OSMOTIC ADJUSTMENT OF SORGHUM GENOTYPES UNDER TWO NITROGEN LEVELS IN THE FIELD

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Abstract

Osmotic adjustment has been given considerable attention in controlled environment studies as a potential drought resistance trait. In this trial, the trait was examined in five genotypes in a field experiment. Nitrogen fertility is declining in many sorghum production regions in Queensland, and there is a need to examine the response of this trait to different levels of applied nitrogen fertiliser. A terminal stress was imposed at 37 days after planting using rainout shelters and a well watered trial was planted at the site as a control. Yields, relative yields,and plant water relations were determined. In one season yields were 48%of the well watered control, and 73% in the second year. Osmotic adjustment was expressed in the first season, but not in the second season of milder water stress. There was a significant interaction effect of genotype and fertiliser rate for osmotic adjustment. Osmotic adjustment was correlated to leaf N concentration in late season. There was, however, no significant difference in water use among four of the genotypes, and hence the genotypic variation in osmotic adjustment is unlikely to be related to variation in water use pattern.

Key words: Sorghum, osmotic adjustment, well watered, water limited, grain yield, water use, leaf nitrogen.

Declining soil fertility, particularly of nitrogen (N), and insufficient rainfall are constraints to sorghum production in SE Queensland and northern NSW. Yield benefits from osmotic adjustment was demonstrated from both a pre and a post anthesis stress (3, 5). Osmotic adjustment (OA) in sorghum has been studied under controlled environment conditions (1, 2) and in the glasshouse (4). Rate of stress development influences the extent of the OA (2). OA must be expressed under water limited conditions over a range of nitrogen levels for the trait to be considered useful in germplasm development. Utzurrum et al. (1998) demonstrated a higher yield in a drought resistant genotype under water stress ?when N was supplied at high levels but not under low N supply. This trial aimed to evaluate the effect of N fertiliser on OA in the field. Genotypes included were those of known OA capacity from previous trials (1, 3).

Materials and methods

This trial was set up as a field evaluation of five genotypes at two levels of nitrogen (40 and 160 kg N/ha) using rainout shelters to impose a terminal stress (water limited trial) from 37 days after planting (dap). Each trial was arranged in a split plot design with mainplots of N and subplots of genotypes and was conducted in 1994/5 and 1995/6 seasons. At anthesis, leaf biomass was harvested from 1m length of the two inner rows of the 3 x 4 m plots and leaf area measured using a belt driven area planimeter. Yields were taken from 1 m of two inner plot rows. Water relations were measured on 5 occasions, following the imposition of water stress, and leaf N concentration was determined on the last expanded leaf at each occasion.

The predawn osmotic potentials were measured after the stress was imposed. The osmotic adjustment for each treatment was calulated as the difference betweeen osmotic potential (adjusted for relative water content) between 43 and 98 days after planting (7). In the 1995/6 trial OA was determined between 42 and 77 dap as the rainout shelters suffered storm damaged, and could not be used beyond this date. Neutron probes were installed to 2 m depth in four of the genotypes in water limited plots.

Table 1: Osmotic adjustment at 98 days after planting, leaf area index at anthesis, yield and relative yield for genotypes at two levels of N fertiliser in the water-limited trial in 1994/5 season (LSD for comparing genotype by N for OA = 0.14 MPa, LAI = 0.69).

Nitrogen Level/ Genotype	Osmotic Adjustment (MPa)	Leaf Area Index (relative to well watered)	Yield (g/m^2)	Relative Yield (relative to the well watered)
40 kg N/ha				
E57	0.37	2.0 (0.61)	438	0.48
QL12	0.42	1.8 (0.69)	273	0.66
Tx610SR	0.32	1.7 (0.81)	423	0.47
Goldrush	0.01	1.5 (0.88)	538	0.67
Tam422	0.24	1.8 (0.90)	222	0.29
160kg N/ha				
E57	0.30	3.1 (0.86)	451	0.47
QL12	0.66	1.3 (0.54)	130	0.33
Tx610SR	0.18	2.0 (0.86)	564	0.53
Goldrush	0.02	1.6 (0.76)	450	0.46
Tam422	0.49	1.8 (0.69)	326	0.44

Table 2: Wateruse of four genotypes from 40 to 112 days after planting in the 1994/5 water limited trial.

Genotype	Water use (mm)	
	40 kg N/ha	160kg N/ha
E57	138	143
QL12	139	123
Tx610SR	132	143
Goldrush	142	133

Results

Yields under water limited conditions ranged from 130 to 564 g/m^2 in 1994/5 and were 48% of that in the well watered control. In 1995/6grain yield ranged from 227 to 458 g/m^2 with a mean relative yield of 0.73 of the well watered plots.

In 1994/5, some genotypes varied their expression of OA depending on the level of N application. In this year and in 1995/6, the same level of background OA (0.08 MPa) occurred as a function of plant maturity in the well watered trials. In 1995/6, osmotic adjustment was not expressed by any treatments even in the water limited trial (data not shown). In the first season, with relative yields less than 0.5 of the well watered, there was a genotype by N fertiliser interaction for OA (Table 1.). In particular, Tx610SR had less OA under high N, Tam422 and QL12 had higher OA under high N and Goldrush expressed almost no OA.

Leaf area index was reduced by water stress to between 54% to 90% of the well watered trial (Table 1) and ranged from 1.3 to 3.1, but it did not relate to the OA expressed in these conditions. Leaf area index at anthesis was highest for E57 at 160 N and lowest for QL12 at 160 N. E57 had the most leaf area at anthesis in both well watered and water limited trials, and OA was expressed at both levels of N.

Crop water use was monitored in four of the genotypes, and water use was lowest for QL12 under 160 kg N/ha, but this was not statistically significant (Table 2). QL12 had a significantly wetter soil profile (data not shown) at the end of the season. Genotypic variation in osmotic adjustment was not reflected in the water use pattern or LAI.

Leaf N concentration was significantly higher in the high N treatments than in the low N treatments and also significantly higher in the well watered compared to the water limited trial ($P<0.05$) for all dates. Within the water limited trial QL12 and Tam422 had similar leaf N for the two nitrogen fertilizer levels for 50 and 69 days after planting (Table 3). For E57, TX610SR and Goldrush the high N fertilizer treatment gave higher leaf N up until 69 dap. Overall the N concentration in the leaf declined until 97 dap and at 97 dap QL12 had higher leaf N concentration ($P<0.0001$), this difference persisted through to the final harvest (data not shown). The number of green leaves maintained at 97 dap varied by genotype. QL12 maintained a mean of 2.7 green leaves and by contrast Goldrush had only one.

Leaf N concentration was consistently higher in the well watered trial at 43 to 97 days after planting (dap). At 97 dap there was a large effect of water stress with all stressed plants containing less than 2% leaf N. The genotypes varied in the leaf N concentration in response to the level of N fertilizer in both the water limited and the well watered trial (Fig. 1). In particular, QL12 had higher leaf N concentration than the other genotypes at 97 days after planting. There was a correlation with a coefficient of 0.86 between OA and leaf N concentration at 97 dap within the water limited plots ($P<0.0013$)(Fig. 2). This is supported by QL12 showing high leaf N and having high OA in this trial. The level of leaf nitrogen is much lower under water limited conditions (Fig. 1) and yet genotype differences in the retention of leaf N under water stress may act as substrate for osmoticums and thus contribute to the genotype capacity to express osmotic adjustment.

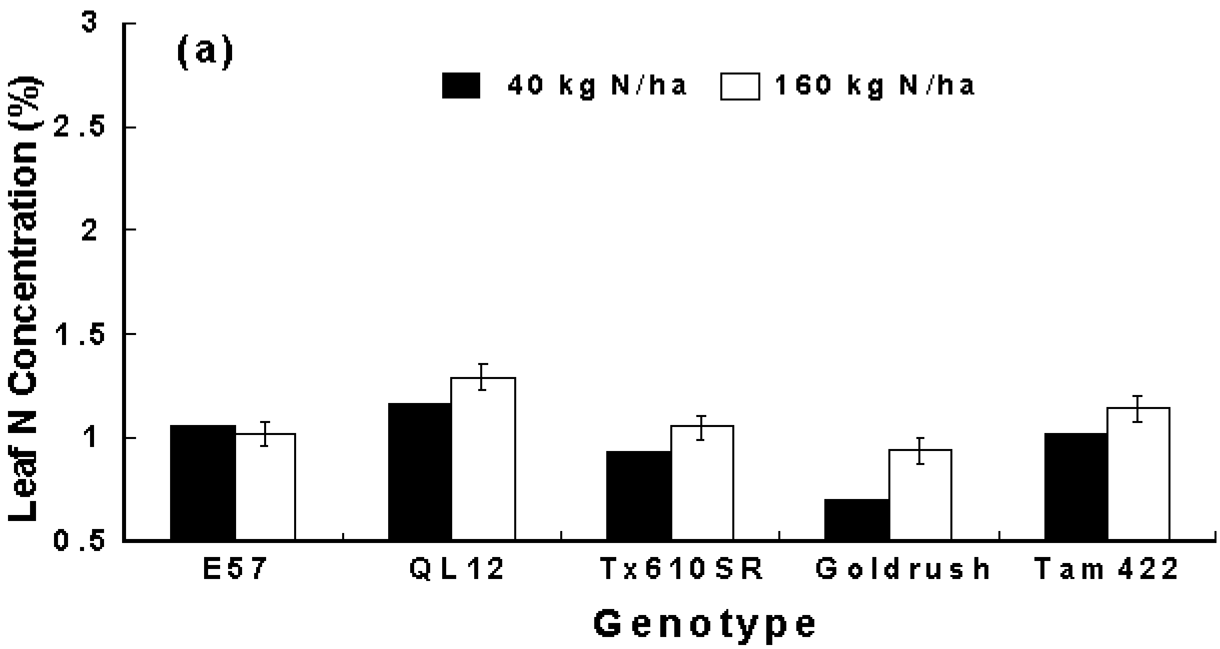

Figure 1

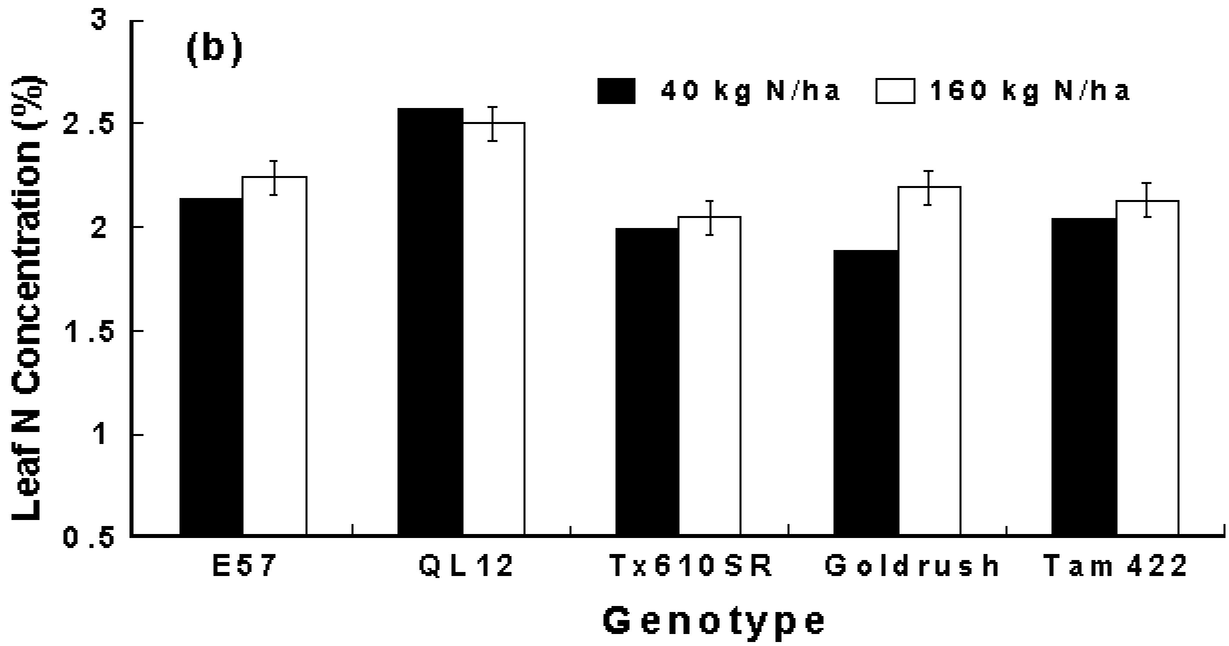

Figure 2

Discussion

Osmotic adjustment was not expressed by some genotypes in a predictable way. Santamaria et al. (5) had classified Goldrush as a high adjuster, and in the present trial it failed to express OA, although in agreement with their work it had a relatively low leaf area. A genotype by N interaction occurred; Tx610SR had a lower adjustment under high N, whereas QL12 and Tam422 showed enhanced adjustment under high N compared to low N. Among these diverse genotypes there was no evidence to associate an increase in grain yield with an increased expression of OA. Leaf area index at anthesis and water use from 40 to 112 days after planting did not relate to OA under these conditions. In fact, the capacity to express OA in water limited conditions seemed more of an innate genotype ability rather than a response to the rate of stress, since water use did not vary inthese treatments. The correlation of OA with leaf N concentration at 97 dap suggests that leaf N status can affect expression. Late application of nitrogen that was shown to reduce leaf senescence, and improve yields (6) may also help in getting a fuller expression of OA. If external environmental factors such as N fertility affect the expression of a trait plant, breeders may be less inclined to include such traits in improvement programs since genotype by environment interactions make gains to selection slower.

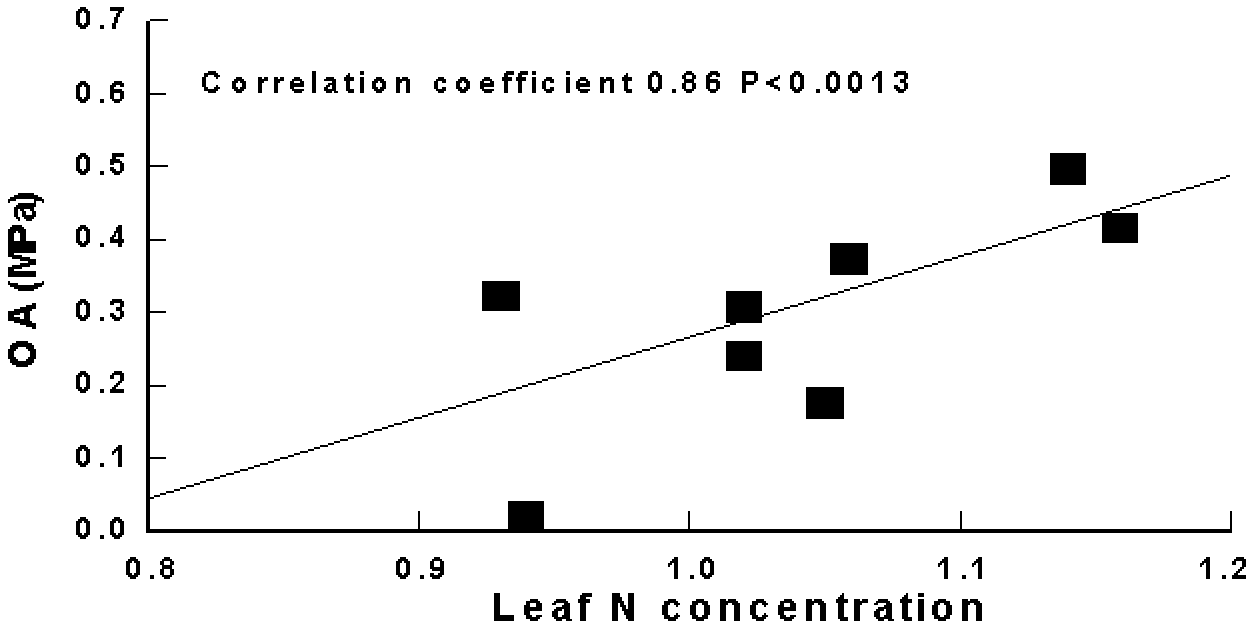

Figure 3

Conclusion

This trial demonstrated that N fertiliser level affects the expression of OA. Water use was similar for four genotypes that expressed OA differently. Thus, under similar levels of water use, and similar LAI at anthesis (LAI was higher for E57) there were different OA outcomes which suggests that retention of green leaves (staygreen), leaf N status and genotype all contribute to the expression of OA.

Osmotic adjustment genes will be of limited use for farmers' field environments unless they are demonstrated to give benefits where waterand nutrient arelimit-ed.'The physiological interactions between staygreen, leaf N status and plant water relations may give further insights into the expression of the OA trait.

Acknowledgment

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