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Compensation in Grain Yield with Induced Uniculm in Grain Sorghum (*Sorghum bicolor L Moench*) in South–East Queensland, Australia

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ABSTRACT: In three field experiments conducted in south–east Queensland, Australia, sorghum was grown under three soil water regimes (rainfed, rain–out shelter: ROS and irrigated) and tillers were hand–removed to examine the growth and water use. The water use was not affected by artificial de–tillering. The grain number on the main stem increased in all three experiments as a result of de–tillering. Single grain weight on the main stem also increased except in the ROS experiment, where there was a general trend to lower water use with de–tillering. Uniculm presents an opportunity for increased grain yield through an improved harvest index, both under favourable and less favourable conditions.

INTRODUCTION

Donald (1968) put forward the theory that a crop without tillers would have a yield advantage over the one with tillers at the same stem density. The argument was based on the fact that tillers arise at different times after sowing, always later than main stem and hence have less time than main stem for their reproductive organ development. Unfertile tillers are also a drain on the limited resources available to the main stem. Later Donald (1979) showed that some barley cultivars produced a higher grain yield (GY) and harvest index (HI) than those with tillers particularly in wet years. In pot studies it has also been shown that de–tillered (induced uniculm) plants use less water in early growth under conditions of limited water availability. The result was

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higher than weight combined with a larger number of grains per head resulting in higher GY (Jones and Kirby, 1977; Kirby and Jones, 1977). In grain sorghum (Sorghum bicolor) it has long been recognized (Karper, 1929) that prolific tillering is disadvantageous when the water supply to the crop is limited. For this reason, uniculm might be useful under dryland conditions. Blum and Naveh (1976) have shown that the early suppression of leaf area development could lead to reduced water use by the crop. In induced uniculm studies in grain sorghum in Australia, (Fukai *et al.*, 1986) it has been shown that plants used significantly less water than those with tillers, but during a wet season experiment in south-east Queensland.

In a programme of crop breeding for environments prone to frequent soil water deficit, it may be useful to achieve a plant type which could thrive under sub-optimal conditions and also produce an economic yield. The work reported in this paper was conducted with two main objectives. They are, (a) to find out if induced uniculm would result in reduced use of water and (b) to examine the adaptability of "UNICULM" sorghum under different soil water regimes.

MATERIALS AND METHODS

The experiments were carried out at the CSIRO Cooper field station Gatton, Queensland in the spring/summer of 1987/88. The details of the site and climate during the experiments are described elsewhere (Peries *et al.*, 1990). The weather conditions are summarised in Figure 1.

The three experiments differed in terms of the supply of water. The first was conducted under rainfed (R/fed) conditions. The second was conducted under two rain-out shelters (ROS) (Foale *et al.*, 1979) and received no rainfall or irrigation from seedling emergence to maturity. The third had an irrigation component of 20 mm per week (in a single irrigation) beginning from 3 weeks after sowing to 11 weeks after sowing, making a total of 180 mm during this period. R/fed and irrigated experiments were located adjacent to the ROS experiment.

The seeds of grain sorghum cv Pride was sown on 22 October 1987 with a tractor-mounted 4-row suction plate (Nodet) seeder, followed by 20 mm of irrigation by sprinkler. Plants were in a North-

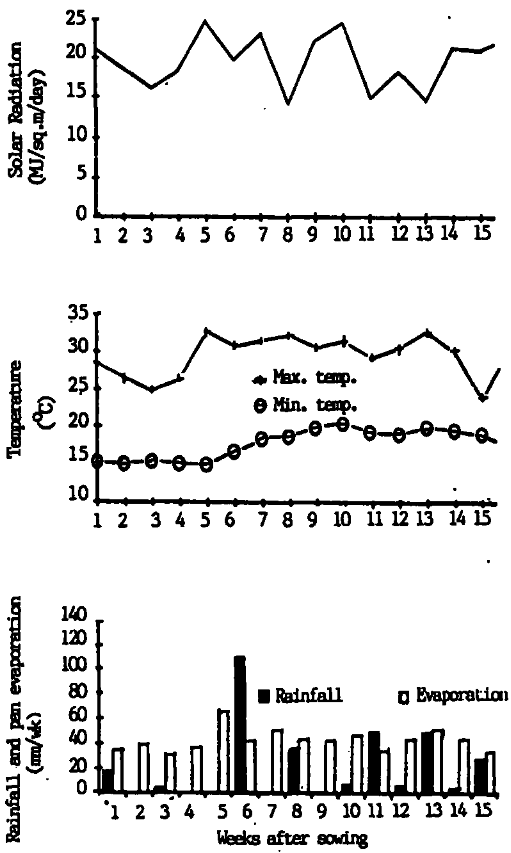

Fig. 1. Weather conditions during the spring/summer experiment of 1987/88.

South direction. Seeds were sown at 0.33 m equidistant spacing. At seedling emergence, the plants were thinned down to the required plant population density ($10/m^2$). The induced uniculm treatment (artificial de-tillering: NR-T) was carried out in the treatment plots beginning around 18 days after sowing (DAS). Hand removal of tillers was continued weekly for about 5 weeks, beyond which no new tillers appeared. The two treatments (NR+T, NR-T) were replicated 4 times in a Randomized Complete Block design. The plots were 12 m x 8 m in the R/fed and irrigated experiments. Due to limited area under the ROS, the plots were made smaller (5.5 m x 3.6 m).

A single aluminium tube, of 2 m length installed near the centre of each plot, provided access for the neutron moisture meter (NMM) (USA DOT 7A TYPE A) for the measurement of the temporal pattern of water use. Measurements were made at 26, 43, 57 and 92 DAS in the ROS experiment and 26, 43, 57, 92 and 106 DAS in the R/fed and irrigated experiments. Measurements were made at depths 30 to 170 cm at 20 cm increments. Water content of the surface 0-20 cm was determined by gravimetric sampling.

A linear probe of 1 m length was used to measure the photosynthetically active radiation (PAR) intercepted by the plant canopies several times between 25 and 80 DAS. A single measurement at the top of the canopy and the average of 10 measurements at the bottom of the canopy were used to compute the amount of radiation intercepted.

Four harvest were carried out for the determination of dry matter. In the ROS experiment, where the plants matured earlier than in the other experiments, the final harvest (physiological maturity) was made at 92 DAS, whereas in the R/fed and irrigated experiments it was carried out at 106 DAS. The first three harvests in all experiments were carried out at 34, 48 and 61 DAS respectively. The harvest area was confined to 1 m^2 in the ROS experiment, whereas it was 2 m^2 in others. At final harvest, heads were threshed and grain yield determined. Three samples of 100 grains were weighed separately to determine mean single grain weight.

RESULTS

Soil water deficit

Temporal change in soil water deficit (SWD) down to 180 cm in the profile for different treatments between 26 DAS and physiological maturity is shown in Figure 2. The deficit was approximately 270 mm when all layers of soil down to 180 cm were at the water potential of wilting point. Following heavy rains at 39 DAS the SWD was small at 43 DAS and then gradually increased up to maturity in the R/fed experiment. There was no treatment difference in SWD with time. Under the ROS, the deficit was around 100 mm with no treatment difference at 26 DAS. The deficit gradually increased with time, with no significant difference at any point in time. In the irrigated experiment the greatest deficit was around 80 mm and it was mostly less than 50 mm throughout the experiment; again with no significant treatment difference.

Tiller production

Data for tiller number (excluding main stem) in the treatment with tillers of the different experiments are summarised in Table 1. In the R/fed experiment the tiller number increased up to 48 DAS and then gradually declined towards maturity. In the ROS experiment the initial tiller number (at 34 DAS) was higher than in the R/fed experiment and then gradually declined with increase in SWD. The irrigated experiment produced a large number of tillers compared to the R/fed experiment initially, but the reduction in tiller number between 48 and 61 DAS was more severe than in both the R/fed and ROS experiments, probably a result of the over-wet soil conditions in the irrigated experiment.

PAR interception

The pattern of radiation interception in the three experiments between 25 and 80 DAS is shown in Figure 3. Under both R/fed and irrigated conditions, radiation interception was similar in corresponding treatments and was higher than under the ROS. In these two experiments, radiation interception increased rapidly upto 57 DAS and then decreased during grain filling in both treatments. The reduction

Table 1. The effect of different soil water regimes on the temporal change in tiller number per m^2.

Experiment	Days after sowing: 34	48	61	106	Fertile tiller number (per m^2)
	Tiller number per m^2				
Rainfed	22	27	25	19	17
ROS	33	28	26	23[a]	7
Irrigated	34	34	24	15	12

[a]: The final harvest in the ROS experiment was made at 92 DAS.

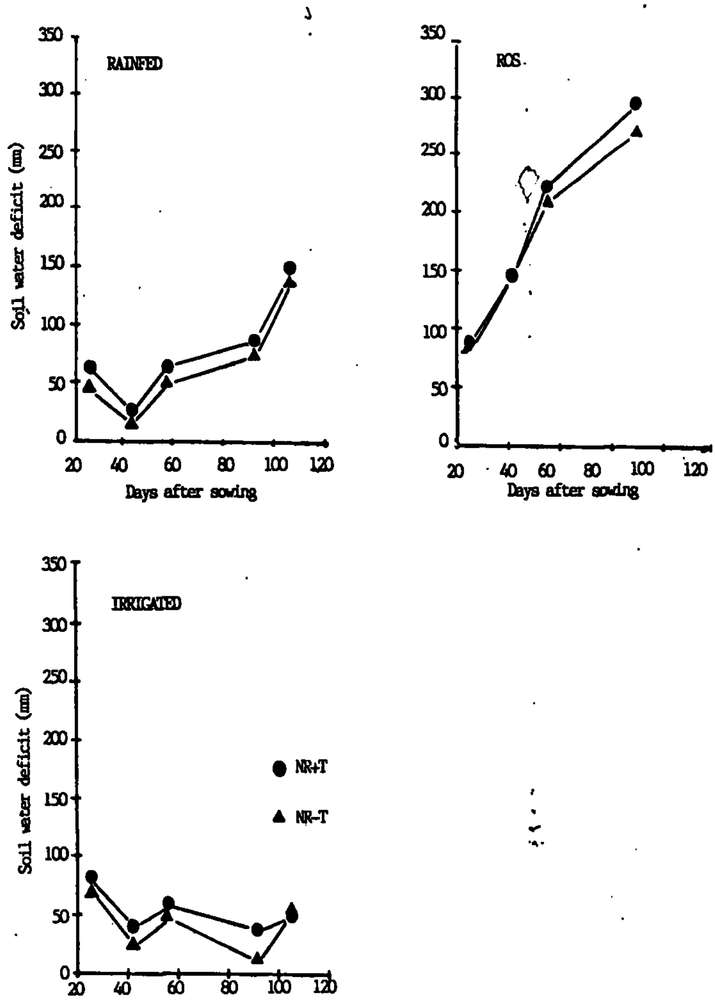

Fig. 2. Temporal change in soil water deficit to 180 cm depth in the three experiments. There were no significant treatment differences.

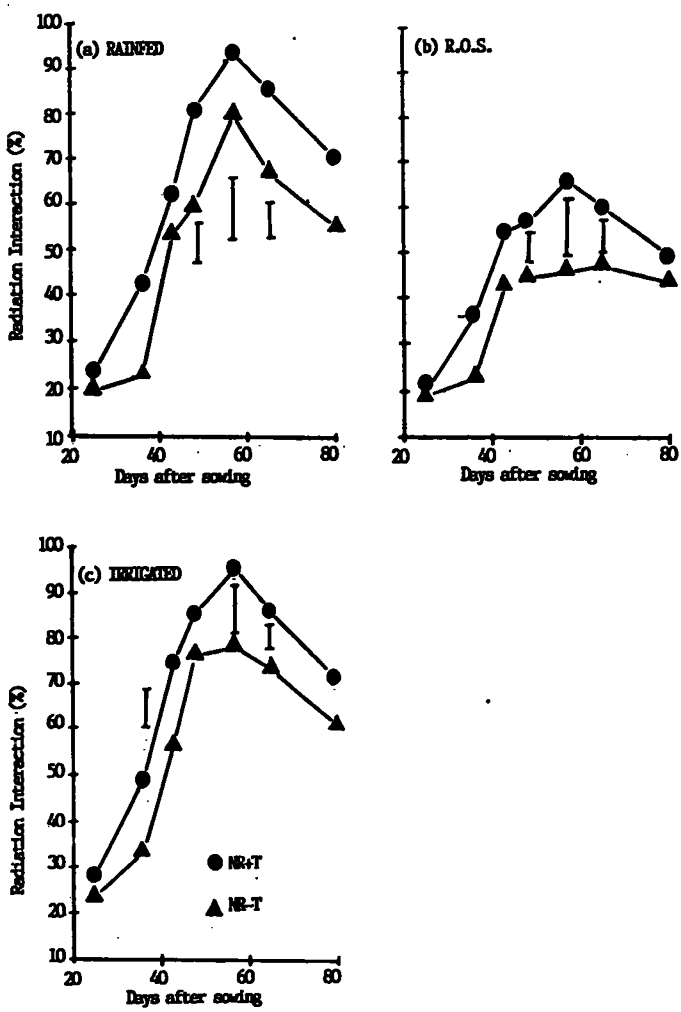

Fig. 3. Temporal change in PAR interception in the three experiments. Vertical bars indicate lsd at P 0.05.

during grain filling was less in the ROS then in the other experiments. In all experiments NR + T intercepted about 20% more radiation than NR − T on occasions later than 34 DAS.

Water use

Water use (*i.e.* evapotranspiration) between the two treatments (NR + T, NR − T) was not significantly affected by artificial de − tillering in any of the experiments (Table 2). Cumulative water use was calculated by considering the soil water content and rainfall for each period. In the ROS experiment, there was a trend to lower water use (176 vs 204 mm) as a result of de − tillering.

Grain yield and its components

Grain yield and its components are presented in Table 3. In the R/fed experiment there was no significant treatment effect although NR − T tended to have a higher GY as a result of a significant increase in HI over NR + T. The single grain weight was significantly increased by de − tillering. There was no treatment difference in grain number per plant but the grain number per head was significantly increased (1164 vs 2937) by de − tillering.

Under the ROS, the grain yield was similar between the two treatments but lower than in the R/fed experiment. There was a significant improvement in the HI as a result of de − tillering. The number of grains per head was again much higher in NR − T (2937) than in NR + T (1359).

Grain yield in the irrigated experiment was lower than in the R/fed experiment. In this experiment too there was not a significant effect of treatment on grain yield, but as in the R/fed experiment, there was a trend to higher grain yield in NR − T (702 g/m^2) compared to NR + T (616 g/m^2). There was also a trend to higher HI in NR − T and the single grain weight increased significantly as a result of de − tillering. Similar to the other experiments, the grain number per head was much higher in NR − T (2347) compared to NR + T (1115).

Table 2. The amount of water use (mm) at different growth intervals.

	Days after sowing				
	(26-43)	(43-57)	(57-92)	(92-106)	Total
	Water use (mm)				
Treatment					
Rainfed					
NR+T	74	98	126	89	383
NR-T	82	99	142	95	397
R O S					
NR+T	63	77	64		204
NR-T	58	62	55		176
Irrigated					
NR+T	115	94	168	44	420
NR-T	105	103	146	75	429

Table 3. The effect of treatment on grain yield and its components (spring/summer 1987/88).

	Total dry matter (g/m^2)	Grain yield (g/m^2)	HI (%)	Single grain wt. (mg)	Grain number per head
Rainfed					
NR+T	1661	758	46	24.7	1164
NR-T	1484	810	55	27.6	2937
lsd($P<0.05$)	ns	ns	3	2.1	244
R O S					
NR+T	1089	573	53	26.6	1359
NR-T	951	556	59	25.6	2179
lsd ($P<0.05$)	42	ns	2	0.5	360
Irrigated					
NR+T	1381	616	45	25.5	1115
NR-T	1378	702	51	30.2	2347
lsd ($P<0.05$)	ns	ns	ns	2.4	311

DISCUSSION

The objective of this experiment was twofold. Would induced uniculm (artificial de-tillering) lead to a saving of water? While there is evidence in the literature (Fukai *et al.*, 1986) that this was possible during a wet season, we could not obtain similar results despite creating three different soil water regimes. The water use by the crop is directly related to the radiation intercepted by the crop (Penman *et al.*, 1967; Fischer and Turner, 1978). However despite the differences achieved in the amount of radiation intercepted (approximately 20%), there was no difference in the amount of water used.

Yield compensation

In all three experiments the total grain yield was not affected by de-tillering. Grain number on the main stem increased in all experiments as a result of de-tillering. A similar compensatory increase in grain number and grain yield of main stems, resulting from early tiller removal has been reported (Bruns and Horrocks, 1984). Single grain weight increased with de-tillering except in the ROS experiment. High temperature under increasing SWD in the ROS probably shortened the duration of grain growth (Gallagher *et al.*, 1976) and hence resulted in smaller grain size compared to the R/fed and irrigated experiments. The improvement in HI as a result of de-tillering was an important consequence. Tillers could often become unproductive if the climate is unfavourable (Gerik and Neely, 1987). Therefore aiming at a uniculm plant in a breeding programme might appear to be useful, for water limiting environments. In the ROS experiment, there was a general trend to lower water use in NR-T than in NR+T. The current study did not indicate a saving in water under R/fed or irrigated conditions. There was however, a trend to slightly higher grain yield for similar water use suggesting that uniculm would perform better under those conditions.

CONCLUSIONS

Induced uniculm (artificial de-tillering) did not lead to a saving of water under the different soil water regimes imposed in the current experiment. There was evidence that grain yield will not be adversely affected by de-tillering. There was generally a robust compensatory increase in grain number on main stems, which occurred both under favourable and less favourable conditions. Uniculm therefore presents an opportunity for increased grain yield through an improved harvest index.

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