Sorghum
Production
and
Research Experiences

© EARO 2005

Editing: Simachew Manaye
Design: Abebe Kirub
Page layout: Kidanemariam Hagos
Printing: Abesolom Kassa
Binding and collation: Woudnesh Mamo and Miftah Argela
Distribution: Aklilu Woube, Enanu Dagne and Bogalech Abebe
Bibliographic input to WAICENT (FAO): Girum Endalew and Mintilu Tekle

Contents

Introduction 1
Adaptation 4
Production 5
Varieties 6
Crop Management 12
Forage properties of sorghum 29
References 30
Annex 31
Sorghum (Sorghum bicolor L. [Moench]), which belongs to the grass family, is one of the most important indigenous cereal food crops. It is classified into 5 basic races: bicolor, guinea, caudatum, kaffir and durra; and 10 hybrid races: guinea-bicolor, caudatum-bicolor, kafir-bicolor, durra-bicolor, guinea-caudatum, guinea-kafir, guinea-durra, kafir-caudatum, durra-caudatum and kafir-durra (Harlan de wet 1972). These basic and hybrid races can be identified by mature spikelet characteristics alone, although head type is frequently helpful (Harlan and de wet 1972; House 1995).

The height of sorghum plant ranges from 0.5 m to more than 5 m. Its stem consists of a sequence of nodes and has a diameter of 0.5-5 cm. It is solid from outside but spongy from inside. It may be dry or with sweet or insipid juice.

Tillering is important in areas where ratoon cropping is accustomed. It varies with cultivar. Most cultivars produce tillers in response to damage by insect pests.

The leaves of sorghum can be 1 m long and 10-15 cm wide. In well-adapted plants, the number of leaves ranges from 14 to 17, but in poorly adapted types and some very long duration types, it may reach 30.
maturity, a well-adapted plant generally has seven to eight functional leaves after lower leaves have died and dropped (House 1995). When the plants grow around knee height, all leaves are expected to appear. This is the stage of floral initiation.

After floral initiation, a panicle develops, and about 6–10 days before flowering, a boot or swelling forms at the top of the plant. The panicle has various shapes ranging from very open (lax) in broomcorn to compact in durra. It is 5–50 cm long and 3–30 cm wide. The peduncle (panicle stalk) can be erect or goose-necked or re-curved depending on its race. On a panicle branch are spikelets. There are two types of spikelets: the sessile (bisexual and fertile) and the pedicelled (sterile or staminate). The sessile spikelet contains two florets, one perfect and fertile, and the other sterile.

Sorghum is a short-day plant, but cultivars vary in their sensitivity to photoperiod. Flowering begins 3–7 days after the panicle emerges from the boot. Blooming starts at the tip of the panicle and progresses downward within 4–5 days. Flowering may take 60–75 days in early maturing lowland types and 10–25 more days in intermediate and highland sorghum types.

Sorghum is often a cross-pollinated crop. Cross-pollination may range from 2–35% (Rooney and Smith 2000), being higher on laxer (open) panicles. It takes about 30–40 days after pollination for the plant to reach
physiological maturity. Physiological maturity is detected when black hilar layer is formed at the point of attachment of the seed, sampled at the base of the panicle, with its glume.

Grain coverage by the glumes depends on the race. In bicolor, the grain is completely covered, but in durras the coverage is only 25%. Caryopsis is blunted or round. It is usually plump but sometimes dented like the high lysine sorghums having a diameter of 4-8 mm and varying size, shape and color with cultivar. The major components of the seed are the pericarp (outer cover), the endosperm (storage organ), and the embryo (that germinates to reproduce a plant). The testa, which may or may not be present, is the layer between the pericarp and the endosperm. This is the tannin containing layer, and therefore, important to the nutritional characteristics of the grain (House 1995).
Adaptation

Sorghum is adapted to a wide range of environments (Annex 1). However, mostly sorghum and millets are crops of the semiarid areas where moisture availability for plant growth is critically important. In areas where rainfall amount is within the range of 250 to 500 mm, distribution of rainfall can be as important as amount (House 1995).

Grain sorghum grows successfully on many soil types but it performs best on medium-textured, light-textured (sandy soils), and less satisfactorily on heavy textured (clay) soils. It tolerates a pH ranging from 5.5 to 8.5 and some degree of salinity, alkalinity, and poor drainage.

In Ethiopia, sorghum grows in 13 of the 18 major agro ecological zones (AEZs) and in 41 of the 49 sub-AEZs. The major agroecological zones have been grossly classified into four broad categories for the purpose of research (Table 1). These are the highlands, the mid-altitude areas, the moist lowlands, and the dry lowlands. The highlands are areas with altitudes of 1900-2700 m. The mid-altitudes are areas with altitudes that range from 1600 m to 1800 m, and the lowlands and the dry lowlands include areas with altitudes of 500-1600 m.
Production

About one million hectares of land are devoted to sorghum production every year. From this, 0.7-1.2 million tones of grain are produced. The national average yield of sorghum in Ethiopia is about 12 q ha\(^{-1}\). However, research has shown that there is a potential to produce 30-60 q ha\(^{-1}\) using improved varieties and improved production practices. Over the last three decades, production area and total production have increased. However, productivity (i.e., production per hectare) did not show any significant parallel increase.

Sorghum production has a number of constraints. Some of them are poor stand establishment, soil fertility decline, insect pests (such as stalk borers \([\text{Chilo partellus}]\)), diseases (such as sorghum anthracnose \([\text{Colletotrichum graminicola}]\)), birds (like weaverbirds \([\text{Quelea quelea}]\)), sorghum shoot flies \((\text{Atherigona soccata})\), sorghum chaffers \((\text{Pachnoda spp.})\), striga, leaf blights, and panicle diseases (like smuts, grain mold).
Varieties

Developing varieties for lowland areas mainly depends on introduction and evaluation of exotic sources due to low diversity associated with recurrent drought and stalk borers (especially, *Chilo partellus*). However, for the highlands where there is immense diversity, the emphasis has been on the evaluation of indigenous sources. So far, the national and regional research institutions in Ethiopia have released about 33 varieties for commercial production. Of these, only 19 are on the current recommendation list. The highland varieties are selected from indigenous collections. These are tall and long maturing in line with the relatively high rainfall and extended growing period of the areas where they are adapted. Mostly they are durra type goose-necked sorghums. On the contrary, almost all the varieties released for moisture stressed lowlands were from exotic sources.

Highland Varieties

**Alemaya 70**

Alemaya 70 was released in 1970. It is a yellow-seeded variety suitable for the highlands of Hararghe and areas with similar climate. It has a compact panicle on its re-curved peduncle. It has bold seeds and is the best-improved variety ever known in Ethiopia for its...
injera making and keeping quality. Its height may be within the range of 250-384 cm. It is relatively resistant to leaf and head diseases. It matures within 175-190 days and has a potential yield of 30-55 q ha\(^{-1}\). The weight of 100 seeds of this variety is 2.9-3.7 g.

**ETS2752**
ETS2752 was released in 1978. It is a white-seeded variety with a big, open, and re-curved panicle. It matures within 190-205 days. Its height is 234-285 cm. It has a potential of giving 30-55 q ha\(^{-1}\). The weight of 100 seeds of this variety is 2.5-3.8 g.

**Chiro**
Chiro was released in 1996/97 for the highlands. Unlike the above two, this variety is red-seeded. The special feature of this variety is its sugary stalk, which can be chewed like sugarcane and excellent for animal feed. Its height may be within the range of 185-257 cm. It matures within 175-190 days. The variety can give grain yield of 42-58 q ha\(^{-1}\). The 100 seeds weight of this variety is 2.4-3.0 g.

**ETS1176**
ETS1176 was released in 2004. It was selected and purified from the Ethiopian highland sorghum local collections by the Ethiopian Sorghum Improvement Program. It is characterized by a compact and goose-necked panicle, and red and plump kernel. It has a grain yield potential of 29-63 q ha\(^{-1}\), and maturity
period of 181–207 days and has a height of 250–410 m.

The color, texture, and flavor of this variety are acceptable for making good quality injera. It is recommended for Arsi Negelle, East and West Hararghe highlands, and areas with similar climate.

**Mid-altitude Varieties**

**IS9302**
IS9302 was selected from the exotic germplasm and released in 1981. This variety has wider adaptation, but it is better suited to the favorable environments of the mid-altitude agroecologies. It is a red-seeded variety with semi-compact, erect, and long cylindrical panicle. Its height is within the range of 100–180 cm. It matures 150–180 days and gives a grain yield of 30–60 q ha⁻¹. The 100 seeds weight of this variety is 2.2–2.5 g.

**Birmash**
Birmash was originally released for Birr Valley and similar areas in 1989. It is a red-seeded variety with semi-compact panicle. Its height may be within the range of 131–233 cm and matures within 150–180 days. It is the highest yielding variety with up to 69 q ha⁻¹ in experimental fields. The 100 seeds weight of this variety is 1.7–2.6 g.

**Baji**
Baji (so named by merging the first two letters of Bako
and Jimma) was released in 1996/97 cropping season. This variety looks like Birmash. Its height may be within 139-164 cm. It matures 150-180 days. Its yield is 31-56 q ha\(^{-1}\). Its 100 seed weight is 2.3-2.7 g.

**Lowland Varieties**

**Gambella 1107**
Gambella 1107 was released in 1976 for the moist lowlands of the country similar to Gambella. It is a white-seeded variety with semi-compact, semi-oval, and erect panicle. Its height may be within the range of 120-200 cm. Part of its head is covered by the flag leaf (the peduncle is not well exserted). It has good *injera* making quality. It matures within 110-130 days and can yield 28-50 q ha\(^{-1}\). The 100 seeds weight of this variety is 2.5-3.3 g.

**76TI#23**
This variety was released in 1979 for the moisture stressed dry lowlands. It is white-seeded with semi-compact, semi-oval, and erect panicle. It has some red spots. The glume is red or brown. Its height ranges from 120 to 140 cm. It matures within 90 days. It is susceptible to leaf diseases and smuts. Its yield is 25-45 q ha\(^{-1}\). The 100 seeds weight of this variety is 2.7-2.9 g.

**Seredo**
Seredo was released in 1986. It is a brown-seeded
variety with semi-compact and erect panicle. The panicle is well erected. It is not eaten by birds (bird resistant) due to its high tannin content. Moreover, it is resistant to leaf and panicle diseases. Its height may be within the range of 110–140 cm. It matures within 90–120 days and yields 20–45 q ha⁻¹. The weight of 100 seeds of this variety is 2.1–2.9 g.

**Meko-1**

Meko-1 was released in 1997/98 cropping season. It is a white-seeded variety with semi loose and erect panicle. Next to Alemaya 70, this is the best variety for injera making and keeping quality. Its height ranges from 132 to 169 cm. It matures within 90–120 days and yields 24–49 q ha⁻¹. The 100 seeds weight of this variety is about 2.9–3.7 g.

**Teshale**

Teshale was released in 2001/2002 cropping season. It is similar in all respects to Meko-1, but it is taller and its peduncle is a bit undulating. It takes only 90 to 120 days to mature. Its height is within 190–200 cm. Teshale can give 25–50 q ha⁻¹. The 100 seeds weight of this variety is around 3.3–3.6 g.

**Gubiye**

Melkassa Agricultural Research Center (MARC) released Gubiye in collaboration with the Purdue University, USA, in 1999/2000 cropping season. The seed is white. It has a semi loose erect panicle. Its
height may reach 110-140 cm. It is resistant to *striga* (a parasitic weed species). This variety matures within 90-120 days. It can give a yield of 14-27 q ha\(^{-1}\) on a land previously infested with *striga*. Moreover, it has a good *injera* making quality. The 100 seed weight of this variety is 2.9-3.7g.

**Abshir**

Abshir was released in 1999/2000 cropping season with Gubiye. Abshir and Gubiye are sister lines and are similar in all respects. However, Abshir has a relatively poorer threshing quality than Gubiye. Its height may reach 110-140 cm. It matures within 90-120 days and gives grain yield of 14-24 q ha\(^{-1}\). It is also good for *injera* making. The 100 seed weight of this variety is 3.3-3.6 g.
Crop Management

Together with variety development activities, crop agronomy or management activities have been carried out by the national and regional programs. As a result, plant and row spacing, seed rate, fertilizer rate, frequency of plowing and weeding recommendations and planting date recommendations for various agroecologies have been made.

Land Preparation

Land preparation is the first step in sorghum production. It must be done with maximum care. The operation is very important in growing sorghum because the crop must be provided with a fine seedbed to ensure uniform emergence. It includes clearing, plowing, harrowing, ridge, and row making. If the previous crop was sorghum or maize, removing or burning of the stubble is very important because some insect pests and diseases may overwinter in it and carryover to the new crop.

Plowing can be done by hand using pickaxe, with oxen or tractor. Although frequency of plowing is determined by workability of the soil, rainfall, and other economic conditions, two to three times plowing is adequate. Mostly the first plowing is done at the end
of the main rainy season; the second right after the first shower of rain and the third before sowing. If three times plowing is impossible, the second plowing can be skipped. In any case, the seedbed should be free from weeds, soil clods and other undesirable materials.

In the dry areas, especially on light soils, moisture conservation, and wind erosion controls are important. Tied-ridges (furrow dams) have been extensively used in the African semi-arid tropics as insitu soil and water conservation systems. If tied-ridges are made before the first heavy rains, they conserve the early rainfall, and allow it to infiltrate, which thus benefits crop growth. Using tied-ridges rather than flat seedbed (farmers practice) in dry crop seasons, significantly increased sorghum grain yield. For sorghum, the spacing of the ridges is 60–75 cm. Since tied-ridges may result in water logging, especially on clay soils when the seasonal rainfall is high, tying should be done on every 6 m distance, whereas in light sandy soils tying every 3 m is recommended.

**Sowing**

Sowing in rows and broadcasting are the two common planting methods of sorghum. If broadcasting is used, seeds should be distributed uniformly. In this case, the seed rate is higher than sowing in rows. Moreover, inter-cultivation, weeding, and other operations are
difficult in broadcasted sorghum. In any way of sowing, maximum care should be taken not to burry sorghum seeds more than 4 cm depth. When sowing in rows, the row-to-row spacing should range from 60 to 75 cm. The seeds are drilled in row and later after emergence; the population can be adjusted by thinning to 88,888 plants per hectare using 15 cm to 20 cm space between plants. For this, 8–10 kg of seed is adequate. However, if sowing is by broadcasting, a high seed rate of 10–20 kg ha⁻¹ should be used due to uneven distribution of the seeds.

Sowing dates must be carefully planned in order to harvest the crop in good time. Late planting causes a high yield reduction due to high stalk borer infestation and late drought. Sowing dates for sorghum vary depending on the agroecology, which in turn depends on the growing period of the crop (Table 1). Sowing date also depends on the availability of rainfall within the time of recommendation. For instance, in the lowland areas, sowing generally should follow the first effective rainfall (about 20 mm) if the time is within the range as in Table 1. In warm and moist soils, it takes only 3–5 days for the sorghum seed to emerge, but it may take up to 10 or more days if the soil temperature is cooler.
Table 1. Sowing dates for different sorghum growing regions

<table>
<thead>
<tr>
<th>Altitude (m)</th>
<th>Growing period (days)</th>
<th>Sowing date*</th>
</tr>
</thead>
<tbody>
<tr>
<td>High (1900-2700)</td>
<td>175-210</td>
<td>15 April – 10 May</td>
</tr>
<tr>
<td>Mid (1600-1900)</td>
<td>150-180</td>
<td>1-15 May</td>
</tr>
<tr>
<td>Low (&lt;1660)</td>
<td>90-130</td>
<td>1-15 June</td>
</tr>
</tbody>
</table>

*Sowing time recommendations only help as indicators of the right time

Fertilizer Applications

The commonly used nitrogen and phosphorus fertilizers for sorghum in Ethiopia are Urea and Diammonium phosphate (DAP), respectively. The blanket recommendation is to apply 50-100 kg ha⁻¹ DAP for low moisture potential areas and 100 kg ha⁻¹ DAP for high moisture potential areas at planting. About 50 kg ha⁻¹ urea for low moisture potential areas and 100 kg ha⁻¹ for high moisture potential areas can be applied as top dressing at knee height stage. It is important to stress local recommendations should be followed wherever such recommendations do exist. Urea and DAP can be applied as band placement 5 cm away from the plant. DAP can also be applied in the row with the seed. In all cases, conserving moisture is advised in moisture stress areas.

Weeding and Cultivation

Since sorghum is a slow starter crop, it competes with weeds poorly that deprive the crop of its water, nutrient, and light requirements. Weed competition
affects sorghum adversely and causes significant yield reduction unless effective controlling measures are taken. A yield reduction of up to 60% may be caused if weeds are not controlled at the right time. If possible, the sorghum field should be free from weeds throughout the season. If not, at least two hand weedings should be done during the critical period of weed-crop competition. The first may be done 20–25 days after emergence (DAE) and the second 45–50 DAE. Alternatively, pre-emergence herbicides, such as Primagram, can be used at the rate of 4 l dissolved in 400 l of water per hectare.

In many parts of Ethiopia, *shilshalo* is practiced. It is a kind of cultivation that uses oxen driven ploughs to thin the dense population to the required level. This enables cultivators to break the crust, reduce runoff, and increase soil infiltration rate in addition to controlling weeds. Experimental results showed that growth and yield could be enhanced if shilshallo is performed at earlier stage (4-6 leaf stage).

**Crop Rotation**

Crop rotation is important due to the following reasons (Cothern *et. al* 2000): to utilize resources; to minimize risks caused by weather or prices; to reduce weeds, disease, and insect problems; to improve soil physical conditions; and to utilize residual nutrients. Sorghum
is a heavy feeder crop. A sorghum crop yielding 6000 kg ha\(^{-1}\) reportedly takes up about 105 kg nitrogen, 15 kg potassium, and 15 kg phosphorus from the soil (Hulse 1980). Therefore, growing sorghum continuously in a given field enhances soil nutrient depletion and yield reduction.

In many sorghum-growing areas, the tradition is producing the crop continuously, though rotation is practiced in some parts. Rotation helps not only to make the soil replenish its fertility but also to control some soil born diseases like head smut. If sorghum is rotated with legumes that can trap *striga*, it will be useful to deplete the seeds of this parasitic weed from the soil. Thus, for sustainable and increased yield, sorghum should be rotated with legumes.

**Intercropping**

In survival oriented agricultural systems, farmers have resorted to mixed cropping or intercropping to minimize certain risks. In many parts of the country, sorghum is usually grown with maize, finger millet, legumes, and oil crops. Intercropping gives space, time, and meets the multiple needs of farmers. Besides, it can give high output, maintain soil fertility, and give greater stability of production. It also smothers weeds, improves ground cover, and reduces soil erosion and evapo-transpiration. The recommended intercropping
practice is to grow two rows of sorghum with one row of haricot bean, which gives a land equivalent ratio of (LER) >1, or mixed cropping of beans with sorghum in rows and broadcasting beans between rows.

**Harvesting and Storage**

Sorghum can be harvested after a black mark is observed on the ear head. The mark is a sign of physiological maturity. The mark can be observed by removing a few seeds from the bottom of the ear head (flowered last). However, since the physiologically mature sorghum may contain moisture of up to 25-30%, it can be left until the moisture level is reduced before harvesting. If bird is a problem in the area or if there is a need to make the land free for the next crop, it can be harvested at the stage of physiological maturity and dried later. The grain can be dried by spreading it in the sun in thin layer.

The essence of storing sorghum is for home consumption and obtaining the right price. For safe storage, the moisture content of the grain should not exceed 12%. Storing only clean grain is important. Moreover, the store should be as clean as possible.
Crop Protection

A large number of pests attack sorghum at various stages both in the field and in the storage. The major pests are insects, diseases, Striga and birds.

Insect pests
Stalk borers, sorghum shoot flies and sorghum chaffers are the most serious insect pests in most sorghum growing regions of Ethiopia.

Stalk borers:
The three major stem borer species of sorghum are the spotted stem borer (Chilo partellus), which belongs to Pyralidae family, the pink stem borer (Sessamea calamistis) and maize stem borer (Busseola fusca), both from Noctudae family. The spotted stem borer is frequent in the lowlands, whereas the pink and maize stem borers are prevalent in the mid and highlands.

Symptom: The symptoms of stalk borers are dead heart of sorghum seedlings, tunnel in the stalks, tattered leaves, and chaffy panicles at later stages.

Control: Crop sanitation including removal of thrash, stubble, and volunteer plants after harvest and destruction of wild sorghum species is proved to reduce stalk borer infestation. Sowing at the onset of the rains (early sowing) reduces damage by stalk
borers. Research results also showed that spreading sorghum stalk horizontally on the ground for 6 weeks is effective (98% mortality of stem borers). Using resistant varieties (no resistant variety in Ethiopia is known to date) is also important to control stalk borers. Alternatively, chemical insecticides like Endosulfan 5% dust at the rate of 8 kg ha$^{-1}$, Cymbush 1g ha$^{-1}$ and Karate 5% EC at the rate of 300 ml ha$^{-1}$ can be used.

**Sorghum shoot flies (Atherigona soccata):**
Sorghum shoot fly belongs to the order Diptera and the family Muscidae. It attacks maize and finger millet. Mostly, it attacks these crops at their early seedling stage.

**Symptom:** The heart of affected seedlings is dead within a month after emergence. The dead heart has a rotten-fish smell. A well-developed yellow apodous larva can be found feeding on the rotten tissue.

**Control:** Early sowing reduces infestation by sorghum shoot fly.

Granular insecticides such as Carbofuran (Furadan) 10G (pre-sowing application) at the rate of 0.2 kg ha$^{-1}$ reduces the level of shoot fly infestation. Karate 5% EC can be applied at the rate of 16 g a.i. /ha at the early seedling stage if some dead heart symptoms are seen.
Sorghum chaffers (*Pachnoda interrupta*): Sorghum chaffers belong to the order Coleoptera (beetles). These are devastating insect pests. However, they appear sporadically.

**Control:** There has never been any effective controlling mechanism other than local farmers' methods (indigenous control options).

Though they are not as dangerous as sorghum stalk borers, sorghum shoot flies and sorghum chaffers; other insect pests like African bollworm, corn leaf aphid and sorghum midges are major field insect pests of sorghum in Ethiopia.

**Storage insect pests:** Angomois grain moth (*Sitotroga cerealella*) and maize weevil (*Sitophilus zeamais* [Motschulsky]) are the most devastating storage insect pests of sorghum in Ethiopia; though more than 30 insect species were recorded. However, secondary weevils, like red flour beetles (*Tribolium castaneum*), are also frequent. Cross infestation occurs whenever clean seeds are kept in infested storage houses or infested seeds are kept in clean storage houses.

**Control:** control measures like keeping the grain clean; mixing it with *tef*, wood ash, and other inert matter protects it from storage insect pests.
Using insecticides like Pirimiphos methyl 2% dusted at the rate of 35 gm/100 kg grain (5ppm) gives adequate protection for about six months. Alternatively, fumigation can be used with phostoxin. Primiphos-methyl 2%, Deltamethrin 0.2% and 2.5%, Malathion 1% and Malathion 1.6% + Perimethrin 0.4% were found to be effective on stored sorghum at Bako.

Diseases

Grain smut/ covered smut (*Sphacelotheca sorghi*):
It has silver-gray sacs containing black spores that replace the developing grains. The membrane is thick and persistent. The sac hardly exceeds the length of the grain. All the grains in a head may be replaced by smut sacs. Cool weather, which is relatively unfavorable for sorghum, is favorable for these smuts.

Loose smut (*Sphacelotheca cruenta*):
Unlike covered smuts, the silvery spore sacs in these smuts are thin-walled membrane and break soon, and the central mass of twisted black fungal threads (the columella) are observed. Plants infected with loose smut may be stunted and tend to produce nodal branches and tillers. Unlike covered smuts, loose smut is able to infect florets directly. Therefore, late heads will have the chance of being infected by spores from earlier smutted heads.
Control: As pathogens are seed-borne, both covered and loose smuts can be controlled by soaking the seed for 20 minutes into cow or goat urine that has been preserved for a week. Alternatively, the seed can be dressed with chemicals such as Thiram at 1:400 and Apron plus. To avoid later infection by loose smut, the smutted heads should be removed as soon as they appeared. The use of resistant varieties is the best option to control these diseases. For instance, Framida is a good resistance.

Long smut (Tolyposporium ehrenbergii) and Head smut (Sphicelothea reliana): These are not so much important as the other two smuts. Long smut pathogen attacks only individual florets. The sacs are long, about three times the size of the seed. It is seed-borne disease.

In head smut, a large sac (Sorus), covered with a white membrane, appears on the side of the boot, which soon bursts and reveals a sooty tangled mass of filaments and spores. Head smut spores are soil-borne, and infect the soil at the seedling stage.

Control: Removing the attacked heads from the field controls the long smut diseases, and head smut disease can be moderated by crop rotation.
Grain mold:
Grain mold is a well-known disease in sorghum growing areas that combine high humidity and warmer climate.

Control: using resistant varieties can control grain mold. Sowing at the appropriate time (maturity date should not be later than the end of the rain) is also important.

Leaf diseases:
Sorghum leaf diseases in Ethiopia include anthracnose, rust, leaf blight, downy mildew, zonate leaf spot, bacterial leaf streak, and stripe. Of this anthracnose, caused by Colletotricum graminicola, is the main one.

Control: Sorghum anthracnose is controlled by growing resistant varieties. IS158, IS2230, NES8827 and NES 8835 are resistant to anthracnose.

Witch Weeds (Striga species)
Witch weeds are becoming the major threats against sorghum production. The two most common ones are Striga hermonthica and Striga asiatica. Striga plants have beautiful purple (S.hermonthica) and red (S.asiatica) flowers. They are semiparasitic plants. These plants attach their haustoria under the ground to the sorghum root system and take out all the nutrients from it.
**Symptoms:** The leaves of host plants will be changed into yellow (chlorosis). Then, they show stunted growth and eventually die. *Striga* plants begin to emerge in about 30 days after the emergence of sorghum (Doggett 1988).

**Control:** Using resistant varieties (host plant resistance) is the best method of controlling *striga* infestation. The following mechanisms of host plant resistance have been known so far: low germination stimulant (lgs) production, using mechanical barriers, inhibiting germ tube exoenzymes by root exudates, phytoalexine synthesis, post attachment hypersensitive reactions or incompatibility, antibiosis, insensitivity to *striga* toxin, and avoidance through root growth habit. Gubiye and Abshir are varieties resistant to *striga* due to low germination stimulant (lgs) production. Birhan is another resistant variety released by the Sirinka Agricultural Research Center for Welo area, and it combines about three mechanisms of resistance.

Rotation of sorghum with non-susceptible legumes is another option. Although most of the damage by *striga* occurs under ground before the emergence of the *striga* plants, hand pulling of the emerged plants is still the most feasible controlling approach for the small-scale subsistence farmers.

Usually, *striga* infestation is very high if sorghum is grown in poor soils. Therefore, the use of a relatively
higher dose of nitrogen fertilizers reduces its infestation.

Trap crops exude *striga* seed germination-stimulant but they are not parasitized because of dead *striga* seedlings. These crops are used to deplete *striga* seed bank from the soil.

Although chemical control is not feasible, target spray of 2, 4-D can be used to control *striga*.

An integrated approach containing the use of resistant varieties, hand weeding before flower initiation, cultural practices that conserve moisture and nutrients, chemical inputs (herbicides and fertilizers) are the best approach to control *striga*.

**Birds**

Every country that grows sorghums has problems with granivorous birds that move into the fields and take the grain (Bullard and York 1985). At present, sorghum production in many parts of the country, especially in the Rift Valley, is abandoned because of birds. Different bird species attack sorghum in Ethiopia. Weaverbirds (*Quelea quelea*), starlings, bishop birds, and doves are some of the major ones. Of these, the most important are the weaverbirds.
**Control:** At present bird damage control focuses on protecting the crop by using non-lethal system (scaring and use of resistant varieties) rather than destroying them, except selective lethal control that destroys colonies of birds that depredate local fields, a control practice that is being preferred in much of Africa (Jaeger and Erickson 1980). For instance, spraying of methiocarb at the rate of 1-4 kg ha\(^{-1}\) on breeding sites have been the most effective control measures in Ethiopia to control quelea.

Some resistant traits have been known to protect themselves against birds. The major traits include panicle shape and orientation (lax panicle, compact panicle, and goose-necked panicle), awned lemma, size (large glumes), size and hardness of grain, seed appearance (color, shape and size), and polyphenols (chemical avoidance). However, the size of the bird, its feeding habits, and movement patterns may affect the kind of characteristics needed to make a particular trait less susceptible to damage (Bullard and York 1985). The most effective resistant is the persistent, bitter tasting seed coat (chemical avoidance) found in brown sorghum varieties, like Seredo. These varieties are third in the bird’s order of preference and are only eaten in the absence of non-bitter varieties or a good supply of grass seeds.

In general, the soil, climate, altitude, market, and cultural practices in the growing area limit the plant
characteristics that would be acceptable (Bullard and York 1985). For instance, brown-seeded sorghums are not only hated by birds but also by producers because of their low food making quality. Moreover, when grown alone, they can also be depredated by birds because birds can eat even grasses when there are no other options. Therefore, no cultivar with a single resistant trait can be effective for all birds.
Forage Properties of Sorghum

In many parts of the country, the local cultivars are preferred by farmers for their high biomass. In some places farmers plant thick stand of sorghum and they later thin it by *shilshalo* when the plants reach about knee height. The thinned out plants are fed to livestock.

Young sorghum plants produce high amount of dhurrin that will be converted into hydrogen cyanide (HCN [Prussic acid]), a poisonous chemical that is able to kill cattle when its concentration is greater than 500 ppm (Cothren *et al.* 2000). The concentration of prussic acid rises during moisture stress and cool weather. Its level reaches a maximum at the eight-leaf stage of development and then decreases until maturity (Benett *et al.* 1990). Therefore, it is recommended that the young plants be spread in the sun before they are given to animals as HCN evaporates when exposed to the sun.
References


Annex 1. Sorghum growing major and sub-agroecological zones in Ethiopia and their characteristics

<table>
<thead>
<tr>
<th>AEZ</th>
<th>SUB-AEZ</th>
<th>Description</th>
<th>Altitude (m)</th>
<th>T° (°C)</th>
<th>RF (mm)</th>
<th>LGP (Days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>A1-1</td>
<td>Hot to warm arid plains</td>
<td>0-1200</td>
<td>&gt;27</td>
<td>100-400</td>
<td>No (irrigation)</td>
</tr>
<tr>
<td></td>
<td>A1-3</td>
<td>Hot to warm arid valleys and escarpments</td>
<td>0-1200</td>
<td>&gt;28</td>
<td>100-600</td>
<td>No (irrigation)</td>
</tr>
<tr>
<td>A2</td>
<td>A2-1</td>
<td>Tepid to cool arid plains</td>
<td>1200-1600</td>
<td>16-21</td>
<td>500-600</td>
<td>&lt;45</td>
</tr>
<tr>
<td></td>
<td>A2-7</td>
<td>Tepid to cool arid mountains</td>
<td>1400-2200</td>
<td>16-27.5</td>
<td>350-800</td>
<td>&lt;45</td>
</tr>
<tr>
<td>SA1</td>
<td>SA1-1</td>
<td>Hot to warm semi-arid plains</td>
<td>500-1600</td>
<td>16-21</td>
<td>300-800</td>
<td>-60</td>
</tr>
<tr>
<td></td>
<td>SA1-2</td>
<td>Hot to warm semi-arid lakes and rift valley</td>
<td>1000-2000</td>
<td>16-27.5</td>
<td>650-700</td>
<td>46-60</td>
</tr>
<tr>
<td></td>
<td>SA1-5</td>
<td>Hot to warm semi-arid mountains and plateau</td>
<td>400-1600</td>
<td>&gt;21</td>
<td>300-700</td>
<td>46-60</td>
</tr>
<tr>
<td>SM1</td>
<td>SM1-1</td>
<td>Hot to warm sub-moist plains</td>
<td>400-1400</td>
<td>&gt;21</td>
<td>200-1000</td>
<td>Double + single (84+120)</td>
</tr>
<tr>
<td></td>
<td>SM1-2</td>
<td>Hot to warm sub-mist lakes and rift valleys</td>
<td>1000-1600</td>
<td>21-27.5</td>
<td>400-800</td>
<td>61-120</td>
</tr>
<tr>
<td></td>
<td>SM1-3</td>
<td>Hot to warm sub-moist valleys and escarpments</td>
<td>1400-2000</td>
<td>NA</td>
<td>300-1400</td>
<td>105-150</td>
</tr>
<tr>
<td></td>
<td>SM1-4</td>
<td>Hot to warm sub-moist river gorges</td>
<td>800-1000</td>
<td>NA</td>
<td>700-1000</td>
<td>75-90</td>
</tr>
<tr>
<td></td>
<td>SM1-7</td>
<td>Hot to warm sub-moist mountains</td>
<td>1400-2000</td>
<td>&gt;21</td>
<td>150-700</td>
<td>61-120</td>
</tr>
<tr>
<td>SM2</td>
<td>SM2-1</td>
<td>Tepid to cool sub-moist plains</td>
<td>1000-2000</td>
<td>16-21</td>
<td>500-800</td>
<td>61-120</td>
</tr>
<tr>
<td></td>
<td>SM2-2</td>
<td>Tepid to cool sub-mist lakes and rift valleys</td>
<td>1400-1800</td>
<td>NA</td>
<td>700-1200</td>
<td>61-120</td>
</tr>
<tr>
<td></td>
<td>SM2-5</td>
<td>Tepid to cool sub-moist plains and mountains and plateau</td>
<td>1600-2200</td>
<td>NA</td>
<td>700-1200</td>
<td>90-165</td>
</tr>
<tr>
<td></td>
<td>SM2-7</td>
<td>Tepid to cool sub-moist mountains</td>
<td>1600-2000</td>
<td>16-21</td>
<td>300-1000</td>
<td>61-120</td>
</tr>
<tr>
<td>M1</td>
<td>M1-1</td>
<td>Hot to warm moist plains</td>
<td>400-1800</td>
<td>21-27.5</td>
<td>250-1500</td>
<td>121-180</td>
</tr>
<tr>
<td></td>
<td>M1-2</td>
<td>Hot to warm moist lakes and rift valleys</td>
<td>1000-1600</td>
<td>16-27</td>
<td>700-1300</td>
<td>120-180</td>
</tr>
<tr>
<td></td>
<td>M1-3</td>
<td>Hot to warm moist valleys and escarpments</td>
<td>400-1800</td>
<td>21-28</td>
<td>250-1200</td>
<td>Double (180)</td>
</tr>
<tr>
<td></td>
<td>M1-4</td>
<td>Hot to warm moist gorges</td>
<td>1000-2000</td>
<td>16-28</td>
<td>600-1600</td>
<td>Double (120)</td>
</tr>
<tr>
<td></td>
<td>M1-7</td>
<td>Hot to warm moist mountains</td>
<td>1000-2000</td>
<td>16-27.5</td>
<td>600-1600</td>
<td>121-180</td>
</tr>
<tr>
<td></td>
<td>M2</td>
<td>M2-1 Tepid to cool moist plains</td>
<td>1000-2000</td>
<td>16-21</td>
<td>NA</td>
<td>Double+single (90-120, 40-60)</td>
</tr>
<tr>
<td>---</td>
<td>------</td>
<td>-------------------------------</td>
<td>-----------</td>
<td>-------</td>
<td>----</td>
<td>-----------------------------</td>
</tr>
<tr>
<td></td>
<td>M2-2</td>
<td>Tepid to cool moist lakes and rift valley</td>
<td>1800-2200</td>
<td>16-21</td>
<td>700-1100</td>
<td>121-180</td>
</tr>
<tr>
<td></td>
<td>M2-6</td>
<td>Tepid to cool moist plateau</td>
<td>1600-1800</td>
<td>16-21</td>
<td>1200-1500</td>
<td>180</td>
</tr>
<tr>
<td></td>
<td>M2-7</td>
<td>Tepid to cool moist mountains</td>
<td>1000-1300</td>
<td>11-21</td>
<td>600-2200</td>
<td>121-180</td>
</tr>
<tr>
<td></td>
<td>SH1</td>
<td>SH1-1 Hot to warm sub-humid plains</td>
<td>400-1000</td>
<td>16-28</td>
<td>700-1000</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>SH1-2</td>
<td>Hot to warm sub-humid lakes and rift valleys</td>
<td>1400-2000</td>
<td>185-22</td>
<td>1000-1400</td>
<td>181-240</td>
</tr>
<tr>
<td></td>
<td>SH1-4</td>
<td>Hot to warm sub-humid gorges</td>
<td>1000-2000</td>
<td>18.5-25</td>
<td>1000-2000</td>
<td>181-240</td>
</tr>
<tr>
<td></td>
<td>SH1-7</td>
<td>Hot to warm sub-humid low to mid high lands mountains</td>
<td>800-2200</td>
<td>17.5-25.5</td>
<td>900-2200</td>
<td>181-240</td>
</tr>
<tr>
<td></td>
<td>SH2</td>
<td>SH2-1 Tepid to cool sub-humid plains</td>
<td>1000-2000</td>
<td>16-21</td>
<td>700-1500</td>
<td>150-240</td>
</tr>
<tr>
<td></td>
<td>SH2-2</td>
<td>Tepid to cool sub-humid lakes and rift valleys</td>
<td>1400-2000</td>
<td>18.5-22</td>
<td>800-1600</td>
<td>181-240</td>
</tr>
<tr>
<td></td>
<td>SH2-6</td>
<td>Tepid to cool sub-humid plateau</td>
<td>2000-2800</td>
<td>13.5-18.5</td>
<td>900-2000</td>
<td>181-240</td>
</tr>
<tr>
<td></td>
<td>SH2-7</td>
<td>Tepid to cool sub-humid mountains</td>
<td>1600-3200</td>
<td>11-21</td>
<td>700-2200</td>
<td>181-240</td>
</tr>
<tr>
<td></td>
<td>H1</td>
<td>H1-1 Hot to warm humid lowland plains</td>
<td>600-1400</td>
<td>22-26</td>
<td>1500-2000</td>
<td>241-300</td>
</tr>
<tr>
<td></td>
<td>H1-2</td>
<td>Hot to warm humid lakes and rift valleys</td>
<td>1200-2000</td>
<td>18-23.5</td>
<td>1200-1500</td>
<td>241-300</td>
</tr>
<tr>
<td></td>
<td>H1-7</td>
<td>Hot to warm humid low to mid highland mountains</td>
<td>800-2200</td>
<td>16.5-25.5</td>
<td>500-2000</td>
<td>241-300</td>
</tr>
<tr>
<td></td>
<td>H2</td>
<td>H2-2 Tepid to cool humid lakes and rift valley</td>
<td>1600-2000</td>
<td>17.5-21</td>
<td>1200-1400</td>
<td>241-300</td>
</tr>
<tr>
<td></td>
<td>H2-7</td>
<td>Tepid to cool humid highland mountains</td>
<td>2000-3200</td>
<td>11-18</td>
<td>700-2200</td>
<td>241-300</td>
</tr>
<tr>
<td></td>
<td>Ph1</td>
<td>Ph1-5 Hot to warm per-humid mountains and plateau</td>
<td>800-1200</td>
<td>23.5-25.5</td>
<td>1100-1500</td>
<td>&gt;300</td>
</tr>
<tr>
<td></td>
<td>Ph1-7</td>
<td>Hot to warm per-humid mountains</td>
<td>1000-2000</td>
<td>17.5-25</td>
<td>1100-2200</td>
<td>&gt;300</td>
</tr>
<tr>
<td></td>
<td>Ph2</td>
<td>Ph2-7 Tepid to cool per-humid mountains</td>
<td>1000-2800</td>
<td>13.5-25</td>
<td>1100-2200</td>
<td>&gt;300</td>
</tr>
</tbody>
</table>

Source: adapted from MOA, 1998.

AEZs = Agroecological zones, Sub-AEZs = Sub-agroecological zones, NA = Not available, RF = Rainfall, $T^\circ$ = Temperature, LGP = Length of growing period.