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NSW DEPARTMENT OF
PRIMARY INDUSTRIES

Grain sorghum

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SUMMARY OF STATEWIDE BEST MANAGEMENT PRACTICES FOR GRAIN SORGHUM

Paddock selection

Grain sorghum, both dryland and irrigated is usually grown on heavy clay soils. Heavy clay soils have a high water holding capacity, capable of supplying the plant with moisture throughout the warm growing season, even in the absence of rainfall.

Wherever possible, use no-till and controlled traffic for dryland crops, as these methods increase soil moisture storage more quickly and deeply than random-trafficked conventionally cultivated fallows. This increase in moisture storage combined with reduced soil compaction leads to increased yields and water use efficiency. Use response cropping in favourable dryland areas to reduce the risk of deep moisture drainage.

Figure 1: A grain sorghum crop near Breeza, northern NSW.

Photo: J. Kneipp

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Sowing time

All hybrids can be sown up until Christmas but no later than early January. After Christmas, use a quicker variety with midge resistance. To reduce the risk of ergot in northern NSW, plant so that crops flower by mid-March. Wide sowing windows occur from September to January, however don't sow too early (cold) or too late (ergot and frost risk) and aim to avoid flowering the crop in the extreme heat of January. Soil temperature should be 16–18ºC and rising.

Plant population

Adjust plant population and row spacing to target yield. Uniformity of population is important; therefore precision planters with press wheels are preferred. Use lower populations in more marginal situations, and increase populations where conditions are more favourable. Suggested plant populations are:
Dryland solid plant 40 000–60 000 plants/ha
Dryland skip row 40 000–60 000 plants/ha
Limited irrigation 80 000–150 000 plants/ha
Full irrigation 100 000–250 000 plants/ha.

Insect control

It is particularly important to monitor and control soil dwelling insects (e.g. wireworms) at sowing. Heliothis can be a problem, especially after flowering. The biological insecticide NPV is effective for the control of heliothis. Midge control may also be necessary in late crops.

Timeliness of harvest

Harvest may be assisted by crop desiccation. The aim is to maximise yield through the assimilation of carbohydrate in the seed, but balance this moisture use with storing water for the next crop. When between 95 and 100 per cent of the grains have formed a 'black layer' (i.e. are physiologically mature), the crop is ready to be desiccated.

Grain handling

Grain moisture should be less than 13.5% for long term storage. Be prepared to dry grain with late sown crops. Plan your grain marketing.

Grazing

Prior to feeding any sorghum crop, seek veterinary advice about the risk of hydrocyanic acid, alkaline (ergot) and nitrate poisoning.

INTRODUCTION

Grain Sorghum (*Sorghum bicolor* (L.) Moench) is the main summer cereal crop grown in northern Australia. It is mainly used in Australia as stock feed in the cattle, pig and poultry industries. Sorghum stubble can also be utilised after harvest as stock fodder. Worldwide, sorghum is an important food source for humans, especially in warm, arid environments.

Grain sorghum is more drought tolerant than maize, the other main summer growing cereal It is therefore an important rain-grown crop in northern NSW from the northern slopes and Hunter, through to western areas such as Walgett. Grain sorghum also plays a critical role as a rotation crop for disease and weed control in the winter cereal based farming system of northern NSW.

The use of practices such as controlled traffic and no-till, which maximise soil water infiltration and enable the plant to extract moisture effectively, are critical in achieving good yields. In addition, sorghum row configuration can be successfully manipulated in western areas to ensure a crop will be harvested, when sown into a full profile of moisture.

As irrigated grain sorghum is usually grown on heavy clay soils, hills or beds are usually used in a furrow-irrigated system.

A range of hybrid varieties are available and being continually improved. Consult your local seed agent for details and refer to the annual publication Agnote Grain Sorghum Planting Guide. Grain sorghum is planted from late September through to mid January and harvested from late January through to May.

HISTORICAL BACKGROUND

International

Grain sorghum is regarded as being originally domesticated around central Africa in the Ethiopian and Sudan regions, before its spread to other areas in Africa and Asia, and more recently to America and Australia. Because of its inherent ability to withstand drought, soil toxicities and temperature extremes more effectively than other cereal crops, sorghum has become the most important food and feed source in many of the world's harsher environments.

National

Grain sorghum was first grown in Queensland in 1938 and in New South Wales in 1940 using dwarf varieties introduced from the USA. Following the development of cytoplasmic male sterility in the 1950's in the USA, hybrid varieties were first grown commercially in Australia in 1962, and within 3 years, farmers had nearly completely switched to growing hybrid varieties.

END USES

Worldwide, sorghum is primarily used as a food source for human consumption, however in Australia the primary use of grain sorghum is as feed for livestock. Sorghum grain is also increasingly being used for ethanol production, as it is often the cheapest feed grain.

In Africa and parts of India, sorghum is cooked as porridge. In Botswana the porridge may be either fermented or unfermented. It is also used to make both unfermented bread (in India and Central America) and fermented bread

Figure 2: Uniform and well established grain sorghum crop east of Moree.

Photo: S. Belfield

Figure 3: In Australia grain sorghum is mainly used to feed livestock.

Photo: J. Kneipp

(Sudan, Ethiopia and India). In Sahelian Africa sorghum is also the most common cereal used in couscous.

FEED VALUE OF SORGHUM

Grain sorghum is commonly used as a feed grain in the north-eastern states of Australia. It is frequently used to feed cattle, broiler chickens and pigs. The feed value of sorghum is very similar to barley, maize and wheat in terms of metabolisable energy (ME) content (Table 1). However, sorghum is less digestible than wheat and barley for some animals. The available energy from any grain generally depends on the capacity to digest the starch in the grain. Sorghum is digested well by pigs and poultry, but generally poorly digested by cattle.

Table 1: Most likely metabolisable energy (ME), dry matter (DM) and protein content of some major cereal feed grains

Grain	Metabolisable Energy (ME) on DM basis (MJ/kg)	Crude protein DM basis (%)
Barley	13.5	11.0
Wheat	13.0	12.0
Sorghum	13.0	9.0
Maize	13.5	9.5
Oats	10.5	10.5

(Source: Blackwood et al. 2002)

Breaking up the seed greatly increases the digestibility of the grain for many animals. It should be either coarsely cracked or rolled, or steam flaked but care should be taken not to powder the grain. Sorghum is very palatable and is therefore useful for mixing with wheat and barley to improve their palatability. As protein and therefore nitrogen in grain sorghum is often deficient, it is advisable to always add 1% urea in the mix with sorghum when feeding to cattle.

AREAS OF PRODUCTION

Almost all grain sorghum in Australia is produced in northern NSW and Queensland (Figure 6). The other small but important area of production is at Kununurra in the north of

Photo: J. Kneipp

Figure 4: Steam flaked sorghum.

Western Australia, where most of the hybrid seed is produced.

Sorghum production, both in area planted and yield (see Figures 5 and 6), differs in Australia from year to year due to the highly variable rainfall pattern and price outlook. During the past ten years the price of sorghum has varied from $80 to $300/t.

IRRIGATED SORGHUM PRODUCTION

Land preparation for irrigated grain sorghum is similar to that for other irrigated crops. Initial cultivations are usually completed in dry soil with discs or chisels to mulch previous crop residue. The aim is to work up 20 to 25 cm of loose soil to allow the formation of hills or beds. Deeper cultivation is sometimes needed to break up compacted layers and improve water and root penetration – following, for example, a wet harvest. Care must be taken that the soil is dry enough throughout the profile when deep ripping to prevent further damage from compaction occurring.

Early land preparation is essential to avoid delays and damage caused by trafficking wet soil during winter. Begin preparation early and aim to have hilling or bed formation completed prior to the end of July. This allows plenty of time for clods to break down and hills to consolidate, increasing the likelihood of good, even establishment.

Pre-irrigation is an important part of seedbed preparation as it improves tilth and bed consolidation. Nitrogen fertiliser is usually applied when hilling up. Additional nitrogen and phosphorus fertiliser may be applied at sowing. Zinc is best incorporated during early preparation.

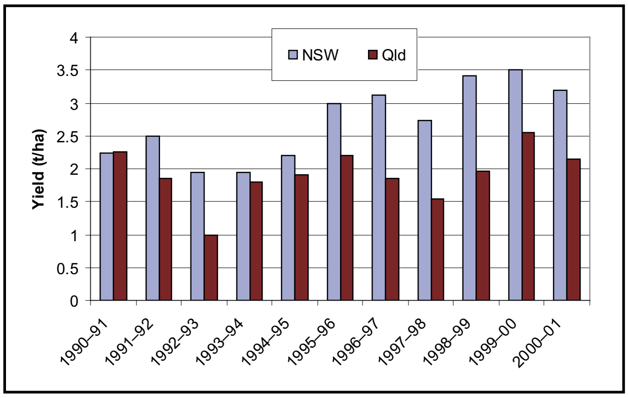


Figure 5: NSW and Qld sorghum yield data for the years 1990–2000 (Source: ABARE and ABS).

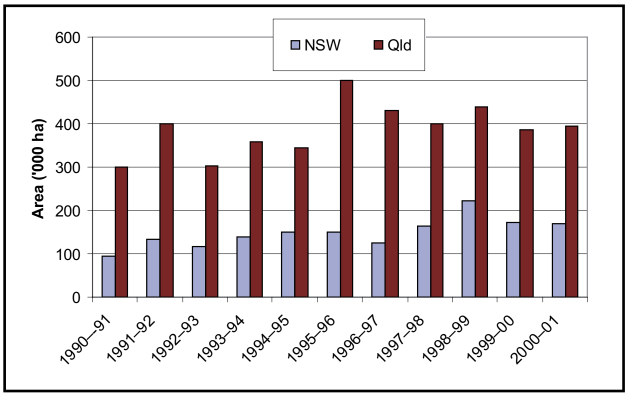


Figure 6: NSW and Qld sorghum production data for the years 1990–2000 (Source: ABARE and ABS).

Precision seeders are used to sow the majority of irrigated sorghum crops. In fully irrigated conditions, target plant populations should be between 200–250 000 plants/ha, while under limited irrigation, plant populations should come back to approximately 100 000 plants/ha. Choose at least two hybrids that are high yielding medium maturity lines. Select hybrids that have little reaction to organophosphate insecticides if grain sorghum is to be sown near other summer crops that may be sprayed with these insecticides.

Quantities of water required for a full irrigation of a sorghum crop will vary depending on seasonal and soil conditions, however budget on 1.4 ML/ha for a pre-irrigation and 3 irrigations of 1.2 ML/ha each during the growing season. The timing of the first irrigation in the absence of significant rainfall will be in mid to late tillering, while the last two irrigations should be at flowering and grain fill. Irrigated grain sorghum crops in northern NSW achieve average yields of 8 t/ha and maximum yields of up to 12 t/ha.

Sorghum residue can be difficult to handle after harvest. Most growers use offset discs at least twice before hilling up for the following irrigated crop.

MOISTURE CONSERVATION AND FALLOW MANAGEMENT

Sorghum should not be planted in a dryland situation unless the soil has stored moisture to a minimum depth of one metre. This rule may be varied in eastern areas, where row configuration may be altered if seasonal outlooks are reasonable. Research and experience has shown that planting sorghum with less than one metre of wet soil significantly reduces yields, increases the risk of crop failure and places a greater reliance upon in-crop rainfall to produce a profitable crop.

Despite its hardiness, grain sorghum needs adequate moisture especially at critical growth stages. If moisture is limited during head formation, potential yield will rapidly decrease.

Figure 7: Furrow irrigated grain sorghum at Moree.

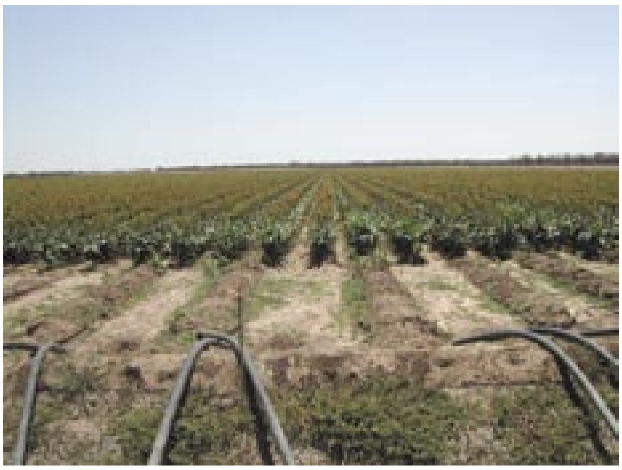


Photo: J. Spenceley

Figure 8: Furrow irrigated grain sorghum. The tall heads are hybrids that have reverted to a parent characteristic.

Photo: J. Spenceley

Photo: J. Spenceley

Figure 9: Drought stressed grain sorghum north of Moree. Many plants failed to produce a head.

Moisture stress during grain filling increases lodging, especially if harvesting is delayed for any reason. Stems may become weakened during nutrient translocation into the grain. Using agronomic practices that increase water use efficiency (e.g. no-till and controlled traffic) and growing hybrids that have a high resistance to lodging significantly reduces lodging. The 'staygreen' trait which is being bred into new hybrids is also assisting to reduce lodging.

Crops should be sown on heavy clay soils that can store and retain subsoil moisture. Heavy clay soils with stored moisture to 1.5 m and receiving 100 mm of effective rain (allowing for evaporation, run-off etc.) should yield around 3.5 t/ha. However, crops starting with only 1 m of subsoil moisture and receiving 50 mm of effective rain will yield only about 1.3 t/ha. NSW Department of Primary Industries has shown that after the initial 100–110 mm of soil water is used, sorghum can produce grain at the rate of about 15 kg/ha/mm of effective rainfall and soil moisture. Note that these figures are based on no subsoil limitations, such as compaction, salinity or sodicity.

Good management practices that result in good stored subsoil moisture and water-use efficiency can achieve long-term yield averages in the Quirindi district of 5.5 t/ha, Gunnedah and Tamworth of 4.0 t/ha, in the Inverell and Narrabri districts 3.5 t/ha and in the Moree district 3.0 t/ha.

The use of no-till and minimum till fallows increase subsoil moisture and the prospects of high yielding and profitable crops. No-till crops following winter cereals consistently yield about 0.5 t/ha more than crops grown after a conventionally tilled fallow. This is due to the ability of no-till fallows to store an extra 30 mm of available water approximately. As a rule, 15 kg/ha of grain is produced for every mm of moisture; i.e. 15 x 30 = 450 kg/ha.

No-till and minimum-till fallows widen the planting window by allowing crops to be sown 6–7 weeks later after good rain. This increases the chances of the crop being planted at the optimum time, hence improving yield potential. No-till fallows greatly increase the chance of a crop being planted, whereas in a conventional fallow planting may not be possible due to a lack of moisture.

NSW Department of Primary Industries research has shown that no-till fallows can be started with one or two sprays of glyphosate after harvest of the previous crop followed by an atrazine spray in late autumn-early winter. This is then followed by a glyphosate or a glyphosate/atrazine spray in September.

Minimum till fallows often have about 2–3 cultivations before a late autumn-early winter atrazine spray. The variable costs for no-till fallows are approximately the same as conventional cultivated fallows.

Profitable sorghum crops have been grown immediately after chickpeas in conditions where the soil is wet to one metre and a moderate to high midge resistant hybrid is used. When considering this option, the likely probability of receiving above average rainfall in the growing season should be investigated.

Avoid growing sorghum following a canola or mustard crop as these crops run down VAM and sorghum has a high dependence on it. Double cropping after a winter cereal crop can be successful if conditions are very favourable; however it has a higher risk of failure than following chickpeas. This may be due to lower water extraction by chickpeas than wheat in many instances in northern NSW.

THE SORGHUM PLANT AND HOW IT GROWS

The plant

The sorghum plant is known botanically as *Sorghum bicolor* (L.) Moench and is a member of the Poaceae family.

Figure 10. A grain sorghum hybrid with an open panicle head.

Figure 11. A white-seeded grain sorghum hybrid with a closed panicle head.

It is a perennial tropical C4 grass that is capable of growing beyond physiological maturity of the grain. The hybrids available for grain production may be either determinate or indeterminate in setting a number of tillers for grain production. Although they can vary, most hybrids grow to around 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, a number of tillers. A vigorous fibrous root system supports the plant and provides water and nutrients for shoot growth. Sorghum roots can extract water to a depth of 1.8 m.

The sorghum head is a many-branched panicle, with small seeds approximately 4 mm in diameter (Figure 10 and 11). The current hybrids may either have an open or closed panicle and the number of seeds per head will vary. Seed weight typically ranges from 24 000 to 37 000 seeds/kg. Seed typically contains between 7 and 12 percent protein. Although, colour of the seed coat varies from white through to brown; red is the most commonly grown colour in Australia.

Wild sorghum types used in breeding programs may be well over 2 m in height, multi-stemmed and have very small seed heads.

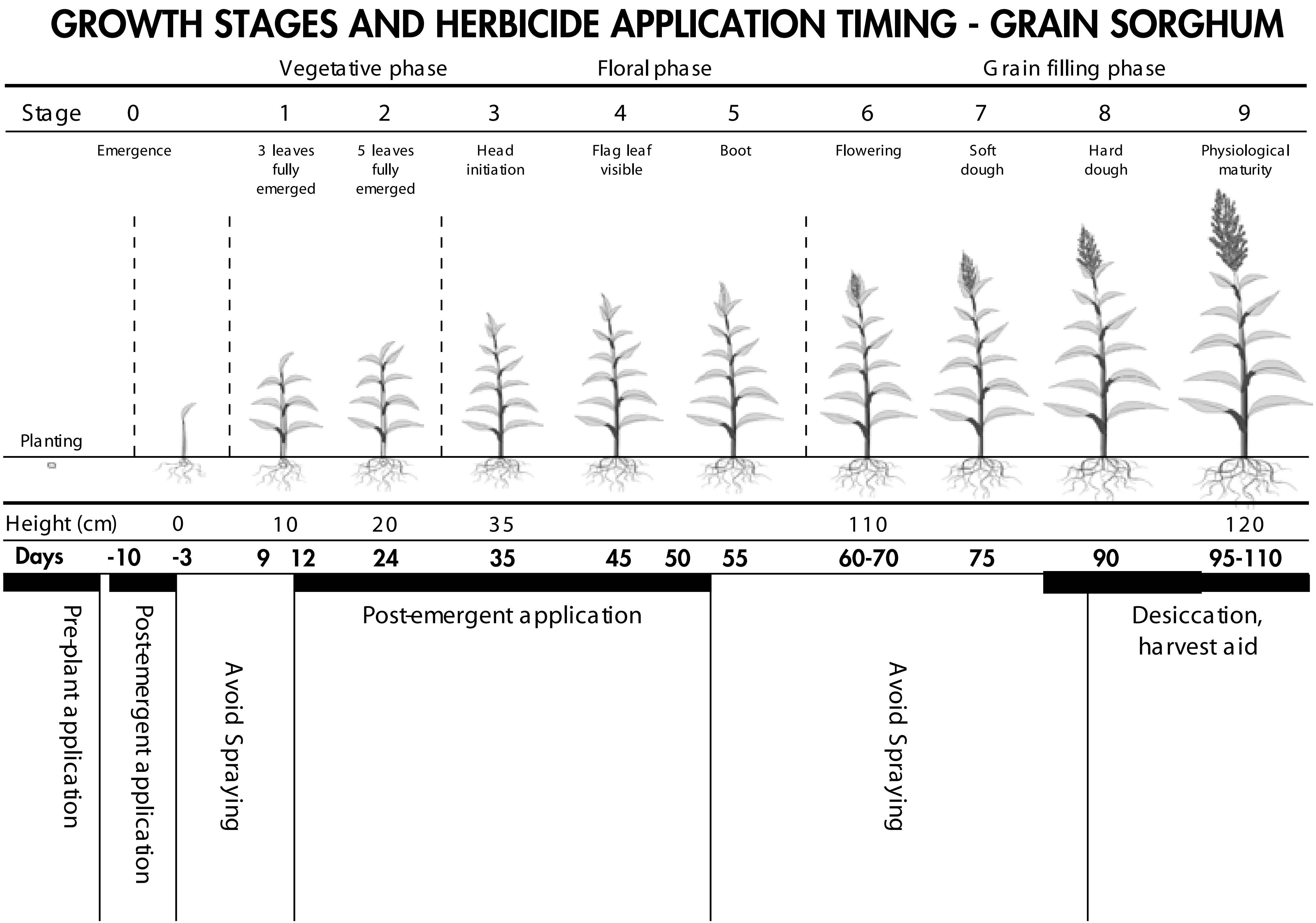
How the plant grows

Depending on location, planting time and hybrid, the sorghum growing season is between 115 and 140 days from sowing to harvest. Growth rates are very sensitive to temperature and moisture, as well as soil fertility and insect and disease damage. The roots grow at approximately 2.5 cm/day.

Sorghum has 10 recognisable growth stages that can be used to plan irrigation, desiccation, insect scouting and insect control (see Figure 10). Note that leaves are counted when the place where the leaf blade and leaf sheath attach, known as the collar, can be seen without cutting the plant apart.

Stage 0 is emergence, i.e. **when the coleoptile is first visible**. This generally occurs between 3 and 10 days after planting, depending on soil temperature, moisture conditions, sowing depth and seed vigour. Conditions for germination `include a temperature range between 16 and 18°C (and rising), soil moisture near field

Figure 12:


GROWTH STAGES AND HERBICIDE APPLICATION TIMING - GRAIN SORGHUM
Vegetative phase
Floral phase
Grain filling phase
Stage
0
1
2
3
4
5
6
7
8
9
Emergence
3 leaves fully emerged
5 leaves fully emerged
Head initiation
Flag leaf visible
Boot
Flowering
Soft dough
Hard dough
Physiological maturity
Planting
Height (cm)
0
10
20
35
110
120
Days
-10
-3
9
12
24
35
45
50
55
60-70
75
90
95-110
Pre-plant application
Post-emergent application
Avoid Spraying
Post-emergent application
Avoid Spraying
Desiccation, harvest aid

capacity, seed depth of around 5 cm and a seedling vigour percentage higher than 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.

Stage 1 extends between emergence and the **three leaf stage**. The growing point is still below the soil surface. This stage will usually begin about 10 days after emergence.

Figure 13: Sorghum Growth Stage 1 – Three Leaf Stage.

Stage 2 is from the three to **five leaf stage**. This occurs approximately 21 days after emergence. The growing point is still below the soil surface. At the five leaf stage, the root system is rapidly expanding and roots produced at the lower nodes may push the lower leaf off the plant. As the lowest (first) leaf always has a rounded tip as opposed to the pointed tips of later leaves, it is a straightforward process to tell how many leaves the plant has.

Figure 14: Sorghum Growth Stage 2 – Five Leaf Stage.

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 now and maturity.

Stage 3 is between the five leaf stage and **growing point differentiation**. The growing point changes from vegetative (leaf producing) to reproductive (head producing) about 30 days after emergence. At this stage the total number of leaves has been determined and the potential head size will soon be defined. Around 30 per cent of the total leaf area will have developed, correlating to approximately one third of the time taken between planting and physiological maturity. This equates to between 7 and 10 leaves, with the lower 1 to 3 leaves possibly being 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 remainder of the season.

Figure 15: Sorghum Growth Stage 3 – growth leading up to growing point differentiation.

Stage 4 is between growing point differentiation and when the **flag leaf becomes visible**. During this stage, the culm and leaves rapidly grow until the flag leaf (the final leaf) becomes visible in the whorl. When the flag leaf emerges, all except the final 3 or 4 leaves should be fully expanded and around 80 per cent of the total leaf area has been grown. While growth and nutrient uptake is occurring at a rapid rate, light interception is being maximised. The head continues development and the lower 2 to 5 leaves may be lost. Because of this, any reference to leaf number should now be made from the top down; the flag leaf being number 1.

Figure 16: Sorghum Growth Stage 4 – flag leaf visible.

Stage 5 is **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 leaf sheath. This failure will hinder complete pollination at flowering.

At stage 6 – otherwise known as **'50 per cent flowered'** or **half-bloom** or generally as **'flowering'** – the peduncle rapidly elongates, pushing the head through the flag leaf sheath. Half-bloom

Figure 17: Sorghum Growth Stage 5 - booting.

Figure 18: Sorghum Growth Stage 6 - Flowering.

is usually defined as the stage when 50 per cent of the heads in the paddock are 50 per cent flowered, however it may also relate to an individual plant. The time required from planting to 50 per cent flowered depends on the hybrid as well as the environment. Modern hybrids usually take between 55–80 days, which represent somewhere between 50–70 per cent 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.

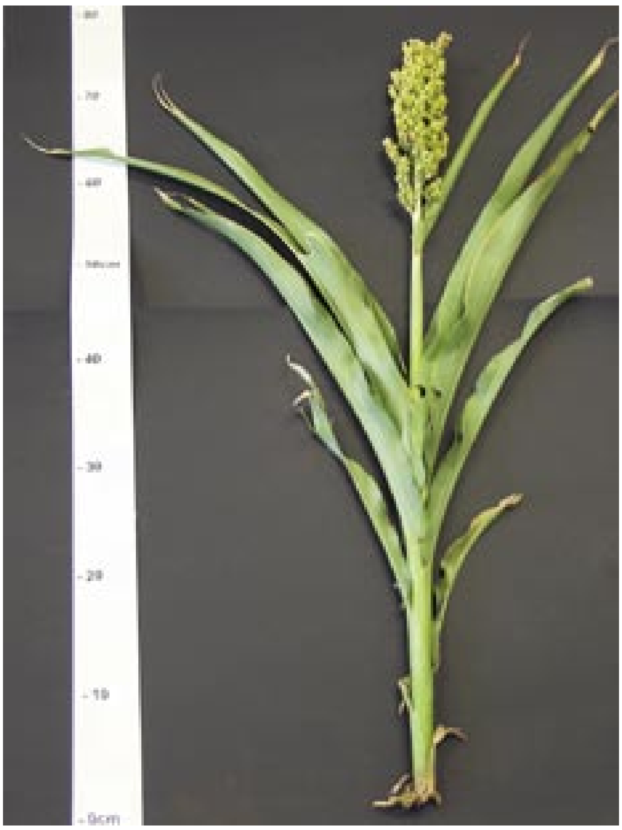
The time a hybrid takes to start flowering depends largely on temperature. For example a medium maturity hybrid planted in the cooler, early October period at Moree flowers in about 80 days. However, if planted in the warmer mid-November period, it flowers in 60 days.

Severe moisture stress during flowering can result in pollen blasting and poor head fill.

A further 3 distinct stages are involved in seed development, the first of which is Stage 7 - ‘Soft dough to medium dough’, followed by ‘Hard Dough’ and finally Physiological Maturity. Entire seed development takes around 30 days.

Stage 7 - ‘Soft dough’ is the stage after approximately half the grain dry weight has accumulated. Following an increase in culm weight after ‘50 per cent flowered’, the culm decreases in weight as the grain rapidly forms.

Figure 19: Sorghum Growth Stage 7 – Soft Dough.



This period includes when the grain is of soft as well as medium dough consistency.

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

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.

Figure 20: Sorghum Growth Stage 8 – Hard Dough.

Physiological Maturity – Stage 9 – 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 (Figure 21). 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 dough and hard dough stages is displaced with

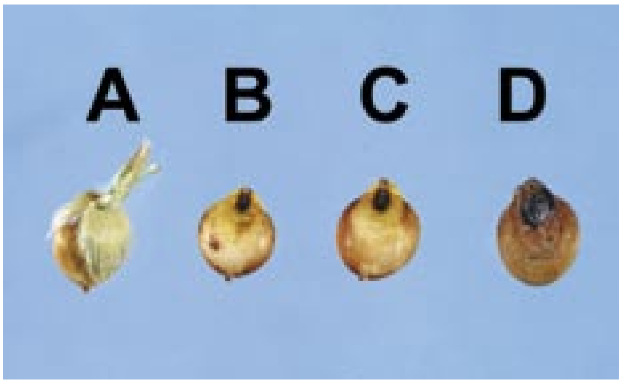


Figure 21: Black Layer Formation – Seeds progress from being less mature (A) to more mature (D). Note the distinct black dot in D, signifying the formation of the black layer.

starch, until water can no longer move in. The seed therefore dries out, typically from around 30% down to 10% or air-dry level. The black layer appears first in the seeds at the top of the head.

After physiological maturity, the remaining leaves that were still functioning, may stay green or may rapidly die. This will vary with how determinant the hybrid is, as well as environmental conditions. If temperature and moisture are favourable, branches may start to grow from the upper parts of the stem, where the leaves attach.

The time between physiological maturity and harvest date will depend on hybrid as well as environmental conditions.

SOWING

Hybrid selection

An up-to-date list of hybrids can be found in Agnote Grain Sorghum Planting Guide available from your nearest NSW DPI office.

No variety excels in all characteristics, therefore to spread your risk grow two or three varieties which have performed consistently in your area.

When selecting hybrids, consider:

- Yield potential (use hybrid trials as a guide).
- Maturity pattern (time and planting conditions).
- As a general guide, later maturing sorghum is higher yielding particularly under good moisture and nutrient conditions. If moisture could be a limiting factor affecting yield, the quicker, earlier maturing hybrids tend to have a greater reliability of producing a reasonable yield, compared to the longer growing types. The choice of maturity pattern types will depend on depth of stored soil moisture and the grower's attitude to risk. Varying the row spacing and/or plant population may alter the desirable maturity length.
- Disease resistance. A range of resistances is available for a number of grain sorghum diseases. Late planted crops are more likely to be affected by rust infection.
- Resistance to lodging (lodging rating).
- Resistance to insects (midge rating).
- Organophosphate (OP) reaction. Grain sorghum hybrids vary in their tolerance to organophosphate insecticide sprays. If grain sorghum is grown near other summer crops that will possibly be exposed to an OP during the season, select more tolerant hybrids to withstand any drift that may inadvertently occur.

Sowing time

Because of the variable rainfall, planting time varies from September to January. The preferred planting time for Moree and Narrabri is late September to late October while for Gunnedah, Inverell and Tamworth districts, mid-October to late November is preferable. Crops should be planted by early January so that flowering finishes by mid-March. This reduces the risk of sorghum ergot infection and yield loss as result of heavy build up of midge and a longer slower drying down period.

If planting late December-early January, plant a midge resistant hybrid. Crops planted into good soil moisture with adequate nutrition can still have good yield potential.

Crop failure is likely from very early planting (problems with emergence) or very late planting (due to cold conditions around flowering). Planting at the earliest opportunity is preferred to avoid midge, ergot and moisture deficit at flowering, amongst other problems.

Sorghum seed should be planted when the soil temperature at 9 am EST at the intended seed depth (about 5 cm) is at least 16°C (preferably 18°C) for three to four consecutive days and rising, with the risk of frost past. Soil temperatures usually reach 16°C in early October


Photo: J. Spenceley

Figure 22: Purpling of grain sorghum leaves due to emergence under cold conditions.

at Moree and mid-October at Gunnedah. Measure the soil temperature using a soil thermometer.

Planting into cold soils slows emergence, reduces germination and establishment and induces seedling blight. Low soil and air temperatures slow plant growth and reduce nutrient uptake (especially phosphorus) inducing 'purpling' in some hybrids (Figure 22). The longer emergence time increases the crop's susceptibility to soil insect damage. Very early-planted paddocks frequently have to be replanted.

Plant population

Target plant population depends on the depth of stored soil moisture, likely growing conditions and probability of above or below average in-crop rainfall. Expected crop yield affects the optimal plant population. Use lower populations in the more marginal areas

Figure 23: Poor and uneven establishment of a crop lowers potential yield and often increases the weed seed burden.

and higher populations where conditions are more favourable. Note that it is not only target population per hectare that is important; an evenly distributed plant population is the key to achieving high yields.

In dryland crops, the population chosen should maximise the chances of having soil water for flowering and grain fill to ensure high, stable yields. Matching plant population with stored soil moisture should result in good potential yield. Low tillering hybrids should be planted at slightly higher populations. Quick maturing hybrids planted in very good conditions may require a higher population than slower hybrids to realise their yield potential in certain environments.

When calculating planting rates allow for an extra 20–25 per cent for establishment losses when planting into a very good seedbed on heavy black soil using press wheels and 40–45 per cent when seedbed conditions are fair or when press wheels are not used.

Obtain the number of seeds per kg and the germination percentage from the bag label.

$$\textbf{Planting rate (kg/ha)} = \frac{\text{Required number of plants/ha} \times 10\,000}{\text{Seeds/kg} \times \text{germ\%} \times (100 - \text{establishment loss\%})}$$

Example

$$\textbf{Planting rate} = \frac{40\,000 \times 10\,000}{30\,000 \times 90 \times (100-25)}$$

$$= \frac{40\,000 \times 10\,000}{30\,000 \times 90 \times 75}$$

$$= 1.98 \text{ kg/ha}$$

Seeding rates vary due to many factors, however as a guide, average dryland rates are usually between 2–4 kg/ha and irrigated rates around 10 kg/ha. This is based on an approximate number of 30 000 seeds/kg and a target dryland plant population of 60 000 plants/ha. With full irrigation, target plant population could be 240 000 plants/ha.

Row spacing

Narrow rows out-yield wide rows under good growing conditions, therefore narrow rows are more appropriate with high-yielding irrigated crops and/or high rainfall environments, whereas wide rows are more advantageous in low moisture, lower yielding dryland situations. The narrow row advantage decreases rapidly as soil moisture reserves decline, especially in more marginal areas. Table 2 is a useful guide to determine which row spacing is more appropriate for a particular target yield in a dryland situation.

Table 2: Optimum row spacing for expected yield

Expect Yield	Optimum Row Spacing
Above 4 t/ha	≤ 0.5 m
3-4 t/ha	≤ 1.0 m
Below 3 t/ha	≥1.0 m

Photo: T. Christian

Figure 24: Grain sorghum planted on a solid row configuration (left) and single-skip row configuration (right). The difference in maturity between the plants is due to the differences in moisture availability to the plants.

A method of conserving water during the vegetative stage of a crop, for use at flowering and grain fill, is broadly termed 'skip row' (Figure 24). This term indicates that the row configuration is changed by 'skipping' or not planting rows. This 'skip row' management strategy has been used with peanuts, cotton and maize, as well as sorghum. When discussing row spacing for sorghum, it is useful to refer to Table 3.

The use of wide or skip row configurations should conserve some soil water for later in the growing season. These configurations are most effective when starting soil water levels are good with the wide areas between rows acting as a buffer for poor or variable in-crop rainfall. In more marginal dryland areas, growers could regard wide rows as mandatory and consider single skip row / double skip row, 1.5 m or 2.0 m rows. These wider rows improve risk management by increasing yield

Table 3: Wide row configurations used to plant sorghum

Row configuration	Rows planted
1.0 m solid plant	All rows planted on 1.0 m row spacing
1.5 m solid plant	All rows planted on 1.5 m row spacing
2.0 m solid plant	All rows planted on 2.0 m row spacing
Single skip	Two rows planted, one row unplanted
Double skip	Two rows planted, two rows unplanted

stability and greatly reducing the risk of crop failure. However, in high yielding environments or seasons, resulting in 1.0 m solid plant yields of 5 t/ha or higher, yield loss of 10–30 % (compared to solid plant) should be expected if wide or skip row configurations are used.

Agronomic management is very important if sorghum is planted on wide or skip row configurations. Plant population should be the same as solid plant on an area basis (same plants/ha). Even (as opposed to patchy) plant establishment within rows will maximise the water use between the wide rows. Good stubble management (ground cover) is necessary to reduce water loss between planted rows. Effective weed control before and during the season is critical, otherwise the advantages of the wider rows will be lost. Wider rows (> 0.75 m) allow inter-row cultivation for

Figure 25: Single skip row grain sorghum growing on the Liverpool Plains.

Photo: G. Butler

weed control, but this will result in additional water loss.

Sorghum sown using wide or skip row spacing should have a lower risk of pest problems (midge), lower herbicide costs (less sprayed area) and more even flowering and dry-down time improving harvestability.

Seed depth

Correct seed placement is essential, whereby the seed is planted deep enough into moisture to germinate and allow its roots to grow down through moist soil into subsoil moisture. The ideal planting depth is between 50–75 mm into moisture.

NUTRITION

Soil tests to estimate nutrient levels should form part of the overall rotation program. Applied fertiliser rates should be determined using soil testing, in conjunction with records of grain production and grain protein levels for individual paddocks. Using this information in association with depth of stored soil moisture, nitrogen fertiliser levels can be calculated based on target yields.

Nitrogen

Nitrogen deficiency symptoms are usually evident on the older leaves, which become mainly pale green with pale yellow chlorosis and pale brown necrosis. The development of pale yellow leaves is the most obvious symptom of nitrogen deficiency.

Low grain protein of sorghum combined with poor yield is a reliable indicator of low nitrogen availability. The QDPI has developed a guide using sorghum grain protein levels (Table 4). If the grain protein levels are consistently below 9% then there is acute nitrogen deficiency. They suggest that yield would almost certainly increase with increased nitrogen supply. If the protein varies between 9–10%, marginal nitrogen deficiency is occurring. Grain yield and protein may increase by increasing nitrogen supply. Above 10% protein, nitrogen may not be limiting yield.

On the Liverpool Plains, average yield was increased by 1.8 t/ha with the addition of 80 kg N/ha in 15 trials during 1990–93. Yields were lifted from 3.7 to 5.5 t/ha. After short fallows following sorghum, the yield was increased by 2.9 t/ha. Suggested nitrogen rates following various dryland crops are outlined in Table 5 and irrigated crops are outlined in Table 6. Rates

Table 4: Using grain protein levels to indicate N deficiency in sorghum

Grain Protein (13.5%mc)	Indicated N supply
Less than 9%	Acute N deficiency. More yield highly likely with more N.
9 to 10%	Marginal N deficiency. Yield may increase with more N.
Greater than 10%	N not limiting. More N will increase grain protein.

Source: QDPI Crop Management Notes – Summer Edition.

Table 5: Guide to nitrogen rates (kg/ha) for dryland sorghum grown on the Liverpool Plains

	Yield Target	
Previous Crop	4 t/ha	6 t/ha
Sorghum, sunflower, cotton	100	140
Cowpeas, mung beans	60	120
Long fallow winter cereal	80	120
Long fallow faba beans	30	90
Long fallow chickpea	45	100
Lucerne (good stand)	0	0

Source: NSW DPI Agnote Grain Sorghum Planting Guide 2004–2005.

Table 6: Guide to nitrogen rates for irrigated sorghum

Previous Crop	Nitrogen Rate (kg/ha)
Sorghum, maize, cotton	180
Soybeans	100
Long fallow wheat	150
Long fallow faba beans	120

Source: NSW DPI Agnote Grain Sorghum Planting Guide 2004–2005 of 80–120 kg/ha of nitrogen are used on high yielding crops grown after winter cereals on the Liverpool Plains. Trials in other areas where soil nitrogen levels have been higher, have given smaller and less consistent yield responses.

Cowpea and mungbean crops may leave up to 40 kg/ha of additional soil nitrogen, while soybeans may result in residual soil nitrogen levels of 25–50 kg N/ha, compared with crops such as sorghum or other cereals. The amount of nitrogen contributed by a pulse crop to the soil largely depends on the quantity of dry matter produced by the pulse crop, the effectiveness of nodulation and the previous soil nitrogen status.

Pulse crops will reduce the loss of soil nitrogen compared to other crops such as sorghum. However, the contribution of a previous summer pulse legume crop to soil nitrogen levels can be very erratic, ranging from actual depletion to an increase of up to 40–50 kg N/ha. Growers are advised to adopt a conservative approach in assuming the amount of nitrogen following pulse crops, unless on-farm experience has given a good indication.

In irrigated sorghum crops, fertiliser use efficiency can be increased by using post-plant applications of nitrogen either as water-run urea or side-dressed nitrogen. This efficiency is dramatically decreased where slow irrigation results in waterlogging and subsequent loss of nitrogen through denitrification.

Nitrogen budgeting is a useful technique that can be used to give an indication of the nitrogen requirements of the sorghum crop.

Nitrogen budgeting

This method can be used to determine the nitrogen requirements of a crop by doing a simple calculation. The quantity of nitrogen (N) required to grow the crop is approximately double the quantity removed in the grain at harvest.

N removed in grain = Target yield (t/ha) x grain protein %
(kg/ha) x 1.6

N required for crop (kg/ha) = N removed in grain x 2

Example

N required for crop (kg/ha) = (5t/ha x 10% x 1.6) x 2

= 160 kg N/ha

Using the above example, if soil analysis confirmed only 80 kg/ha of soil nitrogen was available then a further 80 kg/ha of fertiliser nitrogen would be required to achieve a target yield of 5 t/ha at 10% protein.

Nitrogen fertiliser can be applied in different forms, with anhydrous ammonia (82%) and urea (46%) most common. The choice usually depends on price, availability and convenience of use. Only very low rates of nitrogen can be safely sown with sorghum seed, 5 kg/ha in 90 cm rows and up to 12.5 kg/ha in 36 cm rows. Higher rates should be sown 5 cm to the side of the planting tine. It is the normal practice to apply high rates of nitrogen fertiliser pre-planting in dryland situations, however post-plant application can be utilised especially in irrigated sorghum.

Phosphorus

Sorghum is more tolerant to low phosphorus than winter cereals. Soil levels need to be quite low (below 15 mg/kg bicarbonate) before consistent responses to phosphorus fertiliser occur. Soils with less than 10 mg/kg are likely to respond to added phosphorus. Responses to starter fertilisers may occur in the Moree area and on the Liverpool Plains. Note that applications of phosphorus fertiliser can induce zinc deficiency. An in-crop foliar spray is most effective.

In mild phosphorus deficiency situations, there are few clearly recognisable symptoms. Plants appear stunted with thin stems and dark green leaves. The crop may appear to be uneven and grain maturity may be delayed. When the deficiency becomes more severe, growth is greatly reduced and overtones of dark red or purple develop on the sheaths and blades of older leaves. If the deficiency is very severe, dark brown necrosis often develops near the tip of the leaf blade and advances inwards and along the margins towards the base. Eventually affected leaves wither and die.

Sorghum is more vulnerable to phosphorus and zinc deficiency following periods of long fallow (such as drought) or crops like canola znd mustard, when *Versicular Arbuscular Mycorrhizae* (VAM) level is low.

Zinc

The heavy alkaline soils of northern NSW frequently respond to zinc, thereby improving sorghum yields. Yield responses have been obtained from starter fertilisers containing about 2.5% zinc that are applied at about 40–100 kg/ha in sowing rows, 75–100 cm wide. More reliable responses have been obtained by applying zinc oxide at about 15 kg/ha incorporated into the seedbed well before planting. Symptoms of zinc deficiency develop in the young leaves with broad yellow or white bands between the margins and the mid-vein in the lower half of the leaf.

As noted in the phosphorus section, sorghum is particularly vulnerable to zinc deficiency when *Versicular Arbuscular Mycorrhizae* (VAM) level is low. VAM is a naturally occurring soil fungus that helps plants with the uptake of phosphorus and zinc.

Salinity, sodicity and acidity

Sub soil salinity is reasonably common in the brown, grey and black clay soils in northern NSW. Salinity is the salt concentration in the soil solution. While past research from experimentally imposed salt levels indicates that grain sorghum is tolerant of salinity, more recent research in northern NSW indicates that grain sorghum is much more sensitive to salinity. In this research there was a rapid decline in plant growth and yield as soil salinity increased, especially from Electrical Conductivity (saturated extract - ECe) from 2 to 5 dS/m. These experimental results are supported by grower and agronomist anecdotal evidence that where there is subsoil salinity, grain sorghum has difficulty growing roots into these saline layers.

In addition to sub soil salinity, subsoil sodicity is also reasonably common in northern NSW. A sodic soil has an excess of exchangeable sodium ions attached to clay particles. This excess of ions affects the physical characteristics of a soil, by causing dispersion. When a clay soil disperses with water, the clay particles swell as they are no longer bound together and minimise drainage through the soil pores (spaces). A dispersive soil sets hard when dry. Subsoil sodicity restricts rooting depth due to the soil being so hard. It therefore restricts access to water and nutrients for the crop. Surface sodicity results in surface sealing, reductions in water infiltration and may cause waterlogging on the surface. Application of gypsum can ameliorate the effects of surface sodicity.

Grain sorghum is regarded as being slightly tolerant of soil acidity. It has been successfully grown where soil tests have given pH values of 5.5 in a 1:5 in water solution.

Prior to growing grain sorghum in any paddock, growers should measure the ECe, Chloride, Exchangeable Sodium Percentage (ESP) and pH levels. Once the crop is growing, field observations of where the roots are growing given the seasonal conditions, are also very useful in identifying any issues with subsoil constraints.

DISEASES

Diseases that may be a problem include, head smut, leaf blight, anthracnose, leaf spot, Johnson grass mosaic virus, sorghum ergot and pythium. Select hybrids that are resistant to diseases prevalent in your region.

Leaf rust (*Puccinia purpurea*)

Appear as small purple red or tan spots on the leaves. These can enlarge and form elongated raised pustules, which break to release brown, powdery spores. These can significantly reduce yield and contribute to lodging in susceptible hybrids; hence use only rust resistant hybrids. Rust tends to be a major problem in humid coastal areas and late planted crops. Leaf rust often appears in northern inland NSW towards the end of autumn but usually does not significantly reduce yield.

Head smut (*Sporisorium reilianum*)

Head smut is soil-borne or introduced on seed and tends to be a problem in early-planted crops with seedlings becoming infected during cooler weather. In the Inverell and Warialda areas, the incidence of head smut has been up to 10–15% of the crop. Fortunately due to efforts by sorghum breeders, most hybrids have good levels of resistance.

Johnson grass mosaic virus

Aphids moving between plants spread Johnson grass mosaic virus and cause ‘mosaic’, ‘red leaf’ or ‘red strip’ symptoms on the leaves. The ‘mosaic’ symptoms appear as light and dark green lines on veins. ‘Red leaf’ symptoms cause the leaf to show signs of leaf reddening followed by red spots or large areas of dead tissue. ‘Red stripe' symptoms appear as red or tan stripes parallel to the veins. Johnson grass mosaic virus prevalence has declined, with no significant damage to crops in NSW in recent seasons.

Sorghum ergot (*Claviceps africana*)

Sorghum ergot has been detected in late flowering crops in northern NSW. The fungus infects sorghum heads at flowering and is favoured by mild temperatures (15–30°C), high humidity and overcast conditions. The ergot spores compete with pollen in the unfertilised florets. Ergot can infect Johnson Grass as well as both forage and grain sorghum.


Photo: D. Ward

Figure 26: Johnson grass infected with sorghum ergot on the Liverpool Plains. Note the honeydew from the seeds.

Ergots are creamy coloured sclerotes usually smaller than sorghum seed that replace the developing seed in the plant head. Sorghum ergot can cause harvesting problems with the sticky honeydew clogging machinery. Another major problem is that ergots are toxic to livestock but, provided ergot levels are less than 0.3% by weight, the grain is within safe usage levels for many end users. To reduce the risk of ergot in northern NSW plant by early January so that crops flower by mid-March while the weather is still relatively hot and dry. Agronomic measures such as press wheels and good nutrition that promote even flowering also help.

Seedling blight (*Pythium* spp.)

Seedling blight can be a major factor limiting stand establishment when sorghum is sown into cold, wet soils. *Pythium* spp. appear to be the primary cause of seedling diseases. Sorghum may be more susceptible to Pythium spp. in cool, wet soils due to slowed seed germination, delayed emergence and reduced root growth. Pythium infection can result in failure of the seed to germinate. Infection during or shortly after germination may result in pre- or postemergence damping-off, with symptoms appearing as stunting and mild chlorosis to necrosis of lower leaves and subsequent death of the seedlings. Many fungicides are not effective in controlling seedling disease caused by *Pythium* spp. Hybrid sorghum is generally less susceptible due to increased vigour. Similarly, plants from new or high-quality seed are less susceptible than plants from old or poor-quality seed. Primarily, avoid sowing too early in the season into cool, wet soil which favours infection by *Pythium* spp.

Fusarium stalk rot (*Fusarium moniliforme*) and charcoal rot (*Macrophomina phaseolina*)

Fusarium stalk root is caused by Fusarium moniliforme while charcoal rot is caused by the fungus *Macrophomina phaseolina*. Both diseases are associated with lodging of sorghum plants when moisture stress occurs during grain filling. The lower two to three internodes of sorghum infected with *F. moniliforme* typically contain areas of pinkish pith. Premature plant death can also occur with Fusarium stalk rot with leaves suddenly turning a bluish-grey. Heads on these plants lose their glossy appearance, are smaller and have sterile florets. The grain that develops is smaller than that from uninfected plants. Charcoal rot occurs when M. phaseolina infects the roots of plants growing under moisture stress and high temperature. Unlike Fusarium stalk rot, charcoal rot causes disintegration of vascular tissue and pith. Affected stalks are spongy at the base and tend to lodge in moderate winds. The pith of the stalk of infected plants are characteristically marked with small, dark, charcoal-coloured sclerotia of *M. phaseolina*. Maintaining soil moisture during the postflowering period can minimise the incidence of Fusarium stalk rot and charcoal rot. A balanced fertiliser program is beneficial. High levels of nitrogen and low levels of potassium should be avoided. General recommendations to prevent lodging should be followed (p. 24).

Other diseases

Leaf spot and the other diseases may occur in later planted sorghum. Information on the disease reaction of hybrids is available from seed companies. Planting resistant hybrids at optimum planting time will lessen the disease problem and result in increased yield.

INSECT PESTS

For insect control options, refer to Insect and Mite Control in Field Crops, published by NSW Department of Primary Industries.

Sorghum midge (*Contarinia sorghicola*)

Sorghum midge can severely reduce yields, especially in late planted crops. The midge larvae suck juices from developing seed, shrivel seed and reduce grain development.

Sorghum midge resistance is now available in most newly released hybrids. Midge rating is the factor by which a hybrid's midge resistance exceeds that of a fully susceptible (rating 1) hybrid. For example, a midge tested rating for a hybrid of 4 will suffer one quarter the damage of a susceptible hybrid (rating 1). New hybrids are tested for their midge resistance by the Industry Testing Group comprising the Queensland Department Primary Industries and seed companies. These hybrids are given official midge rating in a logo (Figure 27).

Monitor midge activity on emerged heads before flowering and during early flowering, even if a midge resistant hybrid has been planted.

Crops should be sprayed at 3–4 day intervals when the economic threshold in the table below is reached. This threshold is based on a benefit cost ratio of 2:1. This ratio is appropriate because insecticides are usually less than 80% effective. Use the table as a guide only and seek advice from your agronomist.

2 Standability	3 Midge Rating	4 Grain Colour
****	4	Red
*****	8	Red
*****	5	Red
*****	4	White
*****	6	Bronze

Figure 27: Official industry midge tested rating logos.

Spray for midge when $\frac{NM}{R}$ **is greater than** $\frac{C \times W}{1.4 \times V \times RD}$

where NM = number of midge per m row

R = midge rating of hybrid used

C = cost of control ($/ha)

W = row spacing width (cm)

1.4 = constant

V = value of crop ($/t)

RD = residual life of chemical used (days)

Example

$$\frac{NM}{R} = \frac{4}{3} = 1.33$$

$$\frac{C \times W}{1.4 \times V \times RD} = \frac{17 \times 100}{1.4 \times 155 \times 4} = \frac{1700}{868} = 1.96$$

As 1.33 < 1.96, do not spray at this stage.

Figure 28: An adult sorghum midge. Monitor midge activity on emerged heads before flowering and during early flowering.

Heliothis (*Helicoverpa armigera*)

Helicoverpa armigera (cotton bollworm or corn earworm) is a serious pest of sorghum and other field crops. *H. armigera* has developed resistance to a range of conventional chemical insecticides and can be difficult and expensive to control.

The heliothis moths lay pearly-white eggs on pre-flowering heads. The young heliothis larvae, (caterpillars) mainly feed on the anthers, flower spikelets and other floral parts surrounding the flowers in the plant head. As the heliothis caterpillars mature (see Figure 29) they start feeding on the developing grain. Young larvae are small and hard to see on the sorghum heads. They are easier to detect by shaking the head into a light coloured bucket.

Inspection should start prior to flowering and continue weekly until the crop reaches the soft dough stage. Open head type hybrids tend to suffer less damage than the closed, compact type. Controlling heliothis by spraying conventional insecticides can be difficult as spray failure is highly probable where resistant populations have developed. Under the right conditions, the biological insecticide Nuclear Polyhedric Virus (NPV) has given excellent results (see Figure 30). Deciding when to spray is a balance between the number of heliothis present, the cost of control and the value of the crop.

Critical heliothis number per head $= \dfrac{C \times W}{V \times N}$

where C = cost of control ($/ha)

N = number of heads per m row

W = width of row spacing used (cm)

V = value of crop ($/t)

Example.

Critical heliothis number per head =

$$\frac{C \times W}{V \times N} = \frac{25 \times 100}{155 \times 6}$$

$$= \frac{2500}{930}$$

$$= 2.69$$

Wireworms (*Orondina* spp.)

Wireworms can severely reduce sorghum establishment. The larvae feed on germinating seed and bore into stems of seedlings (growth stage 0). The larvae are 15–25 mm long. Seedlings are destroyed at the growing point. Damage is more severe under cool, wet conditions when growth is retarded. Always use presswheels when sowing as this reduces the carbon dioxide flow from the seed which is what attracts wireworms to the germinating seed.

Wireworm numbers can be particularly high if sorghum is sown into sunflower or sorghum stubble from the previous year. Indicative levels of wireworms may be gathered from burying maize seed traps under the soil at various

Figure 29: Heliothis (*Helicoverpa armigera*) larva. Note that heliothis can vary in colour depending on the food source and age of the larva.

Figure 30: Heliothis (*Helicoverpa armigera*) larva infected with Nuclear Polyhedric Virus (NPV).

locations in the paddock prior to sowing. If wireworm numbers are suspected to be greater than very low, it is strongly recommended that a seed applied insecticide be used. Uneven establishment, problems with weed control and loss of yield may otherwise result.

Cutworms (*Agrotis* spp.)

Figure 31: Common cutworm (*Agrotis infusa*) larva. Note that cutworms can vary in colour depending on the food source and age of the larva.

Cutworm larvae (*Agrotis munda*, *A. ipsilon* and *A. infusa* – see Figure 31) attack young plants by feeding on the leaves and stems. Most damage is caused by older larvae which, by chewing, cut through stems and leaves to gain access to the top growth. They also cause plants to wilt and die by cutting or partially cutting through the stem near or below ground level. Large numbers of cutworms usually move in from the edges of crops and cause damage in patches. As these larvae usually hide under soil clods during the day, inspections and sprays should be done at night.

Black field earwigs (*Nala lividipes*)

Earwigs feed on both live and dead plant material. Adults and nymphs damage crops by feeding on seedlings, but normally most damage is caused when they feed on the roots of young plants and the prop roots of older plants. This root feeding often causes plant lodging. Adults are 15 mm long, shiny black and have a pair of pincers at the rear end of their body. Black field earwig populations are highest, and hence damage is most severe, in soils with a high water holding capacity.

Aphids

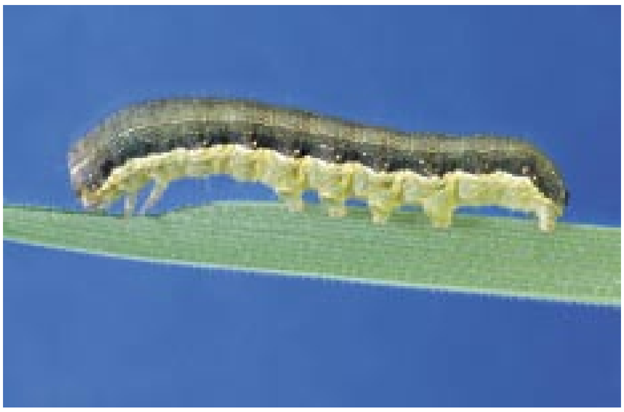
The most common aphid found in sorghum is the corn aphid (*Rhopalosiphon maidis*). The oat aphid (*R. padi*) and the rusty plum aphid (*Hysteroneura setariae*) are also found less frequently. Aphids often infest sorghum heads towards the end of grain fill, but depending on the season may infest the crop anytime just before head emergence through to flowering. Even when conditions are dry there is usually no economic damage and control is seldom worthwhile. The presence of aphids can help maintain natural enemies of other pests. However, if the population becomes very high, head emergence can be impaired, yield and quality may be reduced and aphid honeydew can cause harvester blockages and breakdown. A pre-harvest spray with a knockdown herbicide may avoid the harvest problems caused by aphids.

Armyworms (*Mythimna convecta* and *Spodoptera* spp.)

Armyworms (see Figure 32 and 33) are the larvae (caterpillars) of moths and get their descriptive name from their habit of moving on mass from a depleted food source in search of a

Figure 32: Common armyworm (*Mythimna convecta*) larva. Note that armyworm larva can vary in colour depending on the food source and age of the larva.

Figure 33: Lesser armyworm (*Spodoptera exigua*) larva. Note that armyworm can vary in colour depending on the food source and age of the larva.



new food source. These larvae feed on leaves. They can kill young plants and also decimate yields by causing severe defoliation at flowering. The larvae of most species feed during evening and night and hide near the ground during the day. Numbers often build up after heavy rain.

Rutherglen bugs (*Nysius vinitor*) and Grey cluster bug (*N. clevelandensis*)

Rutherglen (see Figure 34) and grey cluster bugs are frequent pests of grain sorghum, and

Figure 34: Rutherglen bug (*Nysius vinitor*) female adult.

usually occur in hot, dry weather. The adult and immature bugs feed by sucking sap from the plant leaves, stems and heads and when present in large numbers can significantly reduce yield and grain quality. Populations can increase rapidly so crops should be monitored regularly from head emergence to the hard dough stage at as many locations within the crop as possible. It is generally recommended that control should commence when the adults are detected rather than waiting for nymphs to develop. This is because of the potential for rapid population increase and the difficulty in controlling nymphs within the sorghum head.

BENEFICIAL INSECTS IN SORGHUM

Midge parasites and predators

Small parasitic wasps, the most common of which is the black coloured *Eupelmus australiensis*, often appear in sorghum crops at flowering. These wasps parasitise midge larvae. Parasitism does not reduce the initial population of midge larvae and provide extensive protection of the crop, but does suppress subsequent generations and may reduce overall crop damage. The main method of control of midge is to grow recommended midge resistant hybrids.

Figure 35: Trichogramma parasitic wasp (*Trichogramma* sp.).

Figure 36: Telenomus parasitising wasp (*Telenomus* sp.).

Pirate bugs (*Orius* spp.)

Pirate bugs adults and nymphs are predators and are often found in sorghum crops during flowering and grain maturation. Pirate bugs prey on sorghum midge adults, thrips and the eggs of other insects.

Natural enemies of heliothis and aphids

There are a number of insects, which attack heliothis, commonly found in grain sorghum crops. It is important to recognise these beneficial insects so that they can be conserved.

It is the ability to grow sorghum without broad-spectrum insecticides, relying on natural enemies and the application of nuclear polyhedric virus (NVP) or BT to control heliothis, which makes sorghum valuable as a summer trap crop.

Parasitic Wasps

Trichogramma (Figure 35), Telenomus (Figure 36) and Microplitis are small black wasps that parasitise heliothis eggs. The wasps lay their eggs inside the heliothis egg and the developing larvae then eat the host heliothis larvae before they hatch. The developing wasp can be seen through the egg wall using a hand lens. The rate of parasitism can vary from 1.6% to over 90% (as recorded for Trichogramma in sorghum

Figure 37: Orange caterpillar parasitic wasp (*Netelia producta*).

Figure 38: Two toned caterpillar parasitic wasp (*Heteropelma scaposum*).

in the Ord River Irrigation Area). The best way to monitor levels of egg parasitism is to collect brown eggs and record wasp emergence. (Refer to QDPI note 'Trichogramma and Telenomus Wasps are Important Biological Control Wasps').

Other parasites of heliothis include the wasps *Netelia producta* (orange caterpillar parasite – see Figure 37), *Heteropelma scaposum* (two-toned caterpillar parasite – Figure 38), *Lissopimpla excelsa* (orchid dupe) and *Ichneumon promissorius* (banded caterpillar parasite) and several species of Tachinid fly. However the distribution and effectiveness of these parasites in sorghum is not known.

Avoiding broad-spectrum insecticides, such as the organophosphates and synthetic pyrethroids, can conserve natural populations of these parasites. Biological insecticides, such as NPV and Bt should be used in preference to broad-spectrum insecticides. Lengthening the flowering period of a sorghum crop by planting over an extended period can also increase numbers of these parasitoids.

Ladybird beetles

Ladybirds (see Figure 39 for photo of common ladybird larva and adult) are generalist predators and several species occur and feed on a range of pests in sorghum. Adults and larvae are voracious feeders. Depending on species, they prey on aphids, whitefly, leafhoppers, thrips and mites and the eggs and small larvae of heliothis and other Lepidoptera (moths).

Figure 39: Common spotted ladybird (*Harmonia conformis*) larva and adult.

Lacewings

Lacewings, *Mallada* spp. (green lacewings) and *Micromus* spp. (brown lacewings – Figure 40), like ladybirds, are generalist predators. However unlike ladybirds, it is only the larvae that prey on moth larvae and eggs, aphids, whitefly, thrips and mites. Adult lacewings are nectar feeders and consequently their presence in a crop frequently declines in the absence of suitable flowering plants.

Figure 40: Brown lacewing (*Micromus* sp.) adult.

Spiders

Figure 41: Wolf spider (*Lycosa* sp.) adult.

Spiders are predators and play a significant role in suppressing many insect pests. However, the importance of spiders is often underestimated, e.g. wolf spiders (Figure 41) are voracious predators of heliothis, but because spiders do not reproduce rapidly, their population size does not keep pace with their prey and they cannot control their prey when outbreaks occur.

LODGING

Lodging is a significant problem in all dryland growing areas. The most common cause is moisture stress during grain filling whereby the plant diverts energy from the stem to facilitate the reproduction process and hence grain fill. This weakens the stem and allows the development of fungal stalk rots. Fusarium and charcoal stem rots are often associated with lodging, leading to plant death and considerable yield loss as the plant loses the ability to remain

Photo: J. Spenceley

Figure 42: A combination of drought stress as well as pig damage resulted in many of these plants lodging.

upright and falls over. Lodged crops become a problem at harvest time as often the heads can be on the ground.

Crops that remain green with some available soil moisture during grain-fill are generally less prone to lodging. Use only hybrids that have lodging resistance. Lodging is rarely a problem in fully irrigated crops, but can be in partially irrigated crops that become stressed during grain-fill.

Agronomic practices such as controlled traffic, no-till and stubble retention which aim to store more soil moisture during the fallow will enhance the availability of moisture during grain fill. These practices will help reduce lodging. The use of low plant population and wide row spacing, especially in the North-West Plains, also helps. These practices also allow medium maturity hybrids with higher yield potential to be used.

WEED CONTROL

Effective weed control along with an even appropriate plant population, are two critical factors in setting a grain sorghum crop up to maximise yields. Effective weed control is also vital for meeting quality standards and lessening the weed burden for future crops. Recent evidence suggests that the value of sorghum as a rotation crop for crown rot in wheat and barley may be significantly reduced if grass weeds are not effectively controlled.

Figure 43: Poor weed control not only lowers yield, but can lower the effectiveness of the sorghum crop as a weed and disease break for winter cereals.

Photo: J. Spenceley

Long residual herbicides should be used with caution as they can reduce the flexibility of cropping programs. However, effective control of most weeds in conventionally fallowed crops can be achieved relatively cheaply by applying atrazine either before planting, at planting or immediately after planting. Atrazine residues prevent the planting of crops other than sorghum and maize for 18 months after application of 2.5–6.5 L/ha of flowable atrazine.

Metolachlor can be used as a pre-emergent spray for grass control, especially liverseed grass, and to reduce atrazine residues in subsequent crops. If this herbicide is used, then seed should be treated with Concep® II seed safener.

For weed control options, refer to Weed Control in Summer Crops, published annually by NSW DPI.

CROP DESICCATION

Sorghum, being a perennial plant continues to grow beyond physiological maturity of its initial grain crop. A pre-harvest spray of either of the knockdown herbicides glyphosate or a registered diquat product applied to the crop immediately after the end of grain fill, will hasten dry down and should kill or desiccate the crop. This treatment kills immature tillers, desiccating green foliage thereby allowing crops to be harvested much earlier, and more efficiently than if they were not sprayed. Crop desiccation also stops the crop continuing to use moisture, thereby starting the fallow recharge sooner.

The timing of the pre-harvest spray is critical. Crops should be sprayed preferably before the end of March when temperatures are still warm and crops are still green. The aim is to maximise yield through assimilation of carbohydrate in the seed, but balance this moisture use with storing water for the next crop. When between 95 and 100 per cent of the grains have formed a 'black layer' (i.e. are physiologically mature), the crop is ready to be sprayed. This is approximately at


Photo: G. Butler

Figure 44: Harvesting skip-row sorghum north-east of Moree.

dough stage and 25–30% grain moisture (see Figure 20).

Sprayed crops stop using moisture and the profile therefore starts storing soil moisture for the next crop more quickly. Many growers in northern NSW have found that in wet summers, spraying out an early sorghum crop for harvest has given them a high return over 14 months, as it also allowed them to grow a successful chickpea double crop.

Harvest should occur as soon as possible when grain moisture is 13.5% or below, as delay could cause the dead stalks to lodge. Lodging is aggravated when there is moisture stress at grain fill, very strong winds or the hybrid does not have a high resistance to lodging rating.

HARVEST

Harvesting must be done efficiently and rapidly while the crop is at its peak. The aim of the harvesting operation is to deliver the grain in prime condition to its storage. Timeliness of harvest is a crucial factor in ensuring maximum profit from the crop. The harvesting task requires planning as all equipment must be set-up correctly and operated efficiently. Select and correctly match all equipment associated with the harvesting operation.

STORAGE OF GRAIN

After the sorghum is harvested and stored in the silo, it is still vulnerable to attack by insects, mites and fungi. Storing grain for any length of time and protecting it from insect attack is not easy, but it is vital to maintain product quality. Prevent moisture getting into the grain and allowing microorganisms, particularly fungi to spoil the grain. Grain should be regularly checked and remedial action taken if required.

MARKETING

During the last five years Australia has produced on average 1.3 million tonnes of sorghum per year. The average crop yield is approximately 2.3 t/ha. About three-quarters or more of the crop is exported for the feed grain market.

Deregulation of the grain industry has impacted on the way crops are marketed. Good marketing is the progressive accumulation of marketing actions that gives a better than average result.

Knowledge of your costs of production per tonne, will allow quick calculations of how much the crop must return to break-even and therefore make a profit. Harvest time may not be the best time to sell your crop. Spread your marketing strategy by forward selling, consider using hedging tools, and sell part into a pool or from silo direct to end users. Stay in touch with market prices and trends, as prices may vary by $10–40 per tonne during the year.

In the current market, growers must take the initiative to market their crop for values that are above the cost of production and that provide them with optimum profit.

GRAZING AND HAY

It is common for grain sorghum stubbles to be grazed following harvest, especially in times when cattle prices are high. Sorghum crops have also been grazed or baled for hay during drought times when it is likely that they will fail to produce a reasonable grain yield.

There is a potential risk of toxicity to stock if sorghum is grazed, due to hydocyanic acid (HCN) production in the foliage. This is particularly when the crops are young or stressed (e.g. by drought, waterlogging, nutrient deficiency, insects or diseases) and when shorter than 0.5 m.

Sorghum crops that have flowered under cool and wet conditions may be infected with ergot. As discussed in the Disease Section, ergot is readily identifiable by the 'honeydew' oozing from the flowers. This honeydew later dries into a white powder. The developing seed is replaced by a fungal growth which becomes an 'ergot' (a hard, creamy-coloured sclerote about the same size as a sorghum seed). Sclerotes have high levels of alkaloids. Current evidence suggests the stockfeed limit of 0.3% sclerotes by weight in sorghum grain, is suitable for many classes of livestock with some exceptions. Seek current advice on limits for lot-fed cattle, cows and sows. Ergot interferes with weight gain in cattle and milk production in cows and sows.

Other animal health issues such as the potential for nitrate poisoning, especially if nitrogen fertilisers have been used, need to be considered. Growers are urged to seek veterinary advice, prior to grazing.

Sorghum is best cut at or before the early head emergence stage for hay. Grain sorghum varieties are not as suitable as forage sorghum varieties for either hay or silage.

FURTHER INFORMATION

Consult your local NSW DPI agronomist for further information on grain sorghum. NSW DPI and other publications include:

Agfact P3.AE.1 *Sorghum midge*. 1st edition 1983.

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Storrie, A. (2000) *Weed Control in Summer Crops.*

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DISCLAIMER

ALWAYS READ THE LABEL

Users of agricultural (or veterinary) chemical products must always read the label and any permit, before using the product, and strictly comply with the direction on the label and the conditions of any permit. Users are not absolved from compliance with the directions on the label or the conditions of the permit by reason of any statement made or omitted to be made in this publication.

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