Innovations To Help Our Country Grow

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INTRODUCTION

Sorghum [Sorghum bicolor (L.) Moench] is one of Ethiopia’s major traditional food crops. It is a crop that can be grown all over the country, and particularly in areas where there is a problem of recurrent drought. The current area coverage is estimated at more than 1.7 million hectares with a national average grain yield of about 2.01 t/ha. The major challenges that limit higher productivity are: recurrent drought, incomplete use of improved production technologies, striga infestation, and bird attack during grain development (particularly, quelea-quelea), insect pest attacks and occasionally disease outbreaks.

In Ethiopia, the major known striga species that limits sorghum productivity are known as S. hermontica and S. asiatica. Because of these parasitic weed infestations, the yield loss on striga infested soils as estimated by some studies in some parts of the country ranges at between 65-70%. Countrywide, 50% of fields covered by sorghum have been infested by this weed species and thus about 90,000 ton of grain is lost per annum indicating that the challenge posed by striga infestation is increasing.

SUITABLE AGRO-ECOLOGY

Sorghum be grown from sea level to mid highlands in warm temperatures. At higher elevation and cooler temperatures, the plant can grow well, but seed setting is limited due to poor pollen development. In Ethiopia, sorghum grows well in 12 of 18 major agro-ecological zones with an altitude ranging between 400-2500 masl.

Rainfall

Though capable of tolerating recurrent drought, for best production sorghum requires an average minimum rainfall ranging from 400 - 500mm; below this rainfall level, it requires the use of moisture conservation methods.

Temperature

Amongst the cereal crops, sorghum is the most tolerant to recurrent drought. Optimum temperature during growing season is 27 oC-32 oC. Temperatures below 15 oC and above 40 oC are not suitable for grain production. Generally, under Ethiopian conditions, the crop requires a growing period free from frost. This is especially during pollen maturation and pollination.

Soil Types

Sorghum can grow well on all soil types provided moisture is available and soil pH is within an acceptable level, usually from slight acidic to slight alkaline (6.0 to 7.5 respectively). Well aerated and deep soils will always be the best as it is the rule for all crops.
Once grain sorghum emerges, the plant develops in a predictable manner characterized by three distinct growth stages, namely: 1) Growth Stage I (GS I), 2) Growth Stage II (GS II), and 3) Growth Stage III (GS III). A medium-maturity variety requires approximately 32 to 35 days passing through each stage, depending on the maturity and environmental conditions. Modern varieties are insensitive to day length, meaning their rate of development is primarily driven by temperature.

**Growth Stage I**

The first growth stage, GS I, is characterized by vegetative growth. The plant develops its vegetative structures, leaves and tillers, which ultimately support grain formation and growth. Because modern varieties are insensitive to day length, the duration of GS I largely depends on air temperature and the number of leaves genetically predisposed to form on the variety’s main stalk. The more leaves formed by the plant, the longer maturity (e.g., more time is required from planting to harvest) and greater its potential to produce forage and grain. Early-maturing varieties typically produce 15 leaves per plant, while medium- and late-maturing varieties produce 17 and 19 each.

Sorghum can tolerate high degrees of stress from drought, hail and freezing temperatures in GS I with little adverse effect on yield. But insect pests, if untreated, can
irreparably harm the crop. Abnormally dry and/or cool weather promotes the development of damaging pests such as corn leaf aphids, green bugs and chinch bugs. Most post-emergent herbicides are applied during GS I. Follow label directions carefully to prevent crop damage. Prolonged cool, cloudy weather in GS I may also cause a purple coloring on leaf sheaths and blade margins, and the blades can develop an inter-venial yellow striping (chlorosis). The purple color occurs from the accumulation of anthocyanin in the tissue and results from insufficient phosphorous uptake or from the plant’s inability to move sugars from the leaf blade. Leaf striping is often caused from insufficient iron or zinc uptake. Symptoms usually disappear when favorable temperatures return. Iron and zinc deficiencies will be more pronounced in high calcareous soil. Long, sunny days with temperatures below 18 °C favor tiller formation on basal nodes (nodes at the base of the plant) on plants at the four and six-leaf stage; similarly, space planting promote tillering, while more than 12 plants per linear meter suppresses tillering. Panicles of tillers are smaller and flower later than those on the main stalk. Basal tillers formed at this stage can compensate somewhat for losses in plant emergence. Some varieties have a tendency to tiller more than others.

Growth Stage II

The second growth stage, GS II, is the period when reproductive structures of the panicle form and the maximum number of seed per plant are set. It is considered the most critical period for grain production, because seed number per plant accounts for 70 percent of sorghum’s final grain yield. Anything that impedes panicle development during this period reduces the number of seed to be formed, which lowers grain yield.

GS II begins with “panicle initiation” and continues to flowering. The initiation of the panicle starts about 30 to 35 days after emergence when 7 to 10 leaves have fully developed (please note that one to three leaves may have been lost, since the lower leaves die and fall off as the plant grows). Following panicle initiation, the plant abruptly stops forming new leaves and begins to form the plant’s reproductive structures. Although panicle initiation marks the moment when the plant attains its maximum leaf
number, only one-third of the leaf area has formed (Figure 3). The remaining leaf area
develops as the panicle and floral parts form during GS II, a period of rapid growth.
Side-dress nitrogen applications should occur prior to this event, so soil fertility is not
limiting when the crop most needs it.

The flag leaf is the last leaf to emerge from the whorl. It is smaller than the other
leaves and positioned directly below the panicle. When the flag leaf collar appears,
the plant is in the boot stage (Figure 4). The sorghum panicle development is com-
plete and primed for flowering, and the plant has attained its maximum leaf area and
accumulated approximately 60 percent of its total dry matter. Severe drought stress at
this time can impede panicle exertion from the boot and lead to incomplete flowering
(anthesis), seed set and loss in grain yield. The crop’s water requirements are greatest
at this time. So it is important to ensure there is sufficient water for panicle exertion,
flowering and seed set (rain water harvesting by tied ridging becomes very important
at this stage).

The development of the panicle, its floral structures and the remaining leaf area is
extremely sensitive to drought and stresses caused by green bugs, corn leaf aphids and
chinch bugs. Stress reduces the number of florets and, ultimately, the number of seed
in the panicle for grain formation. Furthermore, applications of 2,4-D- or dicamba con-
taining products after panicle initiation can injure and reduce seed number and yield.
Cultivation should be avoided after panicle initiation to prevent pruning the expanding
root system and losing soil water and nutrient uptake.

Flag Leaf Stage
Following growing point differentiation, rapid culm elongation and rapid leaf develop-
ment occur simultaneously until the flag leaf (final leaf) is visible in the whorl. Most
leaves are fully expanded except the final 3 to 4 leaves.

Boot Stage: all leaves are now fully expanded, providing maximum leaf area
and light interception. The head has now developed to nearly full size and is
enclosed in the flag-leaf sheath.

Flowering in grain sorghum
Growth Stage III

The third and final growth stage is grain filling, called GS III. It begins with flowering and continues until dry matter accumulation in the grain stops with the appearance of a black-layer near the point of the seed attachment in the floret.

Flowering typically begins when yellow anthers appear at the tip 5 to 7 days after panicle exertion. Over the next 4 to 9 days, anthers appear incrementally and develop down the panicle. The crop is in full flower (bloom) when 50 percent of the anthers on 50 percent of the plants in the field have emerged.

Environmental stress from heat or drought does not usually affect pollination, but herbicide drift prior to, during or immediately following pollination can interfere with seed set and severely reduce yield. The sorghum midge infestation, a common insect pest in many sorghum growing regions around the globe, is damaging at this stage. The insect can be found laying its egg in the floret and killing the developing seed. One midge per panicle can lower grain yield 10 to 20 percent. Examine plants for other pests, such as green bugs on the leaves and head worms in the panicles, at this stage.

After flowering, plant development centers on grain formation. Sugars, amino acids and proteins produced in the leaves and roots are rapidly transported to the kernel and converted to starch and protein. Seed development progresses from milk to soft dough through hard dough and to physiological maturity over 25-45 days after flowering depending on varieties and environmental conditions. Kernels reach their maximum size (volume) about 10 days after flowering — the milk stage. The seed is soft, and a white milk-like liquid is obtained when kernels are squeezed. The soft dough stage occurs 15 to 25 days after flowering, when approximately 50 percent of the grain weight is accumulated — the kernel can be squeezed between the fingers with little or no liquid present. Sorghum for silage is typically harvested at the soft dough stage when the plant has lost several lower leaves. The plant is quite susceptible to bird feeding at this time. Eight to 12 functional leaves are usually present at soft dough. The hard dough stage occurs when the grain cannot be compressed between the fingers. The grain has accumulated approximately 75 percent of its dry matter.

Plants are most susceptible to lodging (falling over) at this time, resulting from severe drought, plant diseases (charcoal rot) and stalk-boring insects. The seed is physiologically mature when a black-layer appears immediately above the point of kernel attachment in the floret near the kernel base. The kernel is approximately 30 to 35 percent moisture and attains its full dry weight when the black-layer appears. Grain can be harvested at 20 percent moisture without mechanical damage but must be dried to 13 percent or below to be safely stored in bins without drying equipment. Kernels can lose up to 5 percent of the dry matter present at black-layer if the crop fully dries in the field. This is because the kernels continue to convert sugars and amino acids into starch.
and protein, losing carbon dioxide through respiration until the kernels dry to a water content of approximately 15 percent.

Kernel size and weight varies in sorghum, typically ranging from 2.0 to 4.5 millimeters in diameter. On average, kernels weigh about 25 grams per 1,000 seed (40,000 seed per kilogram) but can range from 13 to 40 grams per 1,000 seed (e.g., 25,000 to 77,000 seed per kilogram). Kernel size and weight depend on the plant’s ability to accumulate dry matter during GS III. Weather condition, soil fertility and available soil water influence final size and weight of kernels. Eighty-five percent of the dry matter produced by the plant during GS III goes directly to grain. Only 15 percent of final grain weight originates from dry matter produced during GS I and GS II. An early freeze or severe drought during the soft dough stage will drastically cut dry matter production, resulting in shriveled, light grain.

If growing conditions are favorable when grain is physiologically mature, tillers often emerge from the plant’s upper and lower nodes. These tillers, if left unchecked, produce small amounts of additional grain and increase grain moisture to levels unacceptable for immediate sale, storage or delivery, delaying harvest several weeks. This delay often results in substantial degradation in grain quality, reducing grain price and farm income.

**Physiological Maturity:** maximum total dry weight of the plant has occurred. The time from flowering to physiological maturity varies with hybrid and environmental conditions; however, it represents about one-third of the total time from planting. Grain moisture content at physiological maturity is usually between 25 and 35 percent, but varies with hybrid and growing conditions. If temperature and moisture conditions are favorable, branches may start to grow from several of the upper nodes (places where leaves attach).
AGRONOMIC PRACTICES FOR SORGHUM PRODUCTION

Land Preparation
Depending on the local situations, if land had to be prepared by tillage, frequency of tilling may be limited to 2-3 times and 1-2 times for oxen and tractor ploughing respectively with an interval of 21-28 days.

- The first plow should be conducted as soon as the crop harvest has been completed and the soil still retains some moisture content.
- The second pass as soon as the on-set of short rainfall and after the first flush of weeds had appeared.
- The third round for planting (dry sowing is recommended in moisture stressed areas)

In moisture deficit areas water conservation practices play vital role for sorghum production and productivity. Farmers should make tie ridging every 6 and 3 meters within the rows at the head and end of each row on clay and sandy soils respectively, to harvest rain water, prevent rain water run offs and enhance soil moisture retention.

Planting Method
Sorghum is usually dry planted at the onset of the rainy season. It can be drilled in furrows or can be planted on hills or spots. Drill in furrow at a spacing of 70-75cm between rows and maintain 15cm between plants for short varieties and maintain 20cm b/n rows for tall long season varieties within a row by thinning 10 days after germination. When planted on hills or spot, deposit 3-5 seeds in every hill at a distance of 20-25cm between hills within the same row and 70-75 cm between rows. Use seed with a minimum of 90% germination potential to ensure uniform germination and optimum plant population.

Row planting in sorghum production

Seed Rate & Depth
When drill planted, use 12kg of seed/ha and drill the seed at the bottom of the furrow at a maximum soil depth of 4cm and light cover with soil. Planting depth should never exceed 4 cm.
Planting time
Before planting, make a quick germination test by planting 100 seeds in the soil at 4 cm deep on one meter row and apply water to start the germination process. Keep the soil moist for the next 8 days until most of the seeds had germinated. Then count the number of seedling that had emerged from the soil. A good germination percentage should yield 90% fully germinated seeds or more.

- Planting time is dependent on the onset of rains, and maturity level of the seed variety.
- Midlands (long season varieties): Second week of April to first week of May
- Lowland (dry intermediate maturity): Mid-end June
- Use early maturing varieties in the instance of late time of planting
- Striga resistance varieties such as Gobye, Abshir and Berhan are early maturing types to be planted late mid-June to 1st week of July.

FERTILIZER RECOMMENDATION
- Currently, DAP and UREA are the only fertilizer products, recommended for all cropping systems. However, this situation is likely to change in the very near future as results from work done under EthioSIS on soil fertility mapping for Ethiopia become available. The current findings for Ethiopian soils show nearly all are deficient in N and P, and also S nutrients. For the future, a new fertilizer recommendation will be used which will include NPS as the core nutrients and in addition, the need to apply micronutrients such as Zinc and Boron where applicable.
  - Currently, DAP should be applied at 100kg/ha as basal during planting.
  - Urea: 50kg/ha is recommended and should be applied 35-40 days after emergence in moisture stress areas depend on the availability of moisture. For areas where moisture is reliable, use split application at a rate of 50kg for the first round at 35-40 days after planting and the remaining 50 kg will be applied at panicle initiation.
  - For demonstration purposes, and at FTCs level, use spot application of Urea at a rate of 1.8 grams per spot for every 25 cm within the same row. The Urea must be placed in the soil, not on the soil, at a depth of 7-10 cm and covered by soil. This will help the N element not to be lost as ammonia gas by volatilization.
  - For sorghum varieties resistant to striga, use the same rate of 100kg/ha Urea, but apply it earlier at 25-30 days after planting and immediately after weeding.

CROP ROTATION AND INTERCROPPING
The use of intercropping with legume crops can improve the nitrogen fertility status of the soil. Different places use different rotation and intercropping practices as shown on Table 1 below. Also some farmers use legume, oil and fiber crops.
For other agro-ecologies, intercropping sorghum with field pea, cowpea and other pulse crops is possible. Use of leguminous plant species such as Sesbania, leuqinea or pigeon pea on alley cropping in rows at an interval of 4-6m in the sorghum field without suppressing the yield of the sole crop will serve as earning additional forage, green manure or source of mulching and improve soil fertility level and reducing soil erosion.

### MOISTURE CONSERVATION

- **Use of tie-ridges:** this can be done using tie-ridger by creating water catchments at an interval of 3 meters distance in sandy soils and 6 meters in black soils between ridges on the farm. This minimizes surface runoff by allowing the rain water to stay and infiltrate into the soil, thereby improving moisture availability to the crop.
- **Early first ploughing produces large soil aggregates which enhance rain water infiltration by stopping water run offs and reduce soil erosion**
- **Tie-ridging after seedlings had emerged at 3-6 meter within the furrow**
- **Ridging intervals should be closer to each other for sandy soils and larger for black heavy soils.**
- **To reduce evaporation from the field, light cultivation, mulching, timely weed control and use of reduced seed rate are recommended.**

### Table: 1. List of crops selected for rotation in lowland areas

<table>
<thead>
<tr>
<th>S.N</th>
<th>Region</th>
<th>Wereda</th>
<th>Station</th>
<th>Selected rotation crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tigray</td>
<td>Tankua-Ab-ergelle</td>
<td>Yechilla</td>
<td>All chickpea varieties, Cotton (Roba B 50, Albar 637), Sunflower (Russian black)</td>
</tr>
<tr>
<td>2</td>
<td>Tigray</td>
<td>Lae’lay Adiabo</td>
<td>Degua’lle</td>
<td>Cotton (Roba B 50)</td>
</tr>
<tr>
<td>3</td>
<td>Tigray</td>
<td>Raya-Azebo</td>
<td>Tsega</td>
<td>Cotton (Bulk 202), Sesame (T-85)</td>
</tr>
<tr>
<td>4</td>
<td>Amhara</td>
<td>Guangua</td>
<td>Mota</td>
<td>Sun flower (Russian black), Sesame</td>
</tr>
<tr>
<td>5</td>
<td>Amhara</td>
<td>Metemma</td>
<td>Shehdi</td>
<td>Sun flower (Russian black), Sesame</td>
</tr>
<tr>
<td>6</td>
<td>Amhara</td>
<td>Kallu</td>
<td>Adis-mender</td>
<td>Chickpea (Mariye &amp; Akaki), Cotton (Albar)</td>
</tr>
<tr>
<td>7</td>
<td>Amhara</td>
<td>Kobo</td>
<td>01 mehalen-cha</td>
<td>Cotton (Albar, del, payin)</td>
</tr>
</tbody>
</table>
There are different varieties released for different agro-ecological zones. To date a total of 37 varieties are available (Tables 1-3). Before planting make sure that:

- The seeds are free from weed seed contamination and other foreign materials
- If possible use seed dressing chemicals against insect pests
- Table 2, gives a list of striga resistant varieties, and
- Table 3, presents a list of sorghum varieties for moisture stress agro-ecologies

### Table 2: Sorghum varieties resistant to striga

<table>
<thead>
<tr>
<th>S.N</th>
<th>Name of variety</th>
<th>Year of release</th>
<th>Altitude (masl)</th>
<th>Rainfall (mm)</th>
<th>Yield Farmer (ql/ha)</th>
<th>Research</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Berhan (PSL85061)</td>
<td>2001</td>
<td>Below 1850</td>
<td>600-900</td>
<td>10-30</td>
<td>40</td>
</tr>
<tr>
<td>4</td>
<td>Hormat/ICSB 1112BF</td>
<td>2005</td>
<td>Below 1850</td>
<td>600-900</td>
<td>16-24</td>
<td>23.3</td>
</tr>
<tr>
<td>No.</td>
<td>Varieties</td>
<td>Year of release</td>
<td>Maturity Group/days</td>
<td>Days to flowering</td>
<td>Plant height (cm)</td>
<td>Yield (q/ha)</td>
</tr>
<tr>
<td>-----</td>
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</tr>
<tr>
<td>1</td>
<td>Gambella 1107</td>
<td>1976</td>
<td>Medium</td>
<td>80-90</td>
<td>150-200</td>
<td>30-50</td>
</tr>
<tr>
<td>2</td>
<td>76T1# 23</td>
<td>1976</td>
<td>Early</td>
<td>60-70</td>
<td>120-140</td>
<td>25-45</td>
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<tr>
<td>3</td>
<td>Seredo</td>
<td>1986</td>
<td>Early</td>
<td>65-75</td>
<td>110-140</td>
<td>20-40</td>
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<tr>
<td>4</td>
<td>Meko-1</td>
<td>1998</td>
<td>Early</td>
<td>61-92</td>
<td>157-177</td>
<td>22-33</td>
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<tr>
<td>5</td>
<td>Teshale</td>
<td>2002</td>
<td>Early</td>
<td>65-76</td>
<td>170-210</td>
<td>26-52</td>
</tr>
<tr>
<td>6</td>
<td>Abshir</td>
<td>2000</td>
<td>100-120</td>
<td>83</td>
<td>110-140</td>
<td>15-25</td>
</tr>
<tr>
<td>7</td>
<td>Goby</td>
<td>2000</td>
<td>100-120</td>
<td>80</td>
<td>110-140</td>
<td>19-27</td>
</tr>
<tr>
<td>8</td>
<td>Macia</td>
<td>2007</td>
<td>113-130</td>
<td>55-60</td>
<td>135-150</td>
<td>42-44</td>
</tr>
<tr>
<td>9</td>
<td>Red Swazi</td>
<td>2007</td>
<td>Early/ 106-112</td>
<td>55-60</td>
<td>120-153</td>
<td>30-33</td>
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<tr>
<td>10</td>
<td>Raya (PGRC/E 222878x KAT369-1)</td>
<td>2007</td>
<td>129</td>
<td>82</td>
<td>185.7</td>
<td>37.68</td>
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<tr>
<td>11</td>
<td>Misikir (PGRC/E# 69441 x P-9401)</td>
<td>2007</td>
<td>126</td>
<td>76</td>
<td>123-191</td>
<td>40.73</td>
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<tr>
<td>12</td>
<td>GIRANA-1 (Cr:35 x DJ1195 x N-13)</td>
<td>2007</td>
<td>122</td>
<td>75</td>
<td>135-305</td>
<td>40.86</td>
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<tr>
<td>13</td>
<td>Yeju</td>
<td>2002</td>
<td>Early</td>
<td>68</td>
<td>172</td>
<td>50.9</td>
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<td>14</td>
<td>Birhan</td>
<td>2002</td>
<td>Early</td>
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<tr>
<td>15</td>
<td>Abuare</td>
<td>2003</td>
<td>Early</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Variety</td>
<td>Year</td>
<td>Type</td>
<td>Planting</td>
<td>Harvest</td>
<td>B</td>
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<td>---</td>
<td>---------------------------------</td>
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<td>------</td>
<td>----------</td>
<td>---------</td>
<td>---</td>
</tr>
<tr>
<td>16</td>
<td>Hormat (ICSV1112BF)</td>
<td>2005</td>
<td>Early</td>
<td>71</td>
<td>161-171</td>
<td>23.3</td>
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<tr>
<td>17</td>
<td>Gedo (Gambell 1107 x P9403)</td>
<td>2007</td>
<td>Early</td>
<td>75</td>
<td>116-138</td>
<td>34</td>
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<tr>
<td>18</td>
<td>WSV 387 (Melkam)</td>
<td>2009</td>
<td>Early</td>
<td>76-82</td>
<td>126-163</td>
<td>37-58</td>
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<td>19</td>
<td>P- 9501 x ICSR14 (ESH-1)</td>
<td>2009</td>
<td>Early</td>
<td>71-78</td>
<td>160-243</td>
<td>50-55</td>
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<td>20</td>
<td>ICSA 21 X ICSR 50 (ESH-2)</td>
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<td>Early</td>
<td>61-75</td>
<td>150-192</td>
<td>42-60</td>
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<td>21</td>
<td>Dekeba (ICSR 24004)</td>
<td>2012</td>
<td>Early</td>
<td>75</td>
<td>136</td>
<td>37-45</td>
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<tr>
<td>21</td>
<td>Mesay (MekoXGu-bye-2)</td>
<td>2011</td>
<td>Early</td>
<td>65-79</td>
<td>137-231</td>
<td>38-62</td>
</tr>
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</table>

**Mid-Altitude (1600-1900)**

<table>
<thead>
<tr>
<th></th>
<th>Variety</th>
<th>Year</th>
<th>Planting</th>
<th>Harvest</th>
<th>B</th>
<th>V</th>
<th>Test</th>
<th>Dry</th>
<th>Seed</th>
<th>Colour</th>
<th>Notes</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>IS 9302</td>
<td>1983</td>
<td>150-180</td>
<td>87-120</td>
<td>100-180</td>
<td>30-60</td>
<td>25</td>
<td>Red</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Baji</td>
<td>1995</td>
<td>147-181</td>
<td>107-138</td>
<td>139-164</td>
<td>35-56</td>
<td>20</td>
<td>Red</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Abamelko</td>
<td>2001</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Brown</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Geremew (87 BK-4122)</td>
<td>2007</td>
<td>150-160</td>
<td>103</td>
<td>170</td>
<td>49</td>
<td>40</td>
<td>Red</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Emahoy (Pwo1-092)</td>
<td>2007</td>
<td>136-142</td>
<td>73-78</td>
<td>220-300</td>
<td>40-45</td>
<td></td>
<td>Red</td>
<td>Grain mold resistant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Dagem</td>
<td>2011</td>
<td>158</td>
<td>87</td>
<td>156</td>
<td>27-54</td>
<td>42</td>
<td>Brown</td>
<td>Resistance to grain mold &amp; leaf disease</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
When certified and improved seeds are not available, selection of planting material shall be done as follows:

- Select plants having heavy head (panicle), well matured, dry and free from insect pest damage and disease attack
- Store the selected heads in a place safe from damage from rainfall, and insect pest attack

CROP PROTECTION

Weed Control (Striga management)

There are two major striga species of economic importance found in Ethiopia, namely: a) Striga hermonthica and b) Striga asiatica.

*S. hermonthica* is prevalent mainly in the North, Northwest; South, Southwest and Eastern parts of the country. It produces a distinct violet flower color. It can be found at any altitude above sea level and usually at rainfall of between 700-800 mm. As for *S. asiatica*, it is less common and can be found attacking not only sorghum, but sugar cane as well. *S. asiatica* is found in East and West Hararghe Zones. Also on some areas of the Somali administrative region and as of recently also it has been identified in areas of Western Shoa. A third striga species which has been identified in the wild is *Striga aspera* which shows similar appearance as that of hermonthica. It has been found in Wellega and Gojam as wild species, not yet attacking any crop.
Although soils infested with striga can be found on most soil types, usually those where recurrent drought is prevalent show the most severe infestations. Also, the level of infestation is directly correlated with the way farmers manage their fields. If farmers do not exercise any control measures and poorly manage their fields, there is a likelihood that striga infestation in the soil will increase.

When striga grows without any control measure, can easily produce over 40,000 seeds per plant on any given season. Once these seeds drop into the ground, they stay viable for more than 40 years. That is why it is so difficult to control striga once it is in the soil. Moreover, striga has the capacity to parasitize other crops such as maize, rice, and even tef to lesser degree. Also, when farmers continuously plant the same striga susceptible sorghum variety, it helps on selecting the striga biotypes which are more adapted to that variety and striga seed production can be significantly increased.

For striga control measures, farmers can use different approaches although none of them will completely eliminate the parasitic weed from the soil. One of such options is through crop rotations using a legume crop such as soybean, or chickpeas. When farmers grow a leguminous crop in rotation with sorghum, it helps in promoting the germination of some of the striga seeds present in the soil as a suicidal germination, since striga cannot parasitize the legume crop. Another option is to use striga resistant sorghum varieties (Table 1) which already exist in the country. As these varieties are low germination stimulant, the damage of striga infestation will be reduced. The integrated striga management (ISM), which includes the use of resistant varieties, soil and water conservation practices and the use of N fertilizer along with all recommended practices will manage in reducing the level of infestation. One very promising option for striga control is the use of pull & push technology which involves the growing of a combination of sorghum or maize crop as main crop and the planting of a perennial desmodium leguminous species as an intercrop.

- The critical time of weed control is during the GS I stage of the crop (first 30 days).
- Early weed control helps the sorghum crop develop without competition for light, soil moisture and nutrients, thus, enhancing high grain yield.
Cultural measures to control weed
1 Use of clean seeds
2 Eradicate weeds from the field during the fallow period, before flowering and seed setting.
3 Use of crop rotation
4 Integrating the use of weeding with cultivation practice
5 During seasons having high rainfall, control weeds more frequently and before they attain seed setting.
6 At all times to control weeds, the use of integrated approach is recommended. The complementarities between manual and herbicidal methods of weed control need not to be overlooked. There are many promising herbicides that effectively control aggressive weed species that hinders productivity gains in sorghum based cropping systems.
7 Striga control: From the very nature of this weed, it is very difficult to eradicate striga from infested soils, within short period of time. But the following integrated approach is recommended:
   a. Use striga free seed,
   b. Avoid planting sorghum, maize or finger millet crops on fields that are highly infested by striga and use crop rotation with leguminous crops,
   c. On fields where striga infestation is not severe, use organic or chemical nitrogen-rich fertilizers. Soil nitrogen promotes the germination of suicidal striga seeds.
   d. Frequent hand weeding of the striga weed, before it produces seeds.
   e. Avoid the dispersion/transmission of striga seed by means of farm implements, cattle or other means
   f. Integrate the control measures using varieties resistant for striga infestation

Insect Pest Control
Different types of insect pests attack sorghum at field and/or storage level. Some of the economic important field and storage insect pests with their controlling measures are listed below.
<table>
<thead>
<tr>
<th>Type of insect pest</th>
<th>Cultural control method</th>
<th>Types of pesticide and recommended rate</th>
</tr>
</thead>
</table>
| Army worm            | Chopping the pest using branched stick before they invade the farm land. Prepare deep trench around the field and kill the insects collected in the trench | Malathion 50% E.C at 2lt/ha mixed with 200-300 lt of water  
Fentrathion 50% E.C at 2 lt/ha mixed with 200-300 lt of water  
Diazinone 60% E.C at 1 lt/ha mixed with 200 lt of water  
Savine (Carbaril) 85% W.P at 1.5kg/ha mixed with 200 lt of water |
| Stalk borer          | Slash the infested plant stalk from the base  
Expose the harvested stalk lying down to sunlight 24 weeks before pilling-up  
Roughing infested plants  
Field sanitation and early planting | Simbush (cypermethrine) 1% granule at 3.5kg/ha and inserting in each infected plant whorl  
Diazinone 10% granule at 3.5kg/ha and inserting in each infected plant whorl  
Generally, use chemicals such as cypermethrine 1% granule or Endosulfan 3% granule or (either 1% or 3% or 10%) diazinon granule before the crop growth attains knee height level or Endosulfan 35% EC at the rate of 2 lt/ha or sevin 85% WP at the rate of 1.5kg/ha |
| Cut worm             | Keep the crop land free from piles of decomposing plant residues, which usually attract moths ovipositing their eggs. | Spray the field during the late afternoon, just before evening using 1lt/ha in 200 lt of clean water of Pyrethroids such as Cimbush, Ambush, Cypermetrins or any other Pyrethroids available in the market. |
| African ball worm    | Expose the pupa of the pest to sunlight and the natural enemies using                     | Use Endosulfan 35% EC at the rate of 2 lt/ha or Carbaril 85% WP at the rate of 1.5kg/ha or Cypermetrin 25% EC at the rate of 1 lt/ha.  
Use to spray Yonex 35% EC or Endosulphan at the rate of 2 lt/ha and mix with 200 lt of water |
| Termite              | Early planting  
Plowing as soon as harvesting is completed  
Remove crop residues from the field  
Use of crop rotation | Use 500 cc of Regent (Fipruline) dissolved in 200 lt of water and apply as spray on the termite mounds before sunset. |
<table>
<thead>
<tr>
<th>Type of insect pest</th>
<th>Cultural control method</th>
<th>Types of pesticide and recommended rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weevil (species of moth and beetle)</td>
<td>Keep the storage room clean</td>
<td>Use spraying Actelic 25% EC at the rate of 16-40ml mixed with 1-2 lt of water for 1 ton of grain</td>
</tr>
<tr>
<td></td>
<td>Keep the stored grain at elevated places from the ground</td>
<td>Actelic 50% EC at the rate of 8-20ml mixed with 1-2 lt of water for 1 ton of grain</td>
</tr>
<tr>
<td></td>
<td>Keep the grain properly dried</td>
<td>Actelic 2% powder at the rate of 200-500gm to mix 1 ton of grain using grain mixer</td>
</tr>
<tr>
<td></td>
<td>Keep the grain mixed up with ash (if it is for home consumption purpose)</td>
<td>Mix the grain with Atyleathion 5% powder at 200-500gm for ton of grain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Use fumigant: Aluminum phosphide (phostoxine) 2-5 pellets to fumigate the storage structure or the grain properly covered when the first infestation is observed</td>
</tr>
<tr>
<td>Rats</td>
<td>Keep clean and at a distance the storage structure from the field (to avoid transfer of rats from the field)</td>
<td>Use Lamirat bite (birmidilone) and clirate pellet prepared by 100gm at every 2m on the way to their hole (be sure not to be picked up by other animals)</td>
</tr>
<tr>
<td></td>
<td>Keep the storage structure sealed not to allow rats</td>
<td>Use zinc phosphide each pellet prepared by 25gm the same way the above chemical</td>
</tr>
<tr>
<td></td>
<td>Use rat buffer at the base of storage structure not to allow entrance of rats</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Use cats and rat traps</td>
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</tbody>
</table>

Table 4: Control measures of major storage pests
Diseases
The major diseases affecting sorghum are:
- Smut (head, covered and loose and long)
- Anthracnose
- Bacterial blight
- Grain mold
- Downy mildew
- Ergot

Control measures
- Rouge and burn/bury plants that are showing symptom of infection
- Use crop rotation and ban planting sorghum for 3 consecutive years on fields that harbor inocula of these disease-causing pathogens
- Use of pathogen free seed, seed dressing with appropriate fungicides, timely planting and harvesting
- Particularly for ergot, there is no chemical control method and thus rouging use of clean seed is recommended

Downy mildew (left) and Anthracnose infection results in a reddish discoloration (right) of the sorghum leaves and peduncle respectively

HARVESTING AND STORAGE
Grain sorghum is physiologically mature when moisture content drops to about 30%. At moistures higher than 25%, however, the seeds are too soft to withstand adequate threshing action, leading to either unthreshed heads or cracked seeds. Sorghum dries rapidly, often down to the 12% moisture level needed for safe storage.

Time of harvesting is dependent on the variety of sorghum and agro-ecological condition. Sorghum to mature it requires; 7-8 months at higher altitude areas, 6-7 months at mid altitude areas and 4-5 months at lowland areas. Generally, harvesting will be operational as:
- The head (panicle) gets dry
- Harvesting can be panicle only
- Thresh the sorghum after complete drying. Use of machine threshing is recommended but if not available, hand or animal threshing can be done Store the grain at moisture level 12.5-13%
• Use storage structure that cannot allow rat, moisture or other pests to affect the grain.

Storage
Dry sorghum stores essentially. It should be cleaned before storing. In addition, it should be mechanically spread.