AFA
Our Crops, Our Wealth

KENYA SUGAR INDUSTRY GROWERS' GUIDE

Preface

Sugarcane cultivation in Kenya dates back to the early 19th century and the initial efforts to prepare growers' manual to guide production was by KALRO Sugar Research Institute (formerly KESREF) and some mills.

This Sugar Industry Growers' Guide has been prepared by a Team of Experts (ToEs) drawn from all over the industry. Its purpose was to produce a manual to guide the production and storage of sugarcane-based cropping systems with a view to enhance agricultural growth for food and nutrition security in a stable environment in the Republic of Kenya. To achieve this objective it became necessary for the ToEs to interrogate the current recommended sugarcane best management practices in the whole sugarcane production value chain.

Between 11th and 16th June, 2018, the ToEs went through available data in the following areas; Status of the sugar industry as concerns food security and income generation, husbandry practices namely ecology of sugarcane, soil sampling and testing, seed bed preparation, appropriate planting seed material, planting methods and timing, crop development management (Fertilizer use efficiency, water use efficiency, integrated weeds, diseases and pests management strategies, economics of sugarcane growing, sustainable food production and dissemination of the appropriate technologies, innovations and information.

It is hoped the various stakeholders including the small- and large-scale sugarcane farmers, millers, both National and County Agricultural officers, Policy makers and other private sector participants, will use this manual.

Acknowledgement

We most sincerely thank AFA through Sugar Directorate for priotizing and facilitating preparation of the Sugar Industry Growers' manual to guide sugarcane production. We are grateful to the institutions and staff who participated in the preparation of the draft document and later validation by industry agricultural managers.

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Acronyms

AFA	– Agriculture and Food Authority
DAP	– Diamonium Phosphate
CAN	– Calcium Ammonium Nitrate
TSP	– Triple Supper Phosphate
SSP	– Single Super Phosphate
MOP	– Muriate of Potash
KESREF	– Kenya Sugar Research Foundation
SD	– Sugar Directorate
SRI	– Sugar Research Institute
Kshs	– Kenya shillings
TCH	- Tonne Cane per Hectare
RSD	– Ratoon Stunting Disease
Ha	– Hectare
ToEs	-Team of Experts

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1.0: Introduction

Sugarcane (*Saccharum spp. hybrid*) is a tall perennial grass of family Poaceae (Clark *et al*., 1995). It is native to warm temperate to tropical regions of South and South East Asia. Sugarcane cultivation in Kenya began in the early 19th Century by the Indian settlers in Kibos area (Luckman, 1959). The establishment of two factories, Miwani in Kisumu County in 1922 and Ramisi in Kwale County in 1927, marked the beginning of large-scale commercial sugarcane production in the country for the extraction of sucrose as the major product.

To date thirteen sugar mills namely Muhoroni, Chemelil, Mumias, Nzoia, South Nyanza, West Kenya, Olepito, Kibos, Butali, Transmara, Sukari, Kwale and Busia Sugar Industry are operational. Soin and Miwani sugar factories were not operational (AFA SD, 2017). The sugar industry plays an important role in the national socio-economic development of the country. In 2016, the industry gross turn over from the operations of 12 sugar companies was Kshs. 58.7 billion while payment to farmers for cane deliveries was Ksh. 21.7 billion. In the same year, sugarcane contributed 8.4% to the marketed value of all crops (KNBS, Economic Survey, 2017). Furthermore, the industry supports about 350,000 growers, 85% of whom are small-scale, in 14 counties comprising Kakamega, Bungoma and Busia (Western Province); Kisumu, Migori, Homabay, Siaya and Kisii (Nyanza Province); Narok, Kericho, Nandi, Uasin Gishu and Trans Nzoia (Rift Valley Province) and Kwale (Coast Province) where it is the main source of income and employment for the farming community.

Sugarcane is the fourth major cash crop after tea (*Camellia sinensis* L.), horticultural crops, and Coffee (*Coffea arabica* L.). Approximately 8 million Kenyans derive their livelihood from sugarcane production. Current sugar production ranges from 639,741 metric tonnes in 2016 from 85,761 ha and the lowest of 376,111 metric tonnes in 2017 milled from 67,709 ha respectively The industry contributes about 8.5% of the agricultural GDP and has a major impact on the economies of 14 out of the total 47 Counties nationally. In addition, Counties with potential to practice sugarcane farming in the future comprise Tana River, Kilifi, Baringo and Elgeyo Marakwet.

Sugar consumption in 2017 was estimated at slightly above 1,000,000 metric tonnes (AFA SD Year book of statistics, 2017) against a production of approximately 376,111 metric tones with the deficit met through importation. In the last decade, the average sugarcane yields in the country remained static between 55-60 tons/ha, which is slightly below the world average of 64 metric tons per hectare.

To alleviate food insecurity and poverty in the major sugarcane producing areas, crop diversification among sugarcane farmers will be enhanced by encouraging them to intercrop sugarcane with short-term crops (e.g. legumes) which are compatible with sugarcane growing, dairy farming, poultry farming, pig keeping, fish farming, and bee keeping. Farmers will also be encouraged to adhere to the land use policy which promotes a third of the land be put under food production, increase bio-diversity and contribute to forest cover.

This sugar cane growers' guide has been developed as part of the ongoing efforts to mitigate the low productivity, food deficiency and environmental degradation and guide local farmers to reflect on their cultivation methods.

2.0. ECOLOGICAL REQUIREMENTS FOR SUGARCANE GROWING

2.1 Altitude

Sugarcane is usually grown at low altitudes in most countries. In Kenya, sugarcane grows at an altitude between10-2000 m above sea level.

2.2 Rainfall

Sugarcane requires well distributed rainfall throughout its growing stages save for 1 to 2 months prior to harvest to enhance sucrose accumulation in the cane stalks. An average of 1500 mm per annum would suffice. However, in Kenya amounts ranging from 800 mm at the coastal region to 2000 mm in the higher altitude in the western region of the country have been experienced and where moisture deficit is experienced, supplementary irrigation is recommended.

2.3 Sunshine

Sugarcane is a sun loving plant. Greater incident radiation (sunshine) favors higher sugarcane & sugar yields. About 7–9 hours of bright sunshine is highly useful both for active growth & for ripening).

2.4 Temperature

Optimum cane growth is achieved in temperatures between 24 - 30^0 C. During the active growth period, a minimum mean temperature of 20^0C is required. However, for proper ripening, a mean day temperature of 12-14^0C would be highly desirable.

2.5 Soils

Sugarcane grows in a wide range of soil types but does better in fertile, deep, well-drained soils with a pH of 5-7.5, ground water table below 1.5-2 metre from the surface soil and free from toxic metals such as Aluminum (Al) and Manganese (Mn).

3.0. SUGARCANE ESTABLISHMENT

3.1. Soil Sampling, analysis, interpretation and recommendations

For a sound nutrient management programme, soil testing is a pre-requisite to crop establishment because it guides the grower on soil fertility status and fertilizer application schedule hence increasing fertilizer use efficiency. Farmers should consult extension officers from respective institutions on methods of soil sample collection and delivery to laboratories for analysis & on the interpretation & practical implication of the soil analysis results.

3.2. Land Preparation

Sugarcane remains in the field for many years due to the practice of ratooning. Therefore, a thorough soil preparation once after these years is essential. Thus, land shall be prepared

to create a good tilth, i.e., seed bed with optimal soil water and air relations, which is conducive for sugarcane planting. Land should be prepared, when the soil is moist and not wet. Objectives of land preparation

1. To prepare a seedbed, which permits rapid infiltration of water, holds sufficient amount of moisture & air and permits a ready exchange of air with atmosphere

2. Provide excellent physical conditions for early root penetration, root growth & proliferation

3. Incorporate preceding crop residues and organic manures.

4. Destroy weeds and hibernating pests and disease organisms.

5. Facilitate proper soil chemical and microbial activity.

6. To resist soil erosion

Chronology of Conventional Tillage operations

1) Land Clearance: It involves
   a. Trees, bushes & shrubs clearing,
   b. Stump removal, and
   c. Rock removal by using hand hoes, Graders & bulldozers.
2) 1 st Plough/Primary plough will aid in

a. Breaking the soil into bigger clods-at a depth of 30cm-45 cm depending on soil type, using either disc plough for light soils, Moldboard plough for heavy black soils (Vertisols/Gleysols)

3) 2 nd Plough/ Secondary plough, optional, would be done to break the big clods. Often it is done after 2 weeks of curing using disc plough at a depth of between 25 to 30 cm

4) 1 st and 2 nd Harrow which is necessary to make the final fine seed bed is done as a standard practice at a depth of 20 to 25 cm using either heavy or light harrow for heavy or light soil type, respectively. The heavy harrows should be drawn by tractors of between 150 and 175 HP while light duty harrows by tractors of 90 HP.

5) 3rd Harrow- Optional Mainly for Heavy black soils

6) Planning/Land Leveling- Optional/need basis

7) Furrowing-
   a. Light implement, 75-90 Hp tractors
   b. 15 to 18 cm depth
   c. Inter row spacing 1.2 – 1.5 m
   d. Bank, plane or trough planting

8) Infield and cut- off drains
   a. Infield drains- depends on soil type, slope, water load
   b. 30cm wide and 30cm deep every 50 m apart
   c. Use of Mole, French drains (sand drains) where possible
   d. Infield drains feeds into cut-off drains.
      i. 1m x 1m
      ii. Drains into trenches or natural water bodies
      iii. Conservation structures need to be done

Pertinent Considerations:

1) Quality of seedbed to be achieved
2) Timing of operations
3) Cost of Land preparation
4) Matching implement to prime mover
5) Load per unit area- Soil Compaction

3.3. Seed cane preparation

- Use certified seedcane of recommended varieties for your zone. The

Seedcane should be plant crop or first ratoon obtained from nursery 'B', true to type, free from pests and diseases.

- Seedcane age should be 7-9 months for coastal areas and 10-14months for upland areas preferably 1.5 m in height.
- Cutting knives should be sterilized regularly using appropriate Disinfectants e.g. Dettol, Jik, Lysol to minimize the risk of spreading diseases such as smut , ratoon stunting disease (RSD) and pineapple disease
- Seedcane should be harvested with trash, loaded, transported and off loaded with care to avoid damage to the eye-buds.
  Transport equipment for seedcane from nurseries to the field should be thoroughly cleaned before use in order to minimize spread of diseases
- Prepared Seedcane should be planted timely.
- Care should be taken at the seed cane source at the recipient point to minimize deterioration of seed cane quality and damage to the eye buds.

3.4 Planting

Plant when there is adequate soil moisture supply from rain or irrigation. Plant 3-5-eye budded setts at a seed rate of 6-8 t/ha (2.4-3.2t/acre) depending on the variety and inter row spacing. Apply

- planting fertilizers (phosphatic, Potassic and manures e.g. filter cake) based on site-specific recommended rates and cover the furrows.
- Treat setts with appropriate fungicides and/or insecticides to control major diseases and pests e.g. termites.
- Place setts end to end or overlap slightly depending on soil moisture level and quality of the seed cane.

Cover the setts furrow with soil properly

4.0: CROP MAINTENANCE

4.1 Germination Assessment and Gap Filling

In plant cane, wide gaps of more than 60 cm (2ft) should be filled with healthy seedcane cuttings of the same variety approximately 45 days following the emergence of the earliest shoots.

4.2 Weed control

Weed control is one of the most important operations in sugarcane cultivation. Weeds reduce sugarcane yields by competing for moisture, light, nutrients and space especially with plant cane crops, which grow more slowly in the early stages than the ratoon cane crop types. Recommended weed control entails cultural, manual, mechanical and chemical methods and/or integrated weed management operations. The critical weed control period is within 3 months & 6 months of planting in the coast & west Kenya sugar belt, respectively

4.2.1 Manual (Hand) weed control

Plant crops should be weeded timely using hand hoes (jembes). This may be done up to 4 to 6 times depending on the field weed condition & cane growth stage. However, these recommendations may vary with the ecological conditions and the variety grown.

4.2.2 Chemical (Herbicide) weed control

Chemical weed control involves the use of different pre-emergence and post emergence herbicides. Specific combinations (cock- tails) of chemicals for each agro-ecological zone may be obtained from the extension officer. In ratoon cane, a pre-emergence herbicide treatment is applied after inter-row cultivation. Herbicides can be applied manually through use of knapsacks or mechanically through use of boom sprayers. Tractor mounted Boom sprayers can be utilized on large-scale farms.

A list of cock- tails and rates of application for recommended herbicides is in Annex II

1) **Mechanized application:** Light machines on high floatation tyres recommended. However, ecological consideration is very important during application

4.2.3 Mechanical weed control

This is most suited for ratoon crops but can also be conducted in plant cane at 4 – 6 months with utmost care to minimize crop damage. Inter-row cultivation may be done by oxen-drawn plough or tractor mounted ridger or tines.

The operations include:

1). Animal draft:

Use of animal-drawn mouldboard ploughs.

- 3 passes per row are recommended
- Suitable for small plots
- Can be used even in wet moisture regime

- Has limited soil penetration.

2) Ripping / Sub soiling
    - To break the hard pan
    - Aims at 45 to 60 cm depth
    - Cut old roots to allow development of new roots

3) Disc bedding/ Ridging and tinning cultivation
    - Use of light machines and implements on high floatation tyres to avoid soil compaction
        - Appropriate after fertilizer application
    - Better penetration achieved up to a depth of 18cm

4) Trash shredders
    a. Use manual labor to spread the trash uniformly on the field surface
    b. Use tractor drawn Shredder to cut trash into smaller pieces to facilitate the subsequent operations.

4.2.4 Cultural weed control

Good seed bed preparation, timely planting, use of cover crops and trash mulching are recommended.

4.2.5 Integrated weed management

A combination of manual, chemical, mechanical and cultural methods is more efficient and cost effective. This is highly recommended.

4.3. Fertilizer use

Fertilizers are sources of essential elements called nutrients, which plants need for proper growth and development. There are about 15 nutrients, which are divided into macro- and micro-nutrients. The Macronutrients are needed by the crops in large quantities while micro- or trace-nutrients are needed in very small quantities. However, they are all needed in a balanced ratio for a crop to reach its optimum growth. Examples of primary macro- nutrients are N, P and K while secondary macro-nutrients are Ca, Mg and S micro nutrients are Fe, Cu, Mn, M Zn, B, Mo, Co, Cl & Ni

Fertilizer application should be based on the soil test results. Fertilizers are necessary for increased sugarcane yields. Sugar cane requires balanced nutrition of all the essential elements from both organic and inorganic sources.

4.3.1 Types of fertilizers

Fertilizer comprise of inorganic and organic sources. Out of the inorganic sources there are DAP, TSP, SSP Urea, CAN , MO P and other synthetic composition either as straight or compound sources. Some of the organic fertilizer sources include farmyard manure, Filter press mud, compost manure & green manuring.

Organic fertilizer application

It enhances physical, chemical and biological properties of the soil.

Rate of application depends on agronomic recommendations.

Should be done after ploughing but before harrowing or immediately after harvesting for ratoon management

Application Methods

Manual

No sophisticated equipment is required but it is labor intensive and difficult to spread it uniformly.

Application rate should be site-specific and be based on the results of soil analysis. Precision application is recommended.

Applicators for granular fertilizer are still at infant stage.

Mechanical spreaders

Important considerations in Mechanical application are:

1. Calibration to ensure uniform applications
2. Rate of application in tons/ha as determined by agronomic recommendations
3. Use of PTO powered equipment/implement to spread the manure at a low forward travelling speed (3-5KPH)
4. Use of light machineries on high floatation tyres to reduce soil compaction and stool damages

However, in Kenya manual application is still widely used.

Timing of Fertilizer Application

i. Plant crop

In plant cane, phosphatic fertilizer is recommended at planting. This should be applied uniformly in the furrows prior to setts covering.

Top dressing with nitrogenous fertilizers is recommended at 2months at the coastal region and from 3-6 months in other sugarcane growing areas.

ii. Ratoon crop

Phosphatic fertilizer is also recommended. This should be band applied along the cane row at 0-2 months under coastal conditions and 0-3 months in other sugarcane regions.

Top dressing with nitrogenous fertilizers is recommended in 2months at the coastal region and 3-6 months in other sugarcane growing areas.

N/B: Farmers are advised to apply fertilizer timely. Split application for top dressing is recommended for efficient nutrient uptake.

Deficiency symptoms

i. Nitrogen

- Older leaves first show the deficiency symptom & later die back
- Young leaves are pale green & stalks are slender when under long-term N stress.
- Reduced internode growth
- Leaf sheath prematurely separate from the stalk
- Low yields and low sucrose content.

Notably, too much N causes lodging, delayed maturity, reduced sucrose levels, and increased color of the mixed juice, as well as increasing the risk of certain fungal diseases such as smut and increased susceptibility to stalk borer damage.

Figure 1: Nitrogen deficiency in sugar cane

ii. **Phosphorus**

- Essential for root development
- Older leaves first show symptom of deficiency

- Older leaves prematurely dieback
- Stalks become short & slender
- Thin, narrow short leaves with a bronze blue/green or purple color, affects the older leaves first (Figure).

Figure 2: Phosphorus deficiency in sugar cane

iii. **Potassium**

- Older leaves first show the symptom.
- The symptom appear as localized mottling or chlorosis
- Mid rib may have a red coloration
- Older leaves may be entirely fired
- Stunted growth with short internodes and slender stalks.
- Reduced tillering.

Figure 3: Potassium deficiency in sugar cane

5.0 CROP PROTECTION

5.1 Sugarcane pests and their control

Sugarcane pests are among the important factors affecting the productivity of cane. In Kenya, sugarcane pests include insects, rodents, nematodes and primates. The most problematic insect pests are termites, stem borers, scale insects and of recent sugar cane yellow aphid (Sipha flava L.) has emerged. Sugarcane growers are encouraged to regularly visit their fields and contact extension officers in their areas in case of pest attack. A detailed list of sugarcane pests and their control is shown in Annex I. The following plates can help in quick identification of some of the common pests.

Table 1. Common sugarcane pests	Identity
	Termites
	Termites
	Sugarcane scales
	Sugarcane yellow aphids

Table 1. Common sugarcane pests	Identity
	Sugarcane yellow aphids
	African sugarcane borer
	Mole
	Nematodes

5.2 Sugarcane diseases and their control

Major sugarcane diseases in Kenya include sugarcane smut; ratoon stunting disease (RSD), sugarcane mosaic virus and pineapple disease. Minor diseases comprise leaf rust, downy mildews and leaf spots among others. The major pests and diseases are given in Tables 1& 2 below.

Table 2: Sugarcane diseases and their control

Disease	Causative agent	Symptoms	Control Measurs
Sugarcane smut	• *Ustilago scitaminae*	• Brittle grass like stalks • Black whip like structure	• Plant resistant varieties • Regularly rogue the infected stools before the whips open and burry in shallow pits • Treat the setts in hot waterat 50^0c for 2hrs • Get the seed cane from certified sources/donors
Sugar cane mosaic virus	• Sugarcane mosaic poty virus	• Appearance of pale yellow patches or blotches on the leaves	• Use healthy clean seedcane from clean fields. • Use resistant varieties • Rogue and destroy infected plants if the infection is high.
Ratoon stunting Disease	• *Leifsonia xyli*	• Stunted growth of ratoons	• Treat the setts in hot water at 50^0c for 2hrs • Get the seed cane from certified sources/donors • Weak or stunted crops should not be ratooned • Destroy the old stools completely before replanting the plot
Pineapple disease	• *Ceratocystis paradoxa*	• Red to black internal discolorations of the sett with the smell of pineapples ester • Germination delay or seed	• Dip the setts in a fungicide solution before planting • Field operations which result in better drainage and better tillage will help in control of the disease • Use resistant varieties

Figures 2 to 5 show some of the common sugarcane diseases in Kenya

Figure 4: Sugarcane smut (Ustilago scitaminae)

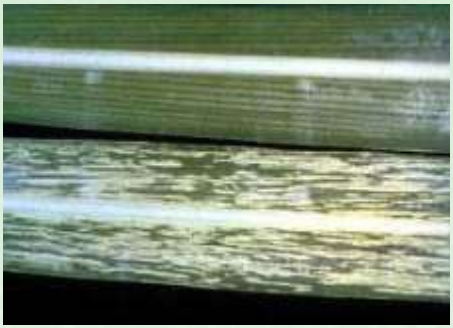


Figure 5: Mosaic (sugarcane mosaic poty virus)

Figure 6: Ratoon stunting disease showing shortening of internodes

Figure 7: Pineapple disease (caused by Ceratocystis paradoxa)

5.3 Common sugar cane weeds in Kenya

Common weeds comprise Cynodon dactylon; Solanum incanum; Cyperus esculentus; Amaranthus Spp.; Commelina bengalensis; Portulaca oleracea; Trifolium repens among others. (Figure 8: Common Weeds in the sugar cane growing areas)

Common name	Botanical name	Identity
Couch grass	*Digitaria spp.*	
Foxtail	*Setaria spp.*	
Oxalis	*Oxalis corniculata*	
Redroot Pigweed	*Amaranthus retroflexus*	

Common name	Botanical name	Identity
White clover:	*Trifolium repens*	
Prostrate spurge	*Euphorbia prostrata*	
Yellow nutsedge	*Cyperus esculentus*	
Crabgrass	*Digitaria sanguinalis*	
Wandering jew	*Commelina bengalensis*	

Common name	Botanical name	Identity
Witch weed	*Striga hermonthica*	

6.0 HARVESTING AND TRANSPORT

6.1 Harvesting

Two ways of Harvesting:

1) Manual Harvesting

2) Mechanical Harvesting

6.1.2 Manual Harvesting

This involves manual use of cane knives to cut cane. It is Labor intensive and cane may be collected in windrows, intermittent heaps or collected into stacks of predetermined dimensions.

6.1.3 Mechanical Harvesting

Done through use of chopper harvesters, this involves:

- Gathering and topping cane
- Severing stalks at ground level
- Feeding cane through the chopper system
- Cutting into billets and feeds onto the trailer for transport.

Advantages

- Used where there is shortage of manual labour
- Has a high output for green harvesting
- Has longer working hours

Disadvantages

- High initial cost
- High EM content (trash)
- Furrow distance & ridge height must be uniform.
- Requires uniform topography
- Requires removal of physical obstacles

- Requires removal of physical obstacles
- Requires the closure of drains
- Fields for nightshift workers shall be selected carefully
- Cane should be standing, not lodged
- Not suitable in wet conditions
- Requires skilled operators

6.2 Loading and Cane Transport

This activity involves loading and delivering cane to the factory.

6.2.1 Loading

Loading can be either manual or mechanical.

6.2.1.1 Manual loading:

- Low output
- Low EM
- Reduced spillage since the cane is secured by wire ropes
- Can be done even in wet conditions
- Applicable on all terrains
- Its labour intensive
- Experiences seasonal variances
- Limited working hours

6.2.1.2 Mechanical loading

Use 3-wheeler and or 4x4-wheel loader during mechanical loading.

- High EM content because of grabbed trash
- Requires skilled operators
- Initial and maintenance costs are high
- High infield cane spillage.
- High cane stool destruction
- Soil compaction at loading points
- Damage to inbuilt farm structure and equipment

6.3 Transport

- Animal drawn carts

- Pick ups
- Lorries
- Tractor drawn trailers
    - Flat bottom trailers - 6 to 7 tons
    - Side loading (Single, double or triple bundles)
    - Bucket trailers (Single (6-7), super single (9-12), and double (12-15) tons
- Tandem trailers
- High payload units (HPU)

Challenges:

- High initial and maintenance cost
- High spillage if not properly secured
- Requires good road network
- Fuel pilferage
- Difficult to operate during wet weather
- Lack of formal training schools or tailor made curriculum for drivers and operators of transport machines

7.0 IRRIGATION AND DRAINAGE

7.1 Irrigation

Sugarcane is a heavy consumer of water. The average water requirement for sugarcane lies in the range of 1,500 to 2,200 mm. In most growing areas, this water requirement is met from the rainfall. Thus, periods of moisture stress is experienced at some stage of crops growth. The most critical periods of high moisture demand are at planting and during the peak growth stages (grand growth phase). When moisture deficit occurs during these periods, a decision must be made whether there is need for irrigation or not.

In Kenya, sugarcane irrigation is done to supplement rainfall, and the intensity depends on the region. In the coast [Kwale], it is done for a period of about 10 months. In South Nyanza, the supplementary irrigation requirement is for about a period of 4 months (June and July; January and February), In Nyando, it is done for a period of 6 to 7 months (July, August,

September, December January, February and March). In Western, it is done for four months (December, January, February and July).

(i) Effects of Moisture stress

1. Decrease rate of germination
2. Decrease tillering
3. Decrease length and thickness of internodes
4. Decrease amount of juice
5. Increase fibre % cane
6. Decrease of both cane and sugar yields

(ii) Logical order of operations

1) Identify irrigation need
    a. Crop water requirement
    b. Precipitation (quantity and distribution)
2) Identify source of water
    a. Quality
    b. quantity
3) Decide on type or method of irrigation
    a. Surface
        i. Flood
        ii. furrow
    b. Overhead
        i. Sprinkler
        ii. Centre pivot etc.
    c. Drip/Subsurface
4) Design of system
    a. Reservoir
    b. Pump
    c. Conveyance structures/Equipment
    d. Distribution equipment

i. Irrigation Scheduling

May be manual, automated or integrated.

Determine moisture level by use of basic clamping (soil Kneading) methods, or sophisticated use of tension meters and other moisture measurement methods.

Practice is to be start when the field is at 50% water holding capacity.

ii. Irrigation interval

This is the number of days between two consequent irrigation events.

a. Soil type- Less interval for coarse textured soils and vice versa

b. Growth stage- Less interval and light application during germination stage and longer intervals during ripening stage. Sugar cane has four distinct growth stages namely: germination (sprouting), Tillering phase, Grand growth phase and Maturing/ripening stage. Water requirement peaks during the grand growth phase and reduces during ripening or maturity phase

7.1.1 Irrigation period

This is the duration of single irrigation event.

Stage of growth- Light but frequent application during germination. However, this change in direct proportion as the crop grows up to maturity phase.

Soil type- for coarse textured soils, lower discharge rate for a longer time Et_c.

Fertigation

Installation of equipment

Use of liquid fertilizer

Methods of irrigation

a. Furrow irrigation

1) Water quality- does not require high quality water
2) Low water use efficiency of only about 40 %
3) Requires relatively high amount of water
4) Gentle slope-Soil erosion, accelerated water discharge
5) Soil type- Not suitable for sandy soils- increases percolation

6) Less skilled labor
7) Less initial cost
8) In case of ratoon crops, the water distribution may be impeded by collapse of the furrows and ridge system.

b. Overhead-Sprinkler

Is a method of supplying water in a network of pipes under pressure and spraying it through the nozzles of the sprinkler over the crop so that it breaks up into fine droplets and falls like natural rainfall onto the ground.

1) Relatively higher Water use efficiency- up to 72 %
2) Requires high quality water to prevent nozzle clogging
3) Requires energy for pressurized water supply
4) Requires skilled operator- discharge from sprinklers must match rate of infiltration or less
5) Higher initial costs
6) Exposed to vandalism
7) Effects from windy weather- uniformity of water supply to sugar cane is affected
8) In some case, requires labor to move the irrigation equipment
9) Land grading is not required

c. Drip Irrigation

Drip irrigation is a precise, slow and frequent application of water through point or line source emitters on or below the soil surface at a small operating pressure (20-200 kpa) and low discharge rate (0.6 to 20 LPH). May be either surface or sub-surface.

1) High Initial and maintenance costs
2) High water application efficiency and high water use efficiency, up to 97 %
3) Require high quality water
4) Requires skilled labor
5) Less labor intensive
6) Operations may be automated, manual or integrated
7) Prone to damages- during mechanical operations, harvesting, transport, rodents, cane fires etc.
8) Bio-clogging-Additional costs in flushing and cleaning
9) Fertigation/Chemigation is possible with this method

10) Low soil erosion
11) Uniform water distribution (Use of pressure compensating emitters) hence uniform growth of sugarcane crop
12) Weed control-Moisture deprivations to other vegetation within the field
13) Low probability in insect and disease dissemination
14) Prone to vandalism
15) May be used in fields with irregular shapes, marginal and undulating land

d. Fertigation

The process of applying fertilizer with irrigation water is called Fertigation. Mostly liquid type of fertilizers or those solid fertilizer sources, which are soluble in irrigation water, are used especially during top-dressing periods.

Mostly used with liquid and water soluble fertilizers

7.2 Drainage

Drainage aims at removing excess water from seedbed. The aim is to:

i. Prevent excess water from entering the plot
ii. Remove excess water from the plot

Effects of excess water to Sugar cane planted

i. Lead to death of cane eye buds
ii. Damages sugarcane roots because of absence of aeration
iii. Reduces/stops the adsorption of elements from the soil
iv. Cane and sugar yield will decrease
v. Impedes mechanized operations in the plot

Lay out of drainage network

1) Infield drains

i. Open furrow
ii. Bank planting at an angle to the contour
iii. French, mole or sand drains

2) Cut- off drains and side drains

i. Receives water from infield drains and side drains

ii. Also prevents water from entering the plot
iii. May be constructed infield for large plots or if water load is higher
iv. Drains into trenches or directly into natural water bodies

3) Trenches

i. Receives water from cut off drains and safely drains into natural water bodies
ii. They may have soil conservation structure e.g. drop structures.

8.0 Cost Benefit Analysis, Sugarcane Crop Diversification and Food Security.

8.1 Cost Benefit Analysis

As any other investment the farmer should focus on getting returns for his money, time and effort invested in sugarcane growing. These therefore involve keeping records and costs of the enterprise development ranging from land acquisition, land development activities (ploughing, Harrowing, furrowing). Planting activities (seedcane, fertilizer and labour cost), cane maintenance (weeding, fertilizer applications, diseases and pests control, drainage and irrigation where necessary), harvesting and transport costs. The farmer in what is called **farm record book** must keep all these costs.

The total cost must then be compared with the final gross revenue obtained from the cane proceeds. This is what is called **cost benefit analysis**.

For the farmer to know the minimum yield that he must obtain without making a loss or gain, he has to divide the total cost of his expenditure with the prevailing cane price. This is called **break-even yield**.

This is very important to guide the farmer to monitor and make necessary adjustments to his expenditures on cane growing activities. Any additional yields got above this breakeven yield if multiplied with the prevailing sugarcane price per ton is what is called **gross margin** and this is what determines the profitability of the sugarcane investment. The farmer will gain more if the yield is above the break-even yield.

Table 1: Typical Record Keeping, Breakeven, Gross margin analysis

ACTIVITY	UNIT	QTY	UNIT COST (Kshs)	PLANT CROP (Kshs)	RATOON CROP (Kshs)
1.0 LAND PREPARATION					
Land Clearance					
Soil Sampling and Testing			1,500	1,500	0
Survey	ha	1	330	330	0
1st Plough	ha	1	8,750	8,750	0
1st Harrow	ha	1	6,250	6,250	0
Furrow	ha	1	5,000	5,000	0
Subtotal 1.0				**20,330**	**0**
2.0 SEED CANE					
Seedcane	Ton	7	4,052	28,364	0
Seedcane transport -(fixed)	Ksh/ton	6	**670**	**4,020**	0
Sub-total for 2.0				**32,384**	0
3.0 FERTILIZER					
Fertilizer(Planting)					
D. A.P	50kg bag	3	1,800	5,400	5,400
Compound(NPK)	50kg bag				
Fertilizer (Topdressing)	50kg bag				
CAN (PC)	50kg bag	5	1,500	7,500	
CAN (RC)	50 kg bag	5	1,500		7,500
Sub-total				**12,900**	**12,900**
4.0 LABOUR					
Planting	Md	35	260	9,109	0
Manual Weeding pc ; 5	Contract	4	8,750	35,000	

Manual Weeding rc ; 3	Contract	3	8,750		26,250
Fertilizer application	md	2	260	520	520
Sub-total 4.0				**44,629**	**26,770**
5.0 INTERCULTIVATION					
Oxen	ha	1.00	4,438	0	4,438
Tractor	ha				
Sub-total 5.0				**-**	**4,438**
7.0 HARVESTING	Ton		216	21,600	17,280
Subtotal 7.0				**21,600**	**17,280**
8.0 CANE TRANSPORT					
Transport Zone E	Ksh/ton		591	59,110	47,288
Subtotal 8.0				**59,110**	**47,288**
9.0 LEVIES					
Out grower levy	Ksh	1% rev	41	4,052	3,242
County Government Cess	Ksh	1% rev	41	4,052	3,242
Presumptive tax	Ksh				
Sub-total 9.0				**8,104**	**6,483**
10.0 TOTAL COSTS	**Ksh/ton**			**199,057**	**115,159**
11.0 TOTAL COSTS PER TON	**Ksh**			**1,991**	**1,439**
12. REVENUE					
Yield	**Tch**			**100**	**80**
Gross Revenue	**Ksh**		4,052	**405,200**	**324,160**
Net Revenue	**Ksh**			**206,143**	**209,001**
Net Revenue per ton	**Ksh**			**2,061**	**2,613**
13. BREAKEVEN YIELD	**Tons**			**49.13**	**28.42**
14. RETURN PER SHILLING INVESTED				**1.04**	**1.81**

** Nzoia sugar -2017.*

For the farmer to manage the fixed costs like land, maintenance and labor the farmer must diversify to other complementary crops as described hereunder.

9.0 ENTERPRISE DIVERSIFICATION

9.1 Introduction

The current cropping system has been predominantly mono cropping of Sugarcane. This has left most farmers economically constrained, food insecure, nutritionally disadvantaged and has resulted into loss of biodiversity. Because of this farming system, most of these pre-

dominantly small-scale farmers remain in abject poverty and their children highly malnourished. Sugarcane crop takes between 18 – 24 months to mature. The average yield of sugarcane per acre currently ranges between 25- 30 tons that at the average net price of kshs 2, 500 the farmer is only assured of Kshs 62,500 for the entire period. Coupled with the relatively long cropping season this requires the farmer to maintain a relatively stable cash flow in his household by diversifying into other sources of income. Some of the diversification programs, which the farmer may pursue, include the following.

9.2 Intercropping cane with short-term crops

Intercropping is a farming system where two or more crops are grown in the same piece of land at the same time. Farmers may intercrop sugarcane with short term crops such as legumes, pulses, onions, tomatoes etc. for food security and extra income while maximizing on the utilization of inter row space and contributing to soil fertility improvement. Common bean (*Phaseolus vulgaris* L.), one of the most popular leguminous crops among sugarcane farmers, has been recommended for double row intercropping between cane rows (Amolo et al – personal communication). Other potential intercrops, which have been successfully grown with sugarcane, include vegetables, millets, maize and sunflower.

9. 3 Crop Rotation

This is a farming system in which two crops are planted in separate plots for some time then exchanged. The main purpose is to intensely utilize the available land but sustainably by ensuring that in one plot a legume crop which restores soil fertility is grown while in the other plot a cereal crop which is a universal miner of soil nutrients is grown.

Due to diminishing arable land area currently the long-term rotation, traditionally practiced (Shifting cultivation) is not practical. Hence, short-term rotation/fallowing using fast growing multi-purpose tree and food legumes have been grown for 6 months before introduction of a preferred crop such as sugarcane or maize (*Zea mays* L). The following species have been used in this cropping system successfully – sunhemp (Crotalaria juncea L.), soybean (Glycine max L.), *Leucaena leucocephala* L., *Sesbania sesban* and *Tephrosia vogelli* L.

Other cropping systems which can also be practiced so as to increase a sustainable food security and income generation include **alley cropping** (cultivation of food, forage or specialty crops between rows of trees) in the high altitude lands and river banks and **relay cropping** (where the relay crop is seeded in a near maturing first crop).

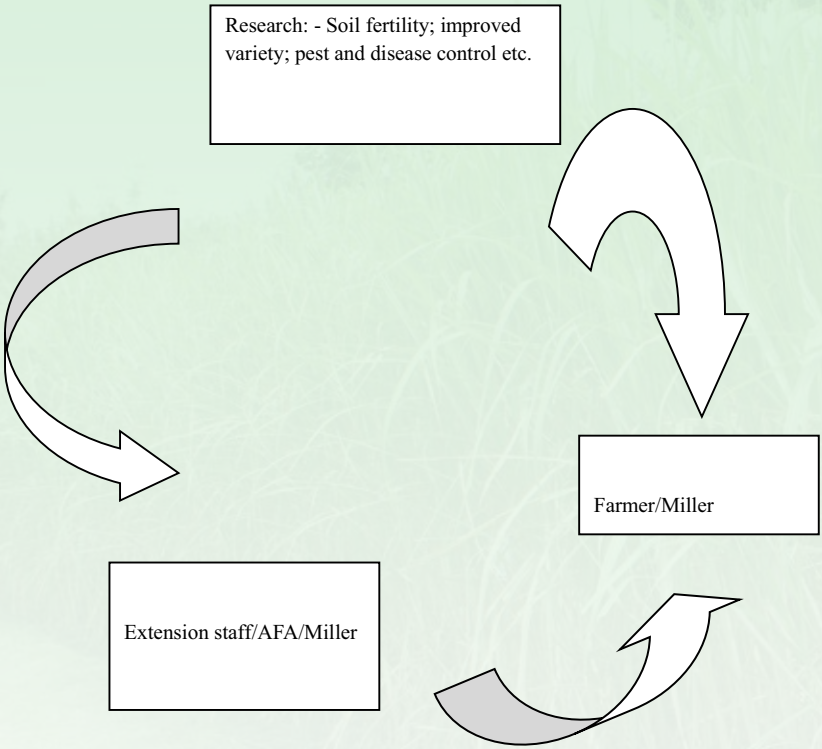
Conclusion

The current practice of only growing sugarcane in the ever diminishing land surface area must stop and the recommended record keeping, gross margin analysis and crop diversification will inform whether farming is a business or a way of life

10.0 ADVISORY SERVICES

10.1 Technology Transfer

Sugarcane technology and innovations are aimed at enhancing productivity at farm level. Extension officers undertake dissemination of these innovations. Farmers can also acquire information through e-learning, pamphlets, leaflets, fliers, attending of open days, field days; ASK shows, farmer's field schools and cooperatives, farmer tailored training organized by stakeholders etc. Technology transfer is as in the schematic diagram below:


Research: - Soil fertility; improved variety; pest and disease control etc.
Farmer/Miller
Extension staff/AFA/Miller

Annex 1. Zonal Fertilizer Recommendations
Inorganic fertilizers

Basal application (DAP; ; SSP; TSP; DSP etc.)

NPK blend 1 for planting in Mumias Sugar zone

Zone	Kgs/ha	Kgs/acre	Bags/ha	Bags/acre
South Nyanza	150-250	60-100	3-5	1-2
Western	200-250	80-100	4-5	2
Nyando	200-250	100-120	5-6	2-3
Coast	150-200	60-80	3-4	1-2

Top dressing (Urea; CAN; MOP)

NPK blend 2 for topdressing in Mumias sugar zone.

Zone	Kgs/ha	Kgs/acre	Bags/ha	Bags/acre
South Nyanza	150-250	60-100	3-5	1-2
Western	200-250	80-100	4-5	2
Nyando	150-250	60-100	3-5	1-2
Coast	150-200	60-80	3-4	1-2

****The fertilizer application rates should be based on individual farm soil analysis and recommendation*

Annex 2: Zonal herbicide recommendations

Pre-emergence			
Zone	**Herbicide**	**Rate/ha**	**Rate/acre**
South Nyanza	Lumax	5L/ha	2L/acre
	Glyphosate + Sencor	2L/ha+2L/ha	0.8 L/acre +0.8 L/acre
	Lumax + Glyphosate	5L/ha + 8L/ha	2L/acre + 3.2 L/acre
	Cadre	0.5L/ha	0.2 L/acre
	Glyphosate +Cadre	2L+0.5L/ha	0.8 L/acre +0.2 L/acre
	Glyphosate + Krismat	2L/ha+2Kg/ha	0.8L/acre +0.8 Kg/acre
	Glyphosate + Velpar	2L/ha+1kg/ha	0.8L/acre +0.4Kg/acre
Western	Sencor + Glyphosate	2 L/ha+2 L/ha	0.8 L/acre +0.8 L/acre
Coast	Krismat +Dual gold	2.5kg+1.5L/ha	1Kg/acre + 0.6L/acre
	Glyphosate	3L/ha	1.2L/acre
Nyando	Velpar	1kg/ha	0.4Kg/acre
	Glyphosate	3L/ha	1.2L/acre
Early Post emergence			
South Nyanza	Krismat + Dual Gold	2Kgs/ha+1Lg/ha	0.8 Kg/acre +0.4L/acre
	Merlin+ Basta	0.2 kg /ha+1L/ha	0.08Kg/acre + 0. 4L/acre
	Velpar	1kg/ha	0.4Kg/acre
	Lumax	5L/ha	2L/acre
	Lumax +2-4D	5L/ha + 1.5L/ha	2 L/acre +0.6 L/acre
Western	Krismat + Dual Gold	2.5 Kg/ha + 1.8 L/ha	1Kg/acre + 0.7L/acre

	Diuron + 2,4 D Amine	3.0 Kg/ha + 1.5 L/ha	1.2 L/acre +0.6 L/acre
	Krismat	2.5Kg/ha	1 Kg/acre
Coast	Krismat +dual gold	2.5kg+1.5L/ha	1Kg/acre + 0.6L/acre
Nyando	Sencor	2L/ha	0.8 L/acre
	Krismat	2-3Kg/ha	0.8 Kg-1.2Kg/acre
	Glyphosate	3L/ha	1.2 L/acre
Late Post			
South Nyanza	Lumax +2-4D Amine	5L/ha + 1.5L/ha	2 L/acre +0.6 L/acre
	Glyphosate+ 2-4D	3-8L/ha/ha+1.5L/ha	0.8L/acre + 0.8Kg/acre
Western	Glyphosate	3-8L/ha	1.2 L/acre - 3.2 L/acre
Coast	Glyphosate	3-8L/ha	1.2 L/acre - 3.2 L/acre
Nyando	Glyphosate	3-8L/ha	1.2 L/acre - 3.2 L/acre

Problematic weeds			
Weed	**Treatment**	**Rate/ha**	**Rate/acre**
Witch weed *(Striga Spp.)*			
Wondering Jew *(Commelina spp.)*	2-4D	1.5L/ha	0.6L/acre
Nut grass (*Cyperus Spp.)*	Servian	50g/ha	20g/acre
Couch grass *(Digitaria spp.)*	Glyphosate	3-8L/ha	1.2 L/acre - 3.2 L/acre

****N/B: Spot treatment using the Teejet wide angle full cone FI-5 brown is recommended with a VAR of 400Lt/ha; Teejet is used in Pre-emergence application; Dribble bar is utilized during post emergence application*

Annex 3: Attributes of commercial sugarcane varieties for the Kenyan Sugar Industry.

Variety	Best Features	Other features	Best Soils	Disease and Pest Reaction	Recommended Zone
CO 617	High Cane yields. Good germinator Good ratooning ability.	High fibre. Medium and fairly erect stalks. Late maturing	Light and heavy clay soils. Tolerant to stress.	Intermediate resistant to smut. Resistant to mosaic virus.	Nyando
EAK 70-97	High Cane and sugar yields. Good germinator. Good ratooning ability. Tolerant to smut.	Medium Maturity High tillering ability Medium and erect	Well drained soils	Tolerant to smut disease and mosaic virus	Mumias Awendo Nyando
CO945	High cane and sugar yields Average fibre Excellent ratooner	Mid maturing Slow germinator Flowers profusely, should be harvested in time. Medium erect stalk	Well drained fertile soils	Intermediate resistant to smut and mosaic	All cane growing zones

CO 421	High cane and sugar yields	Good germinator Good rationing Late maturing	Widely adapted to all cane growing zones	Highly susceptible to smut and mosaic virus	All cane growing zones
CO 1148	High vigour High yield 3-7% over Co 421	Average sucrose Medium fibre. Profuse flowering.	Wide range of soils except gravel and shallow soils, Tolerant to stress	Intermediate resistant to smut. Susceptible to mosaic and leaf rust.	Nyando Awendo Mumias.
CB38-22	High vigour. Tolerant to smut	High cane yield and average sucrose. Medium fibre content. Flowers on shallow and marrum soils.	Heavy clay soils. Marginal and relatively shallow soils.	Tolerant to smut and mosaic virus	Nyando Awendo
N 14	High yields over Co421. High vigour Tolerant to smut	Average cane yields and sucrose. High fibre	Well drained fertile soils. Does not	Tolerant to smut	Awendo Mumias Nzoia Nyando Transma

		content, Profuse flowering.	tolerate water stress conditions		ra
KEN 82-216	Early Maturing High cane yields and sucrose content. High Vigour	Average sucrose and medium fibre content	Well drained fertile soils. Fairly tolerant to water logging	Inter-susceptible to smut	Nyando West Kenya Awendo
KEN 82-247	Early maturing High cane yields over Co 421. High vigour	Average sucrose and medium fibre content	Well drained soils. Does not tolerate drought and water logging	Intermediate resistant to smut and mosaic	Nyando Mumias Nzoia Awendo
KEN 82-401	Early maturing High vigour Yield better than Co 421 High sucrose content	Low fibre content	Well drained soils. Does not tolerate moisture stress	Intermediate resistant to smut and mosaic	Mumias Nzoia
KEN 82-808	High vigour and cane yields	Slight flowering.	Wide range of soils Tolerant to moisture	Intermediate resistant to smut	Kibos Kwale

			stress		
KEN 83-737	High vigour High yields	Average fibre	Heavy to light soils Tolerant to water stress conditions	Intermediate resistant	All cane growing zones
EAK 73-335	High Yields over Co 421	High Sucrose. High tillering ability Low fibre content	Well drained fertile soils	Intermediate resistant to smut	Nyando Mumias Nzoia Awendo
D8484	Early maturing High yields and sucrose content	Low fibre content	Well drained fertile soils. Does not tolerate stress	Intermediate resistant to smut but susceptible to mosaic virus, Pokkah Pong, susceptible to stalk and shoot borers.	Mumias Nzoia Sony Kwale
KEN 82-62	Early maturity High yields over Co421	High fibre content	Wide range of soils from well to poorly drained	Intermediate resistant to smut but susceptible to sugarcane mosaic virus	Nyando Mumias Nzoia Awendo

KEN 82-472	Medium maturing. High yields over Co421	Low fibre content	Well drained fertile soils	Intermediate resistant to smut, tolerant to mosaic	Nyando Mumias Nzoia Sony Transma ra
KEN 98-367	Early maturing High sucrose. Wide adaptation	Fast growing. Tall and vigorous stalks.	Performs well on free draining soils. Fairly tolerant to stress.	Intermediate resistant to smut	Nzoia Mumias Sony Chemeli l Coast
KEN 98-530	Medium maturity, High sucrose, High tillering, Wide adaptability, Moderate fibre.	High tillering ability High stalk population	Wide range of well drained soils. With stands heavy to light soils. Tolerant to stress	Tolerant to smut and mosaic	Kibos Mumias Nzoia Muhoro ni Coast
KEN 98-533	Medium maturity High sucrose content High	Slow germinator Low fibre content	Performs well in drained fertile soils	Intermediate resistance to smut	Nyando, Western Kenya, Sony.

	yields. Wide adaptability				
KEN 98-551	Medium maturity High sucrose content	Tolerant to stress Low fibre content	Well drained fertile soils	Intermediate resistant to smut	Kibos Chemeli l Coast
KEN 00-13	Early maturity High sucrose High yields Wide adaptability	High yields, Fast in growth, Vigorous stalks, Prone to lodge in heavy soils	Well drained fertile soils. Withstands heavy to light soils	Intermediate susceptible to smut	Sony Muhoro ni Chemeli l Nzoia Coast Mumias
KEN 00-3548	Medium maturity. High sucrose content. Good ratooning ability	High stalk population and yields	Wide range of well drained fertile soils	Immune to smut	Nzoia Mumias Sony Coast

KEN 00-3811	Medium maturity. High sucrose content. Low fibre content	Medium and uniform growth. Susceptible to stress	Performs well in drained soils. Poor to drought and water logging	Intermediate resistant to smut	Mumias Sony Coast
KEN 00-5873	Medium maturity Moderate fibre	High in sucrose Uniform growth	Does well in free draining soils	Immune to smut	Nzoia Kibos Coast

Annex 4: Control of Striga weed

Several species infecting different host crops exists. Two examples of those affecting cereal crops, including sugarcane, are *Striga hermonthica* (purple) and *Striga asiatica* (Red).

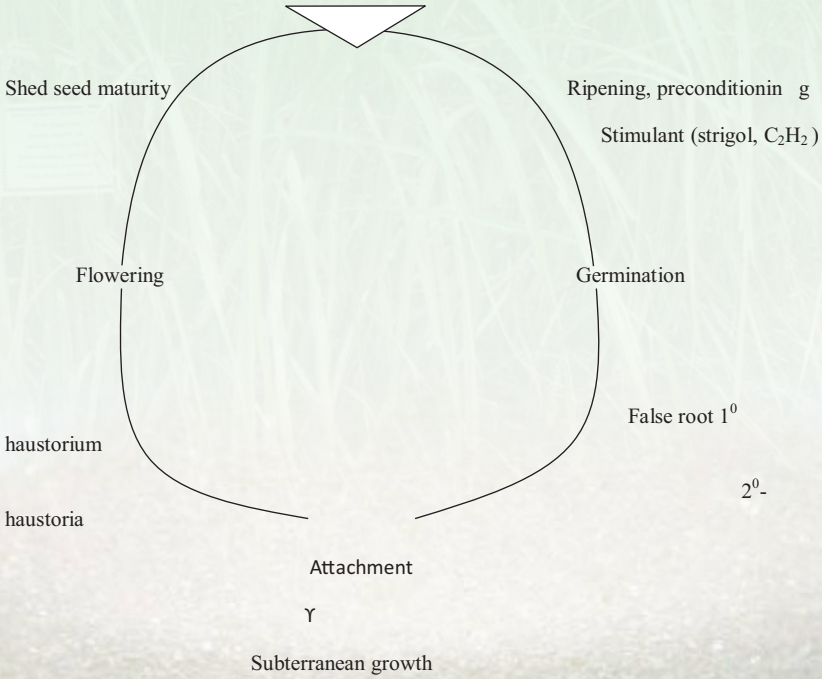
In Western Kenya, *S.hermonthica* is dominant and its hosts include maize, sorghum, finger millet, sugarcane, rain fed rice and Napier grass.

Being parasitic, obligate in nature, the weed, which is also semi-parasitic, has its life cycle closely related to that of the host crop. After maturing, the fruit bursts and shed seeds into the soil. A conditioning (dormancy) period that varies with climate and soil types follows. During this period the weed sort of sleeps when a host crop is grown adjacent to an already pre-conditioned seed, the host releases/excretes a stimulant, strigol, which elicits the weed seed to germinate. Being obligate, the germinated seed develops very poor rooting system. In addition, it develops a false root called haustorium, which grows towards the host root, penetrates and attaches to the vascular bundle (phloem and xylem) of the host. From here the young weeds draws its water and substrates directly from the host plant. The weed also secretes some phytotoxic substances, which poison the host, hence causing stunted growth.

If the infestation is severe, the host plant's growth can completely stop and it dies.

Control

1. Use of trap crops- stimulates germination, which don't encourage attachment (e.g. legumes, cotton, sunflower etc.
2. Use of catch crops – stimulate germination and attach but the crop is destroyed with attached weeds before latter matures
3. Apply farm yard manure- Increased C_2H_2 gas has same germination stimu lant activity like strigol hence causes suicidal germination to the parasitic weed



Strengths in the sugar milling sector

Side loading in action

Side loader in motion

May field Fertilizer Applicator

Herbicide spraying Tanker with mixing unit

Hot water treatment plant

Hot water treatment plant

Hot water treatment trays

Hot water treatment trays

Hot water treated seed Nursery

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