NSW Agriculture

Making the most of available water in wheat production

agnote
ISSN 1034-6848

DPI 468, July 2003

J.M. Morgan,
Principal Research Scientist, Tamworth

www.agric.nsw.gov.au

Periods of drought focus attention on the conditions which tend to maximise the efficient use of water in crop, particularly in wheat production. Efficient use of water or rainfall involves maximising the proportion of the water supply which is used by the crop to produce the grain yield rather than allowing it to be lost from the soil in other ways. The crop water use is the amount of soil water at sowing/ establishment less that remaining at maturity plus that supplied during growth by rainfall or irrigation. The yield divided by the total water used to produce it gives an estimate of grain water use efficiency (WUE) expressed as kg grain per ha per mm water used.

Important factors that promote efficient use of water are illustrated in a study using large plots at Cowra in three different seasons and sites on the one farm (Table 1). The soil type, a red-brown earth, is widely used for wheat production in Australia. The study was conducted over 3 years in the early 1970's to validate a crop model. Treatments consisted of all combinations of 37 kg/ha phosphorus (P), 82 kg/ha nitrogen (N) (applied at sowing) and no fertiliser application, replicated twice. Soil water changes were followed with a neutron moisture meter below 18 cm and by gravimetric analysis at the surface between establishment and maturity.

FACTORS AFFECTING WUE

Adequate supply of phosphorus and nitrogen

Both phosphorus (P) and nitrogen (N) can often be deficient, particularly on duplex or red brown earths. Severe P deficiency, indicated by a low soil test, may reduce the water use efficiency by a large extent. An example is A in Table 1, sown on 21 May 1972. As well as a probable increase in soil evaporation through reduced ground cover, crops with P deficiency mature more slowly exposing them to higher levels of evaporative demand later in the season. In high

Table 1. Water use efficiency for yield (kg/ha/mm) in large wheat plots in 3 seasons at Cowra, NSW. Depth of extraction 50–60 cm. Phosphorus (P) and nitrogen (N) applications were near optimal for this location.

Example	Rainfall	Attribute	+P+N	+P-N	-P+N	-P-N
A	144	Yield (t/ha)	2.5	2.5	0.7	0.8
		Water use (mm)	208	205	193	206
		WUE (kg/ha/mm)	11.8	12.1	3.4	3.6
B	196	Yield (t/ha)	1.4	1.7	1.5	1.6
		Water use (mm)	237	230	238	234
		WUE (kg/ha/mm)	6.0	7.2	6.3	6.7
C	309	Yield (t/ha)	2.0	1.5	1.0	0.9
		Water use (mm)	360	341	356	344
		WUE (kg/ha/mm)	5.6	4.5	2.9	2.6

Table 2. Growth, water use (E_a) and evaporative demand (E_p) in the period between the emergence of the flag leaf and the emergence of the heads of primary tillers of a well fertilised crop sown in May (A in Table 1) and June (B in Table 1) in differing seasons.

Example	Sowing date	Dry wt. (t/ha)	Leaf area index	Rain (mm)	Soil water loss (mm)	E_p (mm)	E_a/E_p	Grain yield (t/ha)	WUE (kg/ha/mm)
A (+P+N)	24/5	3.2	1.9	21	39	54	1.11	2.5	11.8
B (+P+N)	4/6	3.9	2.3	17	73	155	0.58	1.4	6.0

P plots heads emerged at the end of September while in low P plots ear emergence was 17 days later. Nitrogen deficiency may also reduce water use efficiency, but has less effect on maturity.

Avoid late water stress particularly between jointing and flowering

Severe sudden water stress between the emergence of flag leaf and the emergence of the head due for example to hot dry winds (i.e. high evaporative demand), can reduce grains per head (sometimes producing dead or white tips on heads), and numbers of viable tillers. Crops with large bulk or leaf area (and with high water use) may be particularly susceptible. Water use efficiencies and yields are reduced. An example is B in Table 1 sown on 4 June 1971. In that year, due to later sowing, ear emergence occurred in mid to late October. A period of severe stress occurred in early October. Earlier, May sowing, as in the other years, with ear emergence in late September – early October would have reduced this problem. This is shown in Table 2. Although B had a higher biomass and leaf area (both close to maximum), while rainfall was similar (and more soil water was used by B than A i.e. E_a or the rainfall plus soil water loss, was greater), it had much more stress (lower E_a/E_p) due to a much higher evaporative demand (or free water evaporation, E_p). Even though B was a better crop than A shortly before flowering, it finished with a yield 1 t/ha less and a lower WUE (Table 1). Timely sowing or ear emergence is therefore important.

Using wheats with water stress tolerance through high osmoregulation (*o r* gene) can also help combat effects of water stress of this type. This is a cellular process which reduces water loss by accumulation of solutes (mainly potassium) in response to tissue water stress. Lines with this gene have greater yield and biomass under conditions where evaporative demand exceeds water supply. Because they extract more water from greater depth in the soil, the proportion of E_a which is transpired is greater, producing a greater WUE. Effects of water stress on seed set are also reduced. Water use efficiency may also be affected by excessive rain early or late in the crop growth period.

Effective weed control

Weeds contribute to water loss without contributing to yield, thus reducing water use efficiency. Fallow weed control is also important to increase water supply at sowing. The crop in C in Table 1, sown on 13 May 1970, is an example of this. Although a pre-emergence herbicide was used, it was largely ineffective with ryegrass approx. 30% of the total biomass in October. In-crop rainfall and water use were higher than the other years but yields were depressed through severe weed competition, resulting in a very low WUE.

Disease

Foliar and soil borne diseases, particularly with impacts after flowering that reduce harvest index, may be expected to also reduce water use efficiency.

RELATIONSHIP WITH YIELD

In the examples in Table 1, yield is reduced without substantial reductions in water use, by P deficiency, weeds and high evaporative demand especially around ear emergence. It was consequently not related to total in-crop rainfall. On the other hand, for a crop grown at the one site and well supplied with nutrients and with reasonable soil water holding capacity, yield can increase with increasing water supply while the water use efficiency may not be affected very much (Table 3). Here water was applied carefully using pan evaporation and rainfall as a guide. For example, with the highest frequency, water was applied when cumulative pan evaporation less rainfall equalled 50 mm.

Table 3. Water use efficiencies (kg/ha/mm) from results of J Cooper (1980a,b) at Yanco. Clay loam soil with a depth of extraction of approx. 110 cm, rainfall 293 mm.

Irrigation	0	2	3	7
frequency				
Yield (t/ha)	4.3	6.5	7.6	8.1
Water use (mm)	408	635	707	818
WUE (kg/ha/mm)	10.6	10.2	10.7	9.9

TARGET VALUES

WUE values of 10–12 kg/ha/mm (or moderately greater) may be expected from healthy crops with timely sowing/flowering, adequate nutrition and effective weed control (as in example A). This value remains relatively constant when yield varies through changes in water supply, though it may be lower at low yield levels (or low plant densities) where the proportion of soil evaporation may be higher.

ACKNOWLEDGEMENTS

H Maher for technical work, as well as E Chivers, D Lang and funding by the NSW Wheat Industry Research Committee.

FURTHER READING

Cooper JA (1980a). The effect of nitrogen fertiliser and irrigation frequency on a semi-dwarf wheat in south-east Australia. 1. Growth and yield. *Australian Journal of Experimental Agriculture* **20**, 359–364.

Cooper JA (1980b). The effect of nitrogen fertiliser and irrigation frequency on a semi-dwarf wheat in south-east Australia. 2. Water use. *Australian Journal of Experimental Agriculture* **20**, 365–369.

Fawcett RG (1967) Factors influencing the development and grain yield of spring wheats grown in the north-west plains of New South Wales, with special referecne to soil - water – plant relationships. PhD thesis, University of Sydney.

French RJ, Shultz JE (1984). Water use efficiency of wheat production in a Mediterranean type environment. II. Some limitations to efficiency. *Australian Journal of Agricultural Research* **35**, 765–775.

Holford ICR, Morgan JM, Bradley J, Cullis BR (1985). Yield responsiveness and response curvature as essential criteria for the evaluation and calibratiom of soil phosphate tests for wheat. *Australian Journal of Soil Research* **23**, 167–180.

Morgan JM (1984). Modelling environmental effects on crop productivity. In 'The control of crop productivity'. (Ed CJ Pearson) pp. 289–304. (Academic Press Australia)

Morgan JM, Condon AG (1986). Water use, grain yield and osmoregulation in wheat. *Australian Journal of Plant Physiology* **13**, 523–532.

Morgan JM (2000). Increases in grain yield of wheat by breeding for an osmoregulation gene. Relationship to water supply and evaporative demand. *Australian Journal of Agricultural Research* **51**, 971–978.

Edited by Bill Noad
Information Delivery Program
Dubbo, July 2003
Agdex 112/10
Job No. 4287