

# **Defoliation of sorghum and wheat leads to control of phenology and enhanced water use efficiency.**

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## **ABSTRACT**

The proposition that yield and water use efficiency (WUE) can be increased by developing post-sowing crop management to maximise the amount of water used in yield-forming growth processes was examined. Defoliation of sorghum seedlings was found to delay the onset of panicle initiation (PI). Serial defoliation maintained the seedling in a vegetative state, so delay and subsequent onset of PI could be controlled. Defoliation of early-sown wheat crops before 50 days after sowing (DAS) either increased or did not affect yield. Defoliation after 50 DAS, or defoliation in late-sown crops, mostly reduced yield through a reduction in ear number. In-crop foliar nitrogen application to wheat enhanced grain protein and should be viewed as a further in-crop management practice. In conclusion, defoliation can change the vegetative growth and phenology with associated increase in crop WUE.

## **Key words**

Sorghum, wheat, rain-fed, WUE, defoliation.

## **INTRODUCTION**

In central Queensland, about 1.0 million hectares of land are cultivated for rain-fed crop production annually. Variation in the amount and timing of rainfall produces large variation in yields of rain-fed crops in central Queensland. Farmers profit on average one year in five, producing severely water-stressed crops two years in five and not planting in the remainder. Indeed, the average annual rainfall is 600 – 700 mm, with 70 – 80% falling in the summer, leaving winter crops to largely depend upon the small plant available water capacity (PAWC) of ~150 mm held within the largely cracking clays. Current yield levels of wheat and sorghum average 1.5 t/ha. Using water use efficiency (WUE) values of 8.4 and 9 kg grain/mm/ha for sorghum and wheat respectively, double cropping is calculated to use only one-half of the average annual rainfall for crop growth and production. It is not unusual to find sorghum crops that fail from water stress occurring before anthesis due to misalignment of phenology and water availability. The timing of water stress has significant impact upon final yield; for example, equivalent stress around the pollen formation and anthesis period has a proportionally greater effect than prior to or after that period (Craufurd and Peacock, 1993). Due to the variable nature of rainfall, ideal "phenologies" are difficult to determine, and their effectiveness in practice depends upon planting opportunities and the probability of rain events. Additionally, once the crop has been sown, no management has been developed to ameliorate the effects of subsequent water stress. Yet, we believe, much opportunity exists to implement post-sowing management, as is often used in horticulture. Large-scale mechanisation characterises the central Queensland farming systems, and quite recently controlled traffic systems have undergone an exponential rate of adoption (Chapman, 1998). The advent of controlled traffic has opened up new opportunities for agronomic intervention to extensively grown crops, beyond that imaginable before. Our challenge is to use the flexibility and precision of this system to change soil and plant management and improve the WUE of sorghum and wheat - to manage these crops intensively. We have approached this opportunity in a number of ways that are outlined in the following sections:

## **Managing leaf area**

We hypothesise that intervention to reduce in leaf area during periods when water is less available, particularly during vegetative growth, will conserve water for reproductive growth and development stages. Additionally, we hypothesise that canopy manipulation will delay plant development, either before spike or panicle initiation, or before anthesis. Ideally, we wish to capitalise upon both of these outcomes from canopy manipulation. They also offer new planting opportunities (ie, on less than a full profile) if the later risk of drought stress is minimised by canopy modification.

### **Managing in-crop plant population**

Planting high population densities will lead to drought stress sooner than if planting a lower population. We hypothesise that removing plants in-crop, if the likelihood of follow-up rainfall is low, will prevent complete crop failure, and ensure some harvestable yield.

### **Applying side-dressed nitrogen (N) in years when merited by in-crop rainfall**

Rather than applying all nitrogen at planting (and tying up capital, especially when crops fail), we hypothesise that responses to side-dressed N will occur only during wetter years and that a side-dressed N strategy represents a more rational approach to N fertilisation than blanket application at planting.

## **RESULTS AND DISCUSSION**

### **Managing leaf area**

A model developed by Hammer and Muchow (1994) was used to predict the outcomes of defoliation of sorghum planted over a wider than usual planting window in CQ. At present, crops are rarely sown before the soil water exceeds 50% of soil plant available water contents (PAWC). This often occurs late in the season. If a crop could be established on earlier but lighter rain, and maintained in a state of vegetative development, it could then regrow following large falls of rain. Water use efficiency would increase because more of the in-season rain would be used at and after flowering.

We made assumptions about the extremes of sorghum responses to leaf modification. In one exercise, plants were either unmodified (control) or modified to remove all leaf at 200 degree days and then panicle initiation was delayed by 200 degree days (defoliated). The modification was done in all years irrespective of water stress and run with different PAW at sowing for 95 years of weather data at Capella, central Queensland. A large annual yield increase was calculated for modified sorghum, partly a function of greater harvest index but also increased leaf area when the PAW at planting was less than 100% PAWC. For example, planting on 40% PAWC, control yield was 1348 kg ha<sup>-1</sup> compared to 1650 kg ha<sup>-1</sup> for the defoliated crop.

In one-third of years defoliation caused yield to decline, mostly by less than 500 kg ha<sup>-1</sup>, and in one-third of years there were similar small increases in yield. In the remaining years, yield increased by 500 – 1700 kg ha<sup>-1</sup>. These increases are large given average annual yield is only 1500 kg ha<sup>-1</sup>.

A number of glasshouse and field trials were conducted on sorghum from 1997 – 2000 at QDPI, Mareeba and at Walkamin Research Station. In essence, a number of defoliation treatments, varying in periodicity and leaf position down the stem, were superimposed on sorghum genotypes of contrasting maturity groups, at times in combination with drought stress and artificially extended photoperiods. Data on leaf primordia appearance, timing of panicle initiation and anthesis, and on growth and yield were collated. In the initial experiments, both defoliation (above the second leaf ligule, starting 18 days after sowing – das) and early drought stress (starting when leaf 4 appeared in the control) delayed the onset of panicle initiation (PI). A single defoliation marginally delayed PI by up to 11 days, whereas weekly-defoliation delayed PI by more than 11 days; only the weekly-defoliation treatment delayed anthesis by 12 days. Mainstem removal at PI or anthesis naturally resulted in later anthesis of the subsequent tillers. Leaf number was reduced with defoliation (from 12.0 to 10.7 and 9.8 for the once and weekly defoliation, LSD  $P < 0.05 = 0.8$ ), and green leaf area and dry weight at anthesis was halved compared to the control.

Further study of defoliation involved a field experiment with three genotypes and five treatments. It was quite evident that removal only of expanded leaf (ie, twice weekly of all fully expanded leaf blades, until PI in the control) did not delay PI in the early genotype Buster, but did so marginally for the two later genotypes. Removal of all tissue (including expanding) above the second ligule lead to greater delay in PI (19 d in var. Boomer) than did removal of all leaf above the third ligule (12 d in var. Boomer). A bi-weekly application of ethephon also delayed the advent of PI by 9 d. Anthesis was also delayed to a similar or slightly lesser degree by treatments that effected delay in PI. This was matched in the later genotypes by an increase in leaf number, but not for the early genotype Buster. Green leaf area at anthesis was also reduced in the leaf modification treatments, but not significantly by the removal of only expanded leaves. In the same pattern, total and grain dry weight were reduced by defoliation above the second and third ligules, but removal of expanded leaf or application of ethephon was without effect.

Our data, thus far, suggest that leaf modification delays the production of the signal that involves developmental changes (PI) at the apical meristem. Clearly, continual modification over a period of time will maintain the meristem in a vegetative state, and leaf initiation continues to accrue. It is likely that leaf modification acts by preventing achievement of the state of competency necessary to switch to reproductive development, and that expanding and expanded leaves have different inputs on the production signal. Our data show that the effective vegetative period (from the end of defoliation to PI) of Boomer defoliated at the second ligule was 50 d, compared to a vegetative period (sowing to PI) of 70 d for the control Boomer. The 20 d reduction, maintained if rain were scarce, and followed by a significant rainfall, would provide for reduced vegetative water use with consequent increase in water availability at anthesis and grain filling. Control plants would have used up most water before flowering.

For wheat the approach taken was somewhat different. Pot and field trials were undertaken to quantify the effects of defoliation, under natural and modified soil water regimes, and later modelled crop response in order to determine probabilities for effectiveness of the various treatments under variable planting and growing conditions. In experiments with wheat, defoliation was done only once, and always after the onset of reproductive development (the double ridge stage).

Defoliation within seven weeks of a pre-June sowing did not reduce yield compared to the control in field trials at Biloela over three seasons (Table 1). Of prime interest was the effect that early defoliation had on grain yield and WUE, raising both in comparison to the control (Table 1). In the early-maturing cultivar this was in response to higher total biomass, and in the late-maturing cultivar to a greater harvest index. Pot experiments run at Rockhampton gave similar increases in WUE for defoliation treatments.

Relating the direction and magnitude of the change in defoliated plots with the amounts of stored water in the profile at planting, and in-crop rainfall, and accounting for the probability of fallow rain and in-crop rainfall, allowed the elaboration of formulae that could assist producers in assessing risks involved with defoliation. Assuming that only 25% of fallow rain, but 95% of in-crop rainfall can be converted to PAWC, we calculate using 95 year rainfall data for Biloela, that for eight years out of 10, early defoliation at Biloela will result in a yield increase (and a probable increase in WUE too). For defoliation at the late tillering stage there is a 1 in 2 year chance of yield improvement with defoliation. Further estimates suggest that yield loss through early defoliation would only occur in 3% of years, while with late defoliation it would occur one year in five.

**Table 1. Effects of defoliation on grain yield, WUE and related components.**

Year	Sowing date	Cultivar	Defoliation (das)	Yield	Total DM	Harvest index	Grain WUE	Total DM WUE
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-----% increase compared to control-----

1997	28 May	Sunstate	37	5.3	19.3**	4.8	-	-
1998	28 April	Batavia	49	7.3 <sup>+</sup>	2.6	12.5**	22**	16.9**
1999	27 April	Batavia2	37	7.4 <sup>+</sup>	3.2	5.9*	17.8**	8.2*
1999	27 April	Batavia2	50	2.3	3.8	5.1	16.2**	17.6*

Where: +  $p < 0.1$ , \*  $p \leq 0.05$ , \*\*  $p \leq 0.01$

### Managing in-crop plant population

Data from an earlier experiment run in Rockhampton would lead us to believe that under limiting water conditions high population is a liability, with yield declining with increase in population under poor irrigation (from 2200 kg ha<sup>-1</sup> at 40 kg ha<sup>-1</sup> sowing rate to 1500 kg ha<sup>-1</sup> at 120 kg ha<sup>-1</sup> sowing rate in dry conditions) and rising with population under wetter conditions (3600 kg ha<sup>-1</sup> to 4000 kg ha<sup>-1</sup> over the same sowing rates). Harvest index of the high population/dry condition (35.5%) was considerably less than that of the high population/wetter condition treatment (40%).

However, data from a field experiment run in 1999 did not support this hypothesis. Compared over two sowing dates (27<sup>th</sup> April and 27<sup>th</sup> May) removal of 33% of plants at the middle tiller stage did not lead to any change in yield and its components compared to the control; remaining plants produced more ears to compensate for the loss of plants. We believe that this lack of effect was due to the reasonable supply of water throughout the crop, conditions under which the control did not enter into terminal drought.

### Applying side-dressed nitrogen when in-crop rainfall merits

Planting on residual moisture, especially if less than on a full soil profile, predisposes crops to the likelihood of crop failure should in-crop rainfall be non-existent. Planting of wheat under inadequate soil moisture conditions, therefore, is unlikely to be combined with full application of recommended (based on available soil N) nitrogen. We propose that side-dressing of nitrogen would be remunerative to growers in years when stored-profile and in-crop rainfall would support good crop growth.

We studied the effects of nitrogen application rates and side-dressing at a farmer's field site in Jambin, central Queensland. Experiments in 1998 and 1999 concentrated on investigating the interaction between basal N application and defoliation (N raised yield by 20% at 80 vs 40 or 0 kg N ha<sup>-1</sup>, defoliation due to its lateness (51 das) in the late sowing reducing yield by 30%), and between basal N, superphosphate and foliar spray of N. Foliar N (30 kg N ha<sup>-1</sup>) raised yield by 13% ( $P < 0.165$ ) and protein level by 1 percentage point (from the inferior grade to the superior grade,  $P < 0.05$ ), while superphosphate application raised yield by 20% ( $P < 0.05$ ). No interactions between treatments in either year were evident.

## CONCLUSIONS

We have shown that in-crop management, contingent upon PAWC, has the potential to increase grain yield of sorghum and wheat above that of crops not receiving in-crop management. Our understanding of the control and its manipulation of PI in sorghum will assist in manipulating the timing of flowering to coincide with sufficient PAWC to carry the crop to harvest, while in wheat both early defoliation and foliar N spray offer opportunity to raise WUE and grain protein concentration, respectively.

## REFERENCES

1. Chapman, W. 1998. *Second National Controlled Traffic Conference*. 26-27 August, University of Queensland, Gatton.
2. Craufurd, P.Q and Peacock, J.M. 1993. *Exp Agric*. **29**, 77-86.
3. Hammer, G.L. and Muchow, R.C. 1994. *Field Crops Res*, **36**:221-234.