Genotype and Environmental Effects on Harvest Index of Sorghum

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Abstract

The objective of this study was to examine the effects of temperature during grain-filling, crop maturity and plant density on the stability of harvest index (HI) increase in sorghum. Four field experiments sown at different times with three cultivars varying in crop maturity were conducted at Gatton, southeast Queensland. There was a tendency for lower HI with later maturity, but this was not clearly related to differences in rate or duration of HI increase. The average rate of HI increase was $0.0198d^{-1}$, but this was reduced considerably (0.0147) in one experiment that matured in cool conditions. The results indicate that while use of a HI increase approach in modelling grain growth is relatively robust, there are environmental effects (such as low temperature) and a degree of unexplained variability in components of the approach that introduce significant error in yield predictions.

Key Words

Crop modelling, grain growth, maturity, yield, harvest index.

Introduction

Current crop simulation models can retain significant error in predicting grain yield over diverse conditions. Hammer and Muchow (2) developed a sorghum crop model that accounted for 94% of the variation in total biomass, yet only 64% of the variation in grain yield, when tested over a broad range of data sets. Their testing procedure showed a weakness in using the HI increase approach to calculate grain growth and yield. The HI increase approach uses a linear increase in HI from shortly after anthesis until either two-thirds of the time between anthesis and physiological maturity has elapsed or maximum HI of 0.55 is reached (2), and is based on the concept developed for soybean by Spaeth and Sinclair (3). Major concerns with the HI approach are the use of a constant slope for HI increase across all environments, particularly in cool temperatures, timing of cessation of HI increase and possible variation in maximum HI with maturity. Accordingly, experiments were conducted to determine if HI slope, timing of cessation of HI increase and HI maximum were consistent over a range of crop and environmental conditions.

Materials and Methods

Four experiments (Exps.) were conducted at Lawes (lat. 27 ?34' S, long. 152?20' E, altitude 90 m a.s.l.), in south-eastern Queensland, Australia from 1993 to 1995. The sowing dates were 27th September 1993 (Exp. 1), 28th January (Exp. 2), 10th November 1994 (Exp. 3) and 12th January 1995 (Exp. 4). This provided experiments that matured under both increasing and decreasing temperatures.

The first two experiments consisted of three sorghum cultivars and the third and fourth comprised two sorghum cultivars with two densities. Hybrids Pioneer S34, Texas 610SR and Texas 671 were chosen for their contrasting phenology, Pioneer S34 having quick maturity, Texas 671 medium late and Texas 610SR intermediate. Texas 610SR was not included in the third and fourth experiments. The high density treatment used in all experiments was 16 plants m^{-2} while the low density treatment used in the last two experiments was 8 plants m^{-2}. All experiments were grown under moisture and nutritionally non-limiting conditions, and pests were controlled as necessary.

- Biomass accumulation and HI were determined by sampling at 4 to 6 day intervals from anthesis until maturity. Total above-ground biomass was determined after drying samples at 80?C. The panicles from the sample were then threshed and grain mass determined. Harvest index was calculated as the ratio of grain mass to total above-ground biomass.

- Harvest Index (HI) for each plot at each harvest was plotted against Days After Anthesis (DAA). Broken linear equations were fitted to these data to determine the lag phase (time from anthesis to the start of linear harvest index increase), end of linear HI increase, the rate of HI increase and final HI (Fig. 1). Analyses of variance were conducted on these HI attributes as well as on grain yield.

Results and Discussion

Grain yield (data not shown) varied from 4700 to 9400 kg ha^{-1} depending on treatment and experiment. Significant differences were found only between the two hybrids in Exps.3 and 4. There was, however, a tendency for lower final harvest index to be associated with late maturity (three of four experiments – Table 1). This general tendency was not clearly related to changes in timing of start of HI increase, slope of HI increase, or duration of HI increase (Table 1).

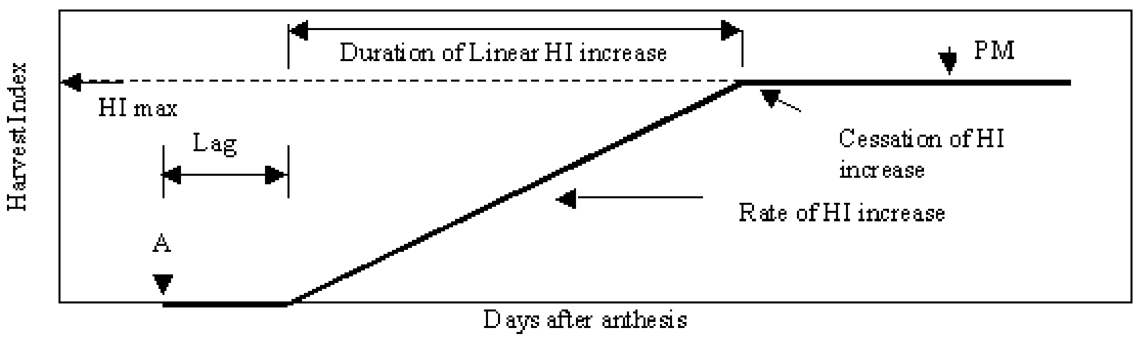

Figure 1. Schematic of broken linear equation for HI showing anthesis (A), lag phase to start of increase in HI, rate and duration of HI increase, cessation of HI increase, HI max and physiological maturity (PM).

Table 1. Harvest Index characteristics measured in the four field experiments.

		Hybrid / Density							
		Pioneer S34		**Texas 610SR**		**Texas 671**		***lsd (P < 0.05)***	
Exp.		**16**	**8**	**16**	**8**	**16**	**8**	***Hybrid***	***Density***
1	Lag phase duration[1]	0.13	-	0.15	-	0.14	-	*n.s.* [2]	-
	HI increase slope (d^{-1})	0.025	-	0.023	-	0.021	-	*n.s.*	-
	Cessation of increase[1]	0.79	-	0.82	-	0.83	-	*n.s.*	-
	HI maximum	0.55	-	0.53	-	0.49	-	*0.019*	-
2	Lag phase duration	0.07	-	0.10	-	0.10	-	*n.s.*	-

	HI increase slope (d^{-1})	0.015	-	0.014	-	0.014	-	*n.s.*	-
	Cessation of increase	0.81	-	0.76	-	0.73	-	*n.s.*	-
	HI maximum	0.46	-	0.42	-	0.43	-	*n.s.*	-
3	Lag phase duration	0.08	0.10	-	-	0.11	0.13	*n.s.*	*n.s.*
	HI increase slope (d^{-1})	0.024	0.023	-	-	0.021	0.019	*0.003*	*n.s.*
	Cessation of increase	0.73	0.85	-	-	0.73	0.84	*n.s.*	*0.09*
	HI maximum	0.56	0.57	-	-	0.47	0.47	*0.02*	*n.s.*
4	Lag phase duration	0.05	0.07	-	-	0.09	0.10	*n.s.*	*n.s.*
	HI increase slope (d^{-1})	0.020	0.019	-	-	0.020	0.019	*n.s.*	*n.s.*
	Cessation of increase	0.75	0.78	-	-	0.61	0.66	*0.07*	*n.s.*
	HI maximum	0.53	0.52	-	-	0.48	0.49	*0.02*	*n.s.*

[1] Expressed as a fraction of the time from anthesis to physiological maturity

[2] n.s. – no significant difference.

- Final HI in Exp 2 was lower than in the other three experiments. This was associated with a much lower rate of HI increase, which was probably caused by the very low temperatures experienced during grain filling in that late sown experiment. Bange et al. (1) described a similar response in sunflower.
- The lag phase prior to linear HI increase was 0.10 of the time from anthesis to physiological maturity when averaged across all experiments. The average rate of harvest index increase across all experiments was 0.0198 d^{-1}, which is similar to the 0.0185 d^{-1} used by Hammer and Muchow (2). The average duration of HI increase across all experiments was 76% of the time between anthesis and physiological maturity, compared with 67% in the current model (2).

Conclusion

These results show that variations in final HI associated with maturity were not clearly related to any one aspect of HI increase (slope, timing), and that certain environments experienced during grain filling affect HI slope. This indicates a difficulty in using the HI approach in modelling grain growth.

References

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