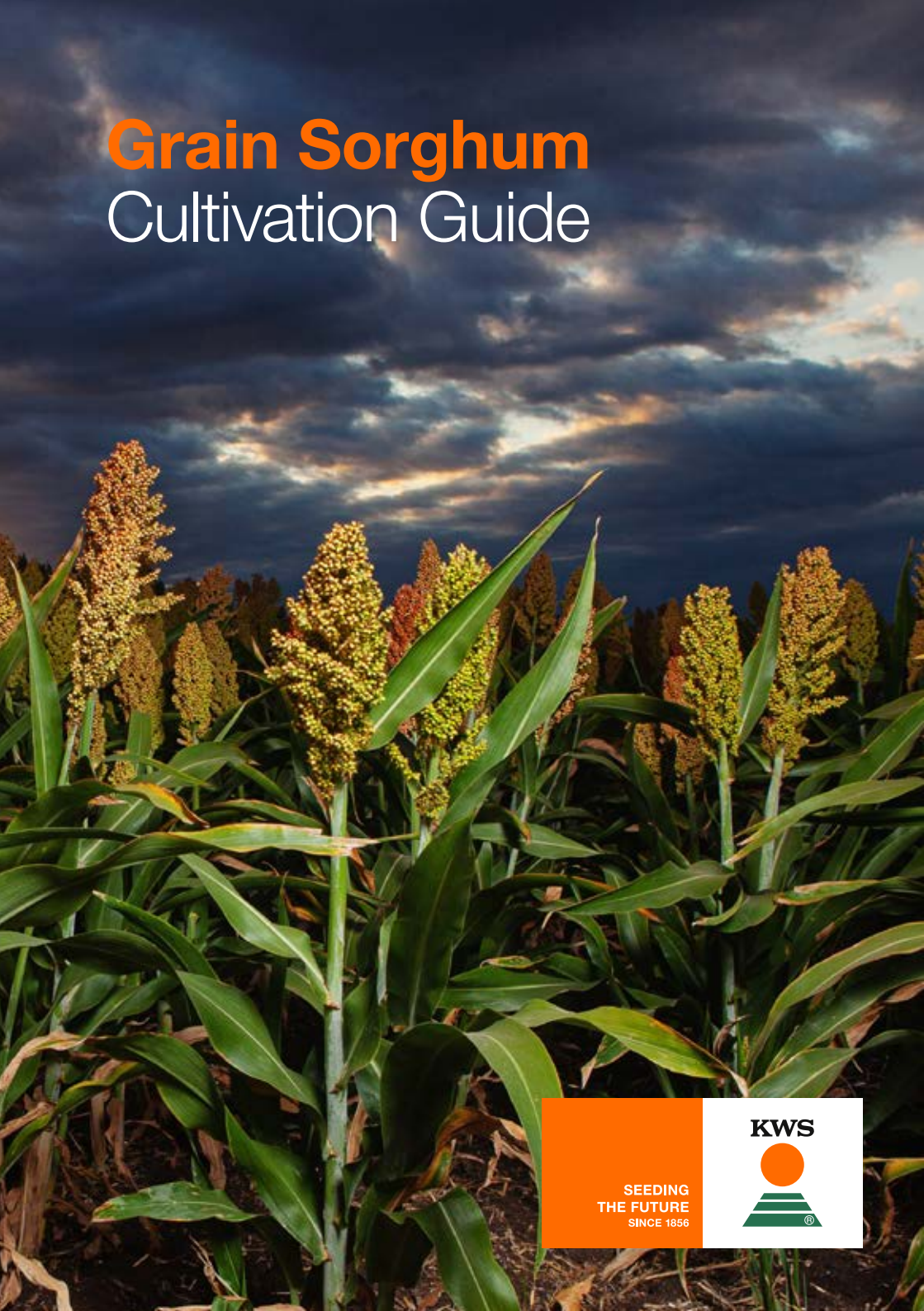
Grain Sorghum
Cultivation Guide



SEEDING
THE FUTURE
SINCE 1856

KWS

Content

Sorghum – a portrait

Sorghum, the cereal of the future

- The first documented use of sorghum dates back to 8000 BC in north-east Africa.
- Sorghum is the fifth most important cereal in terms of acreage. The global area under cultivation is around 40 million hectares and global production is between 60-70 million tonnes. However, it is unbeatable when it comes to development potential. While it is already established as a staple food in Asia and its country of origin, Africa, it is also becoming increasingly popular in the USA, South America, and Europe.
- The constantly growing demand for climate-friendly and sustainable cultivation alternatives is making sorghum a viable option:
- **High water use efficiency:** Due to its dense and deep root system, sorghum can extract and utilize water and nutrients from the soil very efficiently. Combined with its CO_2 absorption mechanism, which ensures a good photosynthetic yield even under dry conditions, sorghum is the best choice when it comes to a drought-resistant cropping systems.
- **Low input** of fertilizers and pesticides (herbicides in particular) compared to maize or sunflower.
- Helps to improve **crop rotation** systems.
- The yield potential of grain sorghum is over 12 t/ha and for silage in southern Europe over 25 t/ha DMY.

- 42% of grain sorghum is used as an animal feed and offers great potential as feed for poultry, pig and dairy farms. It is possible to add 25-70% sorghum to pig diets and up to 50% to poultry diets – current studies show benefits for animal welfare when including sorghum in the diet. One of the biggest advantages of feeding sorghum is the fact that mycotoxins are not an issue.
- Sorghum is very important for human consumption – in 2022 it accounted for 46% of global sorghum production. Sorghum is gluten-free. Due to its properties, it can be used in the brewing industry, as flour for flatbread, pasta, cookies. In the spirits industry, or as a whole grain for porridge or salads.
- Around 8% of global production is used industrially.
- Silage sorghum is used to feed livestock, for biogas or as hay for incinerators. Sweet sorghum is used for bioethanol production and the production of syrup and alcohol for human consumption. The European varieties are very low in tannin (>0.3%) and offer an excellent nutritional profile (for more details on sorghum as animal feed, see the chapter “Grain sorghum as feed”)
- Grain sorghum offers a wide variety of colors, ranging from snow white varieties to cream, bronze and purple. The choice of color can be based purely on preference. Contrary to popular belief, reddish or darker varieties do not have a higher tannin content than white or cream-colored grains.
- Sorghum is limited by low temperatures and excessively moist soils, especially in the early growth phase.

Global production and use

m t	20/21	21/22 (est.)	22/23 (f'cast)	23/24 (proj.)	y/y change
Opening stocks	5.4	4.4	4.4	3.7	- 16.2%
Production	62.6	61.2	57.9	62.42	+ 7.8%
Total supply	**67.9**	**65.7**	**62.3**	**66.1**	**+ 6.1%**
Total use	**63.5**	**61.2**	**58.6**	**62.5**	**+ 6.7%**
of which:					
▪ Food	31.9	28.4	31.0	31.2	+ 0.6%
▪ Feed	25.7	26.2	21.0	24.5	+ 17.0%
▪ Industrial	4.1	4.8	5.0	5.0	+ 0.0%
Closing stocks	**4.4**	**4.4**	**3.7**	**3.6**	**- 3.4%**
Major exporters[a)]	0.8	1.6	1.1	1.2	+ 9.2%
Trade (Jul/Jun)	**9.7**	**12.3**	**6.5**	**9.6**	**+ 47.5%**

[a)] Argentina, Australia, USA
Source: IGC, Rapport Avril 2023

Sorghum breeding timeline

1957
- Breeding of the first CMS Sorghum hybrids in the USA

1980s
- RAGT and Euralis begin breeding
- KWS breeds sugar sorghum due to Rhizomania in sugar beet

2007
- KWS begins with breeding of biomass sorghum

S. bicolor x S. sudanense

S. bicolor ssp. bicolor

2014
- KWS begins with breeding of grain sorghum

2017
- KWS's first registered grain sorghum hybrid KWS LUPUS

KWS LUPUS

2020
- Initiation of Brazil breeding program
- Start of sales: KWS LUPUS

Key breeding goals
- Early maturity varieties
- Low tannin content
- High protein content
- Fusarium resistance

2022
- 22 hybrids in application in Brazil
- Registration of 2 new white grain varieties (in EU)

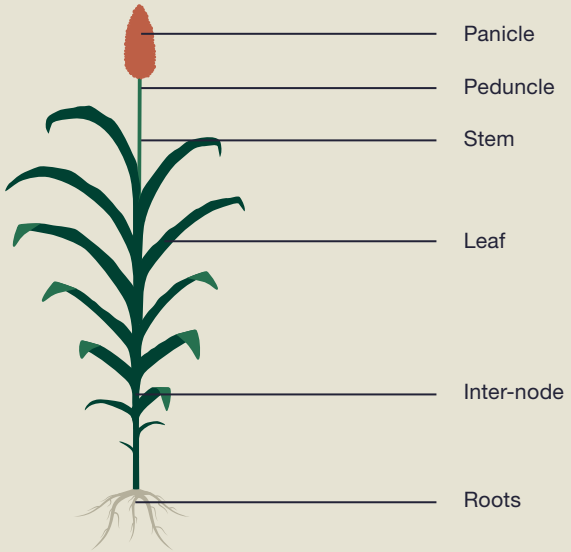
Future focus areas
- Focus on sustainability and low input systems
- Hybrids with further improved drought resilience and yield stability

2024
- Two new registrations

Source: KWS

The physiology of the plant

- The **seeds** weigh between 15 and 40 g/1,000 seeds.
- The length of the **panicle** is between 10 and 60 cm. It consists of small branches arranged in pairs. The number of shooting spikes per panicle depends on their length and the variety.
- The **stem** is smooth, hard and divided into internodes by nodes. The outside of the stem is covered with a thin layer of wax. This wax layer protects it from drying out during dry periods. It reaches a height of between 1.0 to 5.5 m. The **leaves** are 50-100 mm wide and up to 1 m long and, like the stem, are covered with a thin wax film. This means that transpiration is lower and water utilization efficiency is increased, when the wetter conditions are too dry and challenging The midrib can vary in colour, from white to brown (in „brown mid-rib“ types)
- The **root** system is very well developed and can reach a depth of over 1.8m. This gives sorghum an excellent capacity to absorb water and nutrients. In addition to the underground roots, sorghum also develops aerial roots, which improve the anchoring of the stem in the soil and increases the lodging resistance.

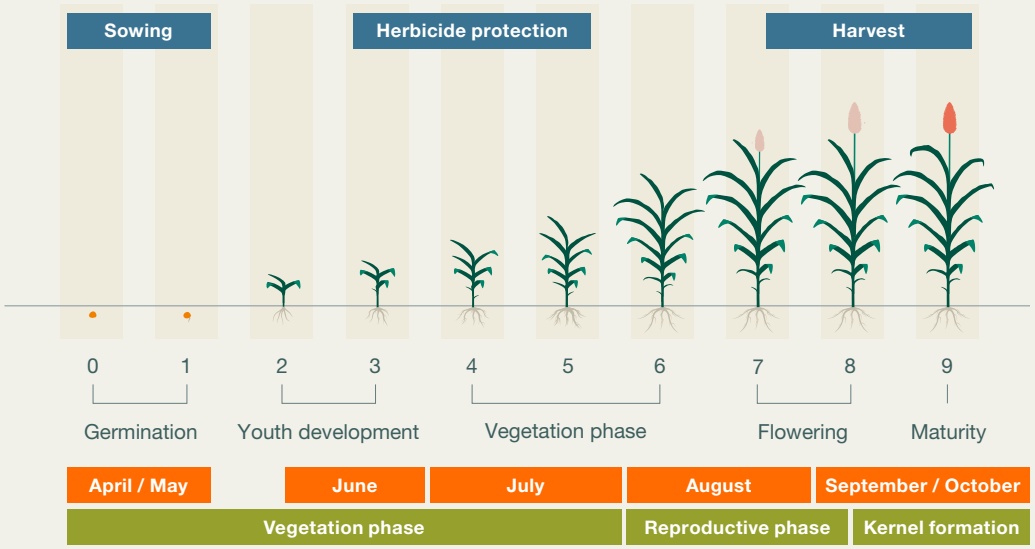


Variety selection

Main Criteria

- Earliness (area, sowing time)
- Color
- Yield potential and stability
- Tolerances of
  - Drought and heat
  - Diseases like *macrophomina*, stem or head *fusarium*, *anthracnose*, *leaf diseases*
  - Coldness
- Resistance to lodging or green snapping
- No apical sterility
- European varieties have a very low tannin level
- Threshing ability

Sorghum growth cycle (central europe)

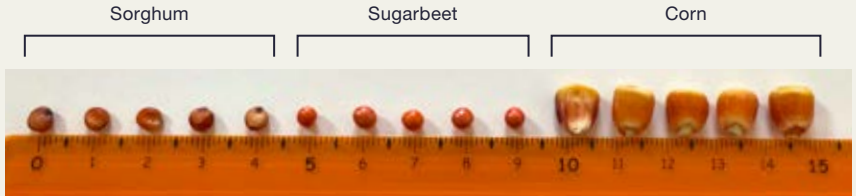


Soil temperature		Days until germination/emergence
12°C	Slow germination rate	> 14 days
15°C	Good germination rate	7-12 days
18°C	Fast germination rate	5-7 days
20°C	Ideal conditions	< 5 days

Sowing

Location, seedbed and sowing

- **Location**
  - Sandy soils preferable to heavy soils → faster to warm up in spring
  - Cold, waterlogged locations should be avoided
  - Locations with *Sorghum halapense* should be avoided, as grasses are hard to control in sorghum
- **Seedbed preparation (comparable to corn or sugar beet)**
  - Well tilled (deep tillage or no till system), settled seedbed with a fine soil structure
  - Higher seedbed requirements than corn
  - Avoid compacted soil
  - Avoid too loamy or clodded soil for good germination
- **Sowing**
  - Single-seed sowing with 37.5 cm or 45cm row-distance
  - Corn single-seed sowing with 75 cm row-distance – adapt density in the row → should not be denser than 5 cm.
  - Drill-seed 12-50 cm
  - Ensure good reconsolidation of soil
  - Smaller row distance = better shading
  - Hole diameter of 2,2 is ideal for sorghum
- **Sowing time**
  - Starting mid May until late June – when soil temperatures ideally are at >12°C in 10 cm depth → influence on harvesting time
- **Sowing depth and density**
  - 2-5 cm depth (pay mind to dryness) at a density of 20-25 kernels/m^2



Comparison of 3 seeding technologies

Weed, pest and disease control

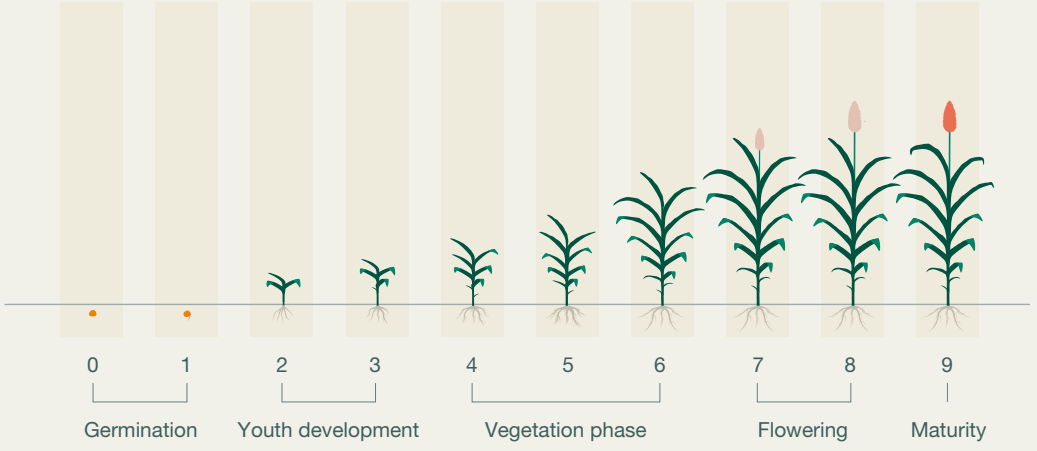
Weed control

- Weed control starts with the choice of field.
- Sorghum does not like fields full of weeds, and in particular plants from the Poaceae family are a serious problem that needs to be controlled. It is recommended to avoid fields with currant grasses and other grasses similar to sorghum.
- Sorghum has slow early vigor, resulting in less competitiveness against most weeds.
- Weed control is important to increase the water and nutrient efficiency of sorghum, using mechanical weed control if necessary.

Combination proven in practice

- **S-Metolachlor** (312,5 g/l) with **Terbuthylazin** (187,5 g/l)
- **S-Metolachlor** in combination with **Concep C** in pre emergence stage
- **Dimethenamid-P** (720 g/l) with **Pendimatalin** (455 g/l)

S-Metholachlor to be banned on EU level as of July 2024. Please check your local regulations.



Weed control
Incorrect timing

Weed control
Correct timing

Fertilization

According to the studies currently available, there is a great similarity in nutrient extraction between sorghum and maize, both of which belong to the family of true grasses.

Under – Foot Fertilization

A corn precision planter enables (in most cases) underfoot fertilization. The early vigor of sorghum is significantly poorer than that of corn. Therefore, the NP (nitrogen, phosphorus) fertilizer in a highly concentrated fertilizer band is suitable for supplying the young plant with nutrients at an early stage and accelerating its development. According to current knowledge, underfoot fertilization has proven to be beneficial in protecting early growth, especially under cool conditions and relatively low soil temperatures. In preliminary studies, both a higher yield and a higher dry matter content could be achieved through underfoot fertilization. Sorghum has a high nutrient uptake. Depending on the soil quality and supply level, the appropriate nutrient removal for the subsequent crop must be taken into account. On a site with an average Nmin supply, a fertilizer dose of around 100 kg N/ha should be applied. Fermentation residues, manure, slurry, and manure water, which are well utilized, if is incorporated before planting.

Fertilization

Nutrient Requirements

- N: ca. 120-140 kg/ha
- P_2O_5: ca. 260-280 kg/ha
- K_2O: ca. 180-220 kg/ha
- Ca: ca. 30-50 kg/ha
- Mg: ca. 15-30 kg/ha

Pest control

Despite some common pests that can attack grain sorghum, such as aphids or cicadas, there are currently no insect pests that have a major impact on sorghum cultivation. In addition, grain sorghum could be grown instead of maize in regions where maize pests, such as the European corn borer are prevalent.

European corn borer (*Ostrinia nubilalis*)
Similar to the corn rootworm, the European corn borer is a minor problem in grain sorghum. When it infests grain sorghum, damage is usually minor and yield losses are not significant.

Corn rootworm (*Diabrotica virgifera*)
Is one of the most important and damaging pests of maize in Europe. Grain sorghum can also be grown in high corn rootworm prevalence areas. This is because sorghum is not a preferred host plant and will not become infested as can sometimes be seen in maize.

Heliotis (*helicoverpa armigera*)
The larvae can cause a lot of damage, mainly by feeding on reproductive organs and seeds. The problem period is between flowering and the vaxy stage.

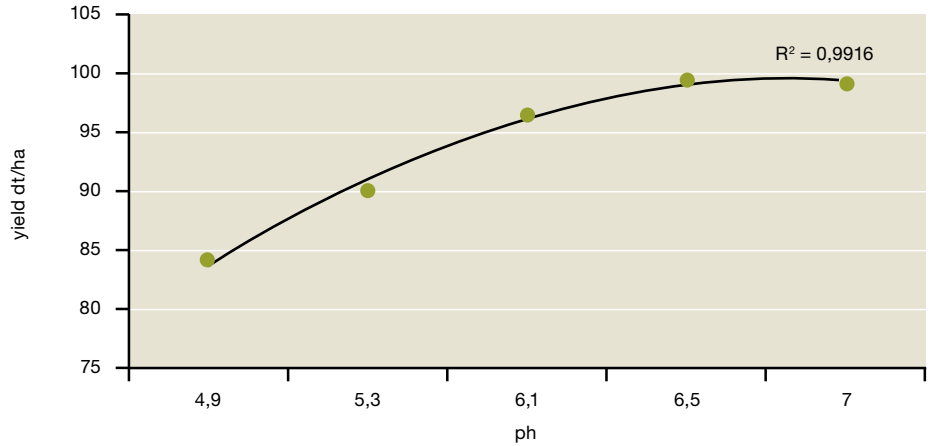
Cicadas (*Zyginidia scutellaris*)
Cicadas feed on plant sap out of the Phloem and Xylem. To collect their food source, they penetrate to access the sap.

Aphids
A number of different aphid species can infest grain sorghum. Infestation can often occur around June. Like cicadas, aphids feed on the plant sap which results in penetrating the plant tissue. Usually, when a plant is infected by aphids, it doesn`t cause significant harm. However, if the aphid population grows too much, the plant can suffer damage, impacting its yield. The severity of damage varies based on the specific aphid type. Additionally, there`s a risk of secondary infection from viruses transmitted by aphids.

Soil pH

- Soil pH is a measure of the acidity and alkalinity of soils.
- pH values range from 0 to 14, with 7 being neutral. Anything below 7 is acidic, and anything above is alkaline. The optimum pH range for most plants is between 5.5 and 7.0-however many plants have adapted to grow at pH values outside this range.
- Grain sorghum grows best with soil pH values between 6 and 7.5.
- Aluminum and/or manganese toxicity may be a problem in more acid soils (pH below 5.5), while phosphorus and/or magnesium may be deficient at this pH level.
- Certain micronutrients may be limited in many alkaline soils (pH above 7.5).
- The micronutrients become less available for plant uptake as the soil becomes more alkaline (pH above 7.5).

Relationship of grain sorghum relative yield and soil pH

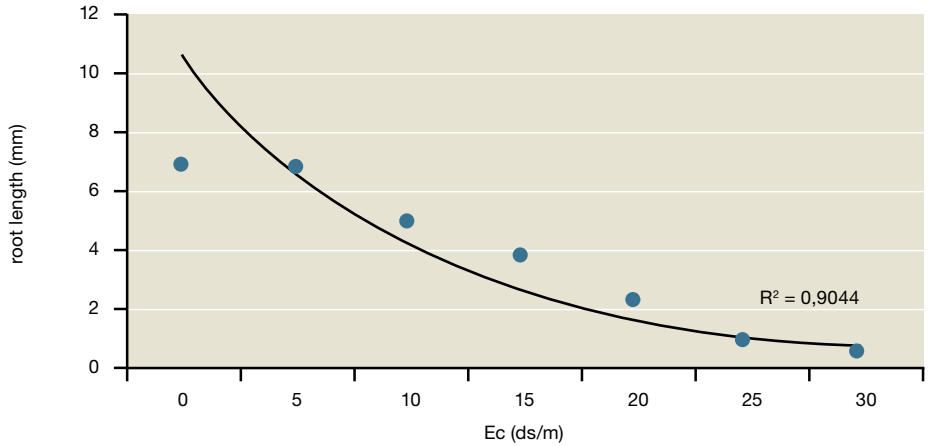


Source: http://www.morningsun.net/article/20110130/News/301309971

Soil Salinity

- Soil salinity refers to the salt content of the soil, the process of increasing salt content is known as salinization. Salinization can be caused by natural processes such as mineral weathering or the gradual retreat of an ocean. It can also be caused by artificial processes such as irrigation.
- Soil salinity is measured by the electrical conductivity of a 1:5 suspension of soil in water. This value is multiplied by a factor determined by the texture of the soil. The corrected electrical conductivity reading is written as ECe and has units of Deci Siemens per meter (dS/m).
- Soil salinity is not considered an advantage for sorghum when the EC value is higher than 3 dS/m.
- Soil salinity above 6 dS/m is dangerous for sorghum and reduces yield potential.
- Salinity also has a negative effect on sorghum germination and seedling development, where genotype and breeding can influence tolerance.

Effect of salinity levels on root length



Source: Tabatabei; Anagholi: Effects of salinity on same charakteristics of forage sorghum genotypes at germination stage

Agronomic details

Harvesting of grain sorghum

It is important to note that in most cases the sorghum plant can be harvested when still green. Below are several tips on how to harvest the sorghum:

- For optimal harvest the following should be considered:
  - At least 35-40 days after flowering
  - Moisture should be between 16-22%.
  - Black layer on at least 90% of kernels
  - Check lower 1/3 of sorghum head for maturity (Sorghum ripens from top to bottom)
- It is possible to harvest at higher moisture levels, but this will incur drying costs. It is necessary for 95-100% of the grain to be physiologically ripe.
- If the weather forecast is not good for harvesting (drying could be an option, depending on local regulations)

The harvester used to harvest sorghum can be a normal harvester used for cereals. Due to the late maturity the height of the cutter bar should be set to 70 cm. This is to avoid processing too many stems and leaves, which would add extra moisture to the grain and slow down the harvesting process.

Startig full maturity

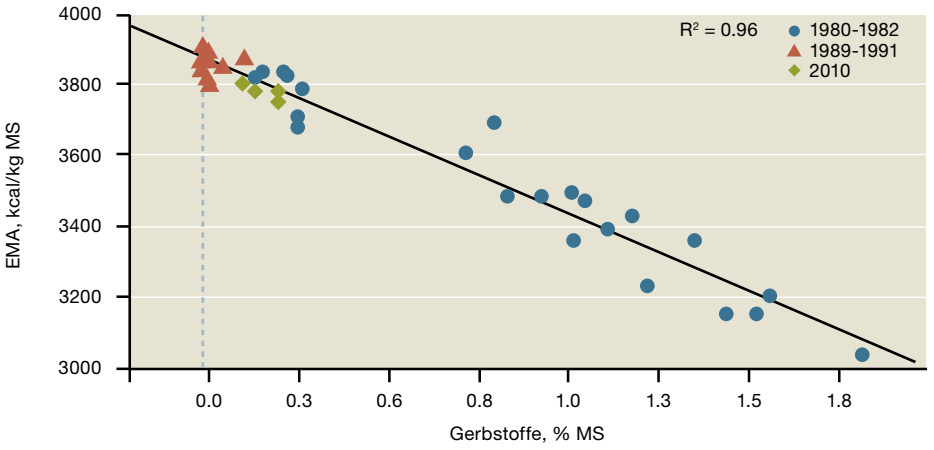
Ideal

source: (PIONEER 2018)

Tannin free sorghum, what is tannin?

Tannins are naturally present in the seed coat and are polyphenols of plant origin. Tannins protect against pathogenic microbes and herbivores. Natural tannin content in sorghum is 1-3%. A high content reduces the feed conversion of livestock. For example, 1% of tannins in feed reduce feed conversion in pigs by 7% and in poultry by 11%. Since the 1980s, varieties in Europe must have a tannin value <0.30%. This means tannin-free sorghum varieties in the EU.

Development of the tannin content of varieties in Europe in the past 30 years



*EMAn: Metabolizable energy measured in poultry
Source: News@lim n°29 ARVALIS-Institut du végétal

Grain sorghum as feeding

Grain sorghum can be safely used as a feed ingredient for poultry, cattle and pigs. The nutritional value differs slightly from that of maize. Grain sorghum has a higher crude protein content, more tryptophan and a higher concentration of usable phosphorus. Dependent upon which animal is being fed, the preparation process required will differ. Because of the strong husk, the grain must be ground before being fed to cattle or pigs as they will be unable to digest the grain. When feeding poultry, grinding is not necessary, however it can be done to increase the rate of ingestion and therefore growth.

Wild sorghum plants have a naturally occurring tannin content of 1-3%. These tannins can have a negative effect on livestock digestion. For example, they can adversely affect feed intake, reduce growth or, in extreme cases, lead to death. However, while negative effects occur at higher concentrations, lower concentrations of tannins have been shown to have a beneficial impact. Low concentrations have been shown to suppress pathogens in the stomachs of

Stomachs of cattle and help control harmful intestinal bacteria in pigs.

As mentioned previously, all commercial sorghum varieties sold in the EU have a tannin content below 0.3%, as required by regulation. This ensures that you do not have to worry about the negative effects while reaping all the positive benefits.

Grain sorghum can be an alternative to maize as a feed ingredient as the nutritional value is similar sorghum is also heaper to produce than maize. In addition, the much better drought tolerance of sorghum compared to maize could be a major advantage in the future years.

Composition of grain Sorghum

The following table shows the nutrient content of sorghum compared to other major crops (corn and wheat). As the table shows, sorghum has good values for protein, tryptophan, threonine and sugar compared to corn and wheat. Despite the higher crude protein content, several essential amino acids have a higher content. For example, the tryptophan and leucine content is higher than in corn. Sorghum has significantly less lysine, but higher digestible P content which can help save on additional food additives.
Good fiber content of sorghum is important for ruminants. Sorghum also has a lower fat and linoleic acid content.

Composition of grain sorghum

In g/kg	Sorghum	Corn	Wheat
Energy (MJ)	14,18	19,2	18,6
Protein (g)	106,2	93,5	137
Total Lipid (g)	34,6	47,4	100
Carbohydrate (g)	720,9	740	713
Sugar (g)	25,3	6,4	17,1
Lysin (g)	2,5	2,8	3,5
Tryptophan (g)	1,2	0,6	1,3
Methionine (g)	1,6	2,4	1,6
Cysteine (g)	1,5	2,3	0,9
Threonine (g)	3,6	3,5	4,3

Source: Australien Summer Grains Conference, 2010, USDA 2019,

Feed value of sorghum

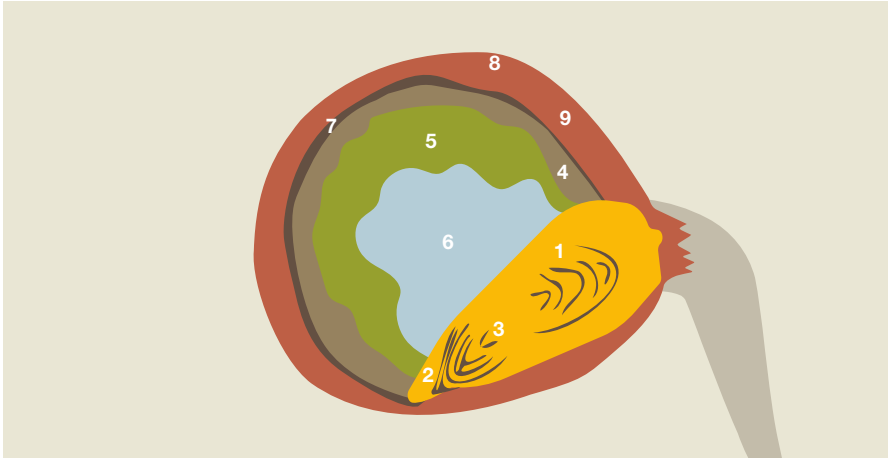
Sorghum has a higher energy value compared to established feeds, despite low content of important essential amino acid (lysine).

Additionally:

- Sorghum has high digestibility (86% digestibility of TM)
- High levels of water-soluble vitamins
- Levels of key nutrients can be highly variable.
  This, it is very dependent on environmental conditions during cultivation

Table comparing the energy values of sorghum with two established feeds

In g/kg	Sorghum	Corn	Soybeans
Feasible Energy beef	13,10	11,55	12,00
MJ Net energy Lactation	8,27	7,30	7,50
Feasible Energy swine	15,85	14,10	13,35
Feasible Energy poultry	13,47	13,65	9,80



Endosperm

Tegument

Germ

1) Radicle
2) Scutellum
3) Plumule
4) Outer endosperm pericarp
5) Vitreous endosperm
6) Mealy endosperm
7) Aleurone layer
8) Seed coat (testa)
9) Pericarp

Pigs

- Generally Sorghum is highly suitable for pigs and can be used in all areas of pig production, especially in piglet rearing and fattening, as it:
  - Ensures a high feed intake
  - Has a high nutrient content
  - Has a high energy content
- Sorghum contains the important first limiting amino acid for pigs, which is Tryptophan
- Sorghum must be ground for pig fattening
  - Feed particle size > 2.8 mm is ideal
  - Feeding in pellets is most effective, crumbs are possible but not as effective
  - Pellets are more economical, less feed can be used and feed efficiency is higher.
- Sorghum is best fed in combination with maize, recommended ration is 30-40% sorghum in the diet. Feeding alone is not as efficient as a combination
- Tannins can have positive effects on pig production without major negative consequences
  - Increased feed efficiency
  - Control of gut bacteria - potential to reduce emissions

Poultry

Mainly used as poultry feed in North and South America, usually ground into pellets due to:

- Faster absorption of nutrients
- Faster growth

Whole grains can also be fed, as poultry are grain eaters. Due to lower xanthophyll content of sorghum is meat less yellow. Sorghum can be fed as main feed, but best results are achieved when combined with other feeds (cereals, maize). The feeding efficiency of sorghum can be improved by adding enzymes. Due to low levels of methionine and xanthophyll, supplementation in the form of feed additives is necessary. Efficiency is mainly increased by phytases, proteases and various oils (fish, soya). Many trials have shown that digestibility can be increased by 3-7%. (Venkata Reddy et. Al. 2008)
In order to achieve optimal results when feeding sorghum, it is necessary exclude high tannin varieties, otherwise there will be a:

- Reduction feed intake
- Reduction weight gain
- Potential for mortality, particularly in chicks

Grain sorghum can be fed on its own, but the best performance is achieved in combination with e.g. wheat and maize. Sorghum should ideally make

Cattle

Sorghum is fully suitable for feeding in milk production (from early to mid-location), due to:

- Dry matter intake and corrected milk yield comparable to maize (fine milled sorghum even increases corrected milk yield compared to maize)
- Steamed grain sorghum in flake form has been found to be preferred by cows in a feeding trial
- Increases dry matter intake
- Higher milk protein content
- Increased milk yield
- No reduction in milk fat content

In meat production sorghum is fed mostly as silage and is increases effective pasture utilization.

There are clear benefits of feeding sorghum in livestock production such as:

- Less crude protein supplementation required
- Cost savings
- Lower production costs
- Increased feed efficiency

As lysine and methionine are the first limiting amino acids in cattle, they must be supplied as feed additives. Methionine supplementation is important predominantly for dairy cows. Tannin levels in cow feeding are less important.

KWS Group
Grimsehlstraße 31
37574 Einbeck
Germany

www.kws.de/sorghum