsh temperature conditions. Severe weather conditions that are occasionally experienced at lambing can contribute to high environmental variance for lamb survival.
- Promote maximum ewe-lamb contact during the first few days after birth. Ensuring strong ewe-lamb bonding enhances colostrum production by dams and increases the intake of colostrum by lambs.
- Cross-foster of weak or orphan or abandoned lambs shortly after parturition
- Rotation of twins during nursing. This could ensure that each twin mates get enough milk.
- Supplement lactating ewes with 375g/head/day concentrate mixture composed of 49% ground maize grain or wheat bran, 49% noug cake, 1% salt and 1% bone meal.
- Keep ewes indoor for 1 to 2 weeks after lambing.
- Wean lambs at 3-4 months of age. There has to be good grazing for the weaned lambs. Better nutrition enhances their natural defences against endoparasites and minimises postweaning mortality rate.
- Advisable not to keep large numbers of maiden ewes (first lambers) and very old ewes (older than 7-yr of age). Young ewes produce lambs with lower body weight and their mothering ability is also poor as a result of lack of experience and a poorly developed udder. The burden of a long repeated pregnancy, lambing and rearing undoubtedly reduce milk production of old ewes.
- Culling of ewes if they are not capable of raising lambs in two or more lambings. Rearing ability is heritable, and that selection for rearing ability offers excellent prospects for alleviating the problem of high lamb mortality.

Finishing yearling Horro lambs

- Select/buy lambs of about yearling age.
- Keep the animals separately for about two weeks before mixing them with other flocks (normal quarantine procedures have to be followed if possible).
- Treat the animals for internal and external parasites.
- They have to be vaccinated for common diseases prevailing in particular area.
- Keep the animals in a clean and dry house.
- Feed introduction. To gradually increase concentrate supplementation from 100g/head/day to 400g/head/day within 15 days period.
- Supplement the animals (300g to 400g concentrate) with 50% ground maize or wheat bran and 50% noug cake or 50% whole maize or wheat bran and 50% noug cake with a small amount of (3-5 g/head/day) salt.
- Feed the animals for a period of three to four month.
- Provide *ad lib* hay each day or there should be sufficient grazing.
- There should be free access to water.
- Fattening should be in line with demand for mutton. The time when sheep price is high (especially, during cultural and religious holy days) has to be identified.
- Lambs being fattened for slaughter should remain entire, unless there are special reasons for castration.

**Selecting ram lambs for breeding purposes**

In order to increase flock fertility, improve the genetic merit of a flock and to reduce the number of breeding males, rams with superior reproductive traits are required. The following traits are important to select breeding rams.

- Select fast-growing weaner ram lambs selected from ewes with high rearing ability within the same ecological region or production systems.
- Mediocre (inferior) ram lambs would be castrated or fattened for slaughter before they reach puberty. The importance of this practice is obvious since keeping both male and female sheep in one flock is the common husbandry practice in our country.
- Avoid use of rams genetically related to the flock. This could be achieved by:
  * exchanging rams with males from other flocks.
  * using fresh rams each year.
- Ram's capacity for more frequent service (libido) has to get due consideration. It is advisable to eliminate those rams, which lack libido.
- Select rams with larger testicle size. Because of the close association between body weight, testes size and testosterone level and the effect of these on mating performance and semen quality, ram lambs should be selected on the basis of their body weight and testes size. Optimum scrotal circumference for mature Horro ram ranges from 28 - 32 cm.
- Both testicles of the rams should be equal in size and normally developed.
- Rams with some kind of defects have to be culled out. Eg. hocked joints. Special attention has to be given to the hind legs since the weight of the serving ram almost depends on the hind legs while serving.
- Select rams with equal length of upper and lower jaws. Animals with equal length of the upper and lower jaws can graze properly.
- Ram lambs should be kept away from the rest of the flock (reared as an all-male group) after weaning but libido tested at monthly intervals commencing at about weaning age. Because, if they are reared with females they will involve in continuous fighting, probably to establish dominance which is associated with aggressiveness and not libido.

**Selecting ewe lambs for breeding purposes**

- Select ewe lambs with functional body conformation, i.e. without any defects.
- Select ewe lambs with good body condition.
- Select ewe lambs with good size and condition of the udder.
- Early breeding ewe lambs should be reared on high level of feeding (greater than or equal to 300g/head/day concentrate supplements, at least up to 7-months of age).
- Ewe lambs can conceive at as low as 18 kg at the expense of age at conception. Horro ewe lambs could be successfully bred at 7-month of age with no adverse effect on subsequent production. For this breed, the body weight requirement at 7-month of age is about 21 kg.
- Select replacement ewe lambs based on weaning or yearling weights. Ewe lambs meant for replacement have to be selected from ewes with high rearing ability within the same ecological region or production systems.
- Select ewe lambs with normal genitalia. Sometimes the clitoris is enlarged, which is the sign of bisexuality. Such ewes seldom get pregnant and should be culled.
- Unproductive animals should be culled.

Finishing old ewes

Aged ewes constitute a considerable part of the annual animal sales; but they are usually poor in body condition and general appearance due to burden of a long repeated pregnancy, lambing and rearing, which undoubtedly reduce their market value. The farmers' common practice is to sale aged ewes as they are, without considering further fattening. As a result of this, low meat yield and low farm income would be earned. Investigation has been carried out to see the effect of pre-market supplementary feeding on old ewes body weight and condition, carcass quantity and quality and came up with the following recommendation.

- Treat the animals for the internal and external parasites.
- Keep the animals in a clean and dry house.
- Supplement the animals with 400g/head/day concentrate mixture composed of 49% ground maize or wheat bran, 49% noug cake, 1% salt and 1% bone meal not for more than 120 days.
- Let them graze during the day and supplemented with quality hay ad lib each day when they come back from grazing.
- Water the animals to appetite twice a day.
- Note that pre-market supplementation of old ewes should be undertaken during the cheap periods, post harvest, when the price of grains goes down reasonably, and also when sheep price is high (festival periods).

References


Introduction

Livestock production is one of the agricultural sectors, which contribute huge resources to the livelihood of the farming community. Apart from this it is one of the major sources of export earning in the country. Livestock production in Ethiopia in general and in Oromia in particular is targeted to the provision of draught oxen. Dairy and beef are by products. Nevertheless, the traditional small holder farming system produces about 97% of the total milk production and all of the beef in the country.

Several indigenous cattle breeds or types exist in the country. Abigar, Danakil, Arsi, Arab, Borana, Abyssinian zebu, Arado, Fogera, Horro and Sheko are the main distinguishable types located in different parts of the country. All indigenous breeds are characterized by low production and productivity. Annual calving percentage is estimated to be about 50% and mortality rate 8.5%. Heifers do not calve before they are 3.5-4 years of age and every two years thereafter. Mature liveweight varied between breeds but on average small breeds weigh 250 kg for females and 280 kg for males, while the larger breeds can weigh as much as 580-600 kg, average carcass weight is only 125 kg. Most of this comes from aged cows or bulls and overworked oxen and the beef quality is poor. Survey and research works done in the area identified low genetic potential of the indigenous breeds (low milk yield, short lactation length, late age at first calving, long calving interval, low fertility and slow growth rate), feed shortage both in quantity and quality and diseases as a major bottlenecks associated with both dairy and beef production. In order to address the above constraints several research works have been done and recommendations drawn. However, those findings are not properly put in a way users can implement them to solve their problem so that increases production and productivity. In this guide an effort is made to review all available resources and discuss the major issues to improve production and productivity of dairy and beef.

I. Dairy production

• The total productivity of a cow is the sum of the values of its milk, its ability to produce progeny and its own value when it is eventually sold as a culled cow.
• Economic return from dairy farms is dependent upon milk production and reproductive efficiency.
• Milk yield, lactation length, calving interval, age at first calving and fertility are the most important economic traits in a dairy enterprise.
• Low milk yield, short lactation length, long calving interval, late age at first calving and low fertility are the characteristics of the indigenous breeds.

1. Genetic improvement for high production and productivity

The indigenous cattle breeds/types are specialized neither for milk nor for meat purposes. To genetically improve the indigenous animals one of the following options can be used
• Selection among the indigenous breeds
• Crossbreeding with high producing exotic breeds

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1.1. Selection within indigenous breeds

- Milk production can be improved through selection within the indigenous animals.
- Farmers can select and keep cows or heifers which are progenies from high producing dams and cull inferior cows.
- Farmers can also use breeding bulls from high yielding cows.

1.2. Crossbreeding

- Crossbreeding of indigenous breeds with temperate dairy breeds is undertaken to combine high milk yield and early maturity of European dairy breeds with hardiness, disease resistance and adaptability of local cattle.
- Crossbreeding is a quick method of increasing productivity.
- A significant reduction in age at first calving and calving interval was observed in crossbreds.
- The increase in milk yield in crossbreds (first as well as lifetime yield) over the indigenous breeds was two-to-three fold depending upon the exotic and indigenous breeds used, level of exotic inheritance, availability of inputs and climatic conditions.
- Crossbreds have sufficient genetic potential to produce milk on the available feed resources and also possess the required tolerance to environmental stress.
  - Milk could be produced under moderate nutrition (e.g. a basal diet of crop residues and/or low N pasture) and a hot and often humid climate.
- Use of improved native breeds for crossbreeding have some role than using non-descript indigenous breeds.
- Holstein crosses were superior to Jersey crosses for growth and production while the Jersey crosses had better reproductive efficiency.
- The level of exotic blood in the crossbred depends on the management skill, feed availability, environment, and health care. However
- An exotic blood level of 50% to 62.5% can be kept under small-scale farmers' conditions. Besides, an exotic blood level of 25% (Horro x Friesian or Boran x Friesian) performed intermediate between 50% exotic and pure indigenous breeds and could serve as an alternative to resource poor farmers.
- If the proportion of exotic blood in the crossbreds is less than 50%, both milk letdown and persistency of milk production are poor compared to crossbreds with 50% and above exotic blood.
- Crossbreds with 50% and above exotic blood have got good dairy temperament, weaning the calf will not influence milk let down. However, keeping higher exotic blood (75% and above) requires high management and suitable environment. Hence are not recommended for hot humid environment and low management level.
- Decline in milk production from F1 to F2 generation was due to diminishing heterosis in part. Large decline could be observed if the F1 bulls used are not properly selected.

2. Reproduction management for high production and reproductive efficiency

- An important pre-requisite for the sustainability of a dairy production system is that cows must have efficient reproductive performance.
- In order to fulfill its role as an economically useful animal to its owner, dairy females must perform the following functions:
  - Grow rapidly from birth until puberty.
• Attain puberty at an early age
• Conceive readily to a fertile mating
• Produce a viable calf
• Produce adequate milk for the calf and extra for sale
• Return to oestrus early during the postpartum period and conceive again
• Continue producing calves and milk at regular intervals till the end of its productive life

• Reproductive efficiency could be measured in different ways
• Heat detection efficiency
• Interoestrus and inter-service intervals
• Calving interval
• Calving to pregnancy interval
• Age at first breeding

2.1. Heat detection

• The most important reproduction traits, which should be considered, are age at first calving and calving interval
• Age at first calving depends on the age the animal reaches puberty (the age at which the first behavioral oestrus accompanied by ovulation and development of a normal corpus luteum in the ovary takes place)
• Generally heifers reach puberty when they reach 55 to 60 percent of their adult body weight. However, the age at which they attain puberty can be highly variable, ranging from 12 to 40 months.

• An adult non-pregnant heifer and cows normally undergo regular oestrus cycles, which have a mean duration of 21 days
• The length of the heat period depends on the breed. Tropical breeds like zebu, have shorter heat periods than European breeds
• Heat period lasts about 6 to 12 hours. To detect heat you should check the cows three times a day; early in the morning, in the afternoon and late in the evening and spend about 20 minutes each time
• Cows will show standing heat for an average of 10 hours
• The best time to breed is 12 to 24 hours after the onset of standing heat.
• Missed heat undetected is the main reason for long calving intervals

• The main signs of oestrus are
• Swelling and reddening of the vulva
• Secretion of clear, glassy, stringy mucus from the vulva
• Relaxation of pelvic ligaments
• Restlessness and/or bellowing
• Decreased appetite and milk yield
• Desire to interact with other animals
• A cow on heat may mount other cows from the front
• A cow in heat attempts to ride other females, a cow on heat may follow them it may also stand besides them
• A cow on heat may put her head on the backs or rumps of other cows
• When you see a cow nudging and butting other cows, suspect heat
- Cows on heat may sniff other cows, bulls also sniff cows on heat
- Standing still when mounted by a bull or another cow

2.2. Breeding

- Cattle breeding could be either controlled or uncontrolled
- Controlled breeding enables to predict the type of calf to be born, grown and bred, what the level of milk production of the progeny will be.
- Controlled breeding can be either natural mating or artificial insemination (AI)
- AI extends the use of well-proven sires to a large number of females whether these sires are from purebred elite herds or from crossbred sires.
- AI offers the possibility of importing semen from top quality bulls from overseas
- AI enables to control sexually transmittable diseases

2.3. Postpartum reproduction

- Postpartum reproduction efficiency determines the calving interval of the cow.
- Return from milk production is maximized with a calving interval of 12 months, a dry period of 60 days and days open of 85 days.
- Short calving interval indicates a combination of optimum management and good reproductive physiological conditions of the cow
- Calving interval is made up of three components
  1. Interval from calving to first oestrus (postpartum anoestrus period)
  2. Interval from first oestrus to conception (service period)
  3. Interval from conception to calving (gestation period)

- Calving interval is affected by factors that affect any one of the three components.
- Heat detection efficiency, number of service per conception, conception rate to first and subsequent services, postpartum body weight and body weight gain, age of the cow affects calving interval.
- After calving the cow has to be bred within 45 to 60 days

3. Improved husbandry for high production and reproduction efficiency
3.1. Calf feeding and management
3.1.1. Newborn calf: First three days

- The newborn needs to be cleaned with clean and dry hay. This will stimulate respiration and blood circulation
- Remove slim from the nose and mouth to assist breathing and holding up the rear legs of the calf, let the head hang down to release any water in the lungs, mouth, or nose
- If the naval is too long, cut it and leave two to three inches from the stalk then dip the naval in tincture of iodine to prevent local infection.
- Feed the calf with colostrum within one to two hours after birth. The optimum time for absorption of antibodies through calf’s small intestine is in the first six to eight hours
- Colostrum should provide the calf with 10 to 15 percent of its body weight.
- The calf should stay with the dam for 3-4 days and suckle adequate colostrum
- To prepare colostrum substitute, whip up a fresh raw egg in one liter of milk and add half a liter of boiled water, one-teaspoon cod liver oil and one dessertspoon of castor oil. This is...
sufficient for one feed and should be fed at blood temperature, three times a day for the first three days.

3.1.2. Newborn calf: From day 3 to weaning

There are two types of calf rearing.

3.1.2.1. Bucket feeding

- In this method of calf rearing the calf is fed measured amount of whole milk by bucket
- The calf needs 10 percent of its live weight in milk each day in order to grow one percent in live-weight per day.
- Horro calves reared on restricted whole milk feeding to one to two liters after one month of age and replacing the other milk with concentrate feed gave a weaning weight of 41.8 kg and daily body weight gain of 170.6g/d till 3 months of age. Restricted calves compensated in growth till weaning at six months and had similar weaning weight with calves reared on unrestricted milk feeding
- To teach the calf to drink from bucket, let the calf suckle on a finger. While the calf is suckling your finger, you slowly bring your hand downward into the bucket until the calf reaches the milk.
- Important points to pay attention to during bucket milk feeding
- Hygiene and cleanness of the bucket to avoid sickness of the calf
- Milk given to the calf is fixed, hence prevents over consumption of milk by the calf.
- Bucket feeding of the calf should start early in life i.e two to three days old.
- Feeding time should be constant every day.
- Calves should be fed as soon as possible after milking
- Feed healthy ones first and sick ones last to prevent disease transmission
- Clean water should be available to calves starting from 3 weeks of age and also supply them with best quality forages (hay, fresh grass or legumes) - this encourages the rumen development and helps to utilize roughage early in life.

3.1.2.2. Suckling

- The common method is to let the calf suckle the dam for about 1-2 minutes before milking and about 20-30 minutes after milking or to milk two or three teats and leave the other(s) for the calf (make sure that you use different teats each day)
- Horro and Horro Friesian calves that suckle for limited time before and after milking grew faster than calves that were bucket fed.
- In indigenous cattle breeds and in crosses with less than 50% exotic blood suckling should be a means of calf rearing since most indigenous animals dry off as soon as the calf is separated from its dam and milk let down is initiated by the presence of the calf.
- Suckling produced 147 and 42% more milk in Horro and Horro Friesian crossbred (50%) cows, respectively and maternal instinct was found to be 5.5 times stronger in the indigenous breeds than the crosses.
- Suckling extended lactation length by 25.9 and 7.5% for the indigenous and crossbred cows, respectively.
- Suckling is considered important for the growth of the calf and productivity of the cow under tropical conditions
• Weaning should be done at 3 months of age or when the calf is able to eat roughage and concentrate of more than one kilogram per day
• At weaning cross bred calves should be eating at least 0.75 kg of concentrate/head/day.
• The ideal weaning weights are 45 kg for small breeds (adult weight 350 kg) and 70 kg for larger breeds (adult weight 500 kg) and provided that the calf has no setbacks
• If feed resource is poor or the calf is not eating adequate feed, postpone the weaning.
• Feeding concentrates to calves could start as early as 2-3 weeks of age
• Animals which have higher birth and weaning weight at calving mature earlier, have higher mature weight and better body weight gain than animals with lower birth and weaning weight

3.2. Growing heifers management

• Age at first calving is one of the most important economic traits that determines the lifetime production and productivity of a dairy cow
• Zebu heifers have longer age at first calving (about 4 years) than crossbred or pure exotic breeds
• The objective in heifer rearing should be to reduce the age at first calving
• Age at first calving has low heritability indicating that management influences the trait. Hence, adequate management starting from calfhood reduces age at first calving
• Crossbred heifers should be bred at 18-24 months of age under good management and feeding conditions.
• The general guideline is that female cattle at birth should have a weight equivalent to 6.3 to 7% of its mature weight, to have increased its birth weight by at least 50% of mature size by 15 months and attain 85% of mature weight by 30 months.
• Growth rate of heifers should enable the heifer to attain a body weight of 200 to 250 kg for zebu and not less than 270 kg in crossbreds at first service.
• Heifer breeding weight than age is the most important determinant for successful breeding
• Rapid growth and early breeding can be achieved by improved nutrition (good quality forage and concentrate) without inducing over fatness.
• The target weight (200 to 250 kg) for breeding Horro heifers can be obtained by daily supplementation of grazing weaned (six-month age) heifers about 0.5 kg concentrate (maize noug seed cake mixture for 18 months).
• Crossbred growing heifers (from six months of age) should be supplemented with 1000g of concentrate mixture per 100 kg live weight to achieve rapid growth and subsequent milk production
• The supplementation of heifers for high growth rate has to be both in the dry and wet seasons. However, preferential supplementation during dry season only can have a significant influence on the weight gain of the heifers. Since the weight gained during wet season is lost during the subsequent dry season.

• To reduce age at first calving, heifers that attained puberty has to be frequently observed for any signs of heat

3.3. Pregnant animal management

• In-calf heifers have high nutritional requirements for its growth and growth of the fetus
• They need to be fed adequately during the last two months of pregnancy (about 2-3 kg concentrate per day depending on the condition of the cow)
• Supplementing pregnant animal with concentrate feed during the last two months resulted in cows with higher calving weight and good body condition thus reduces postpartum anoestrus interval, increases conception rate, shortens calving interval, results in higher milk yield, longer lactation length and higher calf birth weight
• Separate the cow from the herd at least 3 days before calving
• Parturition is expected 9 months and 9 days (40 weeks) after service takes place
• If the pregnant cow is a milking cow, it has to be dried off two months before the expected calving date
• As the calving weight and the postpartum body weight gain during the first three months increase, the probability of getting a cow in oestrus within shorter postpartum period also increases
• The target calving weight for zebu and crossbred cows is generally around 301 to 305 kg to get shorter postpartum anoestrus interval
• A change in calving weight from 216 to 431 kg reduced postpartum anoestrus interval by 88 days (from 138 to 50 days) while a gain of around 500g/d reduced PPAI by 37 days (from 111 to 74 days) indicating that calving weight is the most important compared to postpartum body weight gain in both zebu and crossbred cows

Sings of parturition

• Signs of calving includes enlargement of the vulva, distention of the teats and udder, loss of ligament at the side of the tail head, and restlessness
• The water bags comes through the birth cannal this may take 2 to 6 hours
• When the actual delivery starts, first the front legs come out, then the head, and after that the whole body comes out. Once the front legs are out the calf must be out within an hour. Otherwise the calf might suffocate
• The normal position is with the front leg first and with the nose between the front legs

3.4. Lactating cow management

• Lactating dairy cows are expected to give milk for 305 days
• The cow has to bred 45 to 60 days postpartum
• The cow has to be dried off after 305 days of milking for 60 days
• Peak milk production occurs 4-6 weeks after delivery
• After milking, milk obtained during the first 5 days is colostrum. Thus, start milking normal milk after five days
• The cow should not be bred during the first 45 days postpartum
• The feeding system followed during ante- and post-partum periods highly affects milk yield, calf birth weight and reproduction of the cow
• Higher initial and peak milk yield, longer days to peak production and higher persistency are the preferred good dairy temperaments. Those are improved through improved feeding management
• Dairy cows need an extra feed for each increase in milk yield during the ascending phase (calving to 6 weeks) of the lactation
• The property of a lactation curve is, it increases up to peak yield and then starts to decline there after. Thus, the feed level used has to be adjusted across the lactation. It has to increase
during the ascending phase of lactation and decrease during the descending phase of lactation

- Milk let down could be initiated through either suckling for few minutes or milking thereafter or by keeping the calf in front of its dam
- Milking cows need adequate water
- Change in the feed level, type and time will have an important bearing on the milk production. A change of feed type results in change in milk yield

- There are a number of general rules on how to milk a dairy cow, which should always be followed. Adhering to these rules will decrease the risk of an udder infection (mastitis) and improve the hygiene and quality of the milk
  - Milk regularly and always at the same time
  - Milk in the correct way
  - Clean your hands carefully before milking and keep your nails short
  - Be quite and gentle with the cows

- Cow may continue to produce milk until the next calving. Cows are usually dried off (milk stopped) 50 to 60 days before the expected calving date to allow the mammary system and cow to recover from the stress of lactation before starting another milking cycle
- This dry period helps to replace nutrients that are lost during the previous lactation, store nutrients for the second lactation, and allows the cow to have rest before the next calving.

- Options for drying off a lactating cow
  - Intermittent milking
  - Incomplete milking
  - Complete cessation of milking the cow

3.5. Bull Management

- Increased production by crossbreeding is most easily achieved through the male line by having an improved bull or by using artificial insemination.
- A bull is half of the herd. It is important to have a bull with good conformation and high fertility
- The bull should be well fed every day particularly when the number of cows to be served increases.
  - Feed 2.72 kg good quality forage per 100 kg of body weight per day and 1.8-2.7 kg concentrate daily
  - Don’t feed the bull immediately before service because it causes mounting difficulty.
  - Bulls should be used to serve cows on a regular basis after 2-3 years of age
  - The ratio of bulls to cows should be in the range of 1:30 to 1:50.

4. Feeding system for high production and reproduction efficiency

- Feed is a raw material for milk production
- A dairy cow gives milk in response to the feed level offered
- Lactating pregnant cows require nutrients for maintenance, lactation, and reproduction and for the growth of the foetus
• A dairy cow cannot give high milk yield on roughage feed only. High concentrate supplementation is required

II. Beef production

Several beef production systems exist in the world. Neither of them is intensively utilized in our country. Beef production is a by-product of the other farm activities. Farmers do not practice fattening however over worked oxen and maiden cows contribute the highest share of beef in the market. Although several beef production systems could be mentioned, only available finishing technologies have been reviewed.

To fatten an animal the following points need to be considered:

1. Selection of animal to fatten

In selecting animals for fattening the following points need to be considered

1.1. Breed of animal
• In the western Oromia, the dominant cattle type is the Horro breed/type that is widely spread in east and west Wollega, west Shoa and Ilubabor. Hence, the cattle type to be used for fattening will be the Horro and non-descript cattle type.

• Different breeds respond differently to any feeding system followed.

• Fattening performance of zebu (Horro, Boran) and 50% crossbred bulls fed on a concentrate ration averaging 3 kg per bull per day and ad lib hay for 150 days revealed that the average daily gains of crossbred bulls previously grazed on native and Rhodes pasture were 0.50 and 0.58 kg respectively. The figures for the local bulls were 0.36 and 0.40 respectively.

• Comparison of zebu steers and 50% crossbreeds received either ad lib hay or silage supplemented with 4 kg of concentrate, the average daily gain of all crossbred group was much higher than the Horro steers, i.e., 0.91 vs 0.52 kg.

• Carcass yield of Boran and Horro bulls were studied to assess the inherent capacity of the breeds for meat production. The average dressing percentage was 56.7 and 57.5 for Boran and Horro, respectively.

• In general crossbred animals out performed zebu by an average of 0.325 kg live weight gain per day regardless of the dietary roughage type.

1.2. Age of the animal

• Depending on the age of the animal, different types of beef can be produced. In our country, however, it is uncommon to fatten very young animals and females unless the cow or heifer has fertility problem.

• Depending on the type of feed available, length of fattening period and quality and quantity of feed, the age of the animal could differ. Nevertheless, for shorter period of fattening young growing bulls could be economical.

• If no record is available, age of the animal can be determined by examining the incisor teeth, which are termed broad teeth as indicated in the following Table.
Age Evidence of age

<table>
<thead>
<tr>
<th>Age</th>
<th>Evidence of age</th>
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</thead>
<tbody>
<tr>
<td>Yearlings</td>
<td>1.5-1.75 years</td>
</tr>
<tr>
<td>Two year olds</td>
<td>2.0-2.5 years</td>
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<tr>
<td>Adults</td>
<td>3.0-3.5 years</td>
</tr>
<tr>
<td>Fully grown stock</td>
<td>3.5-4 years</td>
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</tbody>
</table>

N.B. The age at which broad teeth appears will vary according to the breed and the method of rearing

1.3. Body weight of the animal

- Body weight is the most important trait indicating the condition of the animal before and after fattening.
- Body weight of the animal need to be recorded before and after fattening. It is the difference between the final and initial weight of the animal that indicates the increase in weight due to fattening.
- For bulls and steers at a pre fattening weight between 200 and 300 kg, a daily concentrate ration of 4 kg per animal supplemented with hay or silage to appetite, will produce a daily gain of between 0.45 and 0.55 kg for Horro and between 0.60 and 0.85 kg for exotic* horro crossbred animals over a period of three to five months.
- Weighing a bull or an ox is not an easy task under on-farm conditions and this requires weighing bridge. Nevertheless indirect measurements have been suggested based on the relationships of linear body measurements to body weight of the animal. For this reason the following equations could be used to estimate the weight of the animal.

Table 2. Regression equation of live weight(Y) and heart girth(X); and range of live weight and girth in which the equation works for farmers of Horro cattle.

<table>
<thead>
<tr>
<th>Management</th>
<th>Sex</th>
<th>Equation (Y= a+bX+cX^2)</th>
<th>Weight range (kg)</th>
<th>Girth range (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station</td>
<td>Male</td>
<td>Y=85.2 - 2.519X+0.02448X^2</td>
<td>25-500</td>
<td>70-190</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>Y=2.2-0.895X+0.01743X^2</td>
<td>30-380</td>
<td>75-470</td>
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</tbody>
</table>

Based on the equations indicated above the following weight and girth relationships have been developed.

<table>
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<td>162</td>
<td>320</td>
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1.4. Condition of the animal

• The condition of the animal to be fattened also determines the length of time to feed and the degree of finish. It is economical to feed or fatten thinner animals than animals in a relatively better body condition.

• Fattening thinner animals enables to exploit compensatory growth because, thinner animals are more efficient in converting feed to body weight. However, one has to be sure that the loss in body condition is because of nutrition not health.

• Before cattle are sent to market you must estimate the live weight and dressing percentage. The live weight will depend upon the type of stock you produce. The dressing percentage should be not less than 54%. As a guide to dressing percentage, cattle that have a firm covering of flesh over the ribs are suitable for slaughter.

• The condition of the animal before and after fattening can be assessed with the aid of the following informations
  •• Observe the general conformation of the animal. Butchers prefer stock that appear ‘square’ from in front and behind, and rectangular when viewed from the side.
Handle the beast by running the flat of your hand over the ribs and shoulder. The flesh should be firm and evenly distributed in this area. If the beast is over fat, then it will feel soft and fleshy.

Move to the loin, which should be wide and firm. Span your hands across the loin, noting the width, then prod the flesh with outstretched fingers to estimate the depth of muscle.

The loin should continue evenly in to the rump, which is the most valuable part of the animal. Butchers look, therefore, for a long, wide rump. In over fed animals the hock bones will be hardly visible but in commercial stock they should be clearly seen.

The hindquarters should be full of muscle which must be firm to touch. There should be no signs of soft, patchy fat in any part of the body. Overfat heifers will be found patchy around the tail head.

Finally, handle the skin by grasping the hind on the sides or in the flank, or by pressing your fingers into the skin around the shoulders and over the ribs. The skin should feel soft and paliable; a poor hide will be harsh, tight, and thick.

1.5. Sex of the animal

- The order in weight gain is bulls, steers, heifers, and cows, in descending order, under the same feed lot condition. Therefore, it is economical to feed bulls than the other sexes.
- The response of aged bulls and oxen to different feeding regimes is slow and this may not be economical for a fattening enterprise.
- The difference in response to fattening between aged bulls and oxen and growing and young bulls are a result of the type body tissue deposition. Growing animals deposit protein than fat while older animals and castrates deposit fat. Fat deposition is more expensive and requires more nutrients than protein deposition.
- In a 90 day experiment intended to compare the weight gains of bulls, steers and heifers under feedlot conditions where the animals were given 3.7 kg concentrate/head/day and ad lib forage, the weight gains of bulls, heifers and steers were 653, 564.5 and 549 g per head per day, respectively.

1.6. Effect of castration on fattening ability of the animal

- Castration does have an effect on growth and fat deposition of the animal.
- Castration depresses growth rate of growing animals.
- The increase in body weight of the castrate is a result of fat deposition while that of the entire animal is due to lean meat accumulation.
- Fattening bulls and castrate could result in carcass of different quality. Castration results in the distribution of body fat through out the body of the animal while entire bulls deposit fat in its back. In order to exploit the positive sides of castration it is worth to use it on mature bulls.

2. Type of feed, level of feeding and period of fattening

- Type of feed that can be used for fattening
  - Concentrate
  - Improved pasture
• The type of feed and level of feeding to be used for fattening depends on the availability of the feed, cost of the feed and condition, weight, age and sex of the animal and the period of fattening.

• Short period requires higher feed level and feeds of high-energy value. It is economical to feed concentrate to young and more responsive animals than older animals.

• Depending on the type of feed used, a fattening period ranging from 3 to 6 months is enough for finishing cattle.

  • If hay and concentrate is utilized fattening for about 3-4 months is recommended
  • If crop residue and concentrate is utilized finishing for about 3-4 month is enough
  • If concentrate or improved feed is used with any low quality feed about 3-4 months
  • If only native pasture or crop residue is utilized for about 6 months

• A finishing study to determine the level of concentrate intake required for economic live weight gain of Horro cattle over 120 days fattening period

  • Live weight gain increased with increasing level of concentrate intake up to the 4 kg level while the economical level of concentrate feeding seems to be around 3 kgs/head/day over the 120 day feeding period.

  • In comparing the weight gains of Horro steers fed on limited or ad lib silage or hay together with concentrate supplement for 90 days, it was demonstrated that the silage fed group performed better in weight gains than the hay fed group.

  • This experiment was carried out to compare the weight gains of Horro steers fed either silage or hay with a standard amount of concentrate. The first groups were given 13.8 kg silage/head/day while the second group received 4.6 kg hay/head/day. All animals received, in addition, 3 kg of concentrate/head/day during the 90 day feeding period. The live weight of the silage-fed group increased from an average initial weight of 184.9 kg to a final weight of 277.3 kg. The hay fed group increased from an average initial weight of 190.4 kg to a final weight of 266.0 kg. Silage fed animals, therefore, gained faster than their hay fed counter parts to the extent of 187 g/day.

This depends on the type of feed and level of feeding, and weight, age and condition of the animal to be fattened. Younger animals, animals in good condition at start of the fattening, high level of feeding and good quality feed require shorter period of fattening. Fattening on roughage feeds require longer period.

• In the assessment of the economics of fattening Horro cattle under different fattening periods, animals were provided with 3 kg of concentrate and ad lib maize stover. Animals were then fattened for 154 days in round 1, 117 days in round 2 and 109 days in round 3. The work demonstrated that the gross return as well as the net return per animal were highest when the animals were fattened for 109 days.
3. Selection of project area

In the selecting project area/s consider the following:

- Look to the feed production capability of area
- Kind and amount of pasture to be used
- Local market demand
- Proximity to market
- Assess additional source of feed

4. Care of animals for fattening

Animals to be fattened have to be healthy, strong and must have a good frame. They have to be long and fast growing. If the animal is purchased from market, it has to be checked for any health problems and drenched against internal parasites.

5. Marketing animals

In Ethiopia it is usual to see animals been tracked and tracked to distant markets. Both have an effect on the weight and condition of the animals. However, it is preferred to track than trek the animals. Besides, the fattening period has to be adjusted to festivals and holidays.

6. Data Recording

In order to evaluate the profitability of the fattening activity, one has to keep all necessary records of input and outputs.

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Strategies for Effective Technology Transfer in Western Oromia: Some Recommendations

Shimelis Dejene, Dereje Bacha and Gemechu Shale
Bako Agric. Res. Center, P.O.BOX 03, Bako, West Shoa, Oromia, Ethiopia

Introduction

Generally the goal of Agricultural Extension is to stimulate exchange of knowledge, skills and information between all target groups in agriculture so as to improve their quality of life. Farmers are the most important target group, but policy makers, researchers, extension workers and others also need information, knowledge and skills. The extension service provides these things in order to help the people involved to form opinions and make good decisions.

Extension is too often merely seen as a vehicle for spreading scientific and technical progress and technology transfer. Many people tend to perceive it as a practice of extending package and information developed by researchers to farmers. But, this is narrow and highly unsatisfactory understanding because the dissemination of knowledge is not a one-way street from scientists to farmers. Farmers own knowledge must be collected, analyzed, capitalized on, propagated and disseminated. Furthermore, farmers need information on markets, credit facilities, improved technologies and consumer demand. But simply making information more readily available is not enough to ensure that it is used effectively. Linkage and stakeholders participation are critical for the success of extension. Further on, facilitating relations between farmers, extension and research is of paramount importance so as to make the technology transfer effort more effective, improve farm yield, which in turn empower farmers and support for the community livelihoods.

Therefore, reducing poverty and social inequalities, the sustainable use of natural resources, and participatory development are overall objectives to which the current agricultural extension policies can make a significant contribution. These objectives highlight the fact that extension systems must be accessible and useful to the poorest, and address the agricultural development needs of the country.

However, extension has been criticized because it has not been effective as such in disseminating technologies at the rate they should and persuading farmers to adopt a particular recommendation. It has been ineffective, as cited on so many forums and literature, because of inadequate resources available to extension, poorly trained field staff, weak Research-Extension-Farmer linkage, top-down extension and poor communication and input distribution mechanisms.

In our zones, the above inadequacies were resulted in:

I. Inadequate demonstration and popularization of improved technologies
II. Insufficient training of DAs, SMSs and farmers on new and emerging technologies
III. Inadequate promotion work on emerging technologies leading to poor adoption
IV. Lack of location and /or crop specific recommendation; and in some cases complete failure to meet farmers’ priority needs.
Formulation of better extension strategy and linkage planning and implementation can, therefore, influence, improve or respond to specific needs in different agro-ecologies and ensure effective technology transfer and achieve impact.

**Objectives**

The specific objectives of this paper are:

- To set forth the need for strong linkage and adopting linkage mechanisms that are tailored to suit the existing gaps in the flow of information, knowledge and resources during the technology generation and transfer process in Western Oromia
- To suggest possible strategies for ensuring effective technology transfer

**Description of Contextual Factors and Existing Gaps in Technology Development and Transfer in Western Oromia**

1. In mid and high altitude areas of Western Oromia small-scale mixed farming is the predominant source of agricultural production. To improve agricultural performance of this system the regional Government of Oromia has launched (1995) Participatory Demonstration and Training Extension System (PADETES) following the successful introduction of agricultural technologies by SG2000 Ethiopia. The effects of PADETES began to be felt after 1995 in potential areas. There has been substantial increase in maize, wheat, teff and sorghum production and productivity. However, significantly, empirical evidences suggest that there has been little increase in the productivity of livestock and high value crops. This is because emphasis has been given to single and/or limited crop varieties such as maize and wheat. On top of this, the joint review made by the key stakeholders in the zones revealed that there has been far less integration between research, extension, farmer and Ethiopian Seed Enterprise for the adaptation, multiplication and dissemination of some cereal, high value, horticultural and forage crops. The emphasis given to livestock development and natural resources conservation is also unsatisfactory. Thus there is low extension achievement in these disciplines.

2. Concentration of the current extension package program more on crop technology transfer is a prominent problem. Even within the crop itself, it is cereals biased. The greater emphasis given to limited crops resulted in bumper yield, which immediately surpassed the actual demand in the local market. Coupled with poor marketing and disposal systems for farmers' produces in the region, increased grain production occasioned farmers to receive discouraging prices. Alternative crop varieties that enable them obtain alternative cash sources have not been adapted and disseminated. On the other hand, there is no policy protecting the farmers against the risks resulting from market failure.

3. Most of the mandate areas under the jurisdiction of Bako Research Center are difficult to reach because of its broad geographic coverage and communication problems. The center has fewer opportunities to interact directly with farmers and extension workers working in the distant districts. On the other hand, the financial and material resources available to the center are limited. As a consequence of this, its technology development/variety trial and research center based outreach efforts are concentrated in few locations and within short distance. This imposed constraint on the number and types of technologies the center can develop and adapt for specific locations and technology transfer workers deliver effectively to farmers. Improved crop varieties, which were released and introduced long years back are being
cultivated in many remote districts for they have limited access to information and latest developments in all disciplines.

4. Diverse natural environments represent the mandate area of Bako Research Center and complex production systems in which resource poor farmers are striving to produce a wide range of agricultural commodities. Looked at the other way round, that says that responding to the needs in the diverse agro-ecologies requires location specific technology adaptation. However, there is no adequate number of testing sites representing each agro-ecology for the reason that the resources required to deal with these diversities are not available to the center. As a result, agro-ecology based recommendations are lacking. Farmers residing in the different agro-ecologies of the zones have not been benefiting much from research outputs in these areas as there has been no adequate location specific recommendation and seeds of improved varieties, improved breeds, related inputs and information. A uniform fertilizer rate is being used for crop production across different location and soil fertility status. In some instances, improved crop variety dissemination before performance evaluation at each agro-ecology entailed poor performance.

5. Poor seed production and distribution is the other bottleneck for effective technology transfer. There has been concentration of effort by Ethiopian Seed Enterprise on seed types, which provide high profit: maize, wheat, tef, some pulse crops and sorghum. Furthermore, the seed produced by ESE is inadequate, expensive (not affordable by resource-poor farmers) and few crops considered. To add to this, there is no established seed production, certification and dissemination system for forage, horticultural and high value crops seeds. Insufficiency in seed production and supply is, thus, a major impediment to the dissemination, adoption and full exploitation of technological breakthroughs in the improvement of forage, pulse and horticultural crops in the area.

6. Communication problems: Poor infrastructure facility and logistic are major impediments that has seriously been paralyzing research and technology transfer operations intended to meet technological needs in each ecology.

In summary, the agro-ecological zones and production systems to be served by Bako Agricultural Research Center and the respective district extension institutions are diverse, and are very wide in their area coverage. On the other hand, the resources available for research and extension to achieve broad coverage and meet specific needs in diverse farming conditions are severely limited. To add to this, there is no mechanism for the production and dissemination of seeds of improved crop varieties that received little attention by the extension package program. This affected the transfer and subsequent adoption of improved technologies more severely. The extension package program is sharply biased. The linkage mechanisms in use are also so weak to overcome the existing communication gap. Hence, we believe that centralized extension, technology adaptation and seed production and dissemination systems and sharply biased commodity programs will be less effective under the current conditions of Western Oromia. Local level joint planning and implementation of technology development and dissemination will work such that the specific needs in the diverse agro-ecologies can be met efficiently with the meager research and extension resources we have at hand. These issues should also get good recognition by all stakeholders of agricultural development in the region and work jointly so that they can optimize their contributions and improve their efficiency. Keeping in view the technical factors and resource related problems discussed earlier, therefore, the following recommendations are suggested for ensuring effective technology development and transfer in Western Oromia.
I. Ensure effective research-extension-farmer linkage at different levels
II. Intensify on-farm technology testing and dissemination
III. Strengthen farmer participatory Secondary seed multiplication and dissemination programs
IV. Provide regular on-job training for extension workers
V. Push change of policy focus towards improved interaction and diversification

1. Ensuring effective Research-Extension-Farmer Linkage at Different Levels

An effective linkage between agricultural research and extension is quite vital for successful technology development and delivery. Links with technology transfer agencies ensure impact through a wide dissemination of technologies (Merill-Sands and Kaimowitz, 1990).

An effective linkage requires researchers and extension workers who visit farmers together to analyze their problems and to discuss which solutions are possible. Development of good solutions requires contributions from researchers and extension workers who should have a broad knowledge and understanding of the farming system. For example, on-farm trials are a joint responsibility of researchers and extension agents. For decisions what kind of trials are most needed, researchers know most about the possible outcomes of these trials based on their experience and knowledge of the theory. On the other hand, good extension agents know more about which information farmers lack for good decision making. Furthermore, extension agents are in a better position to supervise on-farm trials more closely and to observation, while as researchers are well placed to plan good research designs and to analyze the data properly. Extension agents are also more motivated to disseminate findings of investigations in which they have participated. This implies solutions to agricultural development problems lie in the sphere of improved interactions. Improving linkage is thus a priority means of identifying farmers' priority problems and needs, planning of actions and reaching relevant technologies to farmers.

However, weak linkage constitutes a chronic problem in our country in general and our region in particular and guarantees that research results will not reach farmers adequately. The severe linkage problems, lack of appreciation of the complementary roles between actors and poor communication, considerably reduced performance (Souder, 1980). For example, in Ethiopia, the pre-1993/94 period was characterized by weak links and field level interaction between the institutions involved in research (the then IAR) and transfer (MOA) (Habtemariam, 1997). This resulted in poor and stagnant performance in the main agricultural activities of the country.

But at the time of launching the SG2000 Ethiopia extension program (1993) and the current extension system of the country, Participatory Demonstration and Training Extension System, it was imperative to link the activities of the then IAR, SG2000, Ethiopian Seed Enterprise (ESE) and the MOA so as to achieve the intended goal. The mechanisms that have been used for enhancing linkage are:

I. Joint definition of extension package;
II. Joint evaluation of programs and
III. Joint field visits and review meetings
This improvement in the involvement of various stakeholders in the implementation of the package program has resulted in substantial productivity gains for some major crops. But stakeholders participation is limited to the implementation of the package program in potential areas and more attention was given to few crops. It does not go further into responding to the specific technology needs in the diverse agro-ecological and production systems in Western Oromia. This suggests that still there exist a gap in the flow of knowledge, information, and technology because of inadequate cooperation and communication between the principal partners in the agricultural development process in the region. Cooperation and/or interdependence have been lacking in problem definition, technology adaptation, technology verification, and provision of feedback and technology multiplication. These gaps could possibly be mitigated through enhancing the complementarity of the technology generation and transfer processes. They can complement to each other by amending the linkage mechanisms that have already been adopted by the package program so as to achieve greater coverage than that achieved by the package.

Overall, broad coverage is required to ensure impact through research and extension. Broad coverage on the other hand needs site-specific selection and adaptation of new technologies. Site-specific adaptation and increased agricultural production can be achieved by developing three-way links between research, extension and farmers.

**Recommended linkage mechanisms**

1.1. Joint planning and review:

Joint planning and review mechanisms have widely been used to strengthen links.

1.1.1. Joint problem diagnosis:

It is one of the strategies for ensuring Research-Extension-Farmer linkage. These exercises bring all actors together to define priority problems of the region and decide on research and extension agendas. It helps researchers gain a deeper understanding of farmers' problem and appreciate the potential benefits of feedback from technology users for implementing relevant research.

1.1.2 Joint priority setting

All researchable problems and extension programs should be prioritized and approved in the presence of organizations that involve in research, extension and the farming community. This provides a strong foundation for on-going cooperation and forges a commitment to a common work agenda. Beside this, it enables researchers, technology transfer workers and farmers share common objectives.

1.1.3. Joint programming and review meetings

One of the mechanisms used to strengthen R-E-F linkage is a joint programming and review meeting. It assists rapid communication of research results and provides an opportunity to gain direct and timely feedback from development workers and farmers. It is undertaken to review the previous years' results, diagnose problems and prepare plans for the following years. Council members with the power to make programming decision, and implement proposals, field level extension workers and farmers attend it.
1.2. Collaborative professional activities

Collaborations between professionals from the research center and agricultural development officers in the region promote mutual respect and improve the quality of research and extension works. There are many ventures they should collaborate.

1.2.1. Formal collaboration in on-farm trials and dissemination activities

Professional collaboration in undertaking trials and dissemination activities at field level need to be formalized and get adequate managerial support. On-farm trials need to be managed jointly by researchers and extension workers for better management and to be cost effective. Multidisciplinary surveys also need professional collaboration. Dissemination activities run by the center should also be coordinated with extension.

1.2.2. Joint field visits

Joint field visit, such as annual study tours or field days can have a high impact in strengthening links. Joint field visits to on-farm trials, on-station experiments and extension activities can improve collaboration significantly as researchers, farmers, extensionists and others can have a chance to see the actual performance of varieties or breeds and recommended practices under farmers' condition and actual farming problems.

1.2.3. Joint decision-making on the release of recommendations

Joint decision-making on the formulation and release of recommendations would enable to take sufficient account of the particular agro-ecological conditions in each zone, farmers' circumstances and to incorporate information from researchers, farmers and extension workers into zonal crop recommendations. It will also assist researchers and extensionists to revise recommendations to make them more appropriate for specific local conditions.

1.3. Joint Bako Research Center/MOA adaptive, Verification and Demonstration Variety Trials

The joint adaptive /verification trials should be functional in different agro-ecological zones of the region to generate location specific technologies. The premise here is that farmers in East and West Wellega zones were not exposed to the most appropriate cultivars. Furthermore, solutions adapted to site-specific conditions, rather than blanket recommendation; need to be developed. But Bako Research Center lacks the capacity to develop multiple adaptation directly by itself. Thus, the systematic testing of in zonal trials of released varieties to define their adaptation zone is a necessary condition for effective technology transfer.

1.4. Specific allocation of resources to linkage management (Time, finance and facility)

Many of the linkage mechanisms adopted so far failed because no adequate resources had been specifically allocated to support linkage. Lack of money to meet operating costs for demonstrations, organizing field days, production and circulation of publications, regular review meetings, joint adaptive trials, joint field visits, and Joint package formulation and training workshops has seriously been restraining collaborative activities. Managers of key institutions in the agricultural technology system of the region can indicate the importance
they attach to linkage, thus, by allocating staff time, funds and other resources to support linkage activities. The following measures can be taken to ensure funds are available for linkage activities.

I. Making collaborative activities a line item in each institution's budget
II. Obtain a specific allocation of funds from each partner institution
III. Placing funds under the control of individuals responsible for managing links
IV. Convincing planners and higher officials so that they allocate funds specifically for linkage activities

2. Conduct joint adaptive, verification, and demonstration variety trials

Farmers in our zones are exposed to a limited choice of cultivars. On the other hand, there are many other recent, high yielding varieties, widely adopted elsewhere in the country, which farmers could be given for participatory evaluation, selection and dissemination. Thus there is an urgent need for carrying out joint adaptive, verification and demonstration trials in partnership with extension workers, researchers and farmers

**Formative experience**

Bako Research Center Based-Zonal Research Extension Advisory Council (RCB-REAC) launched adaptive, verification and demonstration variety trials with a view to adapting existing technologies to the conditions of the peasant farming areas. The trials were designed by research staff, covered a range of crops and were widely dispersed throughout the zones. The routine management of the trials was the responsibility of extension workers working at zone, district and village level. It was really a success. It was also learned that partnership between research and extension would be a most effective way of carrying out adaptive trials.

**Strategies for conducting joint adaptive and verification trials**

I. Determine farmers requirements in new varieties or crops
II. Carryout a search for released materials that match these needs
III. Obtain accurate published information with regard to the varieties
IV. Train extension workers in trial management so that they can participate actively in running trials and define their responsibilities clearly
V. Test them in farmer-managed participatory trials, in the most appropriate environment-farmers' fields and the trials should be the simplest possible
VI. Collect data (qualitative and quantitative) before and after harvest on aspects of the crop including taste, market value, storability, threshing characteristics…etc
VII. Evaluate them jointly for better performance
VIII. Find farmer-acceptable varieties amongst the released materials and recommend the very promising ones
IX. Disseminate the information package in the form of manuals, leaflets etc.
X. Demonstrate on enormous farmers' fields
XI. Encourage secondary seed multiplication so as to provide farmers with seeds of improved varieties

3. Strengthen On-farm Community Based Seed Production Schemes: Some strategies

Enhancement of food security and economic empowerment is possible through agricultural progress. This requires increased production and productivity through the use of improved
breeds, seeds and complementary inputs. However, in Ethiopia, despite agriculture is the mainstay of the country's economy, there is only one seed enterprise responsible to multiply and supply improved seeds to farmers (Aberra and Beyene, 1997). Beside this, it has no full-fledged channel to dispatch improved seeds to peasant farmers. Farmers have limited access to seeds of improved varieties and seeds. Many farmers have had no access to seeds from formal institutions such as Ethiopian Seed Enterprise.

On top of this, ESE multiply seeds of only few cereal crops (maize, wheat, tef and sorghum), while no one is responsible for the multiplication and dissemination of horticultural and forage crops and lowland and highland pulses. ESE does not supply significant portions of farmers with the seeds of these crops. Therefore, most farmers use their own saved seed, which are low productivity capacity. Thus, impact on increased production of these crops has not been realized though there are a large number of improved varieties.

Overall, Poor seed production and distribution is a major impediment of technology transfer and adoption in our zones. Therefore, one strategy for promoting the dissemination and adoption of improved technologies is to stimulate on-farm level participatory seed production and dissemination schemes.

Impacts

Three case studies conducted in Kenya and Ethiopia regarding informal seed multiplication and dissemination revealed that:

I. Small farmers have been able to obtain quality seed in time within their vicinity and at affordable price.
II. The programs fostered contacts between researchers, extension workers and farmers.
III. There has been greater adoption of production technologies than ever before among farmers.
IV. Farmers have got the knowledge and experience to grow specifically for seed
V. Sustainable methods of seed production and distribution introduced
VI. Farmers’ capability in seed production and storage techniques improved.

Strategies for Informal Seed Multiplication

I. Select interested seed growers. Selection should be undertaken based on:

A. Willingness to take on credit basic seed and agree to multiply it
B. Willingness to remain with seed multiplication program for some time so that they can gain experience.
C. Willingness to save seed for themselves and pass on some amount of seed to their neighbors on sale or in exchange with other crops seeds or grains

II. Training

Subject matter specialists, extension agents and interested seed growers should be trained and gain the needed skill in seed production, proper application of crop management practices, processing and handling/storage and assure whether the seed meets minimum prescribed quality standards.

III. Seed provision. Farmers should be provided with starter/breeder seed.
IV. Supervision. After seeds are given to farmers, frequent supervision and advise are crucial so as to assist farmers produce seeds that at least meet minimum quality standards.

Strategies for Seed Diffusion

1. Market outlet and availability of seed demand should be assessed and known before embarking into informal seed multiplication.

Market for seed may not be readily available at the point of seed production. But the farmers with the extension staff can develop market by undertaking the following:

   I. Informing seed consumers in meetings where they could buy seed
   II. Organizing field days and field visits on seed production schemes

2. To disseminate the seeds to be produced make contractual agreement in advance with nearby farmers who are interested to buy seeds from seed growers.

4. Provide Regular On-job Training for Extension Workers

It is true that the development agents are the only extension workers who directly teach production recommendation to farmers. On the other hand, the task of teaching farmers to try suitable practices and convincing farmers to try them is not easy. It needs technical competence and good communication skills. Furthermore, the routine management and close supervision of joint Bako Agricultural Research Center/MOA adaptive and verification trials that were launched in our zones have heavily rested and will continue to rest on the extension workers scattered throughout the zones. This has been done without training them in the skills needed to implement and manage on-farm technology testing. Their skills can only be upgraded through frequent and regular on-job training. This has happened very occasionally both in East and West Wellega zones for different reasons. Thus development agents working in these zones have remained less conversant with latest research recommendation and information, principles of on-farm technology testing, communication skills and extension method and approaches. It means they must receive intense support and guidance if they are expected to be capable in assisting farmers and actively implement and manage on-farm technology testing.

5. Push Change of Policy Focus towards Improved Interaction and Diversification

5.1 As it is stated earlier, improvement in productivity by farmers in our zones requires high level of system integration. On the other hand system integration is a costly business. It requires considerable resources to implement and achieve the intended goal. Furthermore, Clear goals can be set, pertinent linkage mechanisms are planned and implemented, non-bureaucratic and adequate managerial supports can be provided for linkage activities and specific resources are allocated to support linkage if there is linkage policy. This means that resources will be available and linkage can be fostered if there is high level of political commitment and policy decisions. Thus, all stakeholders, individuals and institutions should push the formulation of linkage policy, which allow:

I. Better coordination of activities between stakeholders;
II. Better planning and management of linkage
III. Appropriate allocation of resources to linkage

5.2. The current extension package program is specialized in few commodities. It is mainly working on maize, wheat, tef and sorghum. The bias to single or limited commodities did not enable farmers resist household economic disturbances happened as a result of poor marketing channels for the bumper yield being obtained from the current package program. The current low output price combined with recent increases in costs of inputs have discouraged resource-poor farmers to continue intensive farming and adopt improved technologies.

In our zones due emphasis has been given for maize. There has been no strong extension intervention for livestock development. There is also weakness in natural resource management and high value crops technology dissemination. Now we feel that we can go no where with few cereals only as their price is rolling down and farmers became highly vulnerable to economic disturbances. Thus, productivity and farmers' bargaining power should be improved through:

I. Diversification of the extension program
II. Market oriented production; market oriented technology generation and dissemination can be achieved by focussing on high value crops.

Other Considerations for Effective Technology Transfer

1. Careful selection of villages and participating farmers; this is important in order to get the appropriate area needing the technology and interested and/or committed partners

2. Good initial training, sensitization and exposure to successful stories of technologies should be carried out to build in confidence and motivation.

3. The technology at farm level should be of low capital investment since most farmers are resource poor.

4. The technology must have clear advantage in terms of monetary returns and improvement of environment.
   -Monetary (sale of animals, milk).
   -Nutritional (meat, milk).
   -Manure as an agricultural input.

5. The technology must match with the available local resources.

* There is a general tendency for the technology recipients to continuously feel that every thing would be provided free of charge. This should be minimized from the start of extension programs by educating the farmers on the issue of sustainability.
References
