Effects of Water Stress on Growth and Biomass Yield of Five Sugarcane Genotypes

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ABSTRACT

Screen house trials were conducted at the Unilorin Sugar Research Institute, Nigeria, to evaluate the effects of water stress on expansive growth and biomass yield of five selected genotypes of sugarcane such as BD 83/019, BD 83/035, IB 85/43, USRI 86/4 and USRI 86/25. The aim was to determine the effectiveness of such measurements in distinguishing between drought tolerant and susceptible genotypes of sugarcane. Water strees was induced by differential watering intervals of daily, 4 and 10 d corresponding to 100% (no stress), 60% (moderate stress) and 25% (high stress) soil available water (determined gravimetrically). Leaf extension rate (LER), leaf size, plant height and biomass yield showed measurable responses to water stress, decreasing when water is limitined. The results also showed ontogenetic variations in responses of leves at different positions to water stress. Similarly, there were genotypic differences in investigated lines to water stress, which were found to be related to the effects of water stress on biomass yield of genotypes. Consequently, it was concluded that measurement of expansive growth could be very useful for distinguishing between genotypes in their responses to water stress and hence, a promising technique for screening drought tolerance in sugarcane. The advantages of the technique is also discussed.

INTRODUCTION

Agricultural drought is said to exist when the level and distribution of precipitation is sufficiently low to cause serious shortfall in crop yield (Hulse, 1989). To develop cultivars that can withstand drought, it is important to identify genotypes that can survive during stress and / or recover after stress. (Sairam and Dube, 1984). Thus, there is need to evolve method(s) for mass screening of crop varieties with a veiw to speeding up breeding programmes involving drought tolerant and drought resistant varieties. It is widely recognised that plant response to drought condition varies with species (Tanguilig *et al.*1987), although no particular criterion for drought tolerance evaluation has been evolved (Hsiao, 1973). A common procedure for evaluating resistance is to relate yield to a standard cultivar over several years at location where drought is likely to occur (Anderson and Reinbergs, 1985). This process is dependent on year to year change in weather and is extremely time consuming. Hence, breeders nowadays desire a raid, inexpensive screening technique for use on early generations of breeding materials to identify drought tolerance.

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One of the easiest test for a breeder in selecting for drought resistance and / or water use efficiency (WUE) would be to determine the ability of the plant to maintain growth at reduced tissue water potential. Hsiao and Acevedo (1974) reported such test is quick and simple since young leaves of any species grow rapidly enough and can be measured non-destructively with a ruler. This was supported by Ween *et al* (1979) who also suggested that rate of extension growth e.g.leaf development rate, main stem growth rate as traits that could be measured to indicate varietal drought resistance. Leaf expansion is also well known to be very sensitive to water stress (Boyer, 1970; Hsiao *et al.* 1970). The measurement of leaf growth is a sensitive indicator of water stress (Acevedo *et al.* 1971; Eastham *et al.* 1984).

Sugarcane is an imprtant sugar crop in Nigeria whose productivity is largely threatened by perenial drought problem, hence the need to breed and select for drought tolerance in the crop. Consequently, there is the need to identify resistat genotypes (to be used as parent materials) from a large germplasm collection of local and exotic genomes existing at the Unilorin Sugar Research Institute farm. Therefore, the present study was undertaken to evaluate effects of water stress on expansive growth with a view to determine suitability or otherwise of such measurement as a screening technique for drought tolerance in sugarcane.

MATERIALS AND METHODS

A screen house study was conducted at the unilorin sugar Research institute. Plants were grown in 10 litre pots filled with sterilised top soil. The study was designed and laid out as a completely randomised experiment in factorial arrangement with three replications. Five selected sugarcane genotypes namely BD 83/019, BD 83/035, IB 85/43, USRI 86/4 and USRI 86/25 were used as test crop. The water stress treatments including a control (No stress) and two stress levels (moderate and high stress). The moderate and high water stress treatments were achieved by maintaining soil moisture at 60% and 25% soil available water respectively. These 60% and 25% soil available water were found (gravimetric determination) to be corresponded to 4 and 10 d water interval respectively. Two single-budded setts were planted in weach pot and thinned to one seedling after germination. The pots were watered daily after planting upto 6 weeks until commencement of treatment. Fertilizers were applied at 2 weeks after planting at the rate of equivalent to 160 kg N/ha., 200 kg K_2O/ha and 100 kg P_2O_5/ha.

Leaf extension rate in four leaf positions (L8, L10, L12 and L14 from the base) was measured by the method of Tanguilig et al. (1987) as modified by Abayomi (1992). Leaf length (to the nearest mm.) was measured using a metre ruler every other day starting as soon as leaf emerged and continued throughtout the whole growth period. Leaf length was measuered from the ligule of the last fully expanded leaf below to the tip of the newly emerging leaf. The extension rate per day was calculated as follows:

[Xp-Xl]/d,
where,
Xl=last measured length
Xp= present measured length, and
d is measurement interval in days.

Height of the main stalk was measured using a metre ruler at weekly intervals from the commencement of stress application untill harvest. Plant height was measured from the soil level to the last emerging leaf. Each pot was harvested by hand cutting at the soil level. Feesh weight measurement was taken and plant was over dried for 72 h at 80°C for dry weight. Al data were subjected to analysis of variance and treatments means were separated by the Duncan's New Multiple Range Test.

RESULTS AND DISCUSSION

Effects of Water stress on Leaf Extension Rate (LER) and size of leaves

The extension growth in 4 leaf positions was measured during the stress period. The effects of water stress across all genotypes on leaf extension rate and on leaf size are presented in the Figures 1 and 2. The individual response of each genotype studies are shown on the Tables 1 and 2 for the maximum LER and final leaf length respectively. Figure 1 shows that water streass decreased LER consistently throughout the measurement periods in all leaf positions with significant differences at varying periods except in leaf 8. Similarly, both moderate and high water stress treatments decreased leaf length in all leaf position with increasing magnitudes as the stress progressed (Figure 2). However, only the effects of the high water stress was significant on both leaves 12 and 14. The Table 1 shows effects of water stress on maximum LER of five sugarcane genotypes. Marked effects of water stress on LER was recorded at the four leaf positions of all genotypes except BD 83/019. Water stress also reduced final length of leaves at all four positions to varying degrees with significant differences in all genotypes except IB 85/43 (Table 2).

Effects of water stress and genotypes on plant height

The effects of water stress on plant height across all sugarcane genotypes are presented in the Figure 3. Both levels water stress decreased plant height from 14 d after start of the stress until the final measurement date. Significant effects were observed for high water stress from 42-63 d after the start of the stress. The effects of water stress on height of different sugarcane genotypes are presented in the Figure 4. The results show that water stress decreased plant height in USRI 86/25, BD 83/035 and USRI 86/4 with increasing magnitude in that order. However, height of both BD 83/019 and IB 85/43 were not appreciably affected by water stress treatments.

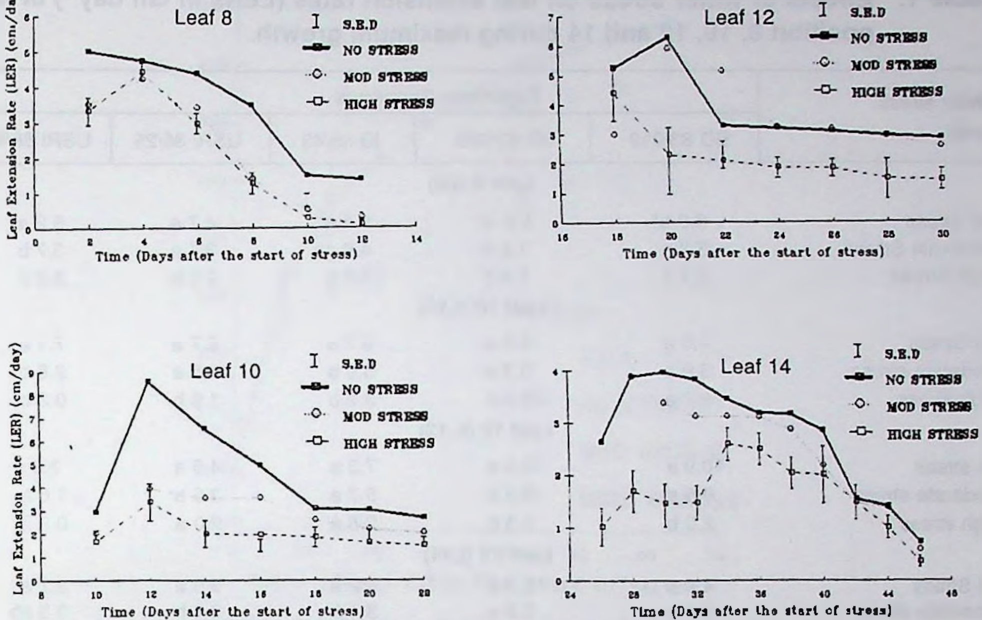

Figure 1. Effects of water stress on LER of leaves 8, 10, 12 and 14 across all sugarcane genotypes.

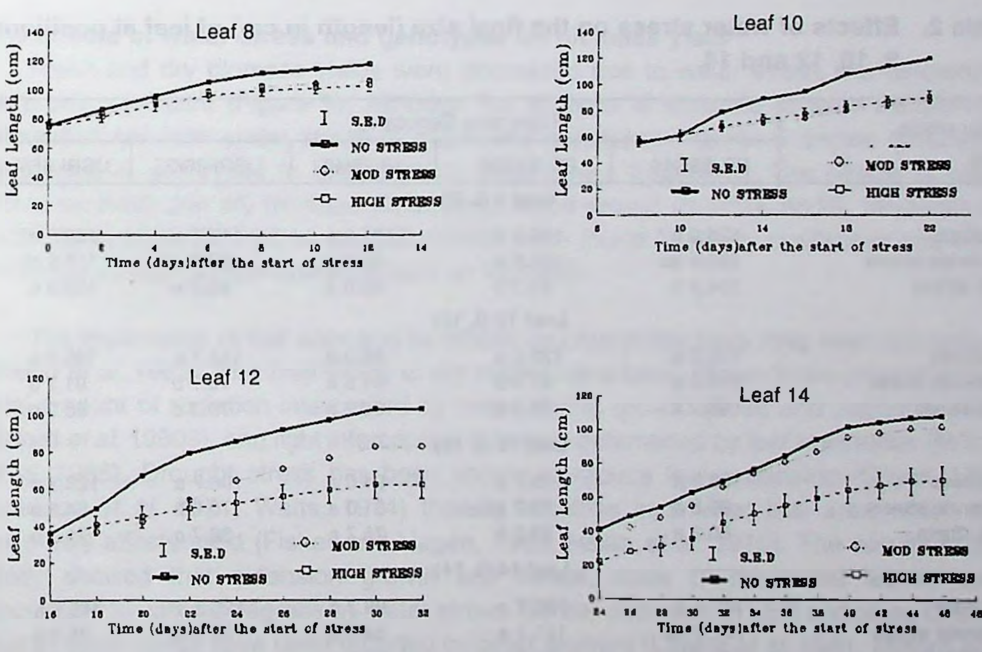

Figure 2. Effects of water stress on sizes of leaves 8, 10, 12 and 14 across all sugarcane genotypes.

Table 1. Effects of water stress on leaf extension rates (LERs in cm day^{-1}) at leaf position 8, 10, 12 and 14 during maximum growth.

Water stress Level	Sugarcane Genotypes				
	BD 83/019	BD 83/035	IB 85/43	USRI 86/25	USRI 86/4
		Leaf 8 (L8)			
No Stress	3.8 a*	5.8. a	5.1 a	4.7 a	5.2 a
Moderate Strees	3.2 a	1.8 b	4.5 ab	3.7 a	3.7 b
High Stress	2.7 a	1.4 b	3.6 b	2.5 b	2.2 c
		Leaf 10 (L10)			
No Stress	4.0 a	4.8 a	9.7 a	8.7 a	7.1 a
Moderate stress	3.9 a	3.3 a	5.0 b	6.5 a	2.8 b
High stress	3.7 a	1.9 a	3.2 b	1.8 b	0.3 b
		Leaf 12 (L 12)			
No stress	10.9 a	10.3 a	7.3 a	4.5 a	3.9 a
Moderate stress	9.5 a	4.9 b	5.7 a	3.5 a	1.6 a
High stress	2.0 b	2.3 b	2.6 a	2.0 a	0.3 a
		Leaf 12 (L14)			
No Stress	4.4 a	5.0 a	4.2 a	5.0 a	3.7 a
Moderate stress	3.4 a	3.9 a	3.1 a	3.4 b	3.3 ab
High stress	3.2 a	3.6 a	2.8 a	1.2 c	1.8 b

* Figures followed by the same letters in a column are not significantly different on Duncan's New Multiple Range Test at P<0.05.

Table 2. Effects of water stress on the final size (length in cm) of leaf at positions 8, 10, 12 and 14.

Water stress Level	Sugarcane Genotypes				
	BD 83/019	BD 83/035	IB 85/43	USRI 86/25	USRI 86/4
		Leaf 8 (L 8)			
No stress	126.9 a *	126.0 a	101.3 a	112.7 a	132.0 a
Moderate stress	120.4 ab	114.8 a	94.2 a	107.8 ab	118.8 ab
High stress	104.2 b	89.3 b	92.0 a	86.5 b	109.3 b
		Leaf 10 (L 10)			
No stress	115.3 a	122.0 a	98.0 a	116.7 a	145.3 a
Moderate stress	110.3 a	87.0 b	91.5 a	78.7 b	91.7 b
High stress	96.2 a	76.3 b	90.2 a	70.3 c	88.0 b
		Leaf 12 (L 12)			
No stress	108.3 a	109.7 a	94.0 a	106.7 a	123.3 a
Moderate stress	95.3 a	79.3 ab	81.0 a	70.0 b	64.3 b
High stress	80.2 a	53.0 b	76.7 a	36.7 c	71.7 b
		Leaf 14 (L 14)			
No stress	127.4 a	126.7 a	96.7 a	120.3 a	115.5 a
Moderate stress	107.3 ab	121.1 a	84.3 a	86.8 a	75.3 b
High stress	73.7 b	85.6 b	69.8 a	32.5 b	74.9 b

* Figures followed by the same letters in a column are not significantly different on Duncan's New Multiple Range Test at P<0.05.

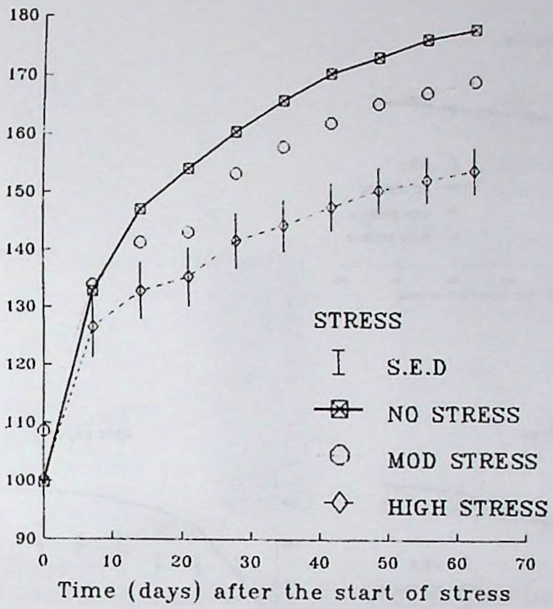

Figure 3. Effects of water stress on plant height across all sugarcane genotypes.

The effects of water stress and genotypes on biomass yield

Fresh and dry biomass yields were decreased due to water stress, but differences were not significant (Figure 5). Although the analysis of variance showed insignificant interaction between water stress X sugarcane genotypes Figures 6 shows dirrerential responses of genotypes to bothlevels of water stress treatments. The effects of water stress on fresh and dry biomass yields were found severe on USRI 86/25, moderate on USRI 86/4, while BD 83/019 and BD 83/035 were found relatively unaffected and while moderate stress had stimulatory effects on IB 85/43.

The importance of leaf area and its effects on crop yields have long been recognised (Frend *et al.* 1962). The final yields of dry matter have been shown to be proportional to total amount of radiation intercepted by crops during growth (Scott and Jaggard, 1978; Milford *et al.* 19809), and light interception is largely determined by leaf area index (Milford *et al.* 1985). Drought stress has been shown to reduce leaf expansion (Boyer, 1968; Acevedo *et al.* 1971; Watts, 1974) thereby resulting in smaller leaf area which can adversely affects yield (Fisher and Hagan, 1965; Hsiao *et al.* 1975). The results of this study showed that extension growth and hence, sizes of measured leaves were decreased to varying degrees by water stress. Similar decrease in LER and sizes of leves due to water stress have been reported by other workers (Lawlor *et al.* 1981; Milford *et al.* 1985; Tanguilig *et al.* 1987; Abayomi, 1992).

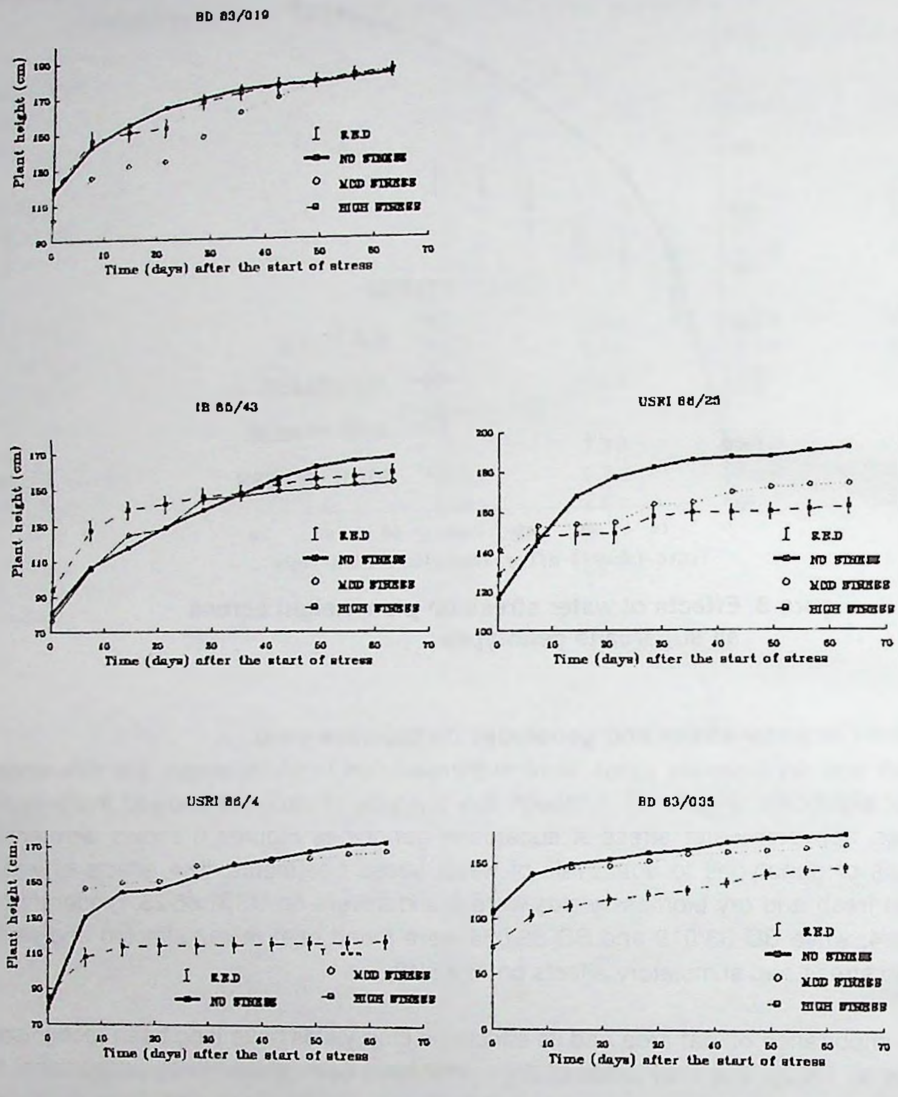

Figure 4. Genotypic response of plant height to water stress.

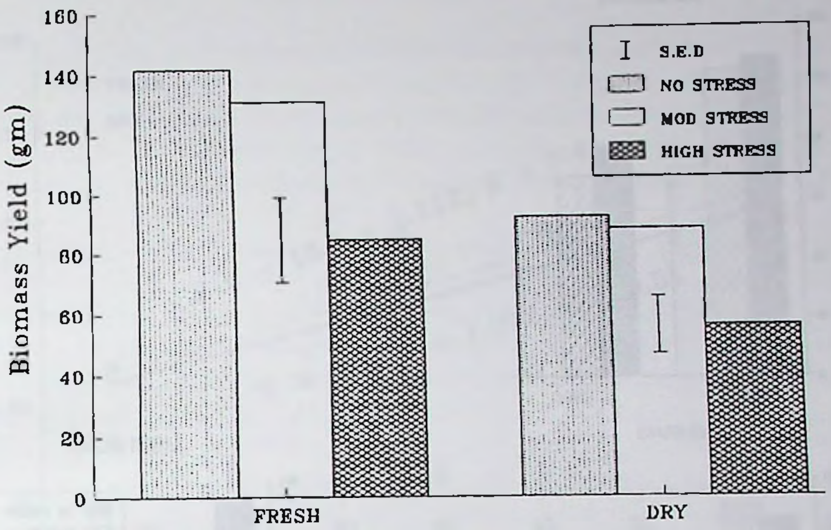

Figure 5. Effects of water stress on biomass yield across all sugarcane genotypes.

Ontogenetic variations in leaf growth was recorded in response to water stress. The results show that magnitude of water stress on LER and final leaf length increased with leaf positions in sugarcane. The youngest leaf (L14) showed greater responses of leaves of different positions to water deficit in wheat. However, lower leaves in sugar beet were shown more sensitive to water stress than upper leaves (Milford *et al.* 1985; Abayomi, 1992). This suggests that position of responsive leaf to water stress depends on the type of crop.

It was observed that variation in plant height under stress condition is one of the causes of variation in crop yield (Hadjichristodoulou, 1987). Similar results were found in this study. Both levels of water stress decreased plant height in all sugarcane genotypes, although decrease was found to be more severe in higher stress condition. Decrease in plant height in response to drought stress was reported elsewhere in wheat (Day and Intalap, 1970; Abayomi, 1992), (Day *et al.* 1978; Lawlor *et al.* 1981) and grain sorghum (Blum, 1989). The relative decrease in plant height under water stress was found to be well correlated with that of biomass yield (Figure 7). Thus sugarcane genotype IB 85/43 suffered relatively smaller decrease in height due to water stress had the highest yield stability (Figure 6).

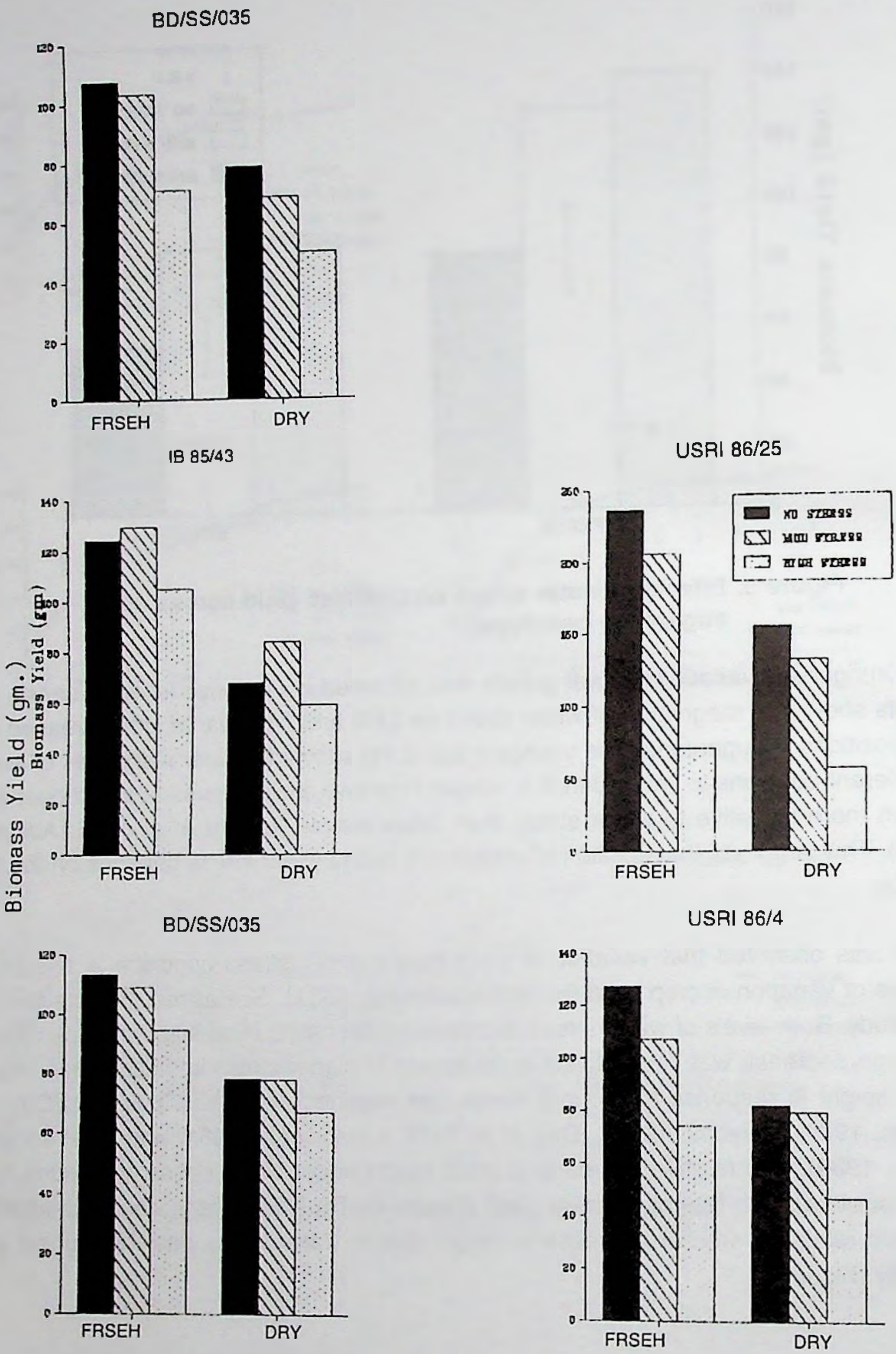

Figure 6. Genotypic response of biomass yield to water stress.

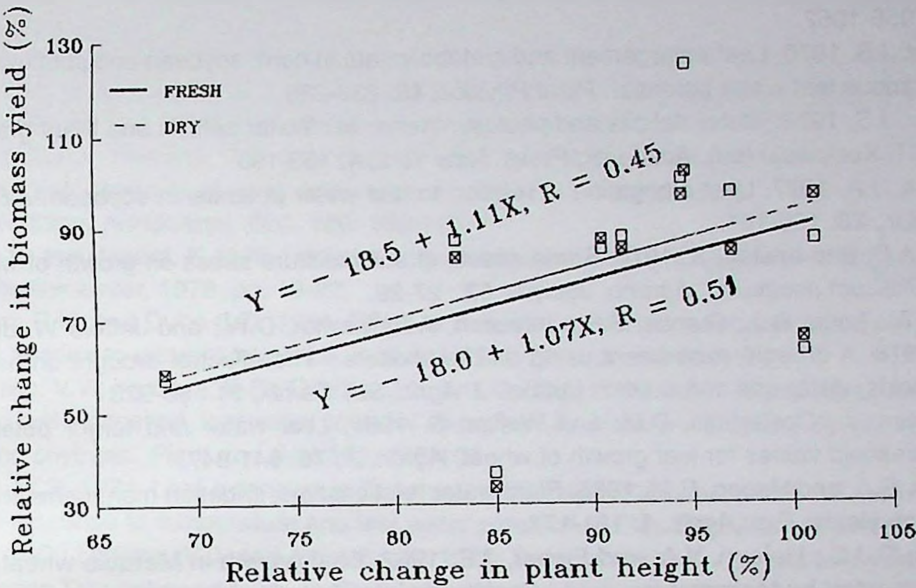

Figure 7. Relationship between relative change in plant height and biomass yield due to water stress.

In conclusion, expansive growth measured as leaf extension and plant height of sugarcane plant showed measurable response to water stress, decreasing when water is limiting as reported for other crops. This effects deceasing when water is limiting as reported for other crops. This effect was also found to be genotype dependent (Tables 1 & 2; Figures 4 & 6). Results demonstrated that measurement of expansive growth could be very useful in distingushing genotypes in their responses to water stress in sugarcane. Moreover, measurement of leaf length and plant height using a ruler is simple, last and inexpnsive and therefore could be a good selection criterion in large scale selection programme. This finding support earlier report on plant height was found to severe well as one component of a multiple selection index for drought resistance in maize (Sischer *et al.* 1983).

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