

ENHANCING SORGHUM PRODUCTION AND MARKETING IN SEMI-ARID KENYA



MANUAL

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1.0 Introduction

Sorghum is an important food security crop especially in semi-arid lands of Kenya. It is adapted in a wide agro-ecological zones. Sorghum requires less water than maize thus offering great potential for supplementing food and feed resources. Although sorghum varieties with a yield potential of 2 to 5t/ha are available, their productivity has remained low, at 0.7t/ha. The major constraints to sorghum production are: inadequate soil moisture, low soil fertility, bird damage, pests and diseases, high cost of inputs, low adoption of improved varieties, weeds, lack of markets and limited utilization options. Farmers consider lack of markets, low producer prices and bird damage as the main constraints to increased sorghum production.

Most sorghum is grown at altitudes of less than 1500 m above sea level. However there are varieties suitable for up to 2400 m a.s.l. It requires a rainfall of 250-400 mm during the growing season. Most dryland sorghum cultivars are those that thrive best in areas with a small range of diurnal temperatures i.e. the day and night temperatures do not differ greatly. Sorghum does best in wide range of soils including sandy, clay and loamy ones. It thrives well on fertile soils but will grow on somewhat exhausted soils.

2.0 Sorghum tolerance to drought

Drought is one of the major limitations to crop productivity worldwide. Feeding more people with less water is a major challenge facing humanity (Foley *et al.*, 2011) requiring crops that are highly adapted to dry environments. The drought tolerance of sorghum is one of the features that make it a valuable crop in the dry areas (Borrell *et al.*, 1999). Evolution of sorghum under pressures of drought has resulted in its favorable physiological properties (Mutisya *et al.*, 2010). It is a repository of drought adaptation mechanisms (Borrell *et al.*, 2014). It can survive drought conditions for some weeks by rolling up its leaves and thus decreasing transpiration. The major advantage of sorghum as a drought tolerant crop is that it can become dormant under adverse conditions and can resume growth after relatively severe drought. Early drought (pre-flowering drought) stops growth before floral initiation and the plant remains vegetative; it will resume leaf production and flower when conditions again become favorable for growth. Late drought stops (post-flowering drought) leaf development but not floral initiation (Borrell *et al.*, 1999). Signs of drought intolerance in sorghum include leaf rolling, death of lower leaves (senescence), stunted growth and low yields. The traits related to drought tolerance in sorghum include early maturity, increased root density (Mutisya *et al.*, 2010) leaf rolling and wax content which will help in reducing leaf temperature and the stay green (Borrell *et al.*, 1999).

3.0 Choice of sorghum varieties

3.1. KARI Mtama-1

This is medium to tall variety depending on the area and rainfall amount received. It has one main erect plant and sometimes has 2-3 straight tillers. It matures in 90-120 days (3 - 3.5 months). The head is big and the tip is divided into several spikelets. The grain is large and white in colour. The average grain yield is 4000kg/ha or 17 (90 kg) bags/acre. KARI Mtama-1 is highly tolerant to stalk borers and aphids. It is a sweet grain sorghum lacking tannins making it palatable to birds. It is suitable for cultivation in Machakos, Kitui, Mwingi, Makueni, Tharaka, Mbeere, Kilifi, Tana river, Marsabit, Moyale and Kajiado districts. The variety grows well in areas with receiving about 250mm of rainfall per season. This variety is good for preparation of different dishes for home consumption. It is also highly marketable due to its white colour and sweet grain.



Photo 1: Farmer with her KARI Mtama 1 Crop

3.2. Gadam

It is semi-dwarf to medium height with a very uniform plant population. It is a very early variety maturing in 85-95 days (2.8 - 3 months) depending on altitude and rainfall amount making it an ideal variety for very dry areas. Its grain is chalky white in colour. The average grain yield is 3,100 Kg/ha or 14 bags/acre. It does well in low rainfall semi-arid areas and dry warm mid-highlands such as Machakos, Kitui, Mwingi, Makueni, Tharaka, Mbeere, Kilifi, Tana river, Marsabit, Moyale and Kajiado districts. The Gadam variety has high brewing quality therefore it is being used in the brewing industry. It is good for commercialization and home consumption.

3.3. Serena

Serena is a medium plant variety with a height ranging between from 150 to 160cm. The stems are medium thin with many straight erect tillers. The leaves are thin and up wards erect. The grain head is the compact conical type with brown grain. It matures in 90-110 days (3-3.5 months). Potential grain yield of 1800-2300 kg/ha or 8-10 (90Kg) bags/acre. It does well in semi-arid areas. It also grows in wetter semi- arid areas. The variety is relatively resistant to bad damage due to tannin in the grains. It grows well in Machakos, Kitui, Mwingi, Makueni, Tharaka, Homabay, Kisumu, Kakamega, Busia and Siaya. Its uses include home consumption as human food and poultry feed. It is also sold to milling industries.



Photo 2: Gadam sorghum stand



Photo 3: Serena sorghum stand

3.4. Seredo

Seredo has thick stems and medium height plants with outward spreading tillers which mature later than the main stem. The head is large and oval at the base and tip. The variety matures in 110-120 days (3.5-4 months). The grain colour is dark brown. The average grain yield is 2700-3600kg/ha or 12-16 (90 kg) bags/acre. Seredo is tolerant to bird damage due to high tannin content in the grains. It does well in wetter areas of lower eastern Kenya, Homabay, Kisumu, Kakamega, Busia and Siaya. The grain is used more for food and poultry feed as well as selling to milling companies.



Photo 4: Seredo Heads

4.0 Planting of sorghum

4.1. Site selection

Birds are a major menace in all major sorghum production areas in Kenya. The problem is more severe in isolated production areas. Avoid establishing crop fields in isolated fields far from homesteads and birds roosting sites.

4.2. Soil and water conservation measures

4.2.1. Bench

Terraces can be the *fanya juu* or bench terrace. The *Fanya juu* terraces are constructed by heaping soil up-slope to make an embankment which forms a runoff barrier leaving a trench used for retaining or collecting runoff. The canal is 0.6 m deep and 0.6 m wide. The soil embankment is about 0.7 m from the surface. Runoff from external catchments is led into the canals for retention to allow more time for water to infiltrate into soil. Crops such as bananas, pawpaw and citrus can be grown in the ditches while other crops like sorghum can be grown within the terrace or between the terraces and benefits from the retained runoff rainwater which could have been lost as runoff. This technique is recommended for areas with slopes greater than 5% (Figure 4).

The bench terraces are similar to *Fanya juu* terraces but do not have a retention ditch at the lower side of the terrace and are spaced closer than the *Fanya juu* so that with continuous maintenance by placing soil on the embankment, a bench is formed by lower terrace embankment with the lower side of the terrace above this one. Rainwater is uniformly spread within the terrace unlike the *Fanya juu* terrace where rainwater is collected at lower side (Photo 4)



Photo 5: Suitable land topography for construction of fanya juu terraces for in-situ conservation of rain water for crop and fodder production in ASALs of eastern Kenya

4.2.2. Zai pits

These are planting pits 30 cm diameter and 15-20 cm deep. Manure or compost is placed at the bottom of the pit and mixed with soil before planting. During digging the soil is thrown down-slope to form a small embankment. The pits are made at a spacing of one meter row to row and 30 cm pit to pit. Pits should not be perpendicular to each other to avoid possible erosion in case of excess rainfall.

Integration of rainwater harvesting with soil fertility improvement like use of manure 2t/ha plus water harvesting in semi-circular hoops can increase sorghum grain yield from 0.36t/ha to 1.96t/ha.



Photo 6: Zai pits planted with fodder crop in semi-arid lands conserves soil moisture for crop growth.

Table 1. Effect of Zai pitting and fertilizer use on grain yield and water use efficiency (WUE) of sorghum at Masinga during the 1995 short and long rains

Treatments/Season	Grain yield (kg/ha)	WUE(kg/ha/mm)
Short rains		
Zai pitting-fertilizer	850	2.85
Zai pitting+ fertilizer	1010	3.38
Long rains		
Zai pitting-fertilizer	900	3.27
Zai pitting+ fertilizer	780	2.83

4.2.3. Tied ridges

These are made to increase surface storage and to allow more time for rainwater to infiltrate the soil. Oxen made furrows are manually tied at 3-5 m intervals. The lower furrow is tied starting from the point between the above tied furrows such that tying is not perpendicular to prevent possible erosion in the farm to give a pattern similar to house construction using bricks. The cross ties are usually of lower height than the furrow so that if they fill, the overflow is along the furrow but not down the slope. This technology is recommended for land having a slope greater than 2% so that the furrows retain rain water that would be lost as runoff if the structures were not in place. Effect of tied and open ridging technology of rainwater harvesting on mean sorghum grain yields across various sites in semi-arid eastern Kenya is shown in Tables 2.

Use of tied ridges normally made by oxen-ploughing will assist in rainwater conservation for increased availability of soil moisture and growth of sorghum leading to increased sorghum grain yields as shown here.

Table 2. Effect of tie-ridging and fertilizer on grain yield and water use efficiency (WUE) of sorghum at Masinga during the 1995 short and long rains

Treatment/season	Grain yield(kg/ha)	WUE (kg/ha/mm)
Short rains		
Flat cultivated-fertilizer	190	0.64
Flat cultivated +fertilizer	380	1.27
Tied ridging-fertilizer	360	1.21
Tied ridging +fertilizer	820	2.73
Long rains		
Flat cultivation-fertilizer	80	0.29
Flat cultivation +fertilizer	350	1.26
Tied ridging-fertilizer	310	1.13
Tied ridging +fertilizer	1,030	3.75

4.2.4. Micro-catchment

Sorghum grain can be increased by planting in micro-catchment plots (provide a sketch of micro-catchment) with some part of the field acting as a runoff catchment of cultivated field of sorghum. This runoff enriches soil water in the cultivated sorghum field leading to increased sorghum growth and yield as shown.

Table 3. Yield of sorghum from trial plots using on-farm external catchment systems during the 1982-1983 long rains

Plot	year	Catchment cultivated are ratio	Experimental plot yield (kg/ha)	Control plot	%yield increase
Katiorin	1982	2:1	775	135	474
Marigat	1983	1:1	540	10	5300

4.2.5. Enhancing yields through deep tillage

Deep tillage is achieved by ploughing the soil to 20cm depth (greater than 6 inches depth) to allow percolation and retention of rainwater in the soil. This improves soil water holding capacity which could not have been achieved without this kind of cultivation.

Use of deep tillage increases sorghum grain yields. Deep tillage allows rain water to enter into the soil and be retained in a deeper soil profile for long than in a shallow tilled soils as shown in the Table5.

Table 5. Sorghum grain yield from a runoff harvesting trials at Katiorin (1981) with different tillage treatments

Treatments	Sorghum grain (kg/ha)	
	1 st harvest	Ratoon harvest
Impounded plot, deep tillage	420	595
Impounded plot, zero tillage	120	-
3 m contour ridges hoop, zero tillage	410	900
Control plot deep tillage	60	325

5.0 Sorghum plant nutrition

5.1. Soil fertility management

Soil fertility can be managed through several strategies including, organic fertilizers/manures, and inorganic or chemical fertilizers. Most soils in sorghum and millet production areas are deficient in both essential macronutrients such as nitrogen (N) and phosphorus (P), and micronutrient zinc which are essential for adequate crop growth. To correct these nutrient deficiencies, a wide range of organic and inorganic fertilizers are used.

5.2. Organic fertilizers/manures

Manure improves soil organic matter, which impacts positively on soil moisture retention and structure. Well-decomposed manure should be broadcasted in the field close to the onset of the rains and mixed with the soil during ploughing. In case of low volumes of manure, it can be spread in bands along the planting furrows and mixed with the soil before seeds are sown. 2 tons per acre is sufficient.

5.3. Inorganic fertilizers

Most soils in sorghum production areas are deficient in nitrogen (N) and phosphorus (P), which are essential for adequate crop growth. Trace element Zinc is often deficient and will need to be corrected by applying zinc sulphate. To correct these nutrient deficiencies, a wide range of organic and inorganic fertilizers are used. The 4R fertilizer stewardship (Right time, Right rate, Right Placement and Right Source) must be followed (IPNI). At planting apply one bag (50kg) per acre of compound fertilizer NPK (20:20:0, 23:23:0 or 17: 17:17) per acre. Top dress with one bag (50kg) of calcium ammonium nitrate (CAN) per acre. The fertilizer is normally drilled along the planting furrows and thoroughly mixed with the soil; the seed is placed in the shallow furrow and then covered. Zinc sulphate is applied as a topdress at 2% zinc sulphate general purpose grade when sorghum is at 4-5th leaf stage.

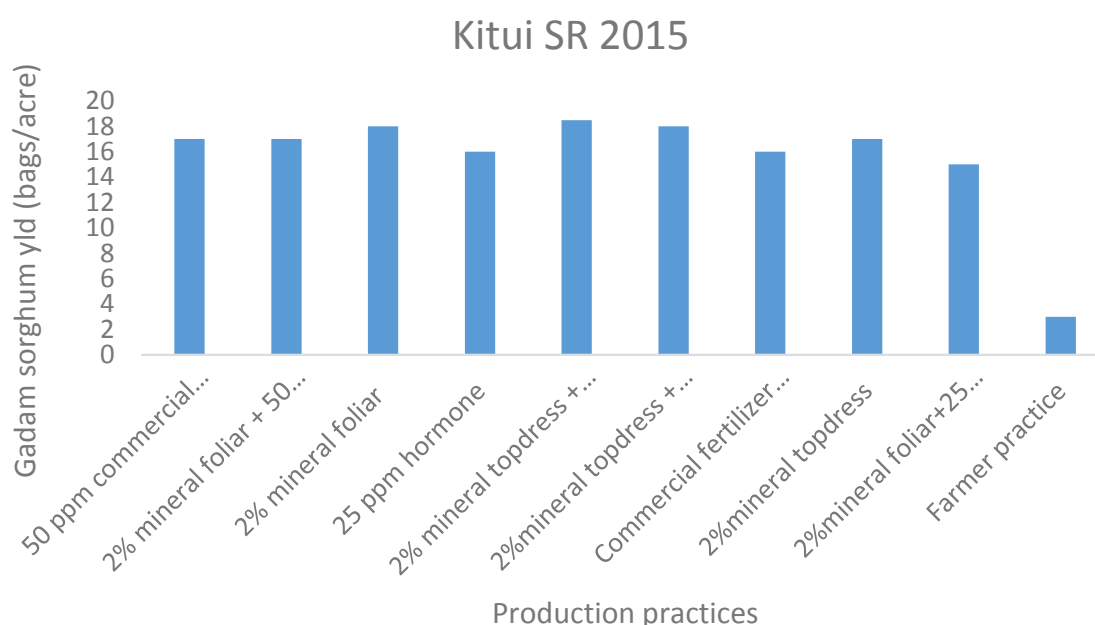


Figure. 1. Effect of growth enhancer and micronutrient zinc on sorghum grain yield in short rains

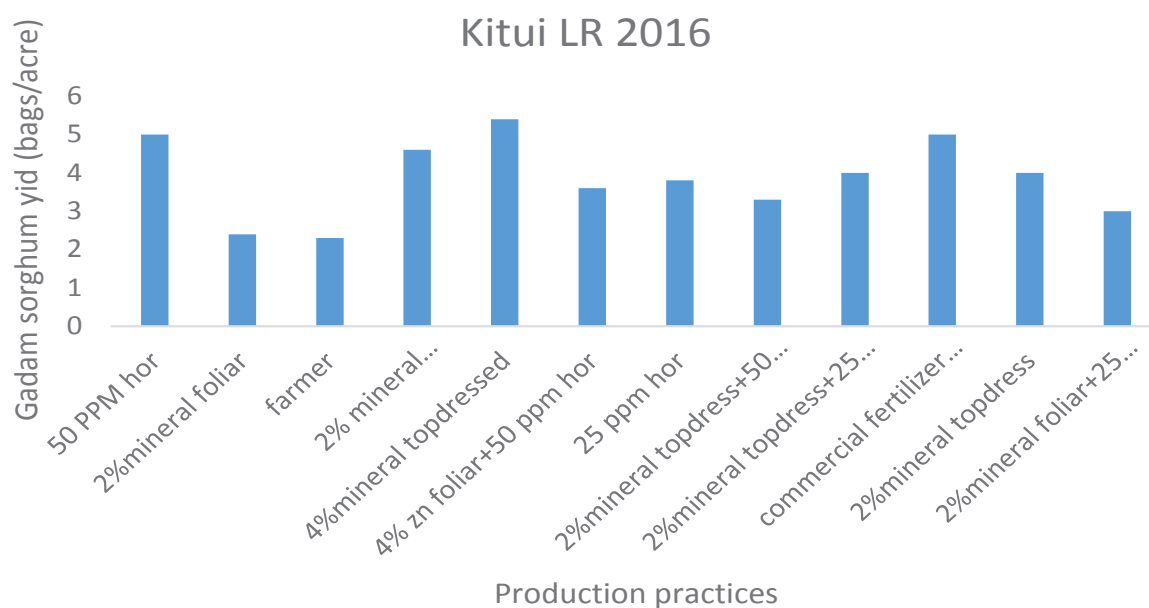


Figure. 2. Effect of growth enhancer and micronutrient zinc on sorghum grain yield in long rains

5.4. Growth enhancers and micronutrient fertilizers

In the semi-arid zones yield of sorghum can be enhanced by use of commercial growth hormone, a 2-4% zinc micronutrient topdress and modest amounts of fertilizer at planting (DAP 50 kg/acre) and additional topdressing with (CAN 50 kg/acre). The sorghum grain yield can be from 2 to 4 (90 kg) bags in seasons of low rainfall and 2 to 17 bags in seasons of good rainfall (Figure 1 and 2).

5.5. Management of acid soils

Soil testing is recommended before planting; however liming is recommended if soils are acidic. Soil testing will give some soil reaction pH which is a measure of soil acidity or alkalinity depending on the soil pH range. The desired management of acid soil depends on the soil pH and the ratio of Calcium to Magnesium. The ideal ratio being 2:1 to decide on whether corrective measure will require lime or dolomitic lime stone application.

Table 6. Soil test interpretations for management purposes

Soil test pH	Rating	remarks
<4.5	Strongly acidic	Very acidic
4.6-5.0	Medium acidity	Medium acidic
5.1-5.5	acidic	acidic
5.6-6.5	Slightly acidic	Slightly acidic
6.6-7.0	Slightly alkaline-to alkaline	Slightly alkaline
>7.0	alkaline	May be saline
Soil with pH less than 5.5 are subject to liming to remove exchangeable acidity that might limit crop production including sorghum.		

5.6. Management of saline soils

Saline soils are either have excess soluble salts, excess sodium or both in levels that affect plant water and nutrient uptake leading to decline in crop yield. There are some areas in semi-arid land with soil salinity problems. The advantage is that, the soils are well drained and salt effect is decreased by the rainfall received in these areas. The salinity is not

severe ($EC_e < 1 \text{ mS/m}$) in sorghum growing areas apart from Kiboko, Taveta and some areas in Kibwezi around Kwa Kyai irrigation scheme. The recommended management is application of manure or compost and frequent soil testing to ensure soil electrical conductivity is below 1 mS/m .

6.0 Sorghum routine management practices

6.1. Land preparation

Planting field should be prepared well in advance and it is recommended that land be ploughed immediately after harvesting the previous crop. All sorghum varieties require a fine seedbed for better seedling establishment. If tractor or oxen plough is used to open up the field, it is advisable to harrow it once in order to break the large soil boulders (Fig. 1). When hand-hoes are used for land preparation, the large soil boulders should be reduced by breaking them to provide a moderately smooth seed bed (Fig. 2)



Photo 7: Poor and good seed bed

6.2. Planting

Planting field should be prepared well in advance, and it is recommended that land be ploughed immediately after harvesting the previous crop. Dry planting is highly recommended. Thus, plant before or at the onset of rains by either drilling in the furrows made by oxen plough or tractor, or hill plant in the holes made by Jembe or Panga. After the onset of the rains, plant shallow but press the soil so that the seed may be in contact with moist soil. Planting depth ranges between 2.5 cm to 4.0 cm, but when dry planted, the depth should be 5 cm.

6.3. Spacing and plant population per hectare

In semi-arid areas the ox-plough yoke is fixed at 90cm (fig 3) so the spacing is 90 cm x20 cm but in manual planting the spacing is 75x20cm (Table 7).

Table 7: Sorghum spacing and seed rates

Crop	Spacing (cm)	Seed rate (kgs/ acre)
Sorghum (sole crop)	Oxen (90 cm × 20 cm)	3 - 4
	Manual (75 × 20)	
Sorghum (intercrops)	90 × 20 and legume between rows of sorghum	3-4
Single alternate rows		
Double rows of legumes	Sorghum 120× 20-two rows of legume between sorghum rows	2-3



Photo 8: Ox-plough made sorghum planting furrows



Photo 9: Hoe made sorghum planting furrows

6.4. Intercropping

Sorghum is often grown in association with pulses such as pigeon peas and green gram. The row arrangement for the cereal and legume could be a single alternate where a legume falls between two rows of sorghum spaced at 90 cm. Two rows of pulses could also be also be alternated with two rows of sorghum.

6.5. Crop rotation

Crop rotation is highly recommended to reduce build-up of sorghum diseases and insect pests and soil fertility improvement. Rotating of sorghum with other cereal crops like maize and millet should be avoided, especially due to Maize Lethal Necrosis Disease (MLND) and that there is no soil quality improvement when a cereal is planted following another cereal. Cereals like sorghum are rotated with legumes because legumes improve soil quality through biological nitrogen fixation and organic matter addition through litter decomposition. Some legumes improve the soil quality better than others and therefore need to know the right legume to rotate with sorghum.

6.7. Weeding

Weeds reduce sorghum yields by competing for moisture, nutrients, space and light. Weeds are also an alternative host to pests and diseases. The first weeding should be done within 1 to 2 weeks after emergence. Two weeding's are recommended. The second weeding is done before topdressing fertilizer is applied about 3 weeks after germination. Chemical weeding can also be done in large-scale farms using recommended herbicides.



Photo 10: Early weeding in sorghum at 1-2 weeks after emergence

6.8. Thinning

Thinning should be done when the soil is moist. This ensures minimal disturbance of the roots of the remaining plants for healthy growth. Thin sorghum seedlings and leave 1 plant per hill. It should be done 1-2 weeks after emergence in semi-arid areas (at 3-4th leaf stage). This is best done after first weeding in order to accommodate appropriate plant density adjustments in case some plants are damaged during weeding. Leaving 2 plants adjacent to it compensates for a gap within the row. Sorghum thinning is done so early to avoid waste of fertilizer to plants that farmer will thin later. To achieve good yields, the vegetative regrowth (tillers) are thinned to ensure 2-3 plants per stool. This ensures formation of large panicles and high sorghum yields

6.9. Rogueing

This is the removal of plants that has characteristics, which are different from the needed variety. Plants taller than the general height of the plant population, whose flower colour deviates from that of majority of other plants, or with grain colour that is different from the majority of plants should be removed.

6.10. Sorghum Ratooning

Ratooning is a practice of getting more than one crop from a single sowing through proper crop husbandry. The well-established root system of the ratoon crop has the ability to utilize the environmental resources better than a freshly sown crop. Ratooning reduces labour requirements by minimizing costs such as ploughing, planting and bird scaring associated with migratory birds between July and August. By flowering in April when temperatures are high ($> 20^{\circ}\text{C}$), sorghum avoids poor seed set associated with low temperatures between May and August

Sorghum is planted in short rains (October-November). When the crop is mature, it is harvested in January or February and immediately cut back to about three inches above the ground. The vegetative regrowth takes advantage of the long rain season, which commences in, mid-March. To achieve good yields, the vegetative regrowth (tillers) are thinned to ensure 2-3 plants per stool. Weeding and other management practices are carried out as for freshly sown crop.

7.0 Protection of sorghum against insect pests

The major insect pests of sorghum include shoot fly, stem borer and birds

7.1. Shoot fly

As soon as the sorghum seedling have emerged, established or one week after germination look out for shoot fly. The yellowish or white maggots bore into the hearts of the shoots and cause characteristic dead heart

7.1.1. Control of shoot fly

- Dry plant or plant early within 7-10 days of onset of rains
- Seed dress with imidacloprid 70
- Increase seed rate 3 to 5 kg/ha
- Spray suitable insecticide e.g. Marshal within 1-2 week after germination and after next 2 weeks

7.2. Stalk borer

The caterpillars feed inside the stalks killing the growing points (die back), stunted plant growth, poorly developed ear heads and complete drying-up of plants in severe infestations. The damage and or presence and symptoms of *Chilo partellus* or *Buseolla fusca* appear as three dots along the middle part of leaf length. As for symptoms of bollworm (*Helicoverpa armigera*) larvae on the leaves, the leaves show long tattered damage with stunted growth for the slow maturing plants (Photo 9).



Photo 11: Sorghum plant damage by various pest larvae

7.2.1. Control of stalk borer

- Destruction or proper storage of crop residues
- Plant early and improve soil fertility and plant vigour
- Scout for borer infestation and apply suitable chemical such as bull dock star at 1-2 kg/acre, spray with Marshal at 80mLs per acre or dress with pepper and ash mixtures in the funnels 6 weeks after germination.

One or two occurrence of dead hearts of sorghum could either be severe attack of the growth bud by either shoot fly or any of the stem borer species.

7.3. Pest surveillance

To manage the stalk borer, shoot fly and other insect pests, it's important to undertake routine surveillance.

7.3.1. Pest surveillance 1

- a) Appearance of bollworm damage. The leaves appear as tattered with evident stunted growth.
- b) Appearance of stem borer damage of three-line dots of fed leaves. Appearance of “dead heart” of growing bud is evidence of shoot fly or stem borer larvae.

7.3.2. Pest surveillance 2

Two weeks later there is need to carry out surveillance to find out if other pests or resurgence of initial is taking place. If no more insect pests then next surveillance will be undertaken at flowering stage.

7.3.3. Pest surveillance 3

If bollworm larvae attack ripening grain at soft dough spray of a contact insecticide like Duthrin® (Lambdacyhalothrin 17.5g/L as active ingredient of synthetic pyrethroid insecticide applied once at the rate of 200ml /ha

8.0 Sorghum harvest, processing and storage

8.1.1. Sorghum harvest at soft dough stage

Birds start visiting the sorghum crop at early soft dough stage. As the grain starts attaining cream white colour bird damage increase exponentially as the grain ripen to hard dough. This presents the most laborious period of sorghum production as the farmer move from one point to another to chase birds away (Photo 12). Harvest of sorghum at soft dough offers opportunity to salvage yield at over 90%.



Photo 12: Sorghum ear 25% damaged by birds at full white



Photo 13: Sorghum harvest at light-green stage

8.1.2. Sorghum harvest at physiological maturity or when head is dry

A sorghum crop is physiologically mature when the grain is hard and does not produce milk when crushed between the fingers. At this stage the heads can be harvested for drying. Alternatively the farmer can wait for the heads to dry in the field and harvest.

8.2. Sun drying, threshing and winnowing sorghum

8.2.1 Sorghum processing

Sun-dried sorghum ears are subjected to hand threshing and winnowed. Winnowing of grain follows after it dries to 10-12% moisture content and safe from aflatoxin infection from the soil. The dry grain can be dusted with insecticide against weevils and safely stored in suitable bags.



Photo 14: Sun drying grain on ears



Photo 15: Winnowing the grain



Photo 16: Grain ready for insecticide dusting

8.3. Harvesting, Dusting and storage

Harvest the crop when the grain is hard and does not produce milk when crushed between the fingers. The heads are broken off by hand and sun dried. The heads are harvested, threshed and dried to less than 13% moisture content. To control storage pests the grain should be dusted with effective storage chemicals (e.g. super actellic) at 50g per bag. A farmers can also use neem (also add scientific name) tree leaves or treat with wood-ash (4-6 kg of ash per bag). Weevils are the main storage pests. The grain is then stored in cool well ventilated stores that don't leak water.

9.0 Cross cutting issues in production

9.1. Economics of using growth booster and mineral supplement in sorghum production

Farming interventions require information on economic returns to investment. Farmers need to grow a sorghum crop that is economically viable. This is especially applicable to sorghum farming in semi-arid eastern Kenya where occasionally several challenges occur.



Photo 17: Sorghum plants treated with growth enhancer and micronutrient fertilizer

9.2. Economic benefits on sorghum grain production

Current sorghum grain production in semi-arid eastern Kenya is 2-4 bags/acre below breakeven of 5 bags/acre. This production level can be enhanced by use of growth booster and zinc mineral. These increases sorghum production to 3bags/acre in poor season rains and to 18 bags/acre over farmer practice in above average rain season.

Economic analysis based on every one shilling spent on production gives back two shillings. This show that use of growth booster and mineral zinc is a viable technology for sorghum production. However use of 50kg DAP/acre at planting plus top-dress with 50kg CAN/acre with sorghum spacing of 90 cm x 20 cm, pest management and bird scaring is recommended.



Photo 18: Sorghum harvest from 25 m2 plot growth with growth booster and mineral zinc supplement and modest fertilizer amounts



Photo 19: Mature sorghum grown using growth booster and mineral zinc supplement and modest fertilizer rates.

9.3. Economics of sorghum cultivation using growth booster and mineral zinc supplement in semi-arid eastern Kenya.

This analysis is based on cost of inputs and sorghum grain yield increase due to application of growth booster and or micronutrient zinc mineral supplement, current market price of grain sorghum of Ksh. 27/kg. Sorghum is planted with 50kg /acre DAP and top dressed with 50kg/acre CAN and growth booster sprayed while mineral zinc supplement is foliar applied or top dressed.

Table 8. Input required per acre for sorghum Gadam production

Input	Unit	Qty	Unit price	Cost
Hormone	Litres	5	1,000	5,000
2% zinc	kg	0.96	50	48
Seed	kg	3.00	125	375
Fertilizer (DAP)	Bag (50kg)	1	4000	4,000
Fertilizer (CAN)	Bag (50kg)	1	2500	2,500
Land preparation	contract	1	2000	2,000
Weeding	Person days	8	500	4,000
Bird scaring	person Days	15	500	7,500
Total Cost				25,423

Table 9. Net revenue per acre of Gadam sorghum treated with growth enhancer and micronutrients

Season	Yield (kg)	Price/ Kg(KES)	Revenue (KES)
Average rainfall (300mm)	1,612	27	43,524

Table 10. Gross profit per acre of Gadam sorghum treated with growth enhancer and micronutrients

Season	Total revenue	Expenditure	Gross profit
Below 300mm	43,524	25,423	18,101

9.4 Sources of growth booster and Zinc mineral supplement

Growth booster and mineral zinc supplement are available in the local market in Nairobi *Ngara*, Organix Company ltd and Amiran Kenya respectively. Growth booster is organic in origin while 2% zinc mineral supplement is Zinc sulphate fertilizer

Rates of application

Growth booster: Apply at 5litres/acre when sorghum is at 4-5 leaf stage by spraying alongside pesticides application in the left.



Photo 20: Topdressing with growth enhancer and micronutrient fertilizer

2%zinc mineral supplement: Top dress at 960g zinc sulphate/acre when sorghum is 4-5th leaf stage or at time of applying topdressing fertilizer nitrogen and incorporate into the soil.

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