Poor water use in wheat an international phenomenon

A CSIRO international analysis has found wheat crops in low-rainfall areas across the globe commonly fail to realise their yield potential because of low water-use efficiency. This article examines why crops in south-eastern Australia yield only half their potential and what farmers can do to improve water-use efficiency in wheat.

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CSIRO assessment of the water-use efficiency in rain-fed wheat has provided some foundations to help the grains industry to improve crop management and develop improved varieties to boost crop yields.

Scientists compared the water-use efficiency (yield per unit water use) of wheat crops in south-eastern Australia to similar crops grown in the dry regions around the globe.

The research analysed 691 crops from south-eastern Australia, the North American Great Plains, China's Loess Plateau and the Mediterranean Basin.

A trademark of all these regions was a severe water deficit during the critical growing stages of flowering, grain set and filling, which significantly reduced crop yield.

Wheat crops grown in south-eastern Australia regularly yield about 40–50 per cent below their potential due to low water-use efficiency.

Water-use efficiency, expressed as the ratio of grain yield and water use, has a maximum of 22 kilograms of grain produced per hectare per millimetre of water use.

But the average water-use efficiency for crops in south-eastern Australia is just 9.9kg/ha/mm. This figure was consistent with the other regions analysed, with China's Loess Plateau producing an average 9.8kg/ha/mm, 8.9kg/ha/mm for the northern Great Plains of North America, 7.6kg/ha/mm for the Mediterranean Basin and 5kg/ha/mm for the southern and central Great Plains. Collectively, this represented 31–44% of the maximum estimated yield potential of the crops for these environments.

At a glance

- The low water-use efficiency of wheat crops in south-eastern Australia is typical of other dry environments throughout the world.
- Large soil evaporation losses are the main constraint to high water-use efficiency in south-eastern Australia.
- Crop management and improved wheat varieties can assist wheat growers to improve crop yields.

Photos: CSIRO

Loss of valuable rainfall through soil evaporation and the high evaporative demand experienced by crops in dry areas during flowering and grain fill reduce crop water-use efficiency and potential grain yields. Management tools such as retaining stubble, reduced tillage, effective weed control and sowing crops with high early vigour can help improve the water balance of cropping systems.

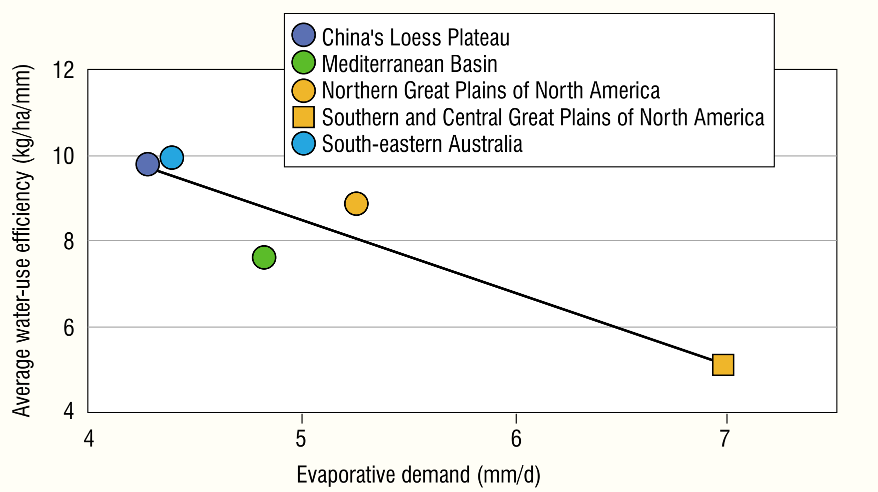
Constraints to water-use efficiency

The study compared several management and environmental (soil and climate) reasons for the low water-use efficiency typical of crops in dry locations. The main influences included massive water losses through soil evaporation; timing of rainfall constraining sowing opportunities and the critical physiological process of grain set and filling; and high evaporative demand during flowering and grain fill.

Soil evaporation

Soil evaporation was the most dominant reason for low water-use efficiency in south-eastern Australia. Some 30–80% of the growing season rainfall evaporates

FIGURE 1 Water-use efficiency and evaporative demand*



* With the changing of the seasons from winter to spring, the drying power of the air increases. The plant is also more sensitive to evaporative demand while it is flowering. Areas with the highest evaporative demand have the poorest water-use efficiency.

Source: CSIRO Land and Water.

from the soil. This means that for every millimetre of water used productively in plant transpiration, one or two millimetres can be wasted through soil evaporation.

Direct soil evaporation is one of several pathways rainfall can follow, in addition to crop transpiration, weed transpiration, run-off and deep drainage. Of these, only crop transpiration is linked to growth and yield.

Soil evaporation, run-off, drainage and weed transpiration serve no production benefit. But there are several management options that can reduce these wasteful water pathways.

Timing of rainfall

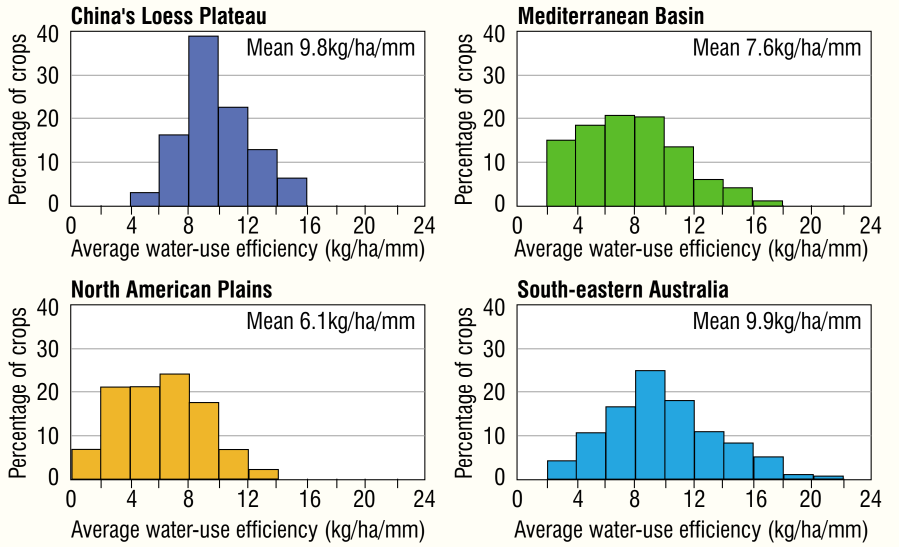
The timing of rainfall is a crucial determinant of grain yield and water-use efficiency, as it can impose agronomic and physiological constraints on the crop.

Agronomically, the onset of rainfall determines sowing opportunities which influence the season length and yield.

Research by the CSIRO in the Mallee showed the average yield of wheat drops 17kg/ha per day delay in sowing from mid-April.

Physiologically, rainfall around flowering is critical, when plant development is particularly susceptible to environmental stresses. High temperatures also lead to high evaporative demand and can compound the deleterious effect of scarce rainfall. When the drying capacity of the air was taken into account, water-use efficiency was directly related to evaporative demand for all four regions analysed in the project (see Figure 1).

FIGURE 2 Water-use efficiency of wheat crops in four regions of the world



A CSIRO international study found poor water-use efficiency of wheat crops was a global phenomenon with crops in dry areas failing to achieve their yield potential, mainly due to valuable rainfall being lost as soil evaporation.

Source: CSIRO Land and Water.

Management and variety options

The knowledge gained from the international analysis will help researchers and producers to develop improved farming techniques to minimise the impact of soil evaporation and improve the water-use

CSIRO research showed intensive cropping rotations could increase gross margins while reducing deep drainage and nitrogen leaching.

efficiency of wheat varieties. The key to improving water-use efficiency is to implement strategies to store rainfall and to reduce the wasteful pathways, chiefly soil evaporation.

Reduced row spacing, early vigour and a sufficient supply of nutrients can favour rapid groundcover growth and reduce soil evaporation.

But the benefits of rapid water use early in the season need to be weighed against the depletion of soil water reserves for the critical stages of grain set and filling.

Stubble retention can contribute to stored soil water, particularly in medium rainfall zones. Weed control is also essential to remove plants that compete with the crop for water.

Sowing as early as possible following the first rainfall also contributes to greater water-use efficiency. But this strategy needs to be weighed against the risk of frost.

A split application of fertiliser can help reduce the risk associated with uncertain amount and timing of rainfall. Improved wheat varieties suitable to dry environments also could help to increase water-use efficiency.

Early vigour and rapid canopy growth are key traits that could help reduce soil evaporation. Current breeding programmes by CSIRO and other research institutions are examining these traits and their influence on water-use efficiency.

Cropping intensification

Another beneficial management option to improve water-use efficiency is cropping intensification — a move away from the traditional low-input wheat–fallow and wheat–pasture rotations.

Cropping intensification involves two main elements — greater frequency of grain crops and higher inputs, particularly nitrogen fertiliser. While this intensive high input option has associated risks in dry seasons, field and modelling research by the CSIRO Mallee Sustainable Farming Project has shown long-term benefits.

Five years of comprehensive CSIRO trials and research in the Mallee have shown that cropping intensification can deliver increased and more stable gross margins, while also having a neutral or positive impact on deep drainage and nitrogen leaching.

The increase in stubble from this type of system protects the soil underneath, reducing wind erosion and improving soil fertility.

Increased fertiliser use can also accelerate plant growth, which can also stem soil evaporation.

About the authors

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Match inputs to soil moisture to lift yields

Farm information

Farmers
Dean and Jeanette Wormald
Location
Loxton, South Australia
Property size
2400ha
Enterprise
Wheat
Annual rainfall
275mm
Soil type
Sandy loam
Soil pH
8.5 (calcium chloride)

Dean and Jeanette Wormald, Loxton, South Australia, have departed from the traditional cereal–fallow rotation and embraced continuous cropping with encouraging results.

Since moving to more intensive cropping during 1994–1995, the Wormalds' average wheat yield has increased from 0.8–1 tonne per hectare to about 1.4t/ha.

The underlying principle of the Wormalds' 2400ha cropping programme is to match inputs to the probable available seasonal moisture to maximise water-use efficiency and crop yields. The amount of fertiliser is determined by the break of the season and the seasonal forecast, which helps the Wormalds to assess how much moisture they expect to receive and what action to take. As a result they subscribe to a private weather forecaster and closely monitor meteorology web sites.

Since 1994, Dean and Jeanette have gradually put in place a continuous crop rotation consisting of three years of wheat, one year of malting barley, one year of oats and one year of chemical fallow.

During 2001 they also adopted a minimum tillage system and gradually introduced press wheels, to improve protection of seed and fertiliser. They found the retention of the 2001 crop residue was a major benefit during a wind event during the spring of 2002, protecting the soil from wind erosion.

The couple has observed improved soil fertility as a result of stubble retention, which they maintain has visually improved plant growth.

Another component of the programme has been a dramatic increase in fertiliser inputs to improve crop vigour.

Dean and Jeanette apply up to 70–80kg di-ammonium phosphate and 40kg urea at

Dean and Jeanette Wormald, Loxton, South Australia, are reaping the benefits of a more intensive cropping system.

sowing during a good year, while a late break and a forecast dry 2004 season caused them to apply only 20kg/ha of urea and 50kg/ha of di-ammonium phosphate.

As a result the crop is likely to yield 0.6t/ha after receiving just 145mm of rainfall during the growing season, which included an unseasonally hot 40-degrees Celsius day during flowering.

While the couple is philosophical about 2004, they are looking forward to the cumulative benefits of their intensive cropping system.