4.1 Irrigated wheat – best practice guide

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Key point

- Seasonal water requirement varies from 360 to 550mm
- A full irrigation strategy or limited water irrigation strategy can be used
- The period leading up to and including flowering is the most sensitive to water stress.
- Good agronomic practices are needed to maximise production and minimise lodging risk
- Starting soil-N determines the most appropriate nitrogen strategy
- Durum out yields bread wheat and quick maturing varieties with good lodging resistance should be used
- Adjust row spacing to manage biomass and tillering – 30cm row preferred
- Aim to establish 100-150 plants/m^2 of bed or hill area
- Planting on rainfall preferred over pre-irrigation and watering up which can delay planting and produce excessive biomass respectively
- Irrigate to encourage secondary root development if needed
- Use plant growth regulators to minimise lodging
- Use disease resistant varieties and a pre-planned fungicide application strategy

Plant Water Use

The amount of water required to produce a wheat crop with maximum yield is not a fixed value as temperature and relative humidity during the growing period along with wind and soil moisture all determine the rate of evaporation from the soil and transpiration from the plant (evapotranspiration or ET_c). In favourable seasons the water requirement may be as low as 360 to 440 mm whereas in a warmer dry year this requirement could be up to 480 to 550 mm to produce maximum yields. Table 1 summarises the results of APSIM simulations for wheat yields and evapotranspiration water use in the Northern Grains Region.

The DAFF Queensland free on-line tool CropWaterUse can be used to examine the seasonal variability in crop water requirement for fully irrigated wheat at your location (see Table 2).

It shows the irrigation demand for 1 June planted wheat at three locations (Narrabri, Dalby and Emerald), assuming that the crop was fully-irrigated to target maximum yield. An irrigation application efficiency of 75% and a 75mm irrigation target deficit are assumed. Results show a large variation in seasonal crop water demand, rainfall and irrigation demand between locations and season types.

Figure1 shows the daily water use in wheat which peaks during flowering and milk development (GS60 to GS70).

Moisture availability at this stage is critical to the yield of the crop. Moisture stress for more than a few days during this period will result in lower grain yield and quality.

The area of irrigated wheat to plant is a function of wheat price, available water and your planned irrigation strategy.

Irrigation Strategies

Full Irrigation

For fully-irrigated wheat (with a target yield exceeding 8 t/ha) where water is not limited, the aim is to maximise yield by scheduling irrigations to match crop water demand and avoid crop stress during the entire growing season. This requires the close monitoring of soil moisture once secondary root development has been completed (normally GS31).

In order to avoid crop stress, do not allow soil water to fall below 50% of plant available water capacity (PAWC). This is commonly referred to as the 'refill point'.

Table 4.1.1 Range of simulated maximum yield (t/ha) and evapotranspiration water use for 90% of years[1], for quick maturing irrigated wheat (Kennedy) on 2m beds in the Northern Grains Region, in the absence of lodging, disease, pest and frost damage

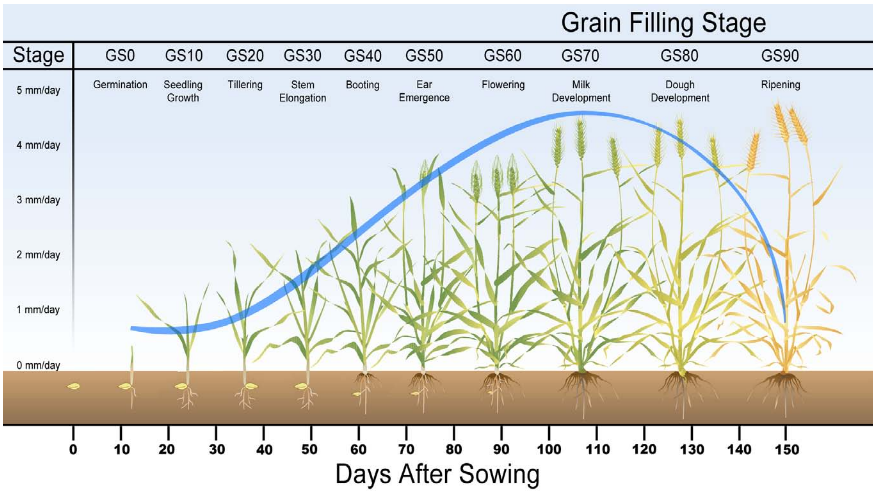
Location	Range of Maximum Yield (t/ha)	Range of Maximum Evapotranspiration water use (mm)
Emerald	6.2 – 7.8	360 – 480
Dalby	7.0 – 9.5	430 – 550
St George	6.4 – 8.2	360 – 480
Goondiwindi	6.8 – 8.7	410 – 490
Walgett	6.7 – 8.3	420 – 500
Gunnedah	7.6 – 9.6	440 - 540

[1] (excludes the top 5% and bottom 5% of years). Source: A. Peake

Table 4.1.2 Comparison of average water requirements for wheat planted on the 1 June at Narrabri, Dalby and Emerald, based on historical weather data (1957 to 2008)

	Narrabri			Dalby			Emerald		
Season Type	Dry	Ave	Wet	Dry	Ave	Wet	Dry	Ave	Wet
Crop ET_c (mm)	403	378	351	432	407	385	536	517	494
In-crop Rainfall (mm)	119	210	335	104	173	258	50	111	231
Irrigation Demand (ML/ha)	3.7	2.6	1.6	4.2	3.3	2.5	6.1	5.2	4.4
No. of Irrigations	4	2	2	4	3	2	6	5	4

Figure 4.1.1 Wheat water use pattern and critical growth stages



Once below 50% of PAWC, crops use more energy extracting the remaining soil water. Plant growth and yield potential will fall considerably if soils are allowed to dry down beyond this threshold.

Make sure water is available for 2 to 3 days before the crop reaches its refill point. The reproductive growth phase typically coincides with an increase in temperature and an acceleration of plant water use. Any delay in water application can cause significant yield losses.

The period leading up to and including flowering is the most sensitive to water stress. Stress at this time will reduce the number of heads per plant, head length, and number of grains per head. It can also restrict root growth. Yield losses from excessive water deficits at this time cannot be recovered by later irrigations.

Key points to consider when scheduling irrigation for fully-irrigated wheat are:

- crop stress must be avoided. ET_c is usually linearly related to crop yield. Stressing the crop at any stage of development reduces ET_c and yield. This yield loss cannot be recovered by irrigating at a later time. To avoid crop stress, it is important to know when to irrigate and how much water to apply. Table 4.1.3 summarises the water management considerations for each growth stage of wheat.
- The application of a fixed water depth at each irrigation can lead to deep drainage losses. It is not necessary to refill the soil profile at each irrigation. Overhead systems are especially suited to application of small irrigation depths, but application depths can also be reduced with surface irrigation systems by increasing siphon flow rates and reducing irrigation runtimes.
- Crops can only extract water from their effective root zone. Therefore, the depth of soil wetted by irrigation needs to be adjusted during the season to respond to increases in root zone depth and irrigation wetted front should not go deeper than the effective crop root zone.
- The soil water deficit to trigger irrigation also depends on the depth of the root zone and needs to be adjusted during the season. Both the ET_c rate and the soil water deficit change daily, so irrigation frequency needs to be adjusted in response to these changes.
- The desired soil water deficit and the irrigation frequency also depend on the irrigation system capacity (mm/day). This highlights how much water the irrigation system can apply in one day, allowing for system breakdowns or maintenance. The greater the system capacity, the greater the soil water deficit that can be replenished quickly.

Irrigations can be scheduled based on soil moisture monitoring using one of the commercial soil moisture monitoring tools available. This equipment can tell you the rate of crop water use and the depth of water extraction.

This can be used to make irrigation scheduling decisions.

Irrigation can also be scheduled based on estimation of crop ET_c from weather data. WaterSched2, a free online irrigation scheduling tool developed by DAFF Queensland is now available. This tool automatically downloads daily weather data from different locations in Queensland and New South Wales and, using farm-specific inputs, conducts a daily soil water balance and economic analysis to determine when and how much to irrigate.

Figure 4.1.2 is an example of the end of season report generated by WaterSched2 for a fully irrigated wheat crop at Dalby in the 2009 season. This report summarises the water, crop and economic data for the crop. It provides the WUE indices for predicted and actual yield achieved. The graph at the bottom of the report shows the daily soil water depletion during the season.

During the season this report provides the information needed by the grower to decide on their most appropriate irrigation scheduling strategy in response to crop water requirements, likely economic returns and whole farm water availability.

Correct timing of the last irrigation will ensure adequate grain fill and also reduce the risk of lodging and harvesting delays. It should be applied around mid dough growth stage (GS80) if readily available water has been used to 60 to 90cm soil depth.

Table 4.1.3 Critical water management considerations by growth stage for wheat

	Zadoks Development Stage	Water Management Consideration
0	**Germination**	Adequate soil moisture essential to establish desired plant population. Waterlogging can increase seed mortality
1	**Main stem leaf production** Seedling Stage is the growth stage from wheat emergence until the plants begin to tiller	Early weed control will conserve plant available water.
2	**Tiller production** Tillering usually starts when the plant has 3- 4 leaves. A (short growth cycle) wheat plant will typically produce 7-8 leaves on the main stem before stem elongation occurs.	Early weed control will conserve plant available water. Good nutrient and water supply are determining the potential number of heads produced by the crop.
3	**Stem elongation** Main stem node production. The maximum potential number of florets (and therefore maximum yield potential) is now set. The tillers produced last during stem elongation will often die. The final number of productive tillers depends on the conditions.	Good nutrient and water supply are determining yield potential. If stress during stem elongation is followed by heavy water application, wheat has the ability to produce new tillers and additional heads. However these additional heads will delay harvest and the risk of losses from lodging and non-uniform ripening usually increases. Soil water depletion should not exceed 50% of PAWC
4	**Booting** By booting each plant should have 2-3 productive tillers depending on growing conditions and crop density.	Water stress will significantly reduce yield. Soil water depletion should not exceed 50% of PAWC.
5	**Heading** The spike (also called the head or ear) is emerging from within the flag leaf.	
6	**Flowering** Pollen is being released and the individual grains are being fertilized.	
7	**Grain milk stage** When the grain is squeezed, a milky solution is apparent.	
8	**Grain dough stage** When squeezed, the grain will still deform slightly, but no liquid is apparent.	Yield is almost set, but water stress will still reduce grain size and yield. Soil water depletion should not exceed 50% of PAWC.
9	**Ripening** Grain is hard and firm and ready for harvest. Grain is best harvested at 14% moisture content. Wetter grain (>14% moisture content) has storage problems.	Lodging will reduce harvestable grain yield.

Source: CIMMYT International Maize and Wheat Improvement Center, 2012

Figure 4.1.2 WaterSched2 End of Season Field Summary report for a fully irrigated wheat crop at Dalby in 2009

WaterSched2

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End of Season Summary

Field Summary

Farm:	josefarm	**Plant Date:**	15/06/2009
Location:	Dalby	**Season:**	2009
Field Name:	josefarm	**Length of Season:**	123 days / 1839 GDD
Field Size:	100 ha	**Irrigation Type:**	Sprinkler 100%
Crop:	Early Wheat	**Irrigation Trigger Deficit:**	50 mm

Water Summary

	mm	ML/ha
Total Irrigation:	300	3
Total Rainfall:	62	0.62
Total Losses:	49	0.49
Starting Soil Water:	210	2.1
Ending Soil Water:	113	1.13
Soil Water Change:	97	0.97
Total Water Input:	459	4.59
Net Water Supply:	409	4.09

Crop Summary

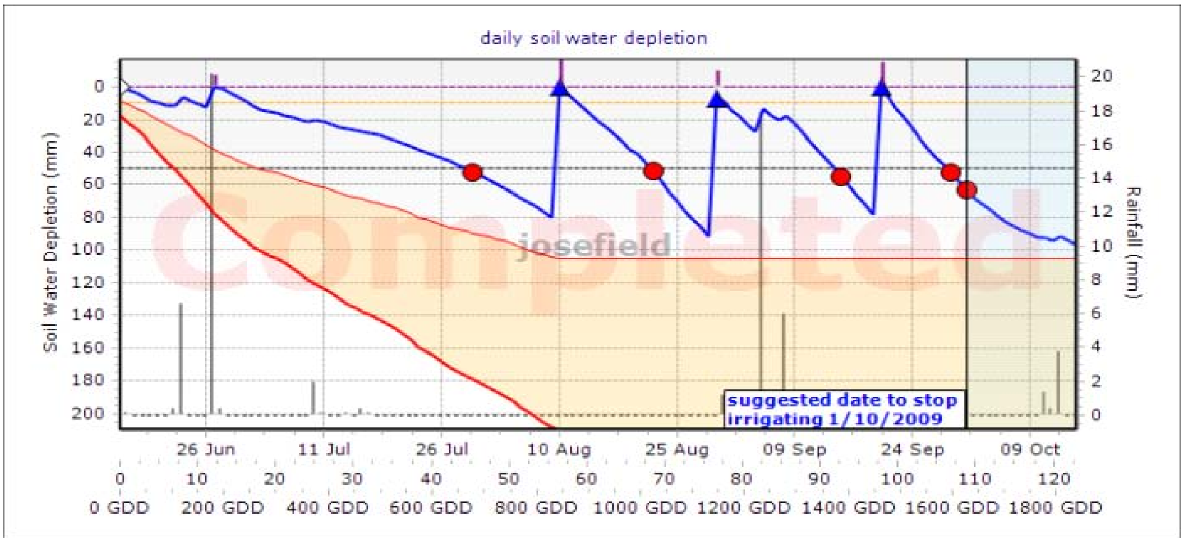
Expected Yield:	8 tonnes/ha
Predicted Yield:	8 tonnes/ha
Actual Yield:	6 tonnes/ha
Accumulated ETp:	409 mm
Accumulated ETc:	409 mm

Economics Summary

Price Per Unit:	$255 / tonnes
Variable Costs:	$808 / ha
Gross Margin:	$722 / ha

Water Use Efficiency

	Predicted	Actual	Gross Margin
Total Water Use Index TWUI	1.74 tonnes / ML	1.31 tonnes / ML	$158 / ML
Gross Production Water Use Index GPWUI	1.96 tonnes / ML	1.47 tonnes / ML	$177 / ML
Irrigation Water Use Index IWUI	2.67 tonnes / ML	2 tonnes / ML	$241 / ML
Crop Water Use Index CWUI	19.55 kg / mm	14.66 kg / mm	$1.76 / mm



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Limited Water Strategies

If there is a high probability of reduced water allocation and insufficient rainfall then the yield target may need to be revised down and supplementary irrigation strategies adopted. Supplementary irrigated crops are 'water limited' – there is not enough water available to fully irrigate the area to be sown. Growers faced with this situation have two main choices:

1. maximise production from the water available
2. grow the largest area possible where a single in-crop irrigation can be applied.

Growers wanting to maximise productivity per ML of water should consider growing a smaller area of crop and matching crop water demand to achieve a high yield. This strategy avoids the extra costs associated with growing a larger area. In general, maximum crop productivity under irrigation is achieved when good soil moisture is available at sowing and then one or two supplementary spring irrigations are applied (one irrigation in wetter districts such as the Liverpool Plains, and two irrigations in drier areas such as Emerald and Goondiwindi).

If a large area of wheat must be planted as part of a rotation, and only a single irrigation is possible, the best timing is one which applies water at the most critical growth stage – from stem elongation though to flag-leaf emergence.

Table 4.1.3. summarises the impact of water stress on wheat at different growth stages.

APSIM simulations suggest that the best timing for a single in-crop irrigation of around 1 ML/ha is from early stem-elongation through to flag-leaf emergence. It will still have time to help the crop develop a little more biomass, yet will also leave some soil water for flowering and early grain filling. This recommendation is based on 40 years of weather data. The best timing of a single irrigation within a particular season will vary depending on the timing of in-crop rainfall, and stored water at sowing.

If two irrigations (or 2ML/ha) is budgeted, then an irrigation applied at early to mid-stem elongation and again between flag-leaf and flowering is recommended.

Agronomy

To achieve high irrigated yields it is also necessary to follow good agronomic practices.

Crop lodging is a potential risk when targeting high wheat yields. Lodging occurs mostly after ear emergence and can significantly affect grain yield and quality. Factors affecting lodging potential include:

- variety lodging susceptibility;
- shallow root systems due to abundant soil moisture or frequent irrigations;
- subsoil constraints like sodicity or compaction;
- high nutrition levels causing plants to grow too quickly; and,
- severe weather during crop ripening.

The range of agronomic practices discussed below is aimed at maximising yield and controlling lodging through canopy management.

Nutrition

Test soil for starting nitrogen (to 90cm depth) and phosphorus (to 20cm depth) in April/May before sowing. Long fallow paddocks with high soil-N require careful management of canopy growth from establishment to avoid lodging. Paddocks sown straight after cotton (low soil-N) are ideal to target maximum yield and manage early season canopy.

At least 275 kg N/ha is required to grow 8 t/ha of wheat. The success of nitrogen application depends on soil type, irrigation system, sowing soil moisture and rainfall and temperature at tillering. Nitrogen can be split applied in low soil-N paddocks (some fertiliser will be required at sowing). In high-N soils nitrogen fertiliser requirements are more safely applied at stem elongation (GS31) – ideally before a rainfall or irrigation event.

In low soil-N post-cotton paddocks, starter fertiliser containing 10-20 kg P/ha will improve establishment.

Variety Choice

On average durum wheat has consistently yielded 1 t/ha higher than bread wheat in northern irrigated wheat trials. In 2011 the durum varieties Bellaroi and Caparoi provided the highest yield potential and lodging resistance. The durum variety Hyperno has high yield potential but was found to be prone to lodging. Quick maturing varieties such as Kennedy and Longreach Crusader are the most likely APH bread wheat varieties to achieve high yields, although Longreach Crusader has shown significantly more lodging resistance than Kennedy in high-N paddocks.

Row spacing

Row spacing can be altered to manipulate vegetative biomass and tillering. In low soil-N paddocks the most appropriate row spacing is 30cm, or 6 rows on a 1.8 metre bed. Wheat performs best at 30 cm row spacing as it responds well to plants being more evenly distributed across the bed.

In high soil-N paddocks wider row spacing will increase intra-row competition, reduce tillering, and assist in the regulation of early season biomass during tillering.

Plant population

A plant population of 100-150 plants per square metre of bed or hill area is ideal in the northern region. Low plant populations of 50-100 plants per square metre of bed can achieve high yield levels but plants do not establish evenly.

Seedbed Preparation

Seedbed preparation has a significant impact on seedling emergence and yield potential. Following pupae-busting, tillage should be used to prepare a new seedbed that is free of clods and cotton stubble. Seedbed tilth needs to be in an optimum condition for seed placement and emergence.

Planting Date

Planting time is a management compromise that balances having the crop flowering soon after the last heavy frost, but still early enough to allow adequate grain fill before the heat in spring.

Varieties differ in the time they take from planting to flowering. Select the planting time for your variety that ensures it will flower after there is little chance (I in 10 years) of a frost occurring.

Sowing early within the optimum range is better suited to low-N paddocks where canopy can be managed through delayed N application, and when irrigating up.

Planting late (within the optimum range) is an alternative strategy to reduce lodging in high soil-N paddocks.

Establishment

Ideally wheat should be planted after a rainfall event which provides planting moisture and ensures seed germination and establishment. This provides the best opportunity to achieve high yields (particularly if starting soil N levels are low). In this situation a uniform plant stand can be achieved and you can manage early season canopy growth and allow an irrigation to ensure secondary root development.

Pre-irrigation is risky as sowing can be delayed if rain occurs. However, establishment can be better in this scenario than if a paddock is dry-sown and watered up.

If the profile is completely dry at planting the only option may be to plant shallow and water-up. This is the least desirable option, particularly if starting soil-N levels are very high. Often, in water-up situations, plants still do not initiate secondary root growth and require further irrigation during tillering which can result in excessive early season biomass. This can predispose the crop to lodging, particularly where soil starting N levels are high.

Secondary Root Growth

Assess soil moisture status at 25-30 days after emergence. If there is dry soil below the sowing depth of seed, apply an irrigation to encourage secondary root development on low soil-N paddocks. Early secondary root development will enhance water and nutrient uptake.

Plant Growth Regulators

Use of plant growth regulators (PGRs) to minimise lodging is still being researched for irrigated wheat. Their use is recommended in high soil-N paddocks where canopy growth is excessive. Check and follow label registrations and instructions.

Disease Management

A pre-planned strategy of fungicide applications based on growth stage and emergence of the top three leaves provides greatest marginal returns when susceptible wheat cultivars are subject to disease.

Where disease onset is early or where susceptible varieties are grown with no up-front protection an application at GS31-32 may be needed. One application at GS39 may be sufficient.

Consider an additional ear-emergence fungicide where stem rust is the primary disease target.

Consider a first-flower spray where wheat or durum is at high risk of Fusarium head blight.

More specific information is also available on root and crown diseases and stripe rust and septoria tritici blotch in irrigated systems.

Further Reading

Lacy, J and Giblin, K 2006 Growing eight tonnes a hectare of irrigated wheat in southern NSW NSWDPI

Sykes, J. 2012 Irrigated Wheat: Best Practice Guidelines in Cotton Farming Systems, Cotton CRC