Avoiding low temperature damage in Australia's rice industry with photoperiod sensitive cultivars

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Abstract

The Riverina region of southeastern Australia is one of the highest yielding rice growing regions in the world. However, consistently high yields are limited by low temperatures during the young microspore stage (midway between panicle initiation and flowering) resulting in pollen abortion and sterile florets. The mean yield reduction due to low temperature is estimated to be 0.68 t/ha/year, which is equivalent to $20 million annually. Most rice is sown in early October to ensure that the critical reproductive period occurs during the warmest time of year (late January to early February). Field trials across four seasons show that when Amaroo and HSC55 are sown early the difference in flowering date is 40 days and this difference is halved. This difference reflects Amaroo's mild photoperiod sensitivity compared to HSC55 insensitivity. The opportunity therefore exists to introduce greater photoperiod sensitivity in cultivars, so that flowering occurs faster for a delayed sowing date, minimising the risk of low temperature damage. Thus a delay in sowing may increase on-farm flexibility and management.

Key Words

rice, low temperature, sterility, photoperiod.

Introduction

Rice growing in Australia is confined to the Riverina region of NSW, centred at 35?S, 146?E. The growing season is characterised by long days and high levels of solar radiation (~32 MJ m^{-2} day^{-1}), with low temperatures at the beginning and end of the season (Figure 1). Daylength varies from 12h to 14.5h throughout the growing season (October - March). Rice is a short day plant, therefore flowering is accelerated in short days. High temperature promotes flowering, while low temperature delays flowering (Summerfield *et al.* 1992). There is a large diurnal temperature variation (~12-15?C) and low humidity. These conditions of (high solar radiation, mostly warm temperatures and a long growing season, particularly during grain filling) provide the basis for high yield potential. Low night temperatures, inducing spikelet sterility have caused significant yield loss in Australia (Boerema 1974). Cool temperatures during the young microspore stage have caused an average of 0.68t ha^{-1} yield loss each year in Australia (Farrell *et al.* 2000).

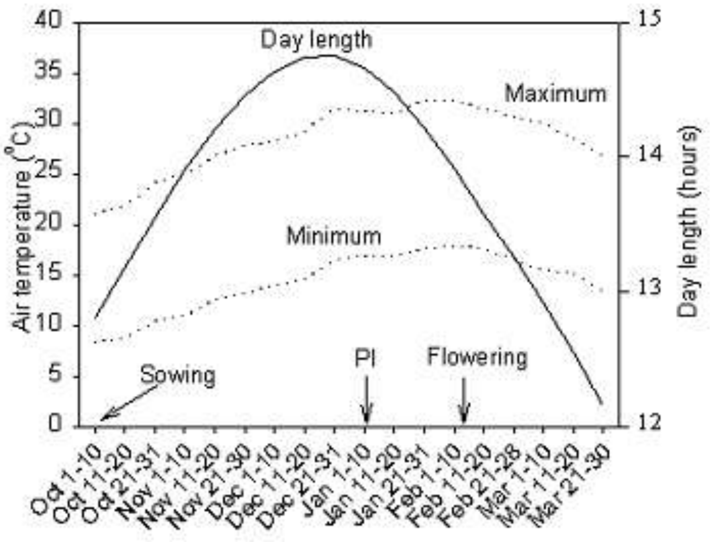

Figure 1. Day length and long term maximum and minimum air temperatures (1955-2002) at Griffith (data courtesy of CSIRO, Griffith).

Rice crops in Australia are sown from late September until mid November, depending on the growing duration of each cultivar. The sowing time of the rice crop is important for three major reasons. Firstly, it ensures that vegetative growth occurs during a period of satisfactory temperatures and high levels of solar radiation. Secondly, the optimum sowing time for each cultivar ensures the cold sensitive stage occurs when the minimum night temperatures are historically the warmest (late January to early February). Thirdly, sowing on time guarantees that grain filling occurs when milder autumn temperatures are more likely, hence good grain quality is achieved.

Clearly the sowing window changes to reflect differences in growth duration. In Australia, high yields were observed for crops flowering before late February, which required longer and shorter season cultivars be sown in late September and late October respectively (Williams and Angus 1994). (Reinke 1993) found that the yields of four cultivars were reduced when sown late (December). He suggested that low temperature during the young microspore stage was not the only factor that limits yield. Other factors must be considered, such as conditions during grain filling.

Materials and methods

Multiple sown field trials were established at Yanco Agricultural Institute in four consecutive years from 1999 to 2002 (Table 1). Fifty-four cultivars were tested in at least one of the four years, with seven cultivars common to each year. The cultivars were selected from different origins and represented different levels of tolerance to low temperature. In this paper comparisons were made between Amaroo, a full season Australian cultivar, and HSC55, a short duration Hungarian cultivar, which were found to differ in their flowering date. In years 1 and 2 the plots were combine sown and were 3.0 x 1.2 m. Plots were sown with a single row planter and consisted of 2 rows, 4 m long in years 3 and 4. Date of flowering was recorded when anthers from 50% of spikelets were visible from half of the panicles. Daily weather data has been recorded at CSIRO Griffith since 1955. Temperature and daylength data was summarised to describe the rice growing environment of the Riverina.

Table 1 Details of the four year field trial.

Year

	1	2	3	4
First sowing	Oct 3, 1998	Oct 8, 1999	Oct 30, 2000	Oct 10, 2001
Last sowing	Dec 31, 1998	Dec 31, 1999	Dec 19, 2000	Jan 21, 2002
Sowing times	9	6	7	5
Number of cultivars	30	28	7	50
Sowing method	Combine	Combine	Hand	Hand
Water depth	Shallow	Shallow	Shallow	Shallow

Results and Discussion

Despite the long term average minimum temperature for the reproductive period being around 17?C, the actual temperature during this critical stage often falls below 15?C (Figure 2). There is clearly an increased risk of low temperature damage at the young microspore stage by sowing rice outside the allocated window. The critical temperature to induce sterility is around 15-17?C for tolerant cultivars and 17-19?C for susceptible cultivars (Satake 1969). The probability of encountering a night temperature less than 15?C is 11% higher at the end of February compared to the beginning.

There was a significant linear relationship between sowing date and flowering date for Amaroo (r^2=0.74) and HSC55 (r^2=0.86) across the 4 years (Figure 3). The flatter slope of Amaroo of 0.54 compared to 0.81 for HSC55, suggest that for a later sowing, the duration to flowering was shorter. This reflects a mild response to photoperiod. In comparison the relationship between sowing and flowering time in HSC55 (y = 0.81x + 88) was steeper, suggesting it is less sensitive to photoperiod. The difference in flowering date between Amaroo and HSC55 is reduced as sowing time is delayed (Table 2). Amaroo flowers on average 40 days later than HSC55 when sown on October 1st and this difference is halved to 20 days for a December 9th sowing.

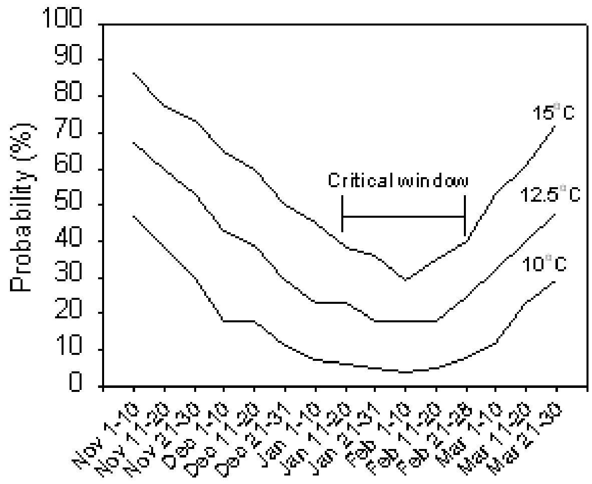

Figure 2 Probability that the minimum temperature on a night is below 15?C, 12.5?C and 10?C in Griffith (compiled from temperature data courtesy of CSIRO Griffith).

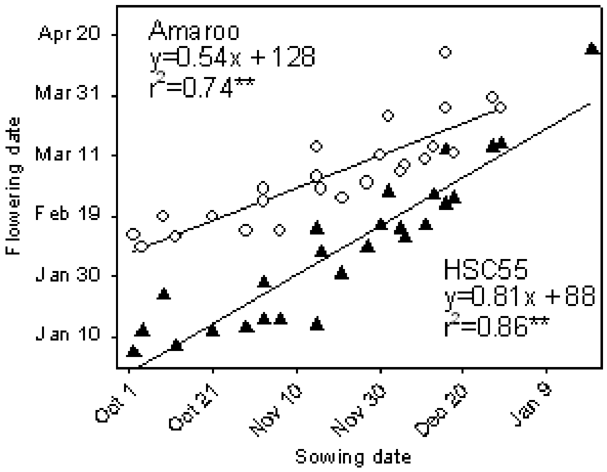

Figure 3 Relationship between sowing and flowering date for Amaroo (○) and HSC55 (▲) across 4 years.

Table 2 Difference in flowering date between HSC55 and Amaroo for a range of sowing dates

	Days to flowering		
Sowing date	HSC55	Amaroo	Difference
October 1	88	128	40
October 21	84	118	34
November 10	80	109	29
November 30	76	100	24
December 20	73	91	18
January 9	69	82	13

Photoperiod sensitive cultivars allow Australia's rice growers to have greater flexibility in sowing time. Amaroo is a full season cultivar that is mildly photoperiod sensitive. Greater benefits exist for growers if shorter duration cultivars with mild photoperiod sensitivity can be developed to suit Australia's environment. Photoperiod sensitivity index (PSI) for each cultivar was calculated by subtracting from 1 the slope of the linear regression of sowing and flowering time. Among the seven cultivars that were tested in the four consecutive years field trials three cultivars were photoperiod insensitive while the remainder were mildly sensitive (Table 3). The PSI of individual cultivars in the insensitive and mildly sensitive groups varied from 0-0.3 and 0.3-0.7, respectively. Photoperiod sensitive cultivars are common in rainfed lowland rice in Southeast and South Asia to avoid late season drought (Fukai, 1999). With the exception of cold months, extreme photoperiod sensitivity would prevent flowering in Australia’s rice growing environment.

Table 3 Origin, photoperiod sensitivity index (PSI) and the resulting classification of seven cultivars tested across four years.

Cultivar	Origin	PSI	Photoperiod sensitivity
M103	America	0.18	insensitive
HSC55	Hungary	0.19	insensitive
Hitomebore	Japan	0.27	insensitive
Doongara	Australia	0.31	weakly sensitive
Millin	Australia	0.35	weakly sensitive
Sasanishiki	Japan	0.42	weakly sensitive
Amaroo	Australia	0.46	weakly sensitive

Conclusion

Increasing the photoperiod sensitivity of Australia’s rice cultivars is one possible way to minimise the exposure of the rice crop to low temperatures at the young microspore stage. To further reduce growth duration while increasing photoperiod sensitivity would increase on farm flexibility. Additionally, increased photoperiod sensitivity and reduced growth duration may lead to a reduction in water use. However, this may be at the detriment to yield potential, and therefore needs further examination.

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