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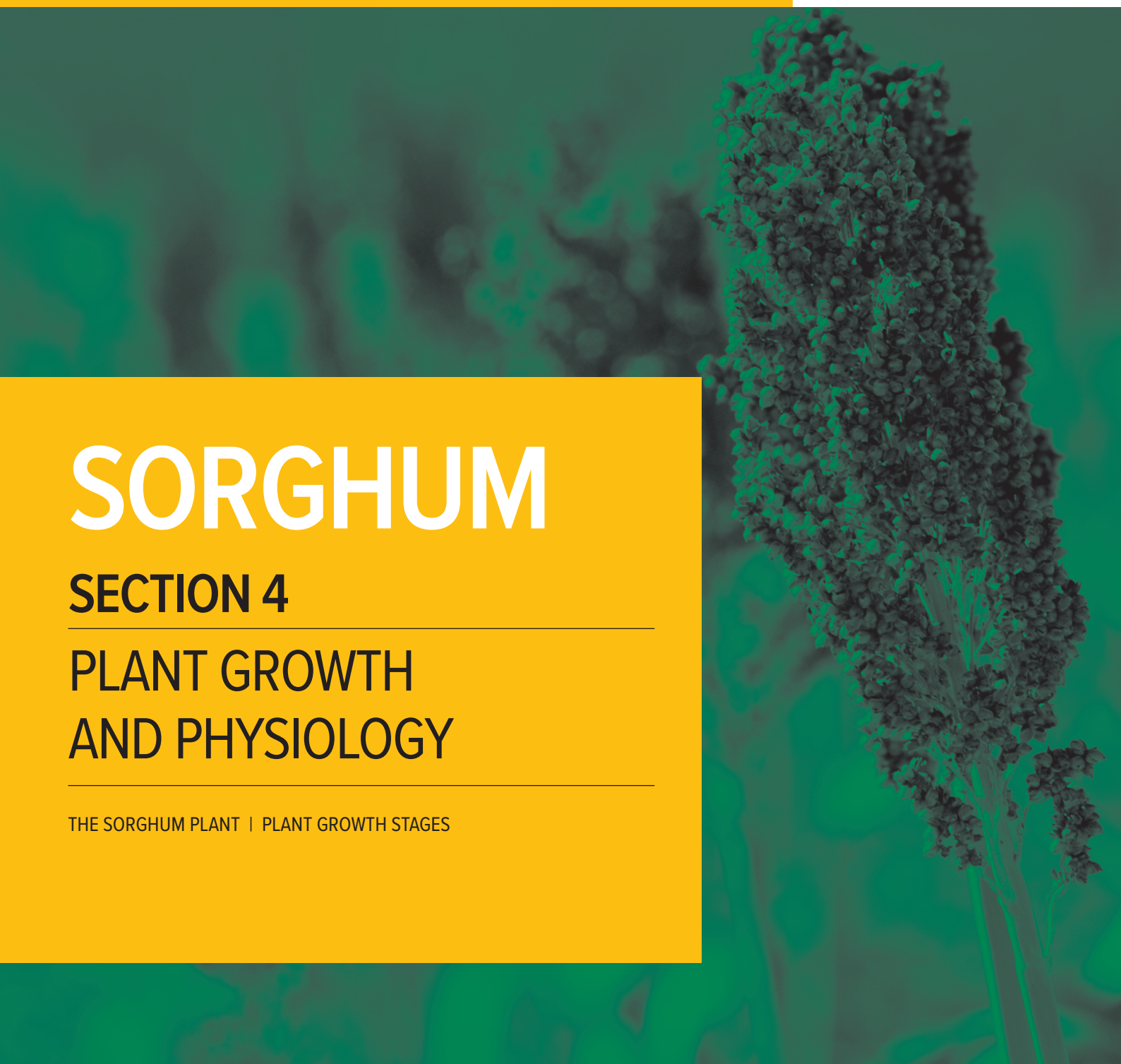

SORGHUM

SECTION 4

PLANT GROWTH AND PHYSIOLOGY

THE SORGHUM PLANT | PLANT GROWTH STAGES

Plant growth and physiology

4.1 The sorghum plant

The sorghum plant's botanical name is *Sorghum bicolor* (L.) Moench, and it is a member of the Poaceae family.

It is a perennial, tropical C4 grass capable of growing beyond physiological maturity of the grain. The hybrids available for grain production may be either determinate or indeterminate in setting the number of tillers for grain production. Although they can vary, most hybrids grow to ~1 m in height. A sorghum plant produces two ranks of single leaves in alternate positions on the stem. The leaves have overlapping sheaths, long, broad blades and, with the exception of the lowest leaf, pointed tips.

Sorghum usually has a dominant stem and, depending on the hybrid and the plant population, several tillers. A vigorous fibrous root system supports the plant and provides water and nutrients for shoot growth.

In the absence of subsoil constraints, sorghum roots can extract water to a depth of 1.8 m.

The sorghum head is a many-branched panicle, with small seeds ~4 mm in diameter. Current hybrids have either an open or a closed panicle, and the number of seeds per head varies. Seed weight typically ranges from 24,000 to 37,000 seeds/kg. Seed typically contains 7–12% protein. Although colour of the seed coat varies from white through to brown, red is the most commonly grown colour in Australia. [1]

4.2 Plant growth stages

Sorghum is a perennial tropical grass with a growing season of 115–140 days. The rate of growth depends upon temperature and moisture primarily, but it can also be influenced by soil fertility, insect and disease damage. [2] The optimum temperature range for growth is 12–34°C.

Growth rates are very sensitive to temperature and moisture, as well as soil fertility and insect and disease damage. The roots grow at ~2.5 cm/day.

Sorghum has 10 recognisable growth stages that can be used to plan irrigation, desiccation, insect scouting and insect control. Leaves are counted when the collar (where the leaf blade and leaf sheath attach) can be seen without cutting the plant apart. [3]

1 NSW DPI (2005) Grain sorghum. Agfact P3.3.5, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/146355/grain-sorghum.pdf

2 N Moore, L Serafin, L Jenkins (2014) Grain sorghum. Summer crop production guide 2014, pp. 5–16, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

3 NSW DPI (2005) Grain sorghum. Agfact P3.3.5, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre/summer-crops/sorghum/sorghum/grain-sorghum

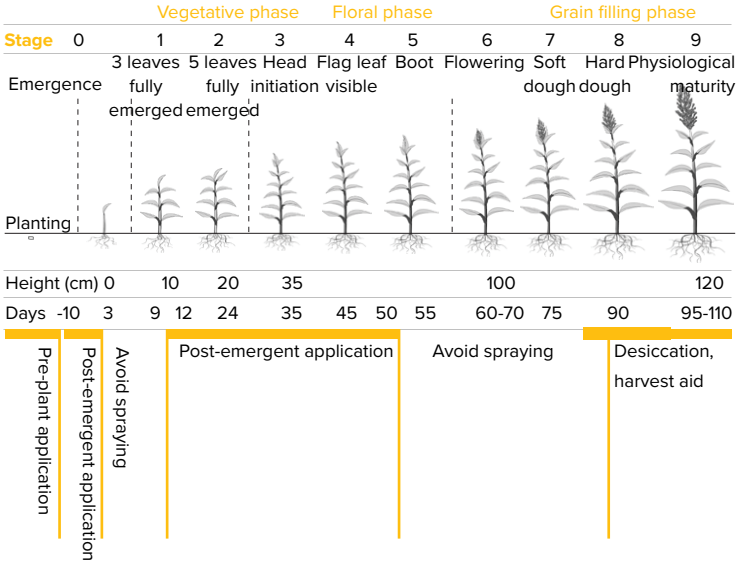

Figure 1: *Sorghum growth stages.*

1. Stage 0. Germination

Emergence usually occurs within 3–10 days of planting. Under warm temperatures, adequate soil moisture, good seed vigour and normal sowing depth, the time taken from planting to emergence is closer to 3 days. Sorghum has hypocotyl emergence, meaning a shoot emerges from the seed and pushes through the soil surface.

Under cold soil temperatures, it takes longer for the shoot to emerge and the risk of insect or disease attack is higher. [4]

Conditions for germination include a temperature range 16–18°C (and rising), soil moisture near field capacity, seed depth of ~5 cm and a seedling vigour percentage >90%.

The seed provides the seedling with nutrients and food reserves. The hypocotyl or young shoot extends from the seed, taking up water. At around day 5, a fibrous root system begins to form from the hypocotyl. During this period, the seed must be protected against soil insect attack. If conditions turn cool and wet, fungal diseases such as pythium may cause losses through seedling death. [5]

2. Stage 1. Three-leaf stage

The growing point is still below the soil surface. This stage will usually begin ~10 days after emergence. Following shoot emergence, leaves will progressively unfold. [6]

3. Stage 2. Five-leaf stage

This occurs ~21 days after emergence. The growing point is still below the soil surface. At the 5-leaf stage, the root system is rapidly expanding and roots produced at the lower nodes may push the lower leaf off the plant. The lowest (first) leaf always has a rounded tip, in contrast to the pointed tips of later leaves.

4 N Moore, L Serafin, L Jenkins (2014) Grain sorghum. Summer crop production guide 2014, pp. 5–16, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

5 NSW DPI (2005) Grain sorghum. Agfact P3.3.5, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/146355/grain-sorghum.pdf

6 NSW DPI (2005) Grain sorghum. Agfact P3.3.5, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/146355/grain-sorghum.pdf

During this stage the yield potential is set. If water, sunlight or nutrients are limiting, yields can be restricted. Dry matter production occurs at nearly a constant rate between this stage and maturity. [7]

4. Stage 3. Growing point differentiation

The growing point changes from vegetative (leaf-producing) to reproductive (head-producing) ~30 days post-emergence.

At this stage the total number of leaves has been determined and the potential head size will soon be defined. Around 30% of the total leaf area will have developed, correlating to ~one-third of the time taken between planting and physiological maturity. This equates to 7–10 leaves, with the lower 1–3 leaves being possibly lost. Following growing-point differentiation, stalk or culm growth increases rapidly. Nutrient uptake is also rapid. This rapid growth allows sorghum plants to be very competitive against weeds for the rest of the season. [8]

5. Stage 5. Boot stage

Leaf area is now at a peak, providing maximum light interception. The head, still enclosed in the flag leaf sheath, is almost developed to full size. The peduncle has begun to elongate and will result in the head becoming visible from the flag leaf sheath. Potential head size is determined. Stressful conditions from lack of moisture or herbicide damage at this stage may stop the head completely growing from the flag sheath. Head death can occur earlier than booting under extreme moisture stress in combination with high temperatures. The sorghum plant will preferentially favor carrying through the primary tiller. Head death can occur earlier than booting under extreme moisture stress in combination with high temperatures. This failure will hinder complete pollination at flowering. [9]

6. Stage 6. Flowering

The peduncle rapidly elongates, pushing the head through the flag leaf sheath. Half-bloom is usually defined as the stage when 50% of the heads in the paddock are 50% flowered; however, it may also relate to an individual plant. The time required from planting to 50% flowered depends on the hybrid as well as the environment. Modern hybrids usually take 55–80 days, which represents 50–70% of the time between planting and physiological maturity.

Sorghum is primarily self-pollinated. Flowering begins at the top and proceeds downward requiring 4–5 days for the whole head to flower. The time a hybrid takes to start flowering depends largely on temperature. For example, a medium-maturity hybrid planted in the cooler, early October period at Moree flowers in ~80 days. However, if planted in the warmer mid-November period, it flowers in 60 days.

Severe moisture stress and/or very high temperatures during flowering can result in pollen-blasting and poor head-fill. Pollen-blast can be an issue at temperatures >36°C. Low night temperatures <13°C can reduce pollination in some hybrids.

Once pollination has occurred, seeds will begin to form, taking ~30 days to reach full development. Visually, the seeds become rounded, up to around 4 mm in size, and will then start to change colour. The final colour varies from white with hybrids such as Liberty White through to red or brown in most sorghum hybrids. [10]

7. Stage 7. Soft dough

Soft dough is the stage after approximately half the grain dry weight has accumulated. Following an increase in culm weight after flowering, the culm decreases in weight as the grain rapidly forms. This period includes the time the grain is of soft as well as medium dough consistency.

7 NSW DPI (2005) Grain sorghum. Agfact P3.3.5, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/146355/grain-sorghum.pdf

8 NSW DPI (2005) Grain sorghum. Agfact P3.3.5, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/146355/grain-sorghum.pdf

9 NSW DPI (2005) Grain sorghum. Agfact P3.3.5, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/146355/grain-sorghum.pdf

10 NSW DPI (2005) Grain sorghum. Agfact P3.3.5, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/146355/grain-sorghum.pdf

As dry matter accumulation is similar across hybrids, the length of this period will strongly influence grain yield, with the longer maturing hybrids outyielding the quicker maturing lines. This holds as long as the plants are not subjected to moisture stress or frost during this period. [11]

8. Stage 8. Hard dough

Approximately 75% of the grain dry weight has accumulated by hard dough stage. Nutrient uptake is essentially complete. Some lower leaves may now have been lost. [12]

9. Stage 9. Physiological maturity

The grain is said to be physiologically mature when a black spot appears at the point where the seed attaches the plant. At this time, the seed is fully mature and will not gain any more nutrients or moisture from the plant (Figure 2). The moisture content is usually ~30% at this time.

If using desiccation, this is the optimum time to apply a registered herbicide to kill the plant, preventing additional moisture use. [13]

Figure 2: *Ripe sorghum grain.*

The length of time between physiological maturity and harvest depends on a number of factors including whether desiccation is used and environmental conditions such as temperature. [14]

The plant has reached maximum total dry weight and maximum grain weight. Physiological maturity can be determined by the formation of a dark spot on the grain on the opposite side from the embryo—otherwise known as black-layer formation. While the seeds develop, nutrients and moisture flow through a series of tubes from the parent to the seed.

Once the grain reaches its maximum size, these tubes become permanently blocked off. This is because the water in the seed during the soft and hard dough stages is displaced with starch, until water can no longer move in. The seed therefore dries out, typically from ~30% down to 10% or air-dry level. The black layer appears first in the seeds at the top of the head. [15]

MORE INFORMATION

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/146355/grain-sorghum.pdf

http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/summer-crops/sorghum/general/summer-crop-production-guide

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/431278/Sorghum-Spray-Out-Timing.pdfa

11 NSW DPI (2005) Grain sorghum. Agfact P3.3.5, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/146355/grain-sorghum.pdf

12 NSW DPI (2005) Grain sorghum. Agfact P3.3.5, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/146355/grain-sorghum.pdf

13 NSW DPI (2005) Grain sorghum. Agfact P3.3.5, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/146355/grain-sorghum.pdf

14 N Moore, L Serafin, L Jenkins (2014) Grain sorghum. Summer crop production guide 2014, pp. 5–16, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

15 NSW DPI (2005) Grain sorghum. Agfact P3.3.5, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/146355/grain-sorghum.pdf