

## Growth, Water Relations and Physiological Changes of Young Durian (*Durio zibenthinus* Murr) as Influenced by Water Availability

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### ABSTRAK

Kesan air ke atas klon-klon durian D24, D99 dan MDUR79 dikaji di dalam dua eksperimen berbeza. Di dalam eksperimen pertama, pokok didedahkan kepada kadar air yang berbeza; 80%, 40% dan 10% daripada kapasiti ladang. Kekurangan air menurunkan kadar pertumbuhan, status air dan kadar fotosintesis pokok. Terdapat bukti kesan klonal ke atas kadar fotosintesis di mana klon D99 menunjukkan kadar fotosintesis yang lebih tinggi daripada klon D24. Di dalam eksperimen yang kedua, klon-klon D24, D99 dan MDUR79 didedahkan kepada suatu jangkamasa kekurangan air daripada 7 hingga 21 hari. Status air pokok dan kadar fotosintesis didapati lebih rendah oleh kerana kekurangan air pada klon D24 jika dibandingkan dengan klon D99 atau MDUR 79. Penambahan proline yang lebih tinggi pada klon-klon D24 dan MDUR79 mencadangkan bahawa kedua-dua klon tersebut lebih toleran terhadap kekurangan air jika dibandingkan dengan klon D24.

### ABSTRACT

The effects of water availability on durian clones D24, D99 and MDUR79 were investigated in two different experiments. In the first experiment, plants were exposed to different water availability: 80% ; 40% and 10% of the field capacity. Water deficit reduced vegetative growth, water status and rate of photosynthesis in the plants. There was evidence of clonal effect on photosynthesis rate where clone D99 showed higher photosynthesis values than clone D24. In the second experiment, plants of D24, D99 and MDUR 79 were exposed to a duration of water stress ranging from 7 to 21 days. Plant water status and photosynthesis rate were more reduced by water deficit in the D24 than D99 or MDUR79. Higher proline accumulation in D99 and MDUR 79 clones suggested that both clones were more tolerant to water stress than clone D24.

### INTRODUCTION

The percentage of survival of young grafted clonal durian plants after transplanting to the field differs in dry conditions. The main problem is related to a lack of water for root development. Plant-water relations are important in controlling stomatal aperture and photosynthesis rate (Hsiao and Acevedo 1984). Plant responses like these will contribute to the differences in the drought tolerance in the plants. In drought-susceptible clones, the physiological processes are adversely affected even by a small reduction in tissue hydration, while those that are drought tolerant possess morphological hydration even under limited water supply (Hanson and Nelsen 1980).

Little has been published on the mechanism contributing to the tolerance of young grafted

durian plants to water stress. This study was undertaken to quantify the level of stress that affects the plant vegetative growth, water relations, stomal response and photosynthesis rate; and to determine the accumulation of proline in the leaves of different clones so as to identify the degree of osmotic adjustment in the plants as it has been proposed that proline acts as an osmoticum during water stress (Kauss 1977).

### MATERIALS AND METHODS

The experiments were conducted in the greenhouse unit, Faculty of Agriculture, UPM, Serdang, Selangor, Malaysia. The mean daily air temperature was  $28.6 \pm 6^\circ\text{C}$  and the relative humidity was  $78 \pm 4\%$  RH. Fig. 1 shows the typical diurnal changes of air temperature and relative humidity

in the greenhouse unit on a dry and sunny day. The experimental materials were young durian clones D24, D99, and MDUR79.

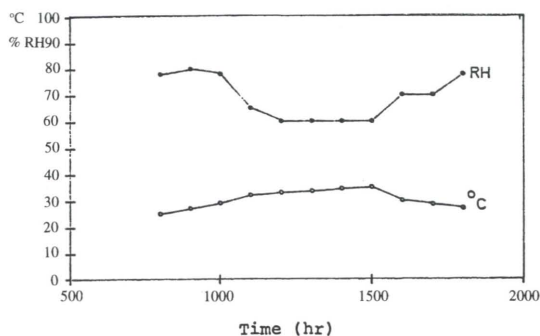


Fig. 1: Diurnal changes in air temperature and relative humidity (RH) in the greenhouse unit on a clear day.

In the first experiment, four-month-old plants D24 and D99 wedge grafted on D8 stock plants were grown in plastic pots containing 17 kg of soil mixture 3:2:1 (top soil: organic manure: sand). The soil mixture was sterilised before planting. Plants were regularly watered for the first two weeks after transplanting. Two levels of water stress were imposed on the plants, i.e. 40% (moderate water stress) and 10% (severe water stress) of the field capacity. The plants were grown in the treatments for 7 weeks. For the control, plants were watered to 80% of the field capacity predetermined by the gravimetric method. The experiment was conducted in a completely randomised design with five replications in a factorial arrangement.

In the second experiment, five-month-old plants of clones D24, D99 and MDUR79, grafted on to unselected seedling stocks (supplied by MARDI Serdang) were grown in pots containing 15 kg of soil mixture. Throughout the experimental period, 8 plants from each clone were regularly watered and 8 others had their irrigation stopped to induce progressive dehydration for a period ranging from 7 to 21 d.

Plant height, leaf area and dry weight of leaf, root and stem were determined at harvest. Root length and volume were also recorded. Leaf area was recorded using a leaf meter (Delta T-Cambridge Ltd, UK). Leaf length was measured weekly with a ruler. Plant parts were oven dried for 48 h at 80°C and the dry weight determined.

Relative water content was determined according to the method of Weatherley (1950). Leaf

discs (10 cm in diameter) were floated for 12 h before the turgid weight was recorded. Canopy transpiration was determined by recording the amount of water loss during each consecutive weighing of the plants. The pots were covered with black polythene sheets to minimise soil evaporation. Stomatal diffusive resistance was recorded using a transit time porometer (Delta - T device porometer Model MK3 Cambridge, UK). Stomatal diffusive resistance was calculated from a calibration curve obtained on a perforated plate with known resistance prior to making measurements. Leaf photosynthesis rate was recorded using an infrared gas analyser Model LCA-2 (ADC, Hoddesdon, UK). Four measurements of different leaves were made for each treatment. The measurements were made when radiation level was within the range of 600-800 W/m<sup>2</sup> for clone D99 and 500-700 W/m<sup>2</sup> for clone D24. Light response curves for these two clones are illustrated in Appendix 1.

In the second experiment, chlorophyll content was determined from the leaf extract following the method outlined by Nose (1987). Leaves were sampled for relative water content, while the adjacent leaves were tested for proline content on day 21. Determination of proline content was based on the method described by Bates *et al.* (1973). Half gram of leaf was ground in 10 ml of 3% sulphosalicylic acid and the extract filtered through a Whatman No. 2 filter paper. Two ml aliquots were sampled for proline estimation by the acid ninhydrin method, and determined by using a spectrophotometer (Shimadzu UV-160A Visible Recording Spectrophotometer).

## RESULTS

There was no significant interaction between clones and water availability with respect to plant vegetative growth. There were no clonal differences in plant height, leaf elongation, leaf area and dry weight of leaves and roots (Table 1; Fig. 2). Root length and root volume, however, were significantly ( $P < 0.05$ ) higher in D99 than in D24 plants.

Water stress had considerable effect on the plant vegetative growth (Table 1). Plants grown in 10% of field capacity (FC) had significantly lower leaf area, leaf and root dry weight, root length and root volume. At harvest, leaf area and dry weight of plants grown in 10% FC were 50% less than those of the control at 80% FC.

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TABLE 1

Effects of water availability on plant vegetative growth at the end of experiment 1 (after 7 weeks in treatment)

	Leaf area (cm <sup>2</sup> )	Leaf dry wt (g/plant)	Root dry wt (g/plant)	Root length (cm)	Root volume (cm <sup>3</sup> )
Clone					
D24	1057a	18.14 a	8.90 a	18.8 a	16.1 a
D99	1034 a	16.32 a	9.96 a	33.3 b	21.8 b
Water availability (FC)					
80%	1258 a	20.80 a	12.68 a	33.4 a	24.5 a
40%	1219 a	19.88 a	10.97a	28.1 b	22.1 a
10%	602 b	9.14 b	4.04 b	16.2 b	9.5 b
Interaction (P<0.05)	ns	ns	ns	ns	ns

Mean separation by DMRT at 5% level

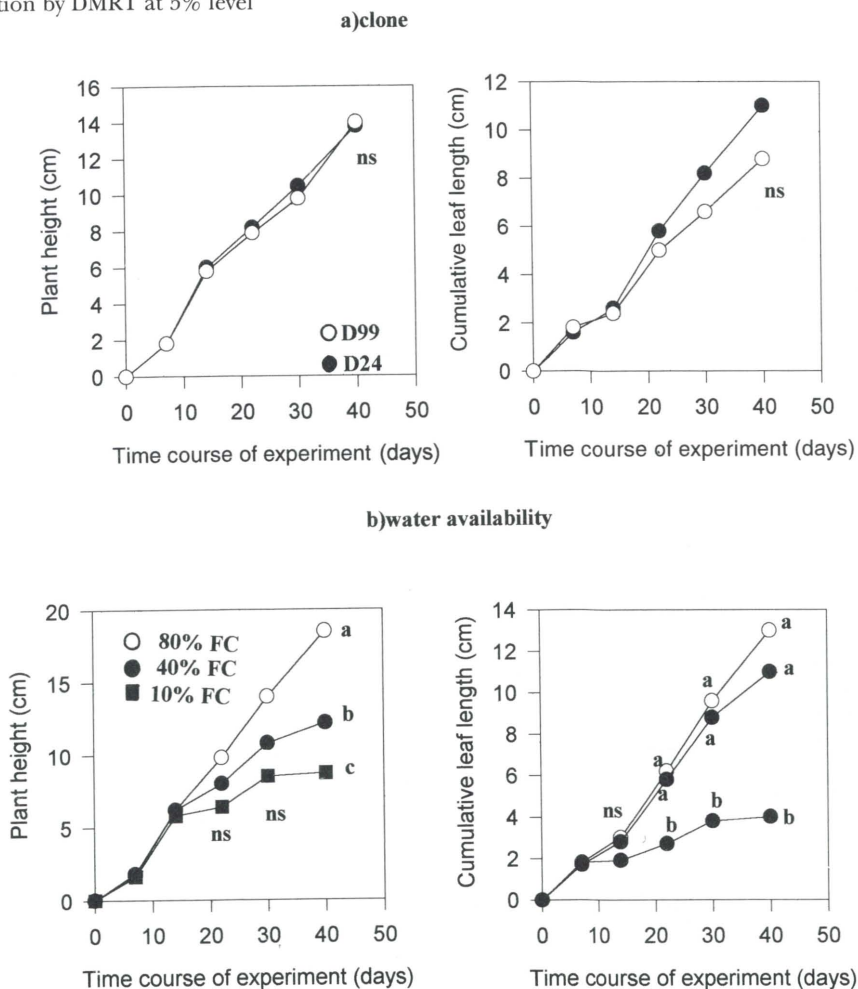


Fig. 2: Plant height and cumulative leaf length as influenced by clone and water availability Means separation by DMRT5%

TABLE 2  
Effects of clone and water availability on relative water content (RWC), canopy transpiration (Tr), internal CO<sub>2</sub> concentration (int CO<sub>2</sub>) and photosynthesis rate (Pn)

Clone	RWC (%)	Tr (ml/day)	int CO <sub>2</sub> (μmol/m <sup>2</sup> /s)	Pn (μmol/m <sup>2</sup> /s)
D24	75.4a	11.2a	333a	2.2a
D99	81.3b	12.2a	326a	5.0b
Water availability (FC)				
80%	78.8	12.8a	324a	5.81a
40%	81.6a	13.7a	321a	4.92a
10%	73.3b	8.6b	344b	0.03b
Interaction (P<0.05)	ns	*	ns	*

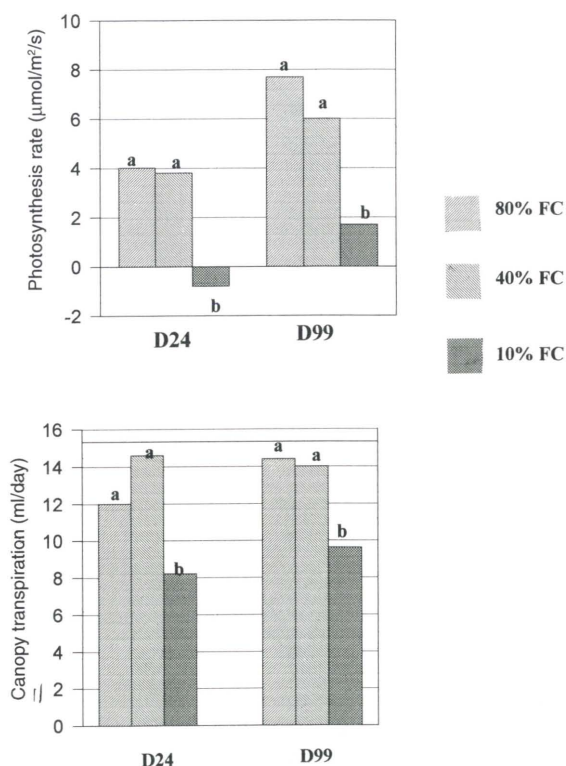


Fig. 3: Photosynthesis rate and canopy transpiration as influenced by clone and water availability  
Means separation by DMRT 5%

The plant water status and photosynthesis rate were determined on the 28th day of treatment. Relative water content, canopy transpiration and photosynthesis rate reduced significantly (<0.05)

in plants grown in 10% FC. In contrast, internal CO<sub>2</sub> concentration increased significantly at 10% FC. Relative water content and photosynthesis rate were significantly higher (P<0.05) in D99 than in D24 plants. No significant clonal effects were found on other parameters (Table 2).

A significant interaction (P<0.05) between clones and water availability on the canopy transpiration and photosynthesis rate was observed. Canopy transpiration and photosynthesis rate reduced significantly (P<0.05) in both D24 and D99 plants grown in 10% FC, the lowest value being recorded for D24 plants. Leaves of D24 plants grown in 10% FC showed a negative photosynthesis rate of -0.8 μmol/m<sup>2</sup>/s (Fig. 3). The highest photosynthesis rate, reaching 7.7 μmol/m<sup>2</sup>/s was recorded for D99 plants under control conditions.

In Experiment 2, changes in plant physiological processes were monitored to determine mechanisms involved in drought tolerance of clonal durian plants. Fig. 4 illustrates the changes in the percentage of soil moisture for a period of 21 d determined gravimetrically. Soil moisture decreased from 23% to 19%, 12% and 9% after 7, 14 and 21 d of water stress, respectively. Similarly, relative water content in the leaves declined to the lowest (48%) in D24 plants after 21 d of treatment. Although relative water content reduced with water stress, no significant difference (p>0.05) was found between D99 and MDUR 79 plants after 14 and 21 d of treatment (Fig. 5).

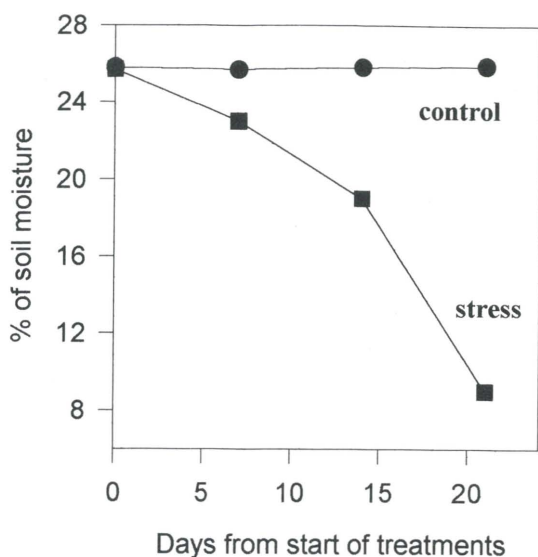


Fig. 4: Changes in soil moisture (%) over stress period

Fig. 6 illustrates the diurnal changes in stomatal resistance as influenced by water stress and between clones, as determined on the 18th day of stress. Stomatal resistance was significantly higher ( $P < 0.05$ ) in D24 compared to D99 and MDUR 79 plants. Highest stomatal resistance was recorded at 1500 hrs reaching  $11 \text{ s cm}^{-1}$  in D24 plants. Stomatal resistance was significantly lower ( $P < 0.05$ ) in MDUR 79 than in D99 plants when measured at 0900 hrs and 1100 hrs. There was no significant difference ( $P < 0.05$ ) between clones under control conditions. Water stress for 14 d resulted in a significant difference in stomatal resistance between clones; D24 plants showed higher resistance than D99 and MDUR79 plants. After 21 d of water stress, D24 plants showed increased stomatal resistance reaching  $6.3 \text{ s cm}^{-1}$  and  $6.01 \text{ s cm}^{-1}$  respectively (Fig. 5). The study showed that higher stomatal resistance reduced the photosynthesis rate of D24 plants to less than  $1 \mu\text{mol/m}^2/\text{s}$  after 20 d of water stress. Photosynthesis rate was 70% less in stressed plants than in the control plants (Fig. 7). Chlorophyll content reduced with increasing duration of water stress. There was, however, no significant differences between clones (Fig. 7).

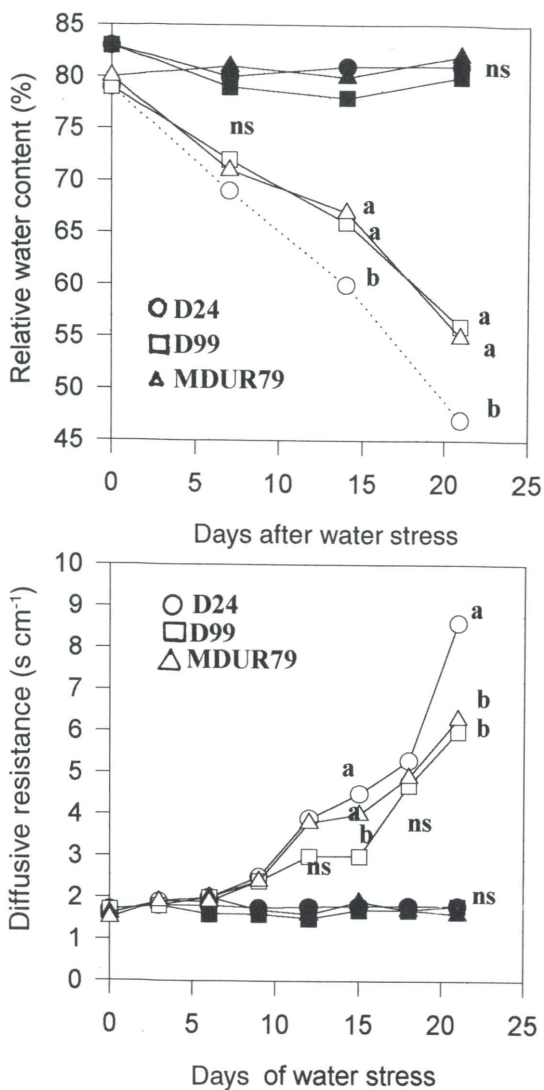


Fig. 5: Relative water content and stomatal resistance as influenced by clone and water availability. Open symbol for stress; closed symbol for well watered. means separation by DMRT5%

There was also a significant clonal difference ( $P < 0.05$ ) with water stress on proline level. Proline level was highest in MDUR79 plants reaching  $93.09 \mu\text{g/g}$ . In water stress treatment, D24 plants showed the lowest proline level which was only  $40.37 \mu\text{g/g}$ , which was almost similar to the levels in the unstressed plants (Fig. 8).

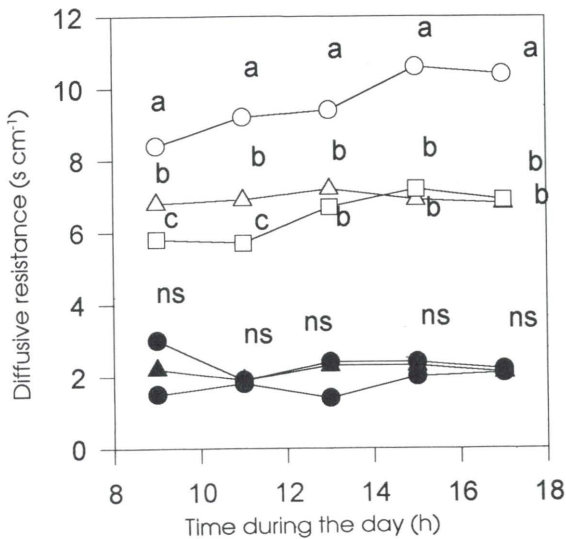


Fig. 6: Diurnal variation of diffusive resistance as influenced by water stress and clone. Closed symbol for control; open symbol for stress; ● = D24; □ = D99; ▲ = MDUR79 Means separation by DMRT5 %

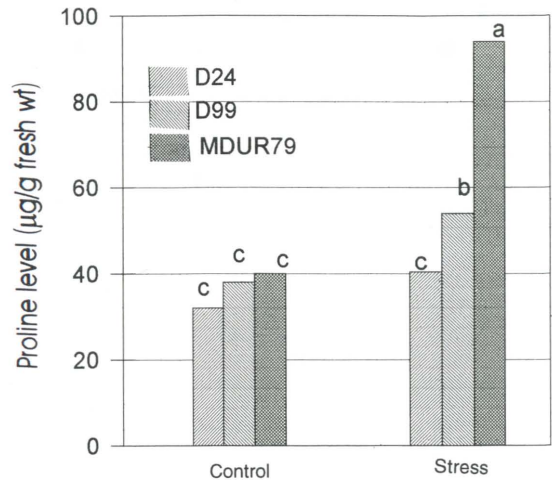


Fig 8: Proline level as influenced by water stress and clones. Means separation by DMRT5

DISCUSSION

The fundamental effect of water stress on plants is the reduction in leaf area and shoot elongation. As shown in Table 1 and Fig. 1, leaf area reduced to 50% when plans were grown in the 10% FC. This experiment, however, showed that leaf area and dry weight of durian plants were not affected under moderate water stress. Begg and Turner (1976) suggested that one of the most important consequences of the sensitivity of cell enlargement to water stress is marked reduction in leaf area which will reduce crop growth rate particularly during early stages of plant growth. The decrease in leaf dry weight (Table 1) is the consequences of reduced leaf area accumulation. Reduction in root growth was also observed in plants grown at 10% FC. Zahner (1968) suggested that the decline in root growth with water stress is due to the limited cell division, cell enlargement and tissue differentiation. The reduction in root growth observed in this study agrees with the findings of Sharpe *et al.* (1988).

In both the experiments, relative water content and activities of physiological processes reduced with water stress. Fig. 9 illustrates a close relationship between soil water status and plant water status indicated by the relative water content in the leaves. The trend is in agreement with the observation by Maruyama and Toyama (1987) on deciduous plants indicating an exponential reduction in xylem pressure with the depletion in soil water. The photosynthesis rate

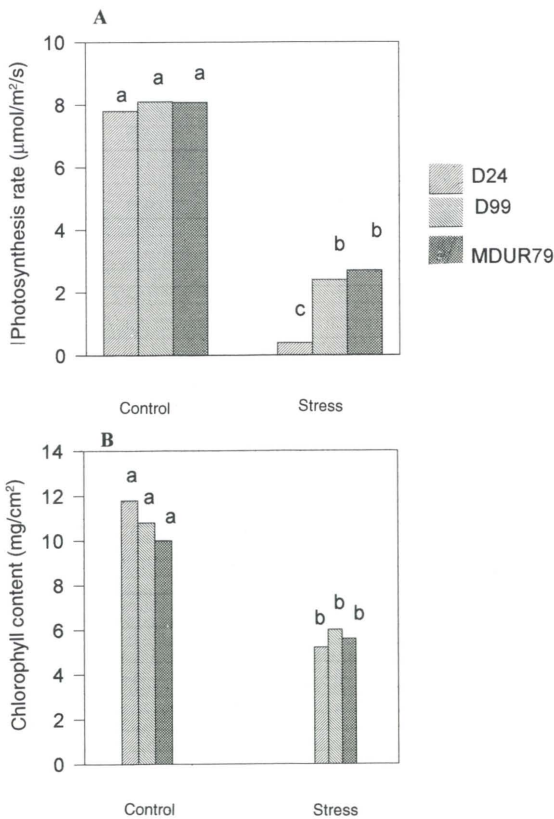


Fig. 7: Photosynthesis rate and chlorophyll content as influenced by water stress and clone. Means separation by DMRT 5 %

of D24 plants grown in 10% FC declined to  $-0.8 \mu\text{mol}/\text{m}^2/\text{s}$  indicating that the plants experienced respiration. However, at this FC of 10%, plants of D99 were still photosynthesizing on the date of observation, although at a slower rate. This fact is further emphasized in Experiment 2 where

water stress severely depressed photosynthesis rate of clone D24, which also had a higher stomatal resistance than MDUR79 or D99.

Osmoregulation is the mechanism utilized by cells to balance their internal osmotic strength with their surrounding (Turner and Jones 1980). The accumulation of proline in the leaf tissue is one of the criteria used to indicate the osmoregulation in plants. The rapidity of accumulation of proline following the onset of dehydration on the plants suggests that proline concentration may adjust rapidly to changes in the aqueous environment of the cells. In this study, proline accumulation was higher in MDUR79 and D99 than in D24 plants, suggesting that both clones could adjust their internal osmotic strength when under water stress. Similar accumulation of proline in other plants grown under conditions of water stress have been reported in many crop plants: potato cultivars (Levy 1983); sorghum (Bhaskaran *et al.* 1985); cultured tomato cell (Handa *et al.* 1986). The results substantiate the observation by local farmers of difficulties in establishing D24 clones especially during periods of drought. From the genetic point of view, it is known that D24 was selected from a high rainfall zone where under its original habitat, it receives daily rainfall. D99

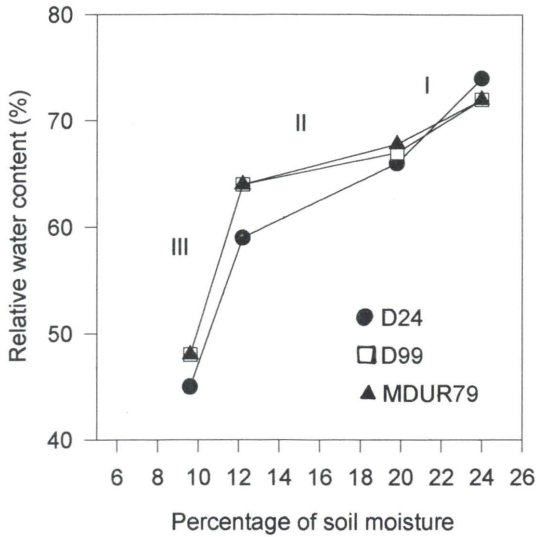
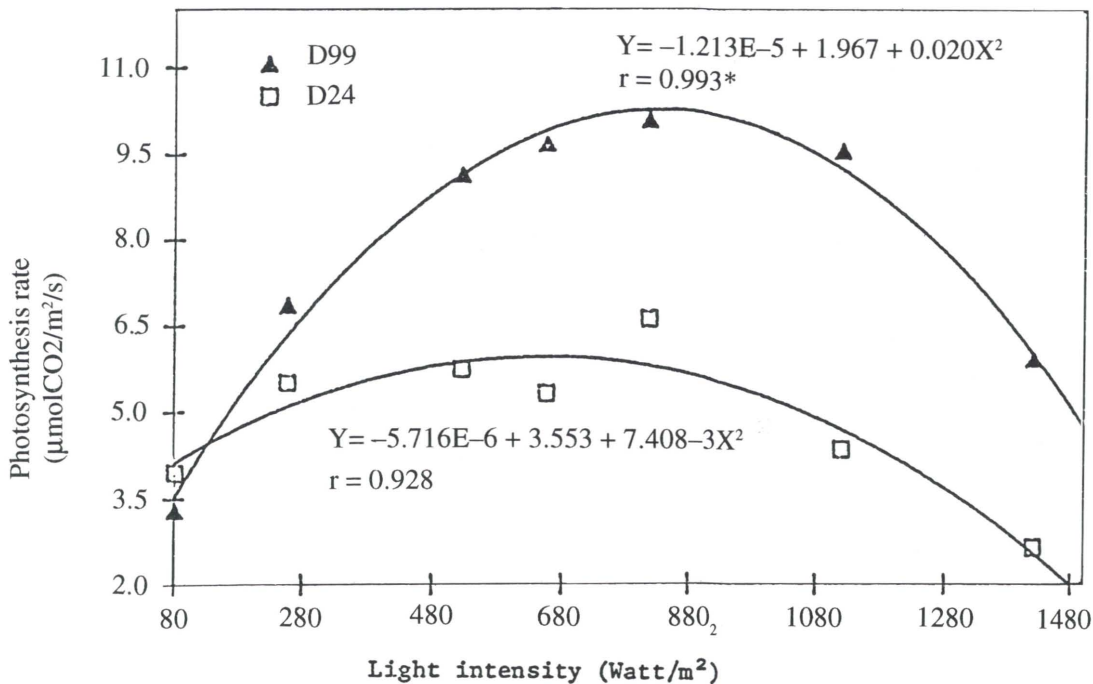


Fig. 9: Relationship between relative water content and % of soil moisture



Appendix 1: Light response curves of D24 and D99 young clonal plants

is a clone from a dry zone and at a higher latitude and it was selected to suit the drier environment while clone MDUR79 is a hybrid having D10 parent obtained from a zone that experiences periods of long water stress. Further analyses of genetic involvement in these clones may clarify the mechanism of such responses to water stress.

### CONCLUSION

The results in this study demonstrate a clear difference in water relations, stomatal responses, photosynthesis rate and accumulation of proline in D24 plants compared to D99 and MDUR79 plants when exposed to water stress. Because of the magnitude of the differences in the parameters examined it would be useful to incorporate the screening of such characters in the early stages of any breeding programme for drought tolerance. The understanding of the clonal responses to water stress could also be beneficial in irrigation planning and management, especially when cultivation is done within an area where water is a limiting factor, or irrigation is a major problem due to topographical differences. Studies also need to be conducted on the improvement of water relation in plants such as the use of water retaining polymers to improve water use efficiency of the plants.

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