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YIELD RESPONSE OF SELECTED MEXICAN AND AUSTRALIAN WHEAT CULTIVARS TO MANIPULATIONS OF THE ASSIMILATE SUPPLY AND GRAIN NUMBER

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SUMMARY

The yield response of two Australian and two Mexican-derived cultivars to shade and drought treatments in the pre-anthesis growth stages were studied in field and pot experiments.

In all control treatments the Mexican cultivars outyielded the Australian cultivars due to a higher grain number per ear. Grain numbers in these Mexican cultivars were reduced more by a given shading or drought treatment at the same ontogenetic stage.

The results indicate that all cultivars respond in grain setting to adverse conditions before ear emergence, such that grain weight is maintained should these adverse conditions continue. There is, however, some genotypic variance in this character with the wheats derived from Norin 10 being less conservative of grain weight than the Australian cultivars tested.

I. INTRODUCTION

The introduction of Mexican wheat genotypes into the breeding programmes of Queensland has led to a marked yield increase in recent years. These Mexican-derived cultivars have also been found to respond better, in yield, to improved water and/or fertility conditions than the older Australian cultivars (Syme 1972).

This yield increase has been largely associated with an increased diversion of assimilates to the ear as shown by their higher harvest indices and the greater number of grains set per ear . In spite of this larger sink for assimilates there is mounting evidence that, under many conditions, the capacity of the ear to accept assimilates limits yield rather than the supply of assimilates (Sofield *et al.* 1974).

This paper describes the effect of manipulating the assimilate supply through shading, and of manipulating the sink via sterilization of ovules, shading and/or drought, on the grain setting and yield of selected Mexican and Australian cultivars.

II. MATERIALS AND METHODS

Field experiment

A field experiment was conducted on a krasnozem soil in Toowoomba, Queensland. To ensure adequate nutrition 30 kg P ha^{-1} as superphosphate and 112 kg N ha^{-1} as urea were drilled in before planting. Near average weather conditions prevailed during the experiment and around flowering the solar radiation averaged 470 ly day^{-1} and the mean daily temperature 14·5°C. Soil water content was maintained by spray irrigation when required.

The treatments consisted of three levels of shade (0, 30% and 78%) applied from ear emergence to maturity to each of four cultivars. The cultivars included two of Australian origin, Spica and Timgalen, and two Mexican cultivars that have high yield potential under local conditions Qt77 (Mayo 54/Norin 10/Brevor/3/*Andes) and WW15 (Lerma Rojo/Norin 10/Brevor/3/3*Andes).

The design used was a fully randomized block with four replicates. Plots consisted of nine rows 17 cm apart sown at 45 kg ha^{-1}. The shades consisted of 6 m x 2 m wooden frames covered with sarlon shade cloth suspended 25 cm above the crop. At maturity the central 5 rows x 3 m were harvested from the covered areas for yield and yield component measurements.

Pot experiment

The pot trial consisted of these same four cultivars grown in the glasshouse at Toowoomba during winter 1974. Each cultivar was sown in 15 cm pots containing 2 kg of air-dried Waco black earth (Beckmann and Thompson 1960) to which the equivalent of 150 kg ha^{-1} of a complete fertilizer was added. Seedlings were thinned to seven per pot. Pots were maintained near field capacity by weekly watering to weight.

The major treatments and their time of application were:—

T0 = Control = no shade, no drought

T1 = Shade flag leaf emergence to ear emergence

T2 = Shade ear emergence to maturity

T3 = Shade flag leaf emergence to maturity

T4 = Drought 10 days following flag leaf emergence

T5 = T4 plus T2

Flag leaf appearance occurred 12 days before ear emergence and 18 days before anthesis. Shade consisted of 78% shade cloth supported 30 cm above and around benches used for this treatment.

An additional treatment was applied to eight plants within each treatment at ear emergence. This consisted of sterilizing the basal two florets of four spikelets in the middle of the main stem ear.

Intermediate harvests, taken at flag leaf appearance and ear emergence, consisted of four pots (replicates) per cultivar and per treatment. Records were kept of the anthesis date of each main stem and this paper only reports yield data from main stems with a common anthesis date of 20 September.

The individual plants were thus taken at datum points in the final harvest and with the restriction due to the presence of only two common shading benches all treatments were taken as fully randomized. Re-randomization within benches was carried out at least weekly throughout the experiment.

III. RESULTS

Field experiment

The final yield and yield components of the four cultivars in response to shading from ear emergence onwards in the field experiment are presented in table 1. The Mexican cultivars were higher yielding than the Australian cultivars under both the control and 30% shade treatments, due primarily to their higher grain number per unit area and per spikelet. There was no reduction in yield of any cultivar by this level of shade.

Under the 78% shade treatment yields of the Mexican (WW15 and Qt77) cultivars did not exceed those of the Australian ones. There was a reduction in the grain setting ability of the Mexican cultivars which did not occur with the Australian cultivars. The grain weight of all cultivars declined slightly but this was responsible for only a small proportion of the decline in grain yield.

TABLE 1

YIELD AND YIELD COMPONENTS OF CULTIVARS IN RESPONSE TO LEVELS OF SHADE APPLIED FROM EAR EMERGENCE TO MATURITY

Treatment		Grain Yield (g m^{-2})	Spikes m^2	Spikelets per Ear	Grains per Spikelet	Wt. per Grain (mg.)	Grains per m^2 × 100^{-1}
Variety	Shade (%)						
WW15 ..	0	316·4 a*	221 a	17·8 a	2·01 a	40 cd	79 a
	30	307·8 a	238 a	17·6 ab	2·04 a	36 e	85 a
	78	203·0 cd	212 ab	15·9 bc	1·56 c	34 e	53 c
Qt77	0	263·4 b	207 b	17·9 a	1·86 b	38 cde	69 b
	30	262·6 b	188 bc	18·8 a	1·96 ab	38 cde	69 b
	78	175·2 d	174 c	18·8 a	1·51 c	35 e	49 c
Spica ..	0	216·4 c	191 b	16·0 bc	1·47 c	48 a	45 cd
	30	215·8 c	180 bc	16·4 bc	1·52 c	48 a	38 d
	78	180·0 d	190 b	15·2 c	1·40 c	44 b	40 d
Timgalen ..	0	211·4 c	235 a	15·0 c	1·48 c	41 bc	52 c
	30	223·6 c	230 a	15·2 c	1·58 c	40 cd	55 c
	78	186·2 d	226 a	14·6 c	1·50 c	37 de	49 c

* Figures in columns followed by different letters are significantly different at P < 0·05.

Pot experiment

Data are presented only for Qt77 and Spica because for the other two cultivars there were not enough plants having the same date of anthesis available at the final harvest. The few plants that were available, however, showed that WW15 reacted as Qt77 and Timgalen as Spica, at least on a main stem basis.

Some major pre-treatment plant characteristics of the two cultivars Qt77 and Spica are presented in table 2. There were few differences apart from plant height between the main stems of the cultivars.

TABLE 2

PRE-TREATMENT PLANT CHARACTERISTICS OF THE MAIN STEM AT FLAG LEAF APPEARANCE FOR TWO CULTIVARS (POT EXPERIMENT)

Parameter	Spica	Qt77	L.S.D. P < 0·05
No. leaves	6·7	6·2	N.S.
Leaf area (cm^2)	129	130	N.S.
Dry wt. stem and ear (g)	0·493	0·516	N.S.
Height (cm)	49	34	5
Total dry wt. (g)	0·940	1·040	N.S.

TABLE 3

MAJOR PLANT CHARACTERISTICS AT EAR EMERGENCE OF THE MAIN STEMS FOR TWO CULTIVARS SUBJECT TO DROUGHT AND SHADING TREATMENTS

Treatment	Control (T_0)		Drought (T_4 & T_5)		78% Shade (T_1 & T_3)	
Cultivar	Spica	QT77	Spica	Qt77	Spica	Qt77
No. green leaves	5·8 a*	5·6 a	5·2 b	5·1 b	6·3 c	6·1 c
Leaf area (cm^2)	101 a	110 a	100 a	109 a	128 b	132 b
Stem dry wt. (g)	1·10 a	1·04 a	0·95 ab	0·86 b	0·82 b	0·66 c
Height (cm)	78 a	62 b	64 b	53 b	92 c	62 b
Ear dry wt. (g)	0·35 a	0·41 b	0·30 ac	0·36 a	0·17 d	0·26 c
Total dry wt. (g)	1·94 a	2·05 a	1·72 b	1·71 b	1·43 c	1·44 c
% Dry wt. to Ear. (%) †	35	41	44	54	35	65

* Figures followed by dissimilar letters in any row are significantly different at P < 0·05.
† Change in dry weight since flag leaf appearance assuming ear weight at harvest 1 was negligible.

The drought treatment which was imposed at flag leaf appearance lasted 10 days and all cultivars recorded a minimum leaf relative water content of 66·4 ± 4·1% before rewatering. In table 3 are shown the results of this drought and the 78% shade treatment 13 days after they were started, 5 days before anthesis, and immediately before the transfer treatments. The drought treatment increased leaf senescence on the subtended tillers whereas the shade treatment reduced it compared with the control (unpublished data); this effect was also apparent on the main stem although at a reduced level. Both main stem and ear dry weights were significantly reduced by the shade treatment but not by the drought treatment which however, did show a decrease in the total dry weight of the main stem.

There were no differences between cultivars in the total dry weight increase of the main stems, within the same treatment between flag leaf appearances and ear emergence. There were, however, differences in the apportioning of this increase between ears and stems with the Mexican variety (Qt77) having a greater proportion diverted to ear growth rather than stem growth especially in the shade treatment.

The final yield and yield components as measured at the final harvest are presented in table 4. The higher grain yield of Qt77 in both the control (T0) and drought treatment (T4) was due to a higher grain number per ear which more than offset the lower weight per grain of this cultivar. The grain yield of the Mexican cultivars was reduced more by a given shade and/or drought treatment, at a given ontogenetic stage than that of the Australian cultivar.

TABLE 4

Final Yield and Yield Components of the Main Stems in Response to Shade and Drought Treatments

Parameter	Cultivar	Treatments: Control (T_0)	F.L.E. to E.E. (T_1)	78% shade from E.E. to Mat. (T_2)	F.L.E. to Mat. (T_3)	Drought F.L.E. to E.E. (T_4)	T_4 plus T_2 (T_5)	Treatment L.S.D. = 0·05
Total no. spikelets	Spica ..	19·5	19·1	19·0	19·7	18·0	18·7	N.S.
	Qt77 ..	23·9*	22·5*	21·7*	22·4*	23·4*	23·2*	
No. grains per ear	Spica ..	24·6	21·4	23·6	12·1	17·1	17·5	4·4
	Qt77 ..	43·6*	29·0*	35·5*	16·3	27·7*	18·4	
No. grains per fertile spikelet	Spica ..	1·6	1·3	1·6	1·1	1·2	1·1	0·3
	Qt77 ..	2·2*	1·8*	1·9*	1·1	1·8*	1·1	
Wt. per grain (mg)	Spica ..	54	49	47	54	51	45	4
	Qt77 ..	41*	47*	32*	40*	44*	34*	
Yield grain (g) ..	Spica ..	1·33	1·04	1·10	0·65	0·88	0·78	0·19
	Qt77 ..	1·76*	1·37*	1·14	0·66	1·22*	0·62	
Mean no. grains set in central florets of the 4 mid-ear spikelets	C† Spica	0·8	0	0·4	0	0·8	0·8	
	S† Spica	4·0*	0	1·6*	0	3·2	2·8	
	C Qt77	2·8	1·6	1·6	0·4	2·4	0·8	
	S Qt77	7·2*	4·0*	4·4*	4·0*	4·0	4·4	

Note.—1. * Cultivar difference greater than P = 0·05.
2. C † is where two basal florets of these spikelets untreated.
S † is where these two basal florets were sterilized.

A major effect of both drought and shade treatments was to influence the grain set per ear and there were marked differences in varietal performance in this character. Thus with Spica a restricted period of shade either before or after ear emergence (T1 and T2) had no effect on grain set per ear whereas such a shade period reduced grain set in Qt77 markedly. The period before ear emergence was more sensitive, in this character, due to effects on both grain set per spikelet and the number of fertile spikelets. In both Qt77 and Spica a prolonged shade period starting at flag leaf appearance (T3) greatly reduced grain setting per ear the effect on Qt77 was more severe such that its grain number per ear was reduced to the same level as that of Spica.

A similar reaction in grain setting occurred in the drought treatments (T4) where with additional shade in the period following the drought (T5) Spica showed no further reduction in grain number per ear whereas Qt77 had a further 20% fall in this yield component.

Whereas grain number reduction due to treatment reached 60% the maximum variation in weight per grain was 20% and was generally similar for all cultivars. Thus grain weight was similar to the control in T3 and T4 and in both cultivars there was a 20% reduction due to the two treatments involving shade from ear emergence onwards. Only when the shade period was restricted to the period between flag leaf appearance and ear emergence (T1) was there a varietal interaction with Qt77 increasing grain weight 15% over control and Spica having a 10% decrease.

In all cultivars and treatments, other than both those involving 78% shade with Spica, there were ovules which whilst competent to form grains did not do so. Both drought and 78% shade, however, reduced the total number of potentially fertile ovules in all cultivars.

IV. DISCUSSION

The Mexican cultivar outyielded the Australian ones in all control treatments due to their higher grain numbers per ear. This was caused by both a higher fertile spikelet number and a higher grain set per spikelet. The additive effect of these two components was partly offset by their lower grain weights.

The reaction of the Mexican cultivars to shading was in accord with the findings of Fischer (1975) in that they showed little yield reduction to 30% shade and a substantial yield reduction in 78% shade. Similarly where 78% shade was applied at flag leaf emergence (F.L.E.) the yield reduction was due almost entirely to a reduced grain number per ear, whereas when the shade was applied at ear emergence (E.E.) it was less, and due to reductions in both grains per ear and grain weight.

The reduction in dry weight yield caused by the 78% shade treatment applied at F.L.E., whilst similar in total in all cultivars, varied in its partitioning. The Mexican cultivars showed preferential partitioning of the increased dry weight to the ear rather than the stem as compared with the Australian cultivars. This difference could be associated with the late and more synchonomous development of spikelets and florets from wheats with a Norin 10 background (Fisher 1973).

Another major difference between cultivars was their ability to respond, in grain setting, to stress between E.E. and anthesis. Thus the Mexican cultivars showed reduced grain setting to stresses applied at E.E. (T2 and T5) over and above those imposed at F.L.E. (T1 and T4) whereas Spica and the few plants of Timgalen of similar anthesis data, did not. Where the 78% shade was applied from F.L.E. to anthesis (T3) the actual number of grains set per spikelet was constant in all cultivars despite the differing number of ovules which were competent to form grains. This suggests that the potential number of sites does not alone control the actual grain set, but rather than a threshold level of some other factor is also required to form a grain. Evans *et al.* (1972) with similar findings, postulated the grain setting to be under the influence of growth substances. Both the higher grain set of the Mexican cultivars under better light conditions and their late sensitivity in grain setting could be due to their later and more synchronomous development changing the concentration of such a threshold factor required for grain set.

The weight per grain was consistently reduced by 20% where shade was imposed at E.E. and continued to maturity. However, where 78% shade or drought was imposed at F.L.E. grain weight was not reduced below the control level. With Qt77 and to a lesser extent WW15 but not with the Australian cultivars, 78% shade from F.L.E. to maturity actually increased grain weight. These results indicate that grain setting responds to adverse conditions prior to E.E. such that the weight per grain can be maintained should these adverse conditions continue. There is, however, some genotypic variance in this character with the wheats derived from Norin 10 tending to over respond in this reduction in grain number. Similarly under good conditions they over-respond in grain setting and are hence less conservative of grain weight than the Australian cultivars tested.

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