Managing sorghum for high yields

A Blueprint for doubling Sorghum production

Dr Peter Wylie
Horizon Rural Management
Dalby 4405

Summary

Grain sorghum production in Australia is set to expand as grain prices increase due to use of grain to produce ethanol around the world. Grain prices are likely to be related to oil prices in the future as ethanol production continues to expand in USA and eastern Europe.

Rising grain prices may limit ethanol production in Australia, but with improved agronomy and prices sorghum production will become more attractive. Sorghum is already the most profitable grain crop in the cooler high rainfall areas, and is becoming more attractive in the hotter western areas. Higher prices will stimulate larger areas to be planted, not only in traditional areas, but in such locations as the South Burnett and coastal Queensland.

There is potential to lift average sorghum yields by 1 t/ha and with a 50% increase in the area grown, 4 million tonnes is a modest projection for sorghum production in Australia by 2012, compared to average production over the last five years of 2 million tonnes. As sorghum production expands, wheat is likely to be in shortfall in Queensland more often than sorghum.

To achieve these high average yields, the most important improvements are farming practices which optimise the conservation and use moisture. Zero-tillage is the main part of this package and despite good progress, adoption remains below 50%.

The planting time of sorghum is important where summer heat affects yields. Sorghum planted early will have better water use efficiency and can produce more yield despite receiving less rainfall on average. Moisture seeking planting could be utilised more to achieve more sorghum planted at the optimum time, particularly in western areas on a long fallow after wheat.

Early planting of sorghum has often been delayed by adherence to soil temperature guidelines. The best time of planting should not be based on the use of soil temperature, but rather on planting times which are likely to result in a good strike. Seed dressings used to reduce pithium and other seedling diseases in wheat may help to make early planted sorghum more reliable.

Better planters and insecticidal seed dressings have improved the establishment of sorghum. Sowing rates need to be reduced in some instances. There is confusion about optimum plant populations and row spacings for sorghum. This is understandable, because constraining plant growth and tillering (using low populations and wide rows) may improve yields in one year and reduce them in another. When sorghum yields are less than 3 t/ha, wide rows may outyield one metre rows. However, most sorghum growing areas have an average yield potential of 3 t/ha and one metre rows are a good compromise.

Good fertiliser management, weed and pest control are important for good sorghum yields. Nitrogen often limits yields in good seasons. Rotational benefits from sorghum in farming systems, including weed, disease and pest control in following winter crops, can result in sorghum having a place in an optimum profit rotation, even if it is less profitable than wheat.

There are opportunities for research on sorghum varieties with adaptation to heat. There may be a conflict in the selection of sorghum for heat tolerance and cold tolerance required for early plantings. Other plant breeding issues include the selection for improved grain quality in sorghum. Improved digestibility will improve the acceptance of sorghum beef feedlotting, while higher starch content will assist ethanol production.

Sorghum may have a role in ethanol production in the northern tropics, produced under irrigation for large scale ethanol production.

Managing Sorghum for high yields

A blueprint for doubling sorghum production

Dr Peter Wylie
Horizon Rural Management
Dalby 4405

Contents — Page

Tables

Figures

Appendices

1. Grain sorghum production set to expand

Grain has been too cheap relative to petrol. The break-even or 'petrol parity' price for sorghum is $300/tonne, at an oil price of $US55/bbl.

As ethanol production develops in Australia, the premium for wheat over sorghum will decline, encouraging more sorghum.

Average sorghum production of 2 mil. tonnes from 778,000 hectares (2.58 t/ha) is likely to increase to 4 mil. t. from 1.1 mil. ha. by 2012

Ethanol production in the USA has already increased the price of grain, which may go higher over the next few years. Higher prices will stimulate increased production of sorghum in Queensland and northern NSW.

Oil prices have retreated from recent highs of more than $US70/barrel to around $US50/bbl, but the production of ethanol remains profitable and construction of ethanol plants is likely to continue in the USA and around the world.

At the start of 2007, there were 113 ethanol plants in the USA, with a total capacity of 5,583 million gallons (21,000 million litres) per year. According to the Renewable Fuels Association, 76 new plants are under construction, with another 7 plants extending their capacity. This will result in total production of 44,000 million litres of ethanol, consuming close 100 million tonnes of corn. The USA has already taken over from Brazil as the world's largest ethanol producer and expansion continues at a rapid rate.

World coarse grain production is likely to be 40 million tonnes short of demand in 2006-07, according to USDA supply and demand projections. Prices for corn have already increased, from around $US2.10 per bushel ($A112/t) in November 2005 to $US4.00/bu. ($A200/t) in January 2007. Increased prices are likely to stimulate extra production and Collins (2006) suggests an extra 10 million acres of corn will be needed by 2008 to supply ethanol plants and to maintain exports. But even with higher prices stimulating additional production, USA farmers may not keep up with demand for grain as ethanol production continues to expand.

Some reports suggest 120 mil. tonnes of corn will be used for ethanol by 2010 – almost half of the total US corn crop. Some 30% of this (on a dry basis) is available to feed users as distillers grains, but net consumption of grain will be in the vicinity of 80 mil. t.

In Australia, three ethanol plants are planned to be built in the northern grain belt, between Gunnedah and Dalby. With a capacity to produce 320 million litres of ethanol per annum, they are likely to consume 800,000 tonnes of sorghum.

Table 1: Production of Sorghum - NSW and Qld - 2001-05

Area		2001	2002	2003	2004	2005	5 Year Average	Estimate 2012*
QLD	Ha	523	589	408	557	565	528	720
NSW	Ha	289	263	257	202	238	250	400
TOTAL	Ha	***812***	***852***	***665***	***759***	***803***	***778***	***1,120***
Production								
QLD	Tonnes	1228	1331	963	1406	1226	1231	2600
NSW	Tonnes	870	785	573	700	950	776	1400
TOTAL	*Tonnes*	***2098***	***2116***	***1536***	***2106***	***2176***	***2006***	***4,000***
YIELD	*t/ha*	***2.58***	***2.48***	***2.30***	***2.77***	***2.71***	***2.58***	***3.6***

Production figures: Australian Bureau of Statistics * Estimate of author

Sorghum is the preferred grain for ethanol because it is generally cheaper than wheat and produces more ethanol per tonne due to a higher starch content (See Appendix 1).

If grain prices rise, sorghum production is likely to meet an additional 800,000 tonne demand along with the additional demand from beef feedlots (See Appendix 3).

There is potential to lift average sorghum yields by 1 t/ha and with an increase in the area grown, sorghum production in Australia is likely to reach 3.5 to 4 million tonnes by 2012. As sorghum production expands, wheat is likely to be in shortfall in Queensland more often than sorghum.

2. Improving yields of grain sorghum

The yields of sorghum are highest in the coolest growing areas, such as Quirindi and Warwick, where dryland yields reach 10 t/ha in 20% of years and average yields of more than 6 t/ha are possible. This yield target can result from the conversion of 400 mm of water (150 mm planting moisture + 250 mm rainfall) by sorghum with a Water Use Efficiency (WUE) of 15 kg/ha/mm.

The yield potential of grain sorghum is above 6 t/ha in cooler growing areas, with 650mm rainfall - where there is a conversion of 400 mm of rainfall at a Water Use Efficiency of 15 kg/ha/mm.

In western growing areas, the WUE is lower, around 11 kg/ha/mm (due to heat and lower yield levels) which results in a yield potential of 3.3 t/ha from 330mm of water use.

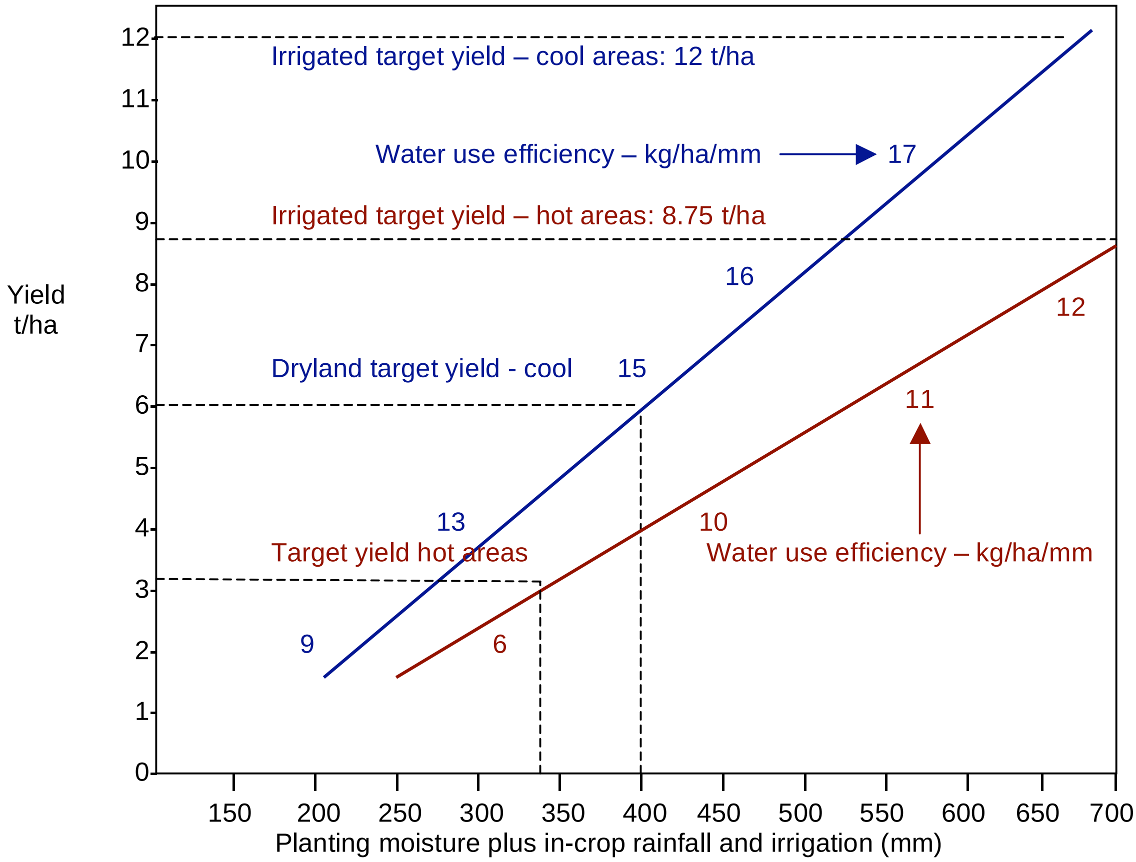
Yield potential of sorghum declines with more heat and less rainfall in the hotter western areas – moving from Quirindi to Wee Waa or Warwick to Roma. Yields of more than 5 t/ha are difficult to achieve in good years in the hotter western areas and average yield targets are more like 3.3 t/ha – resulting from the conversion of 300 mm of water at 11 kg/ha/mm.

To achieve these high average yields, requires good farming practices to conserve and use moisture. Zero-tillage, tramlining, good plant stands, adequate fertilisers, weed and pest control are important.

The main opportunities for improvement in sorghum yields and profitability are:

1. Planting early to help the sorghum avoid summer heat.
2. Moisture seeking planting.
3. Zero-tillage and tramlining.
4. Spray-out of sorghum boosts moisture for the next crop.
5. Avoid or minimise grazing of sorghum crop stubbles – it will reduce the yield of the next crop.
6. Growing some sorghum on long-fallow from wheat – particularly in the hot-dry areas.
7. Adequate nitrogen applications – up towards 17 kg N/tonne of yield potential.
8. Making the most of the good seasons – requires a good nutrient supply with something in reserve.
9. Accurate control of plant populations and tillering to avoid too many plants in moisture stress situations.
10. Good weed control.
11. New varieties selected for either cold start ability or heat tolerance
12. Selection of sorghum for improved digestibility or improved starch content (for ethanol).
13. Seed dressings to reduce pythium and other soil borne diseases – particularly at cold planting times.

Figure 1: Sorghum yield and water use efficiency in cool and hot growing areas



Prepared by the author from numerous data sources. Yield targets are the potential yield with good management, not current practice.

3. Fallow management for sorghum

Zero-tillage is an essential part of modern farming. It can store extra moisture, which produces 10- 25% extra yield of grain sorghum – enough to double profitability.

For dryland production, fallow moisture storage is maximised by zero-tillage and good stubble cover.

Many trials conducted over the years have shown sorghum grown using zero-tillage to yield around 25% higher than sorghum on land which has been cultivated, providing nutrient supply is adequate for the higher yields.

Fallow trials at Billa Billa (Thomas 2000) provide an example of this yield gain, where for 6 sorghum crops grown between 1988 and 1995, grain yield improved from 2.48 t/ha when cultivated to 3.05 t/ha when zero-tilled – an increase of 23%.

At Biloela, in 1992, sorghum was double-cropped on wheat after 240 mm of rain was received in November and December. Rainfall between sowing and harvest was 62 mm of which 50 mm fell prior to flowering. This meant the crop had a dry finish. Grain yield for zero-tillage was 2.4 t/ha versus 1.27 t/ha for cultivated treatments.

The researchers note that it is unlikely that the tillage over 3 months resulted in this large yield difference. The response is

Zero-tillage also reduces compaction and improves soil health for long-term productivity.

Improved soil structure and better moisture storage produced 100% more yield when sorghum was double-cropped at Biloela in 1992.

attributed, at least in part, to the long-term effects of 10 years of zero-tillage on the soil.

After 20 years of different tillage treatments, this trial area is showing ongoing benefits to soil health and yield of crops. Three crops have been grown using no-tillage, with the yield on land no-tilled for 20 years almost 90% higher than crops grown using no-tillage but on land cultivated for 20 years (2.7t/ha average yield versus 1.43 t/ha – Freebairn R. 2006).

As well as fallow storage, moisture utilisation during the growth of the sorghum crop is also likely to be optimised by zero-tillage. A higher level of groundcover will slow reduce runoff and slow evaporation.

Farmers have also found that zero-tillage provides a much greater chance of being able to use moisture seeking planting for an early plant of sorghum on land fallowed from wheat. Moisture stays closer to the surface and in some cases it has been possible to plant sorghum in September, many weeks after the last fall of rain.

Sorghum sprayout

Sorghum can be sprayed pre-harvest with glyphosate to kill the plant. Around 90% of the crop should have reached physiological maturity – with a black layer showing on the grain or the grain in the hard dough stage.

Advantages are that it stops further water use, hastens ripening on late tillers and kills any late weeds. The dry down period to harvest is slightly shorter and the harvesting of a high yielding crop is easier following spraying as the plant material seems to go through the header better.

4. Planting time for sorghum

Optimum Water Use Efficiency (WUE) for sorghum planted in September at Dalby is 16 kg/ha/mm. This is estimated to fall by 33% to 10.8kg/mm for a mid December plant.

Early planting of sorghum can help to avoid hot weather. In general, the earlier the planting date the better. This means a compromise between soil temperatures for good sorghum emergence and trying to get the crop in early to result in avoiding heat and achieving better WUE.

Heat affects sorghum in several ways:

1. Reducing the time from emergence to flowering
2. High night temperatures result in higher respiration levels and less efficient photosynthesis
3. Temporary wilting occurs during the heat of the day
4. Severe temperatures can affect head development

The combination of these factors reduces water use efficiency – resulting in the crop using more water in hot weather to grow the same yield.

The effect of heat has implications for planting time. The effect of delay in planting time for wheat is well documented, with a halving of water use efficiency from around 12 kg/ha/mm at the optimum planting date in May to 6 kg/ha/mm for wheat planted in late July (WUE calculated without subtracting evaporation).

Sorghum is not as greatly affected by heat as wheat, but there are similar effects. The estimated WUE of sorghum from an early plant at Dalby is 16 kg/ha/mm, which drops by 33% to 10.8 kg/ha/mm in December. These estimates and the potential yields at Warwick, Dalby and St George are documented in Appendix 3.

If the effects of extreme heat are taken into account as well as high night temperatures, then planting times from late October to early December, which result in sorghum flowering in January may be the least efficient. Water Use Efficiency appears to improve for plantings after mid-December, corresponding to less extreme heat in February than January.

There is a conflict between ideal soil temperatures and getting the crop in early to avoid heat.

Cold soil planting is less of a problem with modern planters insecticides.

Sorghum will establish at much lower temperatures than the 17-18 degrees C, which is generally recommended.

By selecting cold tolerant varieties, using good insecticide treatment and accurate shallow planting of seed with disc planters, sorghum can be established at much lower temperatures than the 17-18 degrees C, which is generally recommended. Sorghum will still come up at much lower temperatures, it will just take longer and is more prone to disease and insect attack.

Another reason to ignore soil temperatures is that they only reflect the weather over the past few days. What is important is the temperatures over the next week or two after planting.

The alternative to using soil temperatures is to plant according to the expected end of the frost season in a particular locality and paddock on the farm. This means sorghum planting might start around the second week in September in western areas (eg Moree and Roma) – allowing 10 days for emergence before the end of the frost period.

Around Dalby the earliest start of a planting period with reasonable risk is around the third week in September, and a week or two later at Warwick.

Attempting to plant as early as possible means replanting may be needed on occasions, but this will usually be when there is rain soon after planting under cold conditions. The benefit is likely to be better crops in 9 years out of 10.

5. Plant populations and row spacings for sorghum

Plant population is more important than rowspacing

Target populations related to yield are:

40,000 for 3 t/ha
60,000 for 5 t/ha
80,000 for 6.5 t/ha

A large number of row spacing and population studies in sorghum have failed to establish optimum row spacing and plant population estimates (Myers and Foale, 1981).

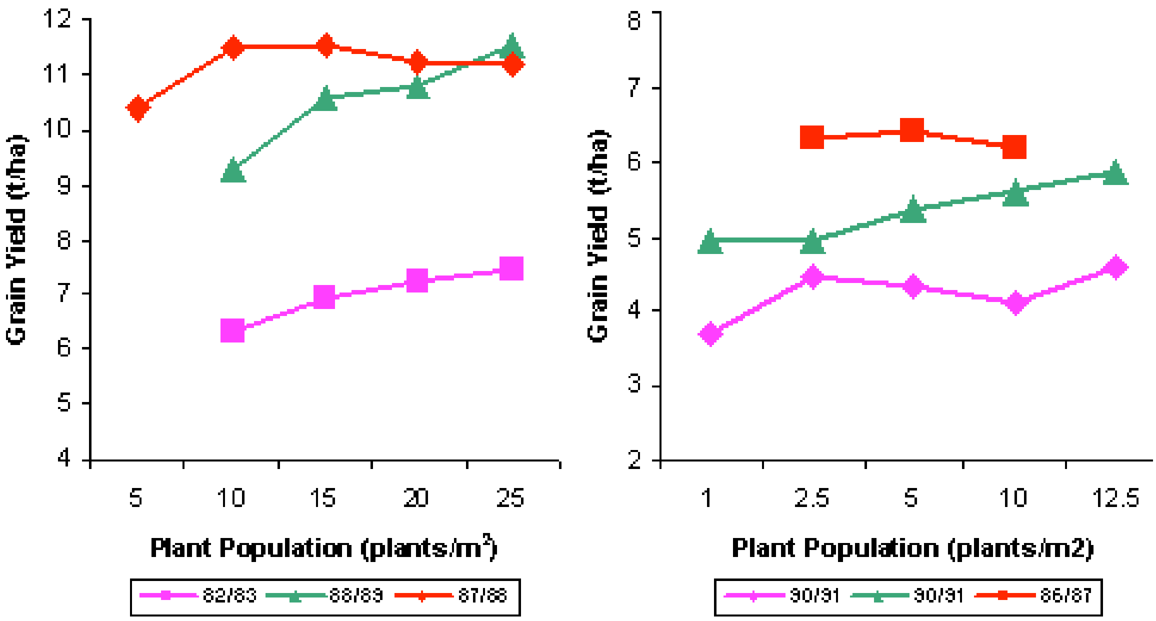
However, some past research has resulted in estimating desirable plant population in sorghum. Thomas et al (1981) suggested a plant population of 60000-80000 plants/ha.

Maximum yield for a range of hybrids at each yield level did not differ significantly from yield at a density of 75000 plants/ha (Wade and Douglas, 1990). They suggested highest grain yields would be obtained with a plant population between 50,000-

100,000 plants/ha under dryland conditions. Butler (2003) supports a plant population of dryland sorghum on the Liverpool Plains of between 50,000 and 80,000 plants/ha.

In lower yielding situations, recent trial work shows plant populations of 40,000/ha to be adequate. See figure 3.

Figure 2: Impact of plant population on sorghum grain yield under (a) irrigation and (b) dryland conditions on the Liverpool Plains. (Dale, 2003)



Early research concluded narrow rows (0.35m) had a greater yield potential than wider rows (0.7 or 1.0 m rows) under favourable conditions, but was also more susceptible to crop failure under water stress (Bygott 1956). Results from Holland and McNamara (1982) suggest increasing row spacing from 0.3 m to 1.20 m can reduce yields (Fig 3).

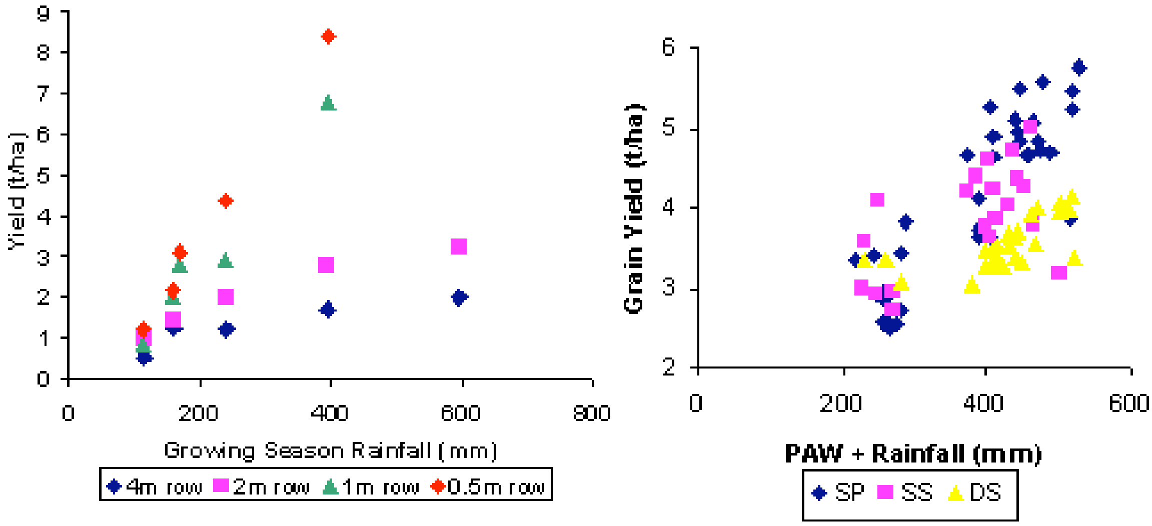
Skip row sorghum

In the drier sorghum growing areas, skip row planting configurations have been used to improve sorghum's reliability. Some spectacular results sometimes occur in dry seasons, where skip-row sorghum can produce a yield of around 2 t/ha, while there has been no harvest of sorghum on one metre rows.

Growing sorghum using skip row configurations involves the suppression of early plant growth which is likely to make more water available at flowering time. Sorghum roots take time to extract moisture from the inter-row space of wide rows, which further delays the onset of moisture stress.

However, the reduction in plant biomass as a result of skip row configurations will reduce grain yield, as the potential yield increases above 2.5 t/ha.

Figure 3: Impact of row spacing on yield as influenced by available water (a) Source: Wade et al (n.d.) and (b) data from skip row sorghum research by Butler G.



Four trials conducted as part of the GRDC Western Farming Systems project presents a typical range of outcomes.

In two of the trials, at Billa Billa and Bungunya, there was no difference between 1 metre row spacing of sorghum and single skip and double skip rowspacings, where there is a gap of 2 metres and 3 metres respectively on each side of two sorghum rows. The mean trial yields of these two trials were 2.8 and 2.7t/ha respectively.

In a trial at Croppa Creek, with higher yields, the 1 metre sorghum and single-skip sorghum yielded 5.5t/ha, but the double skip yielded less at 4.5t/ha.

The fourth trial, harvested at Billa Billa in 2002, had the reverse trend where double skip sorghum showed a slightly better yield of 2.8 t/ha, than sorghum in one metre rows which yielded 2.6 t/ha.

The results of these trials are shown in Table 2 along with many other comparisons made in recent years.

In central Queensland, eleven trials conducted between 2001 and 2004 showed yield benefits from wide-rows when sorghum yields were below 3 t/ha. Out of 11 trials, 5 showed a gain, 3 trials showed a penalty from using wide rows and 3 trials showed no difference (Collins *et al.* 2006).

Long-term modelling for Central Queensland, showed there are more years in which 1 metre rows would produce greater yields than wide rows (Collins *et al*. 2005) However, since 1990, when yield potential has been lower than the long term average, this analysis showed a benefit in yield slightly in favour of wide rows.

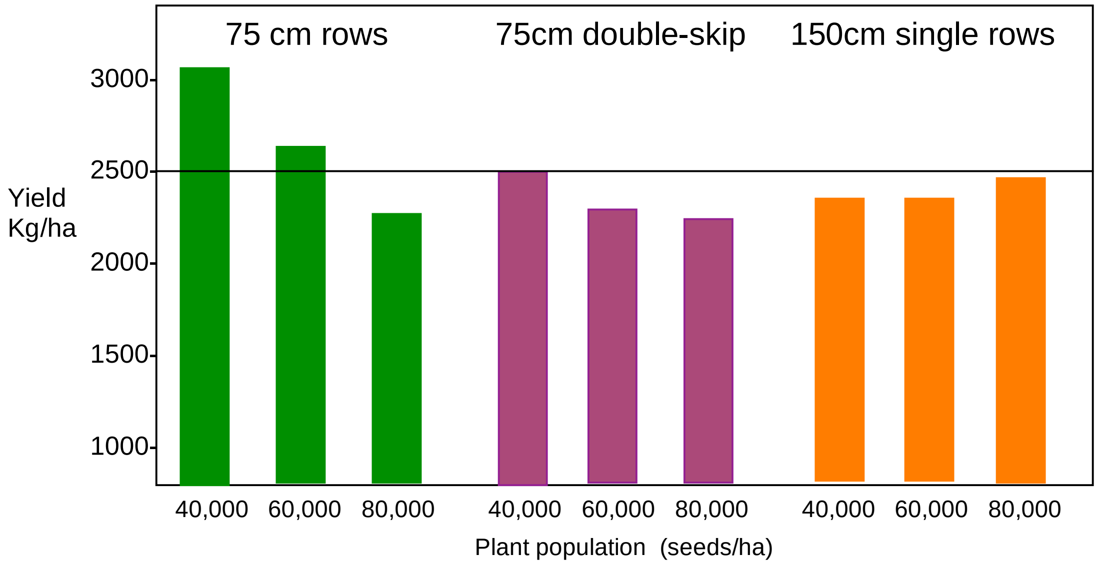
Modelling of sorghum at Dulacca (Hammer 2001) suggested a lower yield threshold of 2 t/ha for penalty from double-skip rows. In this analysis, the ratio of sorghum yield for double-skip rows to that of solid planting was 88% at 3 t/ha and 75% at 4 t/ha.

Table 2: Skip row trials on grain sorghum at various locations:						
Location	Plant date	In-crop rain	Plants/ha	1 metre rows	Single skip	Double-skip
Croppa Creek[1]	6/11/00	409	75,000	5.53	5.6	4.54
Billa Billa[1]	13/11/00	324	81,000	2.91	2.63	2.85
Bungunya[1]	13/12/01	165	46,000	2.62	2.74	2.63
Billa Billa[1]	11/02/02	253	77,000		2.57	2.81
Biloela[2]	7/11/77	594	42,000	3.47	2.96	1.99
Theodore[2]	17/2/78	165	55-73,000	1.8	1.23	1.2*
Croppa Creek[3]	20/10/99	290	60,000	5.1	4.3	3.5
Moree[4]	25/9/04	n/a	42,000	4.04	3.2	2.46
Goondiwindi[4]	5/10/04	n/a	45,000	7.05		4.86
Yallaroi4	27/9/04	n/a	60,000	8.27	5.7	5.11
Moree[4]	27/9/04	n/a	50,000	4.36	3.81	3.86
North Star[4]	27/9/05	n/a	44,000	4.67	5.37	4.04
Westmar[4]	20/9/04	n/a	40,000	4.26	3.8	3.70
Myalla[4]	21/12/04	n/a	40,000		1.86	2.1
Average of these trials				4.5	3.5	3.4
1. Routley et al. 2006; 2. Thomas et al 1981 * 4 m twin rows 3. Butler et al 2001 4. Trials conducted by Pacific Seeds						

An important aspect of wide row sorghum is that when planted closer together in the row, sorghum does not tiller as much and will produce less vegetative growth. This can be an advantage in dry years and help to ration the water in a dry season. However, plant stand is often less in wide rows and if it is too low, the yield penalty in better years can be considerably more than at higher population levels.

A number of trials have demonstrated this effect to show the optimum plant population in wide rows is higher than narrow rows (Thomas et al 1981). In a trial at Condamine (Bidstrup 2001) demonstrated a fall in yield potential as plant population increased for 75cm rows, while there was an increase in yield as plant population increased for 150 cm rows. See Figure 4.

Figure 4: Impact of plant population and rowspacing on sorghum grain yield at Condamine (planted 5th December 2001 - variety Bonus. (Bidstrup, 2002)



Each year and each sorghum crop is different. In the example shown in Figure 3, the sorghum is a low tillering variety planted during the heat of summer. A high-tillering sorghum variety planted early in the season may show a different trend.
It is important however not to consider row spacing without consideration of plant population. In the situation of this trial it was more effective to reduce the biomass of the sorghum crop by reducing the plant population than by extending the row spacing.

Because farmers across most of the northern grain belt should be targeting average yields of more than 3 t/ha, they should generally use a rowspacing of one metre with a low plant population of 35-40,000 plants per hectare in western areas, and increase plant populations with yield potential.

When moisture reserves are low or yield potential is in doubt wide row sorghum may provide a more reliable outcome.

In higher yielding situations, rowspacings around one metre with plant populations of 60-80,000 are a good compromise. While rowspacings of less than one metre may improve yield in some situations, this is mostly due to increased tillering which can be compensated for by higher population. However, moisture remains the limiting factor in most years and having too many plants or too many tillers (with narrow rows) can result in negative effects in years which turn out below average.

6. Sorghum planting

Establishment of grain sorghum has improved in recent years with better planters and improved insecticide treatments which have residual effects on insects which eat the emerging seedling as well as the seed.

Whereas conventional planters in the past have typically only resulted in 40-50% of seeds established as plants, the use of disc planters, presswheels and modern insecticides commonly achieve 70-80% establishment.

Airseeders and a toolbar fitted with single disc openers have performed well in planting sorghum. Extra benefits of precision spacing may occur with maize and sunflower, but sorghum is more flexible and can make up for uneven spacing within the row.

Depth of sorghum planting should be varied in response to moisture and temperature. Planting should be as shallow as possible (around 5 cm) under cool soil temperatures, with depth increasing under hot-dry conditions. Sorghum has been observed to have better emergence from 8-10 cm depth under high temperatures which rapidly dry out the soil surface.

In the 1980's various treatments, including seed soaking and water injection were trialed by farmers in attempts to try and improve sorghum establishment.

Radford and Nielsen (1985) trialed the effects of presswheels, seed soaking and water injection at nine sites in southern and central Queensland. While press wheel compaction hastened and improved the emergence of sorghum in all situations, seed soaking and water injection had little effect on hastened emergence and no effect on the final emergence. Radford concludes that press wheel compaction at 4 N/mm width of presswheel is generally recommended for sorghum sowing.

Trashwhippers can be fitted in front of disc openers to sweep aside some soil and enhance moisture seeking.

Mounted harrows behind the press wheel will level out the ground and stop the pressed ground drying too fast in hot weather.

Moisture seeking planting

Sorghum has been successfully sown onto deep soil moisture several weeks after rain, in early Spring. There is a conflict between sowing shallow because temperatures are cold and having to dig deep to find moisture. There is also a problem in getting disc planters to plant deeply.

One way to assist disc planters plant deeper for moisture seeking is to remove soil in front of the disc units, using a tyne or trashwippers. Often it will need only a small amount of dry soil to be removed to allow the disc opener to penetrate to moisture.

The disc opener generally does not need to plant as deeply as a tyne because it does not mix wet and dry soil.

Leaving a significant trench over the seed can be a disadvantage if rain falls, while the sorghum is emerging. It can be particularly significant if atrazine has been used as a pre-emergence weedicide. The rain will concentrate the atrazine in the seed trench and may reduce the establishment of the sorghum under cool conditions.

Provided the seed is not too deep, raking a little loose soil over the seed trench can help reduce this problem. It can also help to stop the seed trench drying out and cracking when conditions are tough. Some farmers fit chains or mounted harrows behind the planter to bring some loose soil back over the row.

7. Nutrition and fertilizers for sorghum

Over the 2003 and 2004 summers, sorghum yields on the Darling Downs reached 8 t/ha., with the best crops producing around 17kg/ha of grain for each mm of water available. In some cases starting moisture was low with only 100mm of soil moisture at planting, but with rainfall of 440mm, the yield potential from a total of 540mm of water was 9 t/ha.

But many crops did not reach this level. In these big years, nitrogen becomes one of the most important limitations. As yield levels rise and soil fertility declines, nitrogen fertiliser become more important.

Sorghum requires a total of 25 kg of nitrogen (in round figures) per tonne of grain yield, with 17kg/ha of N removed in grain which has 10% protein. (Divide kilograms of protein by 6 to get an approximation of N/t.) This means a 6 t/ha crop requires around 150kg N/ha and 100 kg of N is removed in the grain.

Table 3	Yield targets and N removal for grain sorghum				
	Soil moisture	In-crop rainfall	Water use efficiency*	Target Yield	kg N # removed
Cool areas – better soils (Darling Downs – Liverpool plains)	160	250	15	6.15	102
In between areas with brigalow and box soils	150	250	13	5.20	87
Hotter areas - Moree, Condamine, Roma	130	205	10	3.35	61

* WUE kg/ha/mm of soil moisture at planting plus in-crop rainfall
# Kg N removed based on 10% protein grain: Darling Downs and 11% at Moree

Nitrogen is the main nutrient required for sorghum.

At Colonsay, on the Darling Downs, sorghum responded to P fertilizer, but the small increase in grain yield, contributed only 10% of the profit from fertilizer use, with N fertilizer contributing around 90%. (Lester 2005)

A newly cultivated soil with 1.6% organic carbon can mineralise in excess of 80 kg N/ha/year, but a 80 year old paddock with 0.8% organic carbon is likely to mineralise only 40 kg N in a year.

A nitrogen budget should therefore start with a yield target and then deduct the expected contribution from soil mineralisation. For example a yield of 5.2 t/ha (at 25 kgN/t of yield) requires 130 kg N/ha (for 10% protein grain). If the soil reserve plus mineralisation during summer is expected to be 50 kg N/ha, then the fertiliser requirement is 80 kg N/ha.

Extra soil mineralisation will help produce a good crop in a wet summer. As soils get older, and organic matter declines, this inbuilt fertility is unable to keep up with the demand from a big sorghum crop. If the crop yield potential increases from 5.2 t/ha to 7.5 t/ha, an extra 57 kg of N is needed. Yield will fall short if we have only fertilised for the average crop year.

As yield increases and there is a shortfall of nitrogen, grain protein will decline – sometimes as low as 6%. The total N requirement of an 8 t/ha sorghum crop at a grain protein level of 6.5% is 142 kg N compared with 190 kg N at 10% protein. However, it is generally

Fertilise for average yields and that is all you will get!

To make the most of big yielding years more N needs to be in reserve or applied.

thought that the maximum yield is achieved with grain protein at 9-10% protein, and at lower levels yield is being compromised by a lack of N. (Cahill and Strong 1996)

Strategies to supply N for big yielding crops:

1. Have a pool of N in reserve. This may mean not cutting back on N after a bad season. Soil tests might indicate N left over from the previous crop, but cutting back on N will also cut back the yield potential.
2. Use feedlot manure to boost the organic N levels in the soil and provide more reserves to release more N in a good summer.
3. Applying more N after planting when seasonal conditions are looking good.

Having some N in reserve is like trying to reverse the clock and build a better pool of organic matter and/or have surplus Nitrogen in the soil profile.

Soil N will build up if fertiliser is in excess of requirements in dry years. As long as this is removed every few years, by a big sorghum crop, before it moves too far down and is lost, the efficiency of fertiliser use will be good on deep clay soils. A little extra N will be removed by way of higher grain protein levels in the moderate yield years, but by and large losses of N from fertiliser will be minimal.

This is confirmed by research at Warra (Strong 2005). Over 4 years, the losses from N fertiliser application varied from 5% in a dry year to 26% in a wet year, mostly through denitrification. These years included two years of above average rainfall and Strong suggests the average loss on clay soils is likely to be around 10%. Small amounts of N coming into the soil system from free living algae and lightning during thunderstorms will help to balance these losses.

It makes sense then to move nitrogen fertiliser rates up to crop removal levels, where soil organic matter has declined after 50 or more years of cropping. Some farmers at Dalby are using N at slightly more than removal level on sorghum and have been able to measure an increase in soil organic matter after some big sorghum crops. It should be remembered that any increase in organic matter means extra nitrogen is needed to go into this long-term organic storehouse.

Nutrient removal

Nitrogen is the main nutrient required for good sorghum yields, with total requirements of 85 kg N for a yield of 3.5t/ha, 130 kg of N/ha for a yield of 5.2 t/ha and 150 kg N/ha for a yield of 6 t/ha.

As the soil N level runs down, nitrogen fertiliser rates should be moved up towards the grain removal levels: 60, 86 and 100 kg N/ha respectively (See table 4).

Table 4.	Nutrient requirements of sorghum*				
Sorghum yield	N in grain (10% protein)	N in stubble	Total N required	P removed in grain	K removed in grain
3.5 t/ha	60	25	85	8	12
5.2 t/ha	86	43	130	12	17
6 t/ha	100	48	150	15	20
* Fertiliser requirement depends upon the supply of nutrient from the soil and objectives such as fertility maintenance.					

Sorghum is extremely efficient in extracting P from the soil and a critical threshold for P response is usually around 15 ppm Bicarb P.

However, farmers are using 'sub-maintenance' applications of P fertiliser to help maintain soil fertility and overcome early P needs under cold conditions.

Phosphate removed in grain for a 5.2t/ha crop is in the vicinity of 12 kg P, which equates to 60 kg of MAP. In practice such a high rate may not be needed. The recommended rate will depend upon the soil test level and the recent history of P application.

If the soil test (bicarb or Colwell P) is over 15, then there is a low probability of sorghum responding to P fertiliser. This critical value is half that of wheat, reflecting the efficiency with which sorghum is able to extract P from the soil. Sometimes there is an early response to P, but as the root system and mycorrhizae (VAM) develop this can disappear.

In a mixed sorghum and wheat cropping system, it may be worthwhile fertilising the wheat crop and not the sorghum. However, if soil phosphate is marginal (15-30 ppm Bicarb P test) P fertiliser should be considered when it is planted on a long-fallow after wheat in a situation where VAM levels are low.

The use of P fertiliser is also recommended under cold start conditions, if soil levels are marginal.

P fertiliser is usually applied with the seed, but the suggested maximum rate of MAP on sorghum planted on clay soils in 1 metre rows is 50 kg/ha. This 'safe' rate should be reduced on loamy soils. If more P needs to be applied than this, it needs to be put on away from the seed, either in a separate mix with the N fertiliser or in a separate band.

One of the most economical and effective ways to supply P to sorghum crops is to use feedlot manure. One tonne of aged manure contains around 7 kg P, which means an application of 8 t/ha will supply 56 kg of P/ha, enough for 4-5 crops of sorghum, and longer if the soil P levels are reasonably high and the strategy is to apply around 7-10 kg P/ha/year.

Feedlot manure is an economical way of supplying P and helping to provide a reserve of N – in organic form – to boost yields in high yield summers.

Feedlot manure also applies large quantities of potassium and sulfur which will ensure there are no deficiencies relating to these nutrients. The N component of the feedlot manure adds to the value. In a good summer season, around half the total N should be released during the first crop. If 8 t/ha of manure is applied, this means that of the 128 kg of N in this manure around 64 should be available to the sorghum crop, and could be deducted from the fertiliser requirement.

In subsequent years, the extra N release should be considered a bonus which may boost yields in a good year. In this way manure applications can provide a little extra reserve of N, in an organic form, which can help boost yields in a wet summer.

Table 5.	Nutrient content and value of Feedlot manure				
	Water content	Nitrogen	Phosphorus	Potassium	N & P
Aged manure (wet)	26-32%	16	7	18	
Value of nutrients*		$16	$20	$16	$36
* Nutrients valued at cost of Urea, MAP and MOP.					

For farms within 60 kilometres of a feedlot, the cost of manure is typically around $22-25/t, spread on the paddock, which means manure is good value compared with the equivalent cost of N and P totalling $36. If potassium is of use, the value of nutrients in manure is over $50/t.

8. Weed and pest control

Good weed and pest control are required for optimum sorghum yields. Competition from weeds is one of the main reasons for poor yields in western sorghum growing areas, where farmers have in the past been reluctant to spend money on weed control.

Atrazine is commonly used for weed control, and if grass weeds are a problem, it is usually a good investment. However, it is not effective on urochloa and other strategies should be considered if this weed is present. These include:

1. Use of metalochlor (Dual or Primexta) which provides better control of urochloa. Rain is needed within 10 days to activate this herbicide before too much is lost from the soil surface. However, the longer the time period between planting and the rain which germinates the weeds, the less of a problem is the urochloa, because of more competition from the sorghum. Because of high cost, metalochlor is commonly used as a band spray.
2. Shielded sprays to control weeds in the row with glyphosate. This is a risky operation, particularly with young sorghum. A small amount of spray drift can stunt the sorghum. Calm weather, smooth fields, low drift nozzles and pressures are important. A disadvantage of inter-row spraying is that weeds in the row are not controlled. It is sometimes used in conjunction with a band spray of weedicide at planting time.
3. Integrated weed management of urochloa. This involves consistently good control of urochloa in crops and fallows (particularly after wheat) to prevent it seeding.
4. Delayed sowing of sorghum (late December or January) after several germinations of urochloa.

Atrazine is effective for control of multiple germinations of fleabane and could be applied in advance of sorghum planting in this role.

For most other broadleaf weeds, in-crop weed control is used rather than pre-emergence applications of weedicide. A common herbicide mixture for in-crop weed control is 1.5 l/ha of atrazine plus 0.5 l/ha or starane. Such a mix has been found not to affect the yield potential of sorghum, whereas other herbicide mixes containing Tordon, dicamba or 2,4-D have been known to affect sorghum at times.

Formulas for economic thresholds for midge and heliothis may not work in practice.

Damage from 1 or 2 midge per head is likely to be compensated by increased grain weight from the remaining grains.

Early counts of heliothis commonly decline by 50-80% due to predation and disease.

Midge and heliothis control

Early planted sorghum is unlikely to experience serious midge infestations. Cold-tolerant varieties such as MR Maxi have a midge rating of only 3, but this is usually sufficient to match early midge infestations. Around 6 midge per head would be required before spraying a MR3 rated sorghum would be considered.

Formulas for midge and heliothis spray thresholds may not be terribly useful in practice. They do not take into account the potential for compensation by the sorghum head. Midge affects grain numbers before they develop and the damage from 1 or 2 midge per head is likely to be made up for by increased grain weight from the 75-85% of remaining grains.

Damage by heliothis is less likely to result in compensation by other grains, because the larvae are eating starch. However, there is often a considerable mortality rate in heliothis (predators, parasites and disease) which is not accounted for by the formulae for thresholds. It is common for an early count of 4 to 6 larvae per head to decline by more than 50%, by the time the larvae reach their main damage stage (around 2-3cm long), and early estimates of damaging populations may end up to be not worth spraying.

Control of heliothis has been effective by using virus sprays, provided the control is early enough and larvae populations are not too high.

9. Profit from sorghum and other grain crops

Extra yield and a higher price results in irrigated corn being the most profitable summer grain crop in the cooler growing regions, such as the Darling Downs and the Liverpool Plains. However, there is little difference between sorghum and corn if water is limited and the final yield is affected by heat or drought.

Sorghum is more flexible than corn with respect to stress and the ability to grow high yields with relatively low plant populations. Corn needs high plant populations for high yields, but if the water supply is limited, the downside from the high plants stand is greater.

Sorghum has a slightly higher yield of ethanol than corn and in years to come, the price for sorghum and corn may be much closer, which will result in sorghum being the most profitable grain crop under irrigation.

Table 6: Profit from Dryland Crops – 2007-08

	Sorghum	**Cotton**	**Wheat**	**Chickpea**	**Wheat**	**Sorghum**
	Cool [1]	Cool [1]	Cool [1]	Cool [1]	Hot [2]	Hot [2]
Yield t/ac	2	1.4	1.5	0.9	1.2	1.33
Yield t/ha	5	3.5	3.75	2.25	3.0	3.3
Farm Price	210	420	250	400	250	210
Gross Return	1050	1470	937	900	750	693
Fertiliser	110	80	96	24	62	45
Seed	36	35	35	48	28	24
Weeds	30	65	12	32	12	36
Fuel & Repairs	90	94	90	90	55	55
Fallow spray	45	60	50	50	36	36
Harvest	45	200	40	50	35	35
Freight	0	40	0	27	36	40
Miscellaneous	18	520	20	60	16	16
Growing cost	374	1094	343	381	280	287
Gross Margin	676	376	594	519	470	406
Overhead costs*	225	260	225	225	115	115
PROFIT $/ha	**451**	**116**	**369**	**294**	**355**	**291**

1. Cooler areas with 650 mm rainfall, such as the Darling Downs

2. Hotter drier areas with 550 mm rainfall, such as Moree, Condamine and Roma

* Administration $25 (hot areas, large farms)- 45 (Cool), Labour $45-90, Machinery $45-90/ha

Sorghum is mostly sold 'on-farm' in cooler areas such as the Downs, with $12/t freight in hot areas.

10. Sorghum in cropping systems

Sorghum can have significant benefits in cropping systems.

It is generally the highest biomass crop in the northern grain region and carbon inputs can help to maintain soil organic matter. By comparison a wheat-long fallow-dryland cotton system can deplete organic matter.

Sorghum in rotation with wheat has significant benefits for weed and disease control.

Sorghum is currently the most profitable crop in the higher rainfall areas of the northern grain belt. If cotton prices improve, then sorghum could still play a part in an overall rotation strategy to diversify the summer crop planting and include a high biomass input crop to help maintain soil organic matter levels.

A continuous sorghum cropping system is likely to have more than twice the biomass (organic carbon) input than a wheat–long fallow-dryland cotton rotation.

In a cotton system which includes dryland cotton, sorghum can be grown in the summer following cotton. If the winter season following cotton is dry, sorghum planting may be late rather than early, which reduces the chance of a double-crop change back to a winter crop. In years when there is average to good winter rain, it may be possible to plant dryland cotton after sorghum.

Profit margins show sorghum may be almost as profitable as wheat in western growing regions, if slightly more yield can be achieved to make up for a lower price. See Table 6. In recent years, the price of feed wheat has been similar to prime hard wheat and if sorghum is used for ethanol production, the price premium for wheat over sorghum may decline further. This could make sorghum more profitable than wheat in these areas.

Even if sorghum is not as profitable as wheat there may be benefits in the cropping system. Having summer crop as well as winter crop spreads risk and the workload, which reduces demand for labour and machinery and diversified farms can operate with smaller machinery. For example a 2000 hectare farm might need more than one planter and harvester if it grows only winter crop, whereas one machine may suffice if a significant area of summer crop is planted each year.

Rotation benefits can be substantial from a period of sorghum in a wheat cropping system:

1. A disease break for wheat diseases, such as crown rot and for nematodes.
2. Control of difficult weeds such as wild oats, sow thistle and fleabane can be improved with summer-winter crop rotations.
3. Sorghum rotations can be used to help prevent herbicide resistance.

References:

Bidstrup, R. 2002. Comparisons of Rowspacings & Plant Populations in Grain Sorghum – "Callitris" Trial, Condamine. Unpublished trial report, Pioneer Hi-Bred Australia.

Butler, G. et al. 2001. Skip row sorghum and double crop opportunities. Aust. Grains Field Research Manual. GRDC. 13-14.

Butler, G. 2003. Population density studies in sorghum and wheat - What are the impacts of varying populations and row configuration? GRDC Research Update for Growers - Northern Region - September 2003

Bygott, R.B. (1956). Qld. Ag. J., 82, 581-584.

Cahill, M. and Strong, W. 1996. Are district nitrogen recipes obsolete. 8th Aust. Agron. Conf. Perth. www.regional.org.au/au/asa/1996/contributed/108cahill.htm#P1_39

Collins, K. 2006. Economics of Biofuels: Ethanol and Biodiesel. Statement of Keith Collins, Chief Economist, USDA before the US Senate Committee on Environment and Public Works. www.usda.gov/oce/newsroom/congressional_testimony/Biofuels%20Testimony%209-6-2006.doc

Collins, R. et al. 2006. Manipulating row spacing to improve yield reliability of grain sorghum in central Queensland. 13th Aust. Agron. Conf. Perth. www.regional.org.au/au/asa/2006/concurrent/systems/4522_collinsr.htm

Collins, R. et al. 2005. Matching sorghum rows to rainfall outlook. Aust. Farm J. 16. (2) 37-38.

Downes R.W. 1972. The effect of Temperature on the Phenology and Grain Yield of Sorghum Bicolor. Aust. J. agric. Rex., 1972, 23, 585-94

Freebairn, R. 2006. Research targets slow No-Till response. *Groundcover.* Sep-Oct. GRDC.

Hammer, G. et. Al. 2001. Economic theory of water and nitrogen dynamics and management in field crops. Proc. Fourth Aust. Sorg. Conf. Kooralbyn. CD Rom.

Hammer, G. 2004. Balancing water capture and crop management in sorghum. GRDC Update, Goondiwindi.

Lester, D. and Dowling. C. 2005. Long-term Fertiliser Use: The "Colonsay" and Tulloona Experiments. Proc. Long-term Fertiliser use workshop. Toowoomba.

Mclean, G. et.al. 2006. The effect of row configuration on yield reliability in grain sorghum: II. Modelling the effects of row configuration. 13th Aust. Agron. Conf. Perth. www.regional.org.au/au/asa/2003/c/9/mclean.htm

Munchow, R. and Coates, D. 1986. An analysis of the Environmental Limitation to Yield of Grain Sorghum in the Dry Season in Tropical Australia using a radiation interception model. Aust. J. Agric. Res. 37, 135-48.

Radford, B. and Nielsen, R. 1985. Comparison of a press wheel, seed soaking and water injection as aids to sorghum and sunflower establishment. *Aust. J. Exp. Agric.* 25. 656-64.
Rendell S. 2004. Fuel ethanol production in the Murray and Murrumbidgee river regions of Australia. GRDC Research updates: Griffith and Moama. www.grdc.com.au

Roe, J. et.al. 2006. Another Plant!.. The rapid expansion in the ethanol industry and its effect all the way down to the farm gate. American. Agric. Econ. Assoc. Annual Meeting. Long Beach. CA.

Routley, R. et.al. 2006. The effect of row configuration on yield reliability in grain sorghum: 1. Yield, water use efficiency and soil water extraction. 13th Aust. Agron. Conf. Perth.

Strong, W. 2005. Nitrogen results from the Warra Long-term Trial. Proc. Long-term fertilizer workshop, Toowoomba.

Thomas, G. 2000. Billa Billa Fallow Management Experiments, GRDC report, Project DAQ 196.

Thomas, G. et al. 1981. Evaluation of row spacing and population density effects on grain sorghum over a range of northern Australian environments. Aust. J. Exp. Agric. Anim. Husb. 21.: 210-217

Tiffany D. and Vernon R. 2003. Factors Associated with Success of Fuel Ethanol Producers. Dept of Applied Economics, College of Agricultural, Food and Environmental Sciences.

Wade, L. 1986. Adaptation of grain sorghum in semi-arid environments – a direct testing approach. Proc. First Australian Sorghum Conference.

Wade, L. and Douglas, A. 1980. Effect of plant density on grain yield and yield stability of sorghum hybrids differing in maturity, *Australian Journal of Experimental Agriculture* 30(2) 257 – 264

Wade L.J. and Hammer G.L. 1986. Agroclimatic Analysis for Grain Sorghum in Australia: 1. Temperature and Solar Radiation. Proc. First Australian Sorghum Conference.

Wilson G.L. 1986. Review of Crop Physiology. Proc. First Australian Sorghum Conference.

Zavala-Garcia. F. (date unknown) Lack of genetic adaptation and its effect on dark respiration. www.publish.csiro.au/paper/SA0403379.htm

Appendix 1: Increasing demand and price for sorghum

Why sorghum is better for ethanol?

Ethanol is produced from the starch and sorghum has a high starch content compared with other grains. However, the starch content of grain can vary considerably. For instance, small droughted grain will have a higher protein and fibre content, compared to large plump grains. Grain size per se has not been correlated with starch content however.

The benchmark for ethanol production is now 2.75 gallons of anhydrous ethanol per bushel of corn. This has risen from 2.5 gallons per bushel, due to better enzymes and sophisticated process controls which foster yeast activity in the ethanol process. (Tiffany 2003)

This equates to 410 litres of ethanol per tonne of grain (3.785 litres per US gallon and 39.37 bushells per tonne – NB. there are 38.83 bushells in a short ton, used in the US which means the yield is 404 l./short ton). Assuming the starch content of corn is 60% for 14% moisture grain this equates to 683 litres of ethanol per tonne of starch.

Table 7: Ethanol production from various grains

	Starch % dry basis	Starch in 14% moisture grain	Ethanol Litres per tonne
Sorghum	74	64	437
Corn	70	60	410
Wheat	65	56	382
Barley	60	52	355
Source: Modified from data by Rendell 2004			

Some reported values for the starch content of wheat are in the vicinity of 70% (dry basis), which may mean wheat is not as bad for ethanol as shown in Table 7. But, as for sorghum, there is likely to be variation in the starch content of wheat between varieties and according to seasonal conditions and soil fertility, which affect other characteristics, such as plumpness and protein content.

Feed grain supply and demand

The demand for feed grain in southern Queensland, including the South Burnett, is estimated to be in the vicinity of 1.8 mil.t. (Table 8). This could well increase to 2.2 mil. tonnes by 2010 as feedlots expand and pig and poultry production increase to meet the demands of increasing population in S.E. Queensland.

Assuming the potential for the use by ethanol plants to increase grain demand by 660,000 tonnes over the next five years, the total demand might increase to around 2.6 mil.t. after using 800,000 tonnes of sorghum and allowing for a return of 240,000 tonnes of distillers grain to the feed market.

This could be met by an expansion of feed grain production, which would be expected as grain prices rise.

During droughts, wheat is used to meet shortfalls of feed grains in Queensland, and wheat is brought northwards over the border from NSW. An increase in feed grain production is likely to be at the expense of less wheat for export, pasture converted back to grain production and less cotton production.

Table 8: Demand for feed grains by major users in Qld ('000t)					
	Feedlots	**Pigs**	**Poultry**	**Dairy**	**Total**
D.Downs	620	180	60	6	866
SE	20	40	260	25	345
Sth Burnett	60	110	0	4	174
W Downs	260	15	0	0	275
QLD rest	90	25	20	15	150
Total 2006	**1050**	**370**	**340**	**50**	**1810**
Feed grain demand 2010	**1400**	**380**	**400**	**60**	**2240**
Ethanol 2010 (assumes 3 plants using 220,000 t/year.					**660**
Total demand feed + ethanol – distillers grains					**2640**

Potential increases in the grain price

Sorghum prices are likely to increase in price due to huge increase in worldwide grain demand from ethanol plants and due to seasonal shortages of sorghum in dry seasons.

According to Roe (2006) high profits from ethanol is stimulating the building of ethanol plants and a continuing increase in grain being consumed for fuel rather than food. Roe suggests that, allowing for increases in corn yield (which adds around 7 million tonnes to production each year) and predicted increases in ethanol production to 2012, an extra 13 million acres of corn will be needed to meet demand.

This target will only be met by much higher grain prices, which will encourage farmers to grow more corn and less soybeans, pastures and other crops.

Over the last 12 months world grain prices have increased by 60 percent, with wheat rising from $A170 to $A250/tonne and corn from $A110 to $200. The increasing use of grains for fuel has tightened up grain supplies, which have now been accentuated by a 15 million tonne shortfall due to the Australian drought.

According to market analyst Ray Grabanski, the pricing of corn and soybeans is now being made as a fuel, not as a feed grain. He says their value as a fuel is higher than the value of grains for food/feed in the past few years and argues that $55 crude oil translates into corn prices around $US4.40 per bushell ($A220/t.)

and $8/bushel for soybeans. Despite big price increases corn and soybeans may still be underpriced

Lester Brown says the conversion of agricultural commodities into fuel for cars is now market driven by the fact that grain is too cheap relative to fuel, and not by government subsidies. Between October 2005 and now, building commenced on 54 new ethanol distilleries in the United States Ethanol production which will consume 39 million tons of grain per year, nearly all of it corn.

The building of ethanol plants is accelerating. From November 2005 through June 2006, ground was broken for one new plant every nine days. From July through September 2006, construction starts increased to one every five days. In October 2006, it was one every three days.

Ethanol production in USA is estimated to increase from 4 billion to 10 bil. gallons by 2010.

This will require an extra 10 million acres of corn, some of which will come from set aside land and some growing corn instead of soybean and pasture.

World grain prices have moved up by 60% this year and will increase further as demand tightens.

It is reasonable to expect Australian sorghum to be in the range $200-$250/t over the next few years.

Grain in the future will be priced as a fuel and will increase if oil prices increase.

By the end of 2007 the amount of grain that will be going into ethanol, will be in the vicinity of 80 million tons of corn per year. This does not include numerous new grain-based ethanol distilleries in other countries, principally those in Europe and China.

This clash between motorists and people over the food supply is occurring when 854 million of the world's people are chronically hungry and malnourished and some 24,000 of them, mostly children, die each day. The U.N. Millennium Development Goal of reducing by half the proportion of people suffering from hunger by 2015 is now failing as the number who are hungry edges upward.

We are not likely to run out of grain however. As grain prices rise, production is likely to increase. US Chief Economist, Keith Collins assumes ethanol production will increase from 4 billion gallons at present to 10 billion gallons in 2010 crop year. He says that if exports and feed use are to be maintained, corn area would have to rise to about 90 million acres in 2010, or nearly 10 million more than the average planted during 2005 and 2006. He suggests, out of a total of 36 million acres in the Conservation Reserve Program, up to 7 million acres is good land for corn or soybeans. He also expects increases in corn and soybean production in Brazil and Argentina.

World wheat prices have moved above $US5/bu. ($A242/t @ an $A value of $US0.75.). With a basis over the Chicago futures price of 70c/bu and FOB costs of $40/t, this equates to a port price of $230/t. The export price for sorghum is now at the same level ($230/t). While the corn price is lower than wheat, there are lower FOB costs for sorghum. Depending upon the basis (possibly around $US0.50/bu) and local demand, the export parity price of sorghum might settle around $250 per tonne, Brisbane for a corn price of $US5/bu.

The long-term relationship between wheat and corn prices in the USA is for around $US1/bu premium for wheat over corn. If wheat production improves and corn is in short supply due to ethanol production, the gap between wheat and corn might reduce.

It is impossible to be accurate with forecasts because of factors like the recent Australian drought. Perhaps the major unknown in the future is the crude oil price.

Appendix 2: Effect of heat on sorghum yield and water use efficiency

Reduced yield potential and lower WUE of sorghum in the western growing areas of Queensland and NSW is likely to be a combination of four effects:

1. ***Reduced time to maturity***
2. ***Wilting of the plant on hot days***
3. ***Photosynthetic efficiency is reduced by high respiration on hot nights***
4. ***The effects of heatwaves.***

Heat acts in several ways to reduce the yield potential and water use efficiency of sorghum.

Reducing the period from emergence to flowering

High yields and high WUE in sorghum are promoted by slow growth during the tillering and head formation stage, moderately hot and humid growing conditions during flowering and grainfill and cool night temperatures.

High temperatures reduce the time to flower, which reduces biomass and yield. This effect is much the same, as short maturing varieties, which have a lower yield potential than longer maturing ones. Corn has a higher yield than sorghum under irrigation, partly because the time to flower is longer.

Wade and Hammer (1986) report on the maximum yield of sorghum from various locations, which supports the notion of a heat imposed limit on grain yield in tropical environments.

High night temperatures - higher respiration levels

High night temperatures have been reported to negatively affect grain yield, due to high respiration rates. It is difficult to separate high night temperature effects from high daytime temperatures, which usually go hand in hand.

Downes (1972) found grain yield to decline with high night temperatures. Day temperatures did not affect grain yield except at very high night temperatures (Table 9).

Table 9. Effect of Day and Night Temperatures on sorghum yield

Downes 1972	Yield gm/grain/plant (Texas 610) % Reduction in yield from maximum in brackets		
	Day temperatures		
Night temperature	**36**	**30**	**24**
31	10 (77%)	31 (29%)	29 (11%)
25	37 (16%)	33 (25%)	36 (18%)
19	42 (5%)	44	44

Within normal temperature ranges expected in Queensland, the effect of high night temperatures was to reduce the yield of sorghum by 16 to 25%, but at very high night temperatures, sorghum yield was reduced 77% (Table 9).

Although yield is commonly thought to have a close relationship to biomass, the results of Downes shows a marked reduction in harvest index with increasing night temperatures. The data (Table 5) shows quite significant effects on sorghum at moderate temperatures of 27/22.

According to Downes, "A decrease in harvest index with increases in temperature indicates an impaired efficiency of utilisation of both radiant energy and water reserves, in that proportionately more resources are used for the production of parts other than grain under these conditions."

Table 10. Harvest Index of grain sorghum at different temperatures

Temperature ^{0}C	Harvest Index* variety A	Harvest Index Variety B
33/28	28	28
30/25	28	33
27/22	38	33
24/19	54	50

*Ratio of grain to total above-ground dry matter

Downes 1972

High moisture vapour deficits (high temperatures and low humidity) causes temporary wilting of sorghum.

Some reduction in yield can still occur from high temperatures in the presence of good water supply. If the plant is wilted for part of the day, the photosynthetic capacity of the plant is reduced.

At high temperatures (above 38 ^{0}C, which may be 45 ^{0}C in the field) the plant may not be able to maintain water flow even though soil moisture is adequate. Symptoms of wilting are often evident in the afternoon, with plants turgid in the mornings. This 'supply problem' is likely to worsen as the supply of moisture is from deeper soil layers where the extent of the root system is more limiting

Severe temperatures can affect head development

The effect of heatwave temperatures, which can 'cook sorghum heads in the boot' or reduce pollination, has been observed over many years and is more severe in some varieties than others. Severe temperature effects appear to be worse in conjunction with water stress.

Effects of heat on water use efficiency

As shown in Figure 1, the WUE of sorghum is affected by heat and increases with yield - WUE being lower at lower yields and increasing to a maximum at very high yields.

Some of this effect is due to an improvement in grain to stubble ratio or harvest index as yield increases. Table 10 shows a reduction in harvest index with heat. This was also found by Munchow and Coates (1986), where sorghum planted during the dry season in the Ord river irrigation area experienced more heat and produced a lower grain yield due to a lower harvest index.

Comparisons of sorghum grown on the Darling Downs and the Western Downs show a considerable drop in WUE in the hotter western areas. Part of this effect is due to better soil types and agronomy of sorghum on the Darling Downs, but even the best crops do not do as well in the hotter areas. See Table 11.

Table 11: WUE of sorghum – Darling Downs & Western Downs

	Western Downs		Darling Downs	
	Yield: t/ha	WUE: kg/mm	Yield: t/ha	WUE: kg/mm
1999/00	2.76	7.7	5.28	11.2
2000/01	1.58	4.7	2.68	10.3
2001/02	1.94	8.1	3.59	10.6
2002/03	1.5	4.6	4.13	14.4
2003/04	2.79	6.7	4.64	8.9
Average	2.11	6.36	4.06	11.08
WUE: Western Downs as a % of Darling Downs: 57				
WUE: Darling Downs as a % of Western Downs: 174				

Similar results are evident from Pacific Seeds trial data (Table 12) where the average WUE for hotter sorghum growing areas was 9.2 kg/ha/mm, compared to 15 on the Darling Downs. A feature of this data is the quite high WUE figures for the 2005-06 summer when in-crop rainfall was low and temperatures very high. It is assumed that this result is due to a high proportion of water use coming from soil stored water, following excellent rain in November prior to planting. The use of stored water is more efficient than from in-crop rainfall due to less evaporation.

An analysis of planting times where there were inter-farm comparisons showed a significant effect of heat in Western farms, with average recorded WUE for late planted sorghum vs early sorghum for 13 comparisons, some 33% lower.

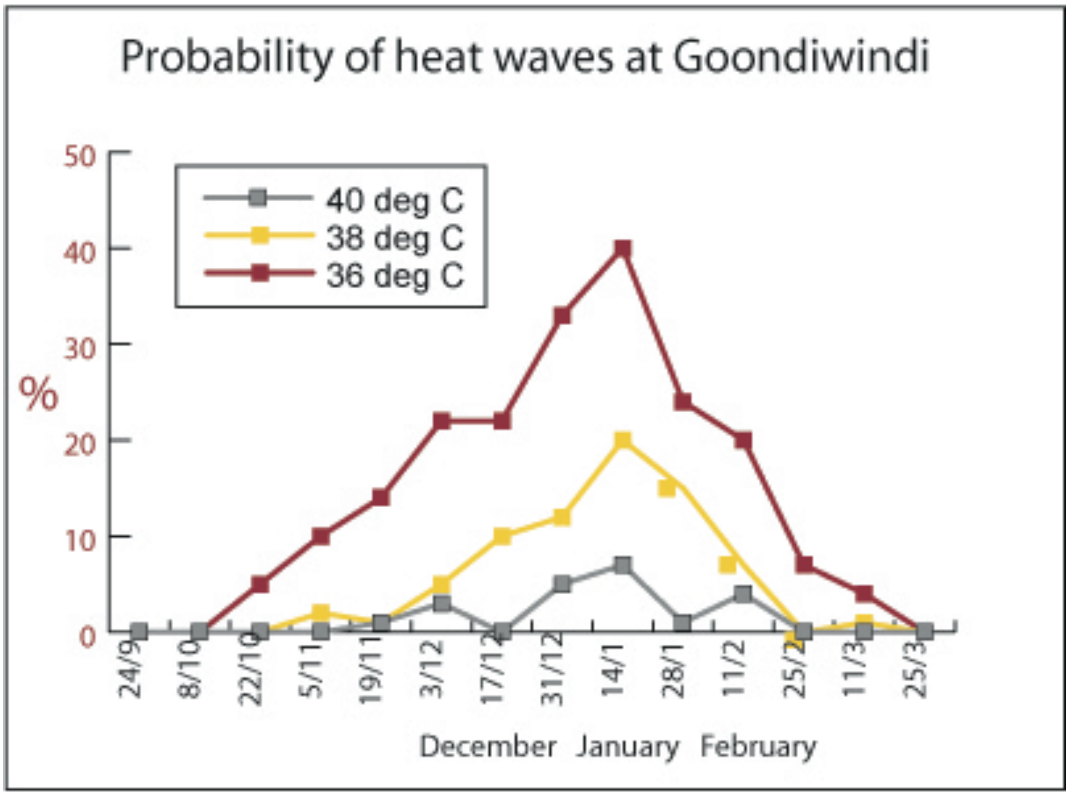
A similar but smaller effect was recorded on Darling Downs farms indicating WUE was 15% less for later plantings. See Table 12. Some of the lowest WUE figures were from sorghum crops planted in late November and early December, where the full impact of shortened time to flower and heat at flowering is experienced.

The data also shows a trend for higher WUE for crops planted in late December and early January. These crops would experience a shortened time to flower but have cooler weather at flowering and during grainfill, when moisture stress is most likely.

Table 12: WUE of sorghum – Early and late plantings					
Western Downs			Darling Downs		
Plant	Yield: t/ha	WUE: kg/mm	Plant	Yield t/ha	WUE: kg/mm
Sep-Oct (13 crops)	3.04	9.9	Sep-Oct (12 crops)	4.67	11.53
Nov-Jan (15 crops)	2.15	6.6	Nov-Jan (15 crops)	3.5	9.83
Late as % of early	70	66	Late as % of early	75	85
Reduction	30%	33%	Reduction	25%	15%
*Inter-farm comparisons where early and late plantings were made during 2000-2004. Recordings from benchmarking reports of Horizon Rural Management					

Figure 5: High temperatures at Goondiwindi

(probability of 3 consecutive days of temperatures exceeding 36, 38 and 40 deg.C.)



Source: Bureau of Meteorology

Appendix 3. Yield estimates for sorghum at different planting times

Estimates of the yield potential of sorghum at different planting times, based on field experience is at odds with the output of the APSIM model.

Field experience suggests sorghum will have higher water use efficiency when planted early, which means yield potential can be higher than later plantings, despite less in-crop rainfall (on average)

Early planting could be particularly important for good yield potential of irrigated sorghum planted in hot areas, such as Moree and St George.

Farmers and advisers experience is that early planted sorghum tends to have the best yield potential, and sometimes outyields later planted sorghum, even though it has received less in-crop rainfall.

Summer weather has been extremely hot in recent years and if this is an on-going trend, then consideration of sorghum planting time becomes important.

Modelling should provide a good indication of the best planting times for sorghum and any changes to water use efficiency. However, the output of the APSIM model suggests there is no difference in the Water Use Efficiency of sorghum at different planting times which experience different levels of heat (Figure 5).

The model suggests November as the best time to plant sorghum, despite the fact that sorghum planted in November will flower in January and is exposed to some of the worst of the summer heat.

There is no doubt that sorghum planted in early November and December has the highest risk of 'heatwave' conditions when grain can be 'cooked in the boot' or the pollination affected if high temperatures are compounded by moisture stress.

Estimates have been made of the yield of sorghum at different planting times based on field experience and information gleaned from research reported in Appendix 3 of this report. Water Use Efficiency calculations have been made objectively by adjusting both for heat and a reduced time of flowering. The yield estimates in Table 11 involve a 2.5% reduction in WUE per degree of average temperature over the sorghum growth period and a 2.5% reduction in WUE per day of reduction in time to flower. These figures have been selected to generate yield estimates consistent with field observations of grain sorghum. Yield estimates are compared with those of APSIM.

Selection of planting time is not always an option for dryland sorghum, but to date early planting times have often been overlooked because of low soil temperatures. It is also possible to use moisture seeking planting at times if there is useful rain in August.

Late planting in December or January is another option for sorghum to experience less heat and have an extended grain filling period. According to APSIM, a January planting time is the best for both Dalby and St George.

Planting time is important for irrigated sorghum, whereby the yield potential of sorghum in hot areas, such as Moree and St George may be considerably higher for sorghum planted in early September compared with even a month later.

Table 13. Estimates of yield and WUE for different planting times at three locations

Warwick

Yield and WUE of Sorghum planted on 15th of the Month

	Sep	Oct	Nov	Dec	Jan
Planting soil moisture	150	150	150	150	150
In-crop rainfall	296	302	308	282	231
Water used by crop	446	452	458	432	381
Average temperature	19.42	21.58	22.75	22.83	21.50
Days to flower	76	72	68	66	66
Yield reduction	0	15	28	34	30
WUE kg/ha/mm	17.6	14.9	12.6	11.7	12.3
Yield kg/ha	7841	6724	5777	5053	4680

Apsim kg/ha	6500	7000	7400	7250	5500
WUE kg/ha/mm	14.6	15.8	17.0	18.2	15.8

Dalby

Yield and WUE of Sorghum planted on 15th of the Month

	Sep	Oct	Nov	Dec	Jan
Planting soil moisture	150	150	150	150	150
In-crop rainfall	286	319	325	294	225
Water used by crop	436	469	475	444	375
Average temperature	21.42	23.58	24.50	24.42	23.08
Days to flower	74	70	66	64	64
Yield reduction	0	15	28	33	29
WUE kg/ha/mm	16	13.5	11.6	10.8	11.3
Yield kg/ha	6968	6340	5488	4795	4244

Apsim kg/ha	5250	5600	5400	6600	6500
WUE kg/ha/mm	15	15	14.9	18	19

St George

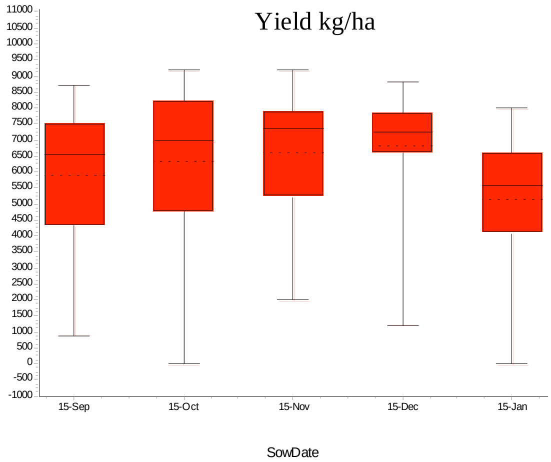
Yield and WUE of Sorghum planted on 15th of the Month

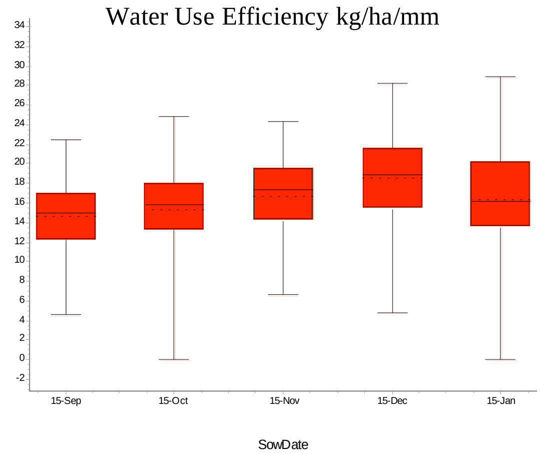
	Sep	Oct	Nov	Dec	Jan
Planting soil moisture	150	150	150	150	150
In-crop rainfall	188	205	220	217	184
Water used by crop	338	355	370	367	334
Average temperature	23.25	25.42	26.33	26.08	25.00
Days to flower	72	68	64	62	62
Yield reduction	0	15	28	32	29
WUE kg/ha/mm	14.4	12.2	10.4	9.8	10.2
Yield kg/ha	4860	4328	3855	3589	3397

Apsim kg/ha	2650	2400	2800	3100	3450
WUE kg/ha/mm	17.6	15.4	14	14.6	19.6

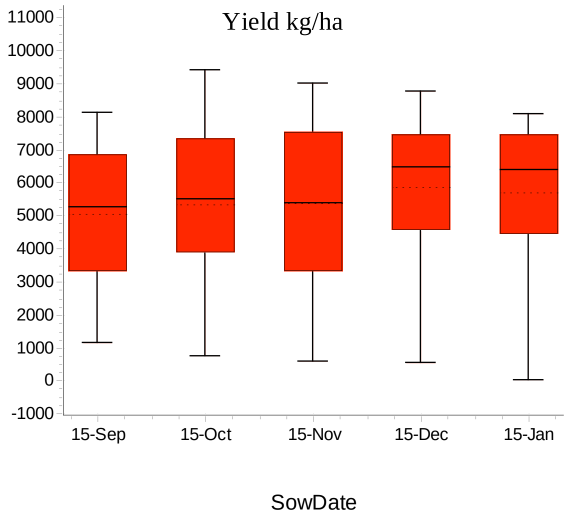
Figure 6: Yield potential and sowing date – Apsim model results

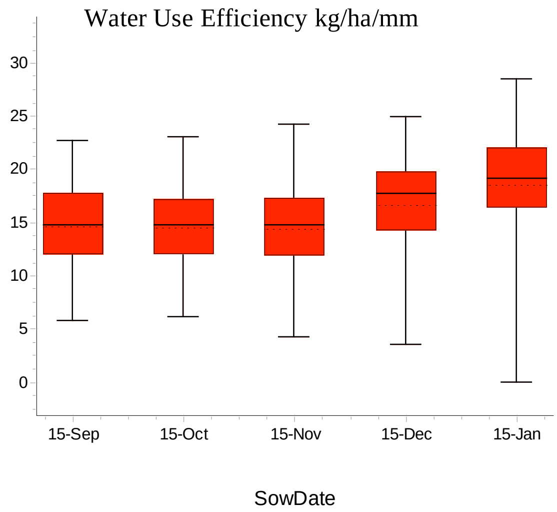
1. Warwick 180mm soil moisture, 60,000 plants, 100 kg N/ha



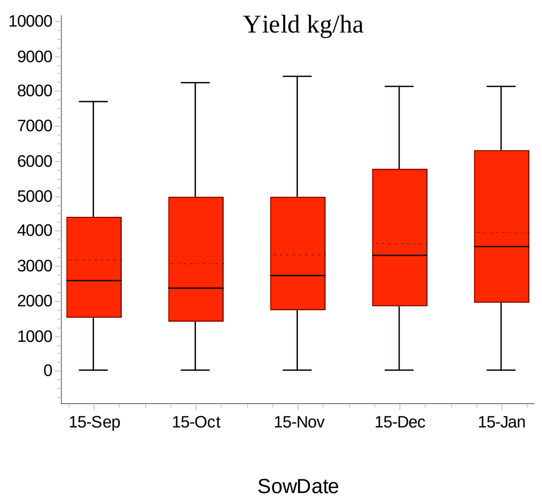


2. Dalby: 180mm soil moisture, 60,000 plants, 100 kg N/ha





3. St. George: 180mm soil moisture, 60,000 plants, 100 kg N/ha,
(40,000 plants and Medium maturing cv for WUE chart)



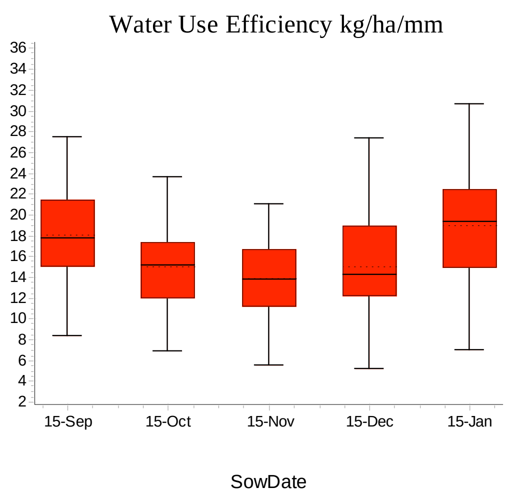


Table 14: Pacific Seeds Trial Data								
	Year	Plant date	Seeds/ha	Yield Kg/ha	Soil Water	Rainfall mm	Water use	WUE kg/ha/mm
Bogabilla	2005	28/9/04	45000	4977	200	217	417	11.9
Moree	2005	25/9/04	42000	2597	180	167	347	7.5
Billa Billa	2005	5/10/04	45000	5073	180	256	436	11.6
Moree	2005	27/9/04	50000	3919	200	192	392	10.0
Gurley	2005	14/10/04	50000	3120	180	187	367	8.5
Garah 2	2006	15/11/05	45000	2690	150	271	421	6.4
Gurley	2006	7/10/05	45000	1510	160	219	379	4.0
Westmar	2005	20/9/04	40000	3715	180	142	322	11.5
Condamine	2005	19/11/04	55000	1053	108	90	198	5.3
Kindon	2005	7/9/04		4850	180	262	442	11.0
Billa Billa	2006	9/11/05	45000	3653	200	160	360	10.1
Condamine	2006	8/12/05	55000	3730	200	139	339	11.0
Chinchilla	2006	13/12/05	40000	2296	200	92	292	7.9
Dulacca	2006	16/11/06	45000	3190	180	136	316	10.1
Western Downs/NSW			46308	3312	178	181	359	9.2
Bowenville	2005	29/11/04	65000	6237	240	136	376	16.6
Brigalow	2005	28/10/04	55000	5683	200	166	366	15.5
Warra	2005	1/11/04	50000	5500	180	122	302	18.2
Jandowae 1	2005	1/11/04		6255	200	149	349	17.9
Jandowae 2	2006	10/11/05	52000	5580	120	228	348	16.0
Dalby	2006	4/11/05	60000	8403	200	306	506	16.6
Bowenville	2006	4/11/05	65000	8179	220	201	421	19.4
Broxbourne	2006	3/11/05	100000	7859	180	229	409	19.2
Bongeen	2006	29/10/05	75000	6744	180	286	466	14.5
Dalby	2006	15/11/05	55000	4006	200	185	385	10.4
Macalister	2006	19/12/05	90000	5730	200	191	391	14.7
Jimbour	2006	31/10/05	75000	5744	200	176	376	15.3
Pirrinuan	2006	31/10/05	60000	2935	180	133	313	9.4
Jandowae 1	2006	4/11/05	51000	7175	200	225	425	16.9
Warra	2006	13/12/05	72000	5463	120	177	297	18.4
Darling Downs			66071	6100	188	194	382	15.5
Overall Average			56190	4706	183	187	371	12.7

Data from trials in 2005-06 shows average yield from:

1. hotter western areas averaged 3.3 t/ha with WUE of 9kg/ha/mm.
2. Darling Downs averaged 6.1 t/ha with WUE of 15.5 kg/ha/mm.