



Sorghum production

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INTRODUCTION

Sorghum [*Sorghum bicolor* (L.) Moench] is an indigenous crop to Africa, and though commercial needs and uses may change over time, sorghum will remain a basic staple food for many rural communities. The latter is especially true in the more drought prone areas of South Africa where this hardy crop provides better household food security than maize.

Sorghum is mainly cultivated in drier areas, especially on shallow and heavy clay soils. The production of sorghum in South Africa varies from 100 000 ton (130 00 ha) to 180 000 ton (150 000 ha) per annum. The Free State and Mpumalanga Provinces are the largest contributors to the area planted to sorghum and sorghum production.

In recent years, there has been a shift in sorghum production from the drier western production areas to the wetter eastern areas. This change has resulted in the identification and development of cultivars which are more tolerant to lower temperatures.

MORPHOLOGY, GROWTH AND DEVELOPMENT

Sorghum belongs to the grass family, *Graminea*. It is essential that producers know the crop they are cultivating in order to develop the most effective production practices (Fig. 1).

Root system

The roots of the sorghum plant can be divided into a primary and secondary system. The primary roots are those which appear first from the germinating seed. The primary roots provide the seedling with water and nutrients from the soil. Primary roots have a limited growth and their functions are soon taken over by the secondary roots.

Secondary roots develop from nodes below the soil surface. The permanent root system branches freely, both laterally and downwards into the soil. If no soil impediments occur, roots can reach a lateral distribution of 1 m and a depth of up to 2 m early in the life of the plant. The roots are finer and branch approximately twice as much as roots from maize plants.

Leaves

Sorghum leaves are typically green, glasslike and flat, and not as broad as maize leaves. Sorghum plants have a leaf area smaller than that of maize. The leaf blade is long, narrow and pointed. The leaf blades of young leaves are upright but the blades tend to bend downwards as leaves mature.

Stomata occur on both surfaces of the leaf. A unique characteristic of sorghum leaves is the rows of motor cells along the midrib on the upper surface of the leaf. These cells can roll up leaves rapidly during moisture stress.

Leaves are covered by a thin wax layer and develop opposite one another on either side of the stem.

Environmental conditions determine the number of leaves, which may vary from 8 to 22 leaves per plant.

Stem

The stem of the plant is solid and dry, to succulent and sweet.

Under favourable conditions more internodes develop, together with leaves, producing a longer stem. The stem consists of internodes and nodes. A cross section of the stem appears oval or round. The diameter of the stem varies between 5 and 30 mm. The internodes are covered by a thick waxy layer giving it a blue-white colour. The waxy layer reduces transpiration and increases the drought tolerance of the plants. The root band of nodes below or just above the soil surface develops prop roots.

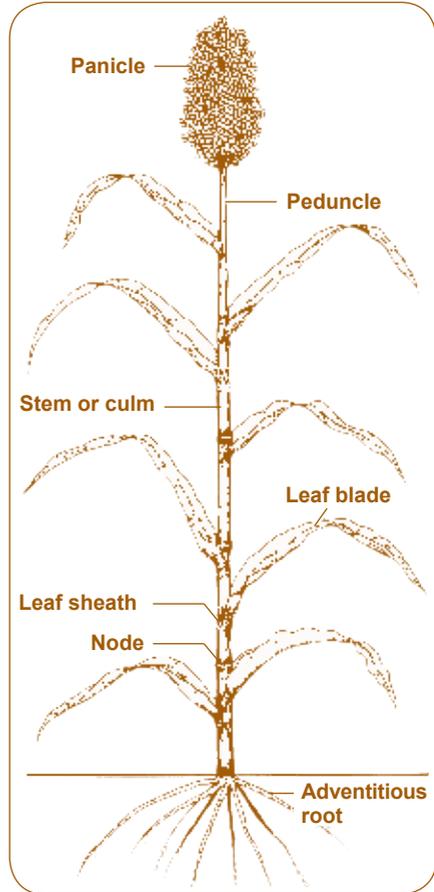


FIG. 1. Botanical parts of a sorghum plant

(After: MURDY, D.S., TABO, R. & AJAYI, O. 1994. *Sorghum Hybrid Seed Production and Management*)

The growth bud develops lateral shoots. Sometimes the growth buds higher up the stem may also develop lateral shoots.

Inflorescence (panicle)

The inflorescence of sorghum, the panicle, may be compact or open. The shape and colour of the panicle varies between cultivars. Panicles are carried on a main stem or peduncle with primary and secondary branches on which the florets are borne. The peduncle is usually straight and its length varies from 75 to 500 mm. Each panicle contains from 800 to 3 000 kernels which are usually partly enclosed by glumes. The colour of the glumes may be black, red, brown or tan.

The flowers of sorghum open during the night or early morning. Those at the top of the panicle open first and it takes approximately 6 to 9 days for the entire panicle to flower. Because of the structure of the flower, mainly self-pollination takes place. A small percentage of cross-pollination (approximately 6 %) occurs naturally (Fig. 2).

Seed

The ripe seed (grain) of sorghum is usually partially enclosed by glumes, which are removed during threshing and/or harvesting. The shape of the seed is oval to round and the colour may be red, white, yellow, brown or shades thereof. If only the pericarp is coloured, the seed is usually yellow or red. Pigment in both the pericarp and testa results in a dark-brown or red-brown colour. The sorghum grain consists of the testa, embryo and endosperm.

Seed coat

The seed coat consists of the pericarp and testa.

Pericarp

This is the outermost layer of the seed and consists of the epicarp, hypodermis, mesocarp and endocarp.

TABLE 1. Composition of the sorghum grain as a fraction of total mass

Description	Percentage (%)
Seed coat	7,3 – 9,3
Embryo	7,8 – 12,1
Endosperm	81,1 – 84,6

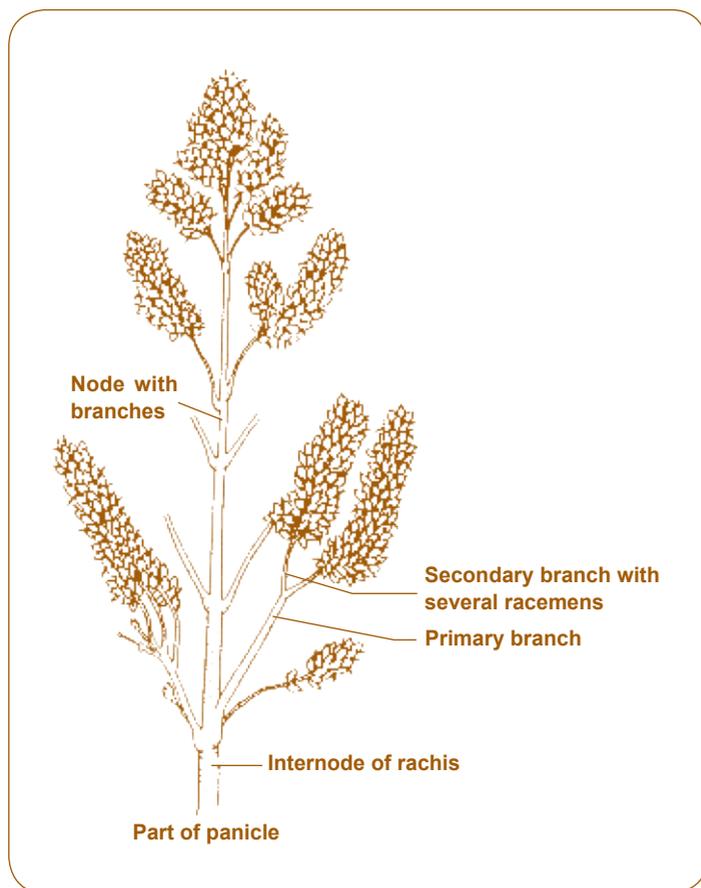


FIG. 2. Botanical parts of the inflorescence of a sorghum plant

(After: MURDY, D.S., TABO, R. & AJAYI, O. 1994. *Sorghum Hybrid Seed Production and Management*)

Testa

The testa is situated directly below the endocarp and encloses the endosperm. Apart from the role of the testa in the colouring of the seed, it contains a tannin-like substance with a bitter taste. The presence thereof results in less bird damage to sorghum. In the absence of a testa, bird damage increases significantly. The bitter taste of sorghum with a testa, however, makes it less acceptable as food for humans and animals.

Embryo

The embryo contains those parts, which give rise to the new seedling. The new plant, which is already a complete unit, depends on the right moisture and temperature conditions to start developing.

Endosperm

The endosperm consists of hard and soft endosperm. The endosperm supplies the seedling with nutrients until it can take up its own nutrients.

Growth and development

The growth and development of sorghum are divided into the vegetative and reproductive growth stages (Fig. 3).

Vegetative growth stages

Identification of the sorghum growth stage during vegetative growth is done according to leaf development.

Reproductive growth stages

The identification of the reproductive growth stage is done according to the development of grain kernels.

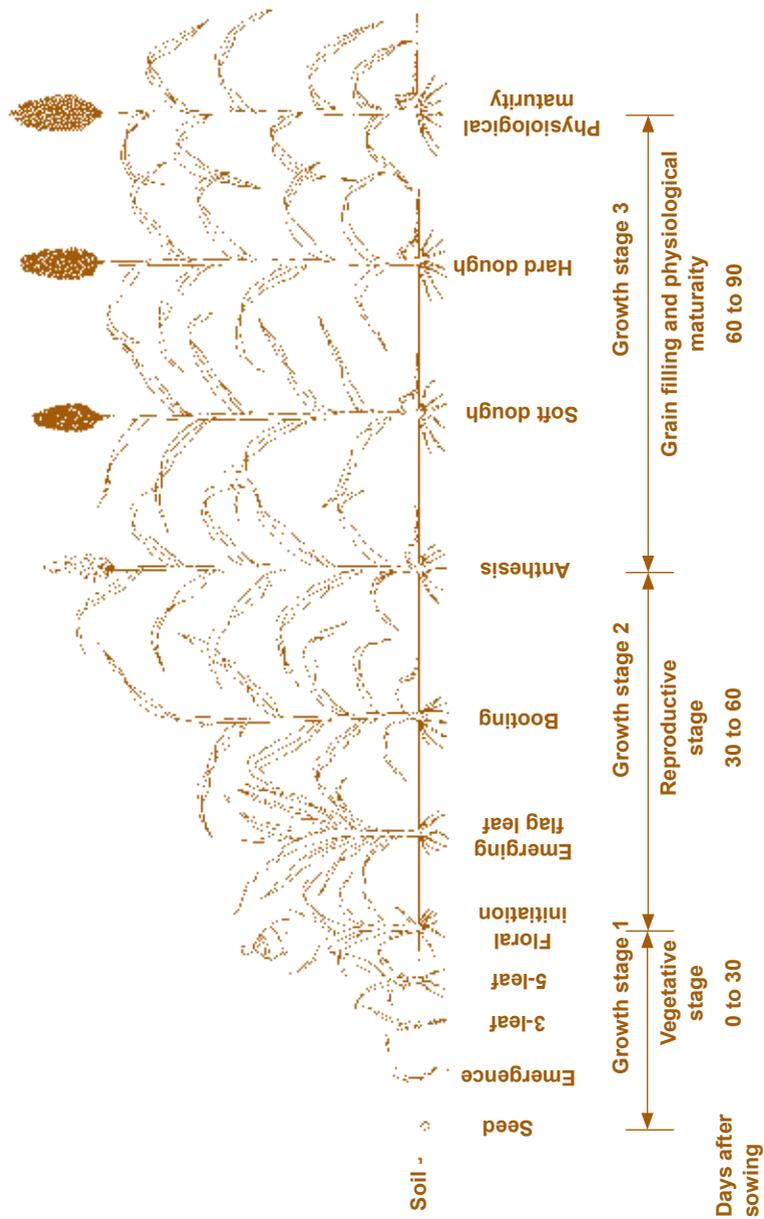


FIG. 3. Growth stages of a 90-day-old sorghum plant

(After: MURDY, D.S., TABO, R. & AJAYI, O. 1994. *Sorghum Hybrid Seed Production and Management*)

GROWTH REQUIREMENTS AND ADAPTATION

The optimum growth requirements of sorghum plants, in order to exploit its inherent yield potential, are a deep well-drained fertile soil, a medium to good and fairly stable rainfall pattern during the growing season, temperate to warm weather (20 – 30 °C) and a frost-free period of approximately 120 to 140 days.

Soil requirements

Sorghum is mainly grown on low potential, shallow soils with high clay content, which usually are not suitable for the production of maize. Sorghum usually grows poorly on sandy soils, except where a heavy textured subsoil is present. Sorghum is more tolerant of alkaline salts than other grain crops and can therefore be successfully cultivated on soils with a pH (KCl) between 5,5 and 8,5. Sorghum can better tolerate short periods of waterlogging compared to maize. Soils with a clay percentage of between 10 and 30 % are optimal for sorghum production.

Climatic requirements

The climatic requirements for the production of sorghum are divided into temperature, day length and water needs.

Temperature

Sorghum is a warm-weather crop, which requires high temperatures for good germination and growth. The minimum temperature for germination varies from 7 to 10 °C. At a temperature of 15 °C, 80 % of seed germinate within 10 to 12 days. The best time to plant is when there is sufficient water in the soil and the soil temperature is 15 °C or higher at a depth of 10 cm.

Temperature plays an important role in growth and development after germination. A temperature of 27 to 30 °C is required for optimum growth and development. The temperature can, however, be as low as 21 °C, without a dramatic effect on growth and yield.

Exceptionally high temperatures cause a decrease in yield. Flower initiation and the development of flower primordia are delayed with increased day and night temperatures.

Plants with four to six mature leaves that are exposed to a cold treatment (temperatures less than 18 °C) will form lateral shoots. However, in plants in or beyond the eight-leaf stage, apical dominance will prevent the formation of lateral shoots.

Temperatures below freezing are detrimental to sorghum and may kill the plant. At an age of 1 to 3 weeks, plants may recover if exposed to a temperature of 5 °C below freezing point, but at 7 °C below freezing, plants are killed. Plants older than 3 weeks are less tolerant to low temperatures and may die off at 0 °C.

Day length

Sorghum is a short-day plant, which means that the plant requires short days (long nights) before proceeding to the reproductive stage. The optimum photoperiod, which will induce flower formation, is between 10 and 11 hours. Photoperiods longer than 11 to 12 hours stimulate vegetative growth. The tropical varieties are usually more sensitive to photoperiod than the quick, short-season varieties. Sorghum plants are most sensitive to photoperiod during flower initiation.

Water requirements

Sorghum is produced in South Africa on a wide range of soils, and under fluctuating rainfall conditions of approximately 400 mm in the drier western parts to about 800 mm in the wetter eastern parts.

Drought tolerance

Sorghum is able to tolerate drought better than most other grain crops. This can be attributed to:

- An exceptionally well-developed and finely branched root system, which is very efficient in the absorption of water.
- It has a small leaf area per plant, which limits transpiration.

- The leaves fold up more efficiently during warm, dry conditions than that of maize.
- It has an effective transpiration ratio of 1:310, as the plant uses only 310 parts of water to produce one part of dry matter, compared to a ratio of 1:400 for maize.
- The epidermis of the leaf is corky and covered with a waxy layer, which protects the plant from desiccation.
- The stomata close rapidly to limit water loss. During dry periods, sorghum has the ability to remain in a virtually dormant stage and resume growth as soon as conditions become favourable. Even though the main stem can die, side shoots can develop and form seed when the water supply improves.

Production potential

It is essential for the sorghum producer to make a realistic yield estimate. Production practices such as planting density, fertilisation and cultivar choice depends on the planned yield. Various methods, each having limitations, can be used to determine yield potential. The most reliable method is to use long-term yield data from each producer. This reflects the inherent yield of the specific environment, as well as the effect of agronomic practices such as fertilisation, soil cultivation, plant density, weed control and pest control as well as the managerial skills of the producer.

CULTURAL PRACTICES

Tillage

Tillage, in particular primary tillage, is the foundation of any crop production system and is the most expensive practice in the production of sorghum.

The effect of tillage on soil properties

Tillage in a farming system refers to the physical manipulations of the soil with the objective of changing the structure, hydraulic properties and stability to such an extent that plants will grow and produce optimally.

A modern approach of managing soil structure in row crops consists of:

- A planting zone where conditions must be optimal for planting and growth;
- A managing zone between the rows where soil structure should be relatively receptive to maximum infiltration of water and air while minimising erosion and weed growth.

Effect of tillage on soil physical properties

TEXTURE AND STRUCTURE

Texture refers to the size of the mineral soil particles and is the single most important physical property of the soil. It involves the ratio of sand, silt and clay in a specific soil. This ratio determines the capacity and strength of structures that are formed as well as the ability to store water. Clay soil can therefore store more water than sandy soil as a result of greater specific surface. The arrangement of primary soil particles with each other to form larger units is known as structure. Higher clay content and other cementation agents such as iron and aluminium oxides in the soil increase the degree of structure formation. The objective of tillage is to maintain the existing structure of the soil or to improve the structure of poorly structured soils. Use of the incorrect tillage implements breaks down structural units and reduces the ability of the soil to comply with the growth requirements of the plant.

Processes in soil directly affected by tillage

Infiltration and evaporation

The most important processes affected by tillage include infiltration and evaporation of water. Certain types of clay soils expand or shrink with wetting and drying. This leads to large cracks being formed from the surface downwards, which increases the evaporation surface considerably. It is therefore important under these circumstances to keep the topsoil loose in an evenly structured layer.

Germination and root growth

Soil temperature and water affect seed germination. Germination and root growth are affected by tillage methods in the sense that the soil temperature can be manipulated and evaporation limited.

Erosion

The type of tillage affects vulnerability of the soil to either wind or water erosion. Finely structured topsoil favours both types of erosion, while a coarse structure restricts erosion. Plant residue may also be left on the soil surface to combat erosion.

Implements and soil tillage

The aims of soil tillage are weed control, incorporation of residues, reduction of wind and water erosion and improvement of soil structure. A fourth aim that is most important in intensive farming, especially where use is made of heavy tractors and implements, is countering compaction.

Primary tillage implements

Mouldboard ploughs

This implement is used to turn sods up to 300 mm deep and is particularly effective on heavier soils where a considerable degree of structure is present. Turning the soil also has the advantage that weed seeds and unwanted crop residue can be buried deeply. Mouldboard ploughs are not recommended on sandy soils, because poor structure units which may exist, can be destroyed, promoting wind erosion.

Disc ploughs and discs

The disc plough has a slicing action with the main advantage that better penetration is obtained under dry, hard conditions, with an additional

advantage that wear is lower than in the case of a mouldboard plough. The implement is useful on hard, dry soils where loss of structure is not too critical. It is on no account recommended for sandy soils.

Chisel ploughs

Chisel ploughs are used mainly to loosen the soil to a limited depth of 250 mm. Best results are obtained if the soil is relatively dry, because the chisels break the soil, creating structural units. If conditions are too dry, however, big clods are formed, which restrict plant development.

Rippers

Rippers are used when deep cultivation is necessary and turning of the soil is undesirable. If soils are tilled annually to the same depth, a plough-sole develops. This confined layer prevents infiltration and root development. To ensure better drainage, conservation and utilisation of water, it is essential to break this layer regularly. Under wet, clay conditions, the main disadvantage of the ripper is that it compacts the soil laterally and inwards, which can limit lateral root development.

Secondary tillage implements

Rotary tiller

Under ideal conditions, on moist clay soils, this useful implement can prepare the seedbed in one operation. On dry, sandy soils it can, however, destroy the structure within a very short period.

Tine cultivators

Tine cultivators include a variety of hoeing implements, which are mainly used for controlling young weeds, but also for breaking surface crusts. These implements are only effective on moist soils. They are completely ineffective on dry, clay soils.

Harrows

Harrows include a variety of implements. The tine harrow is primarily used to level the seedbed once it is in a fine condition. The primary objective of the disc harrow is to break surface crusts, but it can be used to break clods to obtain a fine seedbed.

ESTABLISHING PRACTICES

Planting date

The planting date of sorghum is determined by the first spring rain, distribution of the seasonal rainfall, soil temperature, frost-free period and the cultivar to be planted. Normally sorghum is planted in South Africa from mid-October to mid-December. Sorghum is sensitive to low temperatures. The ideal soil temperature for germination is 15 °C at a depth of 10 cm. The crop is also sensitive to frost, and planting should be delayed until the date of the last frost has passed. It is important to choose the planting date so that the period of critical moisture need (head initiation) does not coincide with a drought period.

Planting depth

Sorghum has a small seed and should be planted shallow. A planting depth of 25 mm is satisfactory with sufficient water. Under drier conditions the seed should be planted deeper, but no more than 50 mm. Planting depth is also determined by soil type. On heavy soils, the planting depth should not be more than 25 mm, while on light soils, the depth can be up to 50 mm.

It is important that the soil surrounding the seed is firm to ensure rapid absorption of water and, eventually, germination.

Row width

Sorghum is planted in areas with a wide range of rainfall and soil conditions. Wide rows are recommended for the low rainfall areas and on soils with

a poor water-holding capacity. In areas with good, deep soils and a high rainfall, narrow rows (0,91 m) are recommended.

Depending on the long-term rainfall, soil type (potential) and factors mentioned already, sorghum is planted in 0,91 m, 1,5 m or 2,3 m rows. The inclusion of a 2,3 m strip within the narrow rows is important if pest control is to be done with a tractor or sprayer.

Plant population

Poor seedbed preparation, insufficient water, insects and diseases can result in poor stand. The quantity of seed should therefore be increased to compensate for a poor stand. On the other hand, if germination is good, the population may be too high for prevailing water and nutrient supply.

Recommendations regarding plant population for sorghum are usually expressed in kilogramme seed per hectare. The seed size of sorghum cultivars varies from 30 000 to 40 000 grains per kilogramme. Recommendations, therefore, vary from 3,0 to 7,0 kg seed per hectare.

Planting method

Sorghum is normally planted with maize planters. Adaptations should be made by using the correct planter plates and gear ratios to obtain the correct plant populations.

CULTIVAR CHOICE

Cultivar planning aims to reduce risks by avoiding drought periods during the most critical growing stages of the plant, such as flowering and seed set. Cultivars differ in their reaction to the environment and the climate, which can be used in planning the seed package.

The yield potential of the farm or field should be known as well as the long-term rainfall pattern to be able to make the best cultivar choice. The long-term rainfall data will be a guide for the choice of the correct growing season length of the cultivars suitable for that area.

Isolated or small areas of sorghum are prone to bird damage. When selecting bird resistant cultivars for such areas, contracts should be

TABLE 2. Plant population and seed requirements for different row widths and in-row spacing

In-row spacing (mm)	Plants per hectare (kg seed/ha)		
	0,91 m rows	1,5 m rows	2,3 m rows
10			434 700 (12,4)
15		444 444 (12,7)	289 800 (8,3)
20		333 333 (9,5)	217 350 (6,2)
25	439 560 (12,6)	266 666 (7,6)	173 913 (5,0)
50	219 780 (6,3)	133 333 (3,8)	86 956 (2,5)
75	146 520 (4,2)	88 888 (2,5)	57 971 (1,7)
100	109 890 (3,1)	66 666 (1,9)	43 478 (1,2)
125	87 912 (2,5)	53 333 (1,5)	34 478 (1,0)
150	73 260 (2,1)	44 444 (1,3)	28 985 (0,8)

negotiated prior to planting, as this grain is not easily accepted by industry.

Cultivars with a wide adaptability would be a good first choice when starting with sorghum production. Multiseasonal results can be used to select specific cultivars, which can be incorporated into the cultivar package after proper testing on the site.

Agronomic characteristics such as disease and insect resistance, lodging and head placement should be kept in mind when compiling a cultivar package.

FERTILISATION

To assess the correct quantity of fertiliser to be applied for optimal yield, soil samples should be taken according to the recommendations of an accredited soil laboratory (Guidelines are available from The Director, ARC-GCI, Private Bag X1251, Potchefstroom 2520).

Fertiliser recommendations made according to the soil analysis should be applied accordingly.

Symptoms of deficiencies that may be observed in the field are as follows:

- *Nitrogen (N) deficiency*—young plants are light green or yellow-green, at a more mature stage the older leaves start yellowing first, with a characteristic inverted V-shape.
- *Phosphorus (P) deficiency*—under wet, cool conditions leaves of young plants may turn dark green with reddish-purple margins and tips.
- *Potassium (K) deficiency*—a deficiency of K is initially noted as yellow or necrotic leaf margins, beginning at the lower leaves and spreading to the upper leaves.

WEEDS

Weed control during the first 6 to 8 weeks after planting is crucial, as weeds compete vigorously with the crop for nutrients and water during this period.

The root parasite *Striga asiatica* (L.) Kuntze or witchweed (*rooibloom*) can damage the crop and mainly occurs under low input farming conditions. The parasitic plants are single stemmed with bright red flowers.

Most of the damage is done before the parasite emerges from the soil. The symptoms include leaf wilting, leaf rolling, and leaf scorching even though the soil may have sufficient water. The tiny seeds are disseminated by wind, water and animals, and remain viable in the soil for 15 to 20 years. Rotation with cotton, groundnut, cowpea and pigeonpea will reduce the incidence of *Striga*. Hand pulling the plants before flowering may be useful.

Methods of weed control

Physical methods

Weeds can be removed mechanically, by hand or with implements.

Cultural practices

Ploughing during winter or early spring is an effective method of controlling weeds.

Chemical methods

Chemicals formulated as liquids, granules or gases can be applied to kill germinating or growing weeds or seeds.

Control of nut-grass with pre-emergence herbicides is not effective when applied after emergence. It is important to cultivate fields before applying herbicides.

Wild sorghum in sorghum fields can only be controlled mechanically or by hand hoeing.

PEST CONTROL

Integrated pest management

Integrated pest management is a system whereby various methods are applied to protect the crop by suppressing insect populations and limiting damage. These measures include the following: chemical control, biological control, plant resistance and cultural control.

Preventative control

For both chilo borer and the maize stem borer the economic threshold level of 10 % infested plants in a sorghum field applies. This value implies that there are sufficient larvae in the field to cause economic damage and that chemical control should therefore be applied.

For bollworm on sorghum the economic threshold level is, when an average of two larvae occur per panicle. Only then should spraying take place. In the case of aphids, timely control is very important, but spraying at first indication of an infestation is not necessary. An indication that the aphid population is nearing economically important levels is when virtually all plants are infested. Spraying at this stage will ensure that the crop is free from aphids for the greater part of the most sensitive period, namely grain filling.

Cultural control

This implies that pest populations are suppressed by cultural practices, which are detrimental to the pest. These practices include soil cultivation during winter, eradicating volunteer plants, cultivar choice and adapting planting times.

Biological control

Natural control of pests occurs on a continuous basis in fields where natural enemies attack all the life-stages of insect pests. Aphids and diapause larvae of stem borers are particularly vulnerable to natural enemies. The complex of natural enemies can be protected to a certain extent by using insecticides which are more environmentally friendly, and which are not very poisonous to nontarget organisms.

MARKETING, USES AND PRODUCTS

Grading

For grading purposes sorghum is divided into the following classes:

Class GM

This includes malt sorghum that does not have a dark testa (condensed tannins), is listed as a GM cultivar and meets the requirements of Class GM sorghum as stipulated by the grading regulations.

Class GL

This includes sorghum which does not have a dark testa (condensed tannins) and is from a GM cultivar that cannot be graded in the Class GM sorghum or from a GL cultivar as stipulated in the cultivar list, and meets the requirements of Class GL sorghum as stipulated by the grading regulations.

Class GH

This includes malt sorghum which has a dark testa (condensed tannins) and is from a GH cultivar as determined by the cultivar list, and meets the requirements of Class GH sorghum as stipulated by the grading regulations.

Other sorghum

This includes sorghum which does not meet the requirements of Class GM, Class GL and Class GH sorghum.

Sorghum products for the consumer

Malt

Commercial malt is produced from GM cultivars with specific characteristics.

Industrial malt is produced from GM and GH cultivars. Condensed tannins in GH cultivars are neutralised before malting commences. The malt is used in the industrial production of sorghum beer.

Beer

Preparation of beer is a lengthy process covering 3 days. Ingredients for the preparation of beer are malt, meal and yeast.

Beer powder

Instant beer powder is a premixed product that consists mainly of sorghum malt, a starch component and brewers yeast. A 24-hour period is needed before the beer can be consumed.

Sorghum meal

Sorghum meal, also known as Mabele, directly competes with maize meal. Sorghum with condensed tannins is not used for meal production .

Sorghum rice

Sorghum rice or corn rice is whole, decorticated sorghum.

Livestock feed and other animal products

Livestock feed is the most important market for surplus sorghum, as it competes effectively with other grain products in terms of price and quality.

Sorghum is an important component in poultry feed and good progress has been made in the manufacturing of dog food, as well as pigeon and ostrich food.

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