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Full Length Research Paper

Identification of moisture stress tolerant oil palm genotypes

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Oil palm seedlings were subjected to water stress by suspension of watering. At 9 days of stress, water potentials had decreased to -2.4 Mpa. Moisture stress under these conditions provoked about 20% damage to the cellular membranes, as measured by electrolyte leakage. Relative water content and protein content of moisture stressed plants were reduced compared to well watered seedlings. Although the direct target of this damage in the membranes, (proteins or lipids), has not been examined in this study, observed decrease in extractable leaf protein could suggest some relation between some parameters which decreased with increased stress such as membrane integrity damage and protein loss. There were measurable differences between progenies in the parameters studied. The implication is that progenies were affected to different degrees by drought and such differences could be exploited for selecting drought tolerant genotypes.

Key words: Oil palm, moisture stress, seedlings, water potential, membrane stability.

INTRODUCTION

Plants contend with complex environmental changes such as varying sunlight, heat, salinity and moisture availability as seasons change and the oil palm is no exception. Although variations in these parameters are not necessarily harmful, beyond certain limits they become sources of stress to the plant which impose limitations on plant functioning. In extreme cases, stresses could kill the plant. To survive and remain productive, plants have evolved adaptive strategies, some of which are morphological while others are physiological (Jones et al., 1981; Levit 1980; Rao et al., 1993).

The oil palm(*Elaeis guineensis* Jacques) is cultivated in the rain forest belt of West and central Africa where it benefits from abundant rainfall. It is also grown in Asia as well as South America, also under conditions of rain-fed agriculture. However, in Africa, except perhaps for the Congo, the West Africa dry season introduces a period of moisture deficit to the environment, which affects the growth and productivity of the oil palm. It is known that inflorescence initiation and differentiation in oil palm are strongly affected by available moisture (Sparnaaij et al., 1963). It is this phenomenon that results in the seasonal alternation of male and female cycles commonly observed in oil palm in West Africa. One of the strategies adopted by this species to overcome the effects of moisture deficit is the presence of a well-developed carbohydrate storage organ, the pseudo bulb/cabbage. This organ helps the palm to withstand periods of drought during which time the carbohydrates stored are mobilized. Another strategy is the reduction of sink demand by modulating flower and fruit bunch production and sex ratio (Sparnaaij et al., 1963), while in extreme cases, these flowers and bunches may be aborted.

Early Studies of young oil palm seedlings root development in a rhizotron system show that different progenies exhibited significant differences in root development, which could be exploited in selection programmes (Conaire et al., 2005). These differences could also confer advantages in times of moisture deficits to progenies with profound roots. The experiments reported here form part of a project to investigate

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physiological changes that occur in the oil palm as this crop adapts to moisture changes in the environment in which it grows. This information will help to select among germplasm collections for moisture stress tolerant genotypes as well as develop new management practices for improved productivity, especially in environments that are sub-optimal.

MATERIALS AND METHODS

Plant material

The oil palm seedlings used were sown in topsoil, in plastic buckets of about 33 cm (diameter) and 36 cm (height), and raised for about 18 months. At the onset of stress, these seedlings were transferred to the green house. While control plants received daily watering, watering was suspended for stressed plants for the duration of stress. Moisture stress treatment was imposed for nine days at the end of which severe moisture stress symptoms including wilting and drying out of lower leaves began to appear. Seedlings were then re-watered copiously at the end of the stress cycle of 9 days to saturation. Each treatment involved four plants. The trial was arranged as a split-plot design replicated four times with watering as the main plot and the progeny as the split plot. Both sets of plants were monitored and all samplings were made from leaf 3, using leaflets from the leaf mid-region.

Leaf water potential

Leaf water potential measurements were made using a pressure chamber (Scholander et al., 1965), utilizing a leaflet per sampling, three leaflets per plant, at each sampling date.

Relative water content

Relative water content was measured according to Gonzalez and Gonzalez-Vilar (2001). Leaf discs were harvested from at least three leaflets and immediately weighed to obtain fresh weight. They were subsequently immersed in deionised water overnight at 4°C. The next day, leaf discs are reweighed after blotting to dryness and then put in dryer to obtain dry weight. Relative water content was obtained as follows:

$$RWC= (FW-DW)/ (SW-DR) \times 100$$

(RWC = relative water content, FW = fresh weight, DW = dry weight, SW = water saturated weight)

Membrane stability

The degree of membrane damage due to stress was determined using methods similar to those of Sullivan (1972). Leaf discs were washed with distilled water, put in treatment tubes, covered and incubated at 60°C for 20 min. The tubes were subsequently transferred to 10°C for 12 h for the electrolyte to diffuse out into solution. From the conductance value, the membrane stability was calculated (Martineau et al., 1979) as follows:

$$R\% = 1 – [(C1 – T1/T2)/ (C1 – C1/C2)] \times 100$$

T = treatment sample, C = control sample while 1 and 2 refer to initial and final conductance respectively. T1/T2 is a relative measure of the amount of electrolyte leakage and is proportional to cellular membrane damage.

Soil conditions

The soil used for the study was topsoil previously collected from the field that had been fallow for some years. The soil was mixed and sieved, using a hand sieve, for homogeneity and to eliminate clumps and pebbles. The plastic buckets into which the seedlings were sown and raised were filled with this soil.

RESULTS AND DISSCUSSIONS

The rate of appearance of moisture stress symptoms depends on the available soil volume and the size of the plant. The results presented here were obtained from using eighteen months old oil palm seedlings in standard nursery conditions but by replacing polybags with stronger plastic buckets of 33 x 36 cm which were perforated at the bottom for drainage. It was observed that stress from drought, as monitored by the leaf water potential, became pronounced from the fourth day of stress (Figure 1) although it was already noticeable even at two days. It progressed rapidly and at nine days of water stress, leaf water potentials in stressed plants had attained between -2.1 and -2.4 Mpa. At this point, severe stress symptoms of wilting and senescence were observable on some of the leaves of stressed seedlings. The oil palm tends to protect its growing point and the younger leaves, especially the spear leaf which is the newest leaf, while sacrificing the older leaves to be lost in times of stress.

Water content is closely related to water potential as the ease with which water can be squeezed out under pressure from the tissues is a reflection of the abundance or dearth of water in the tissue. Expectedly therefore, in the drought stressed plants the leaf water content continued to diminish as stress continued. Meanwhile in the well watered plants, relative water content was stable at about 90% (Figures 2a and b). Over a period of eight days, leaf water potential measurements were obtained for different progenies (Figure 1 and Table 1). This was to permit a comparison of the progenies. While progenies E51 had the highest leaf water potential values from day 4 till day 8, E7 had the lowest. E8 and E55 were intermediate. While a marked reduction in water content could be noticed from the 4th to the 6th day of stress in these seedlings (Figures 2a and b; Table 1) it remained at about constant levels from the 6th till the 8th day of stress. It follows therefore that different progenies suffered different degrees of water loss provoked by stress in comparison to the non-stressed plants. Progenies E7 and E8 lost up to 23% of their water contents while progenies E51 and E55 lost less water and could be therefore more tolerant to moisture stress judging by their relative ability to hold on to moisture.

Cellular integrity in plants is provided by the cell

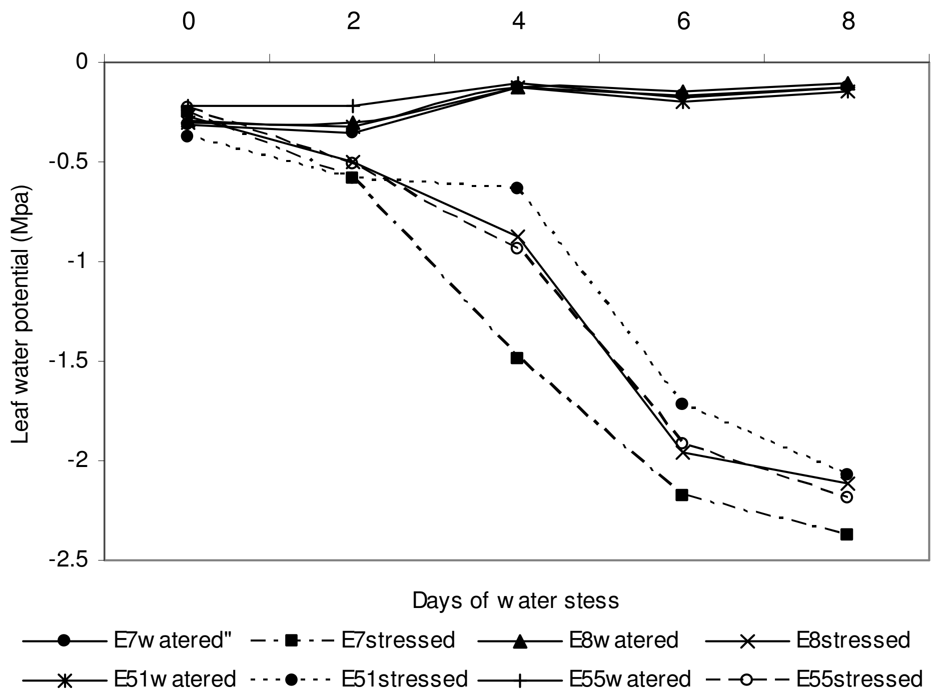

Figure 1. Leaf water potentials (ψ) of oil palm seedlings of different progenies subjected to moisture stress.

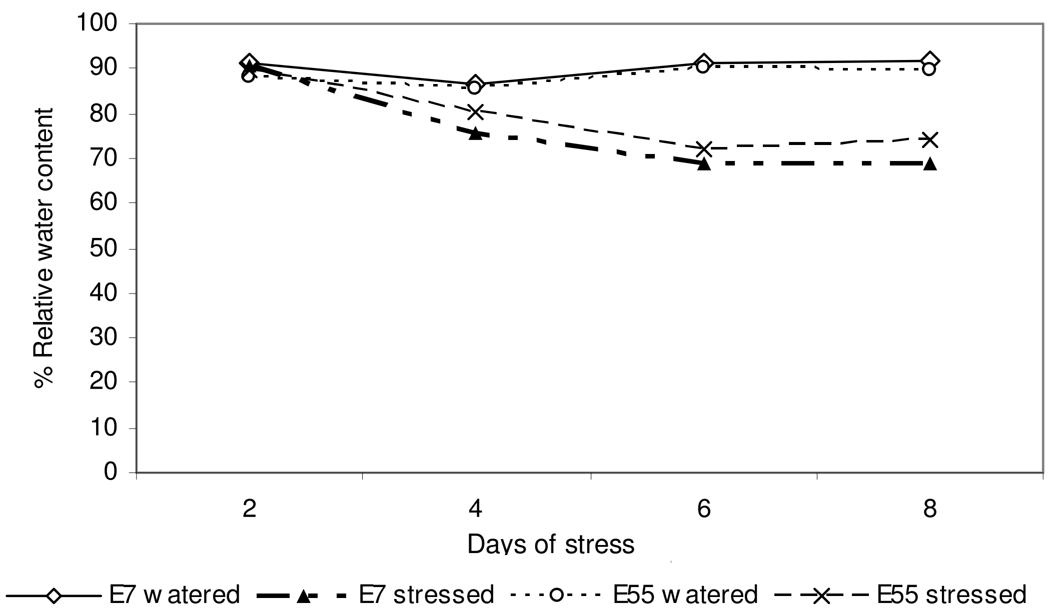

Figure 2a. Relative water content changes in oil palm seedlings of two genotypes during water stress.

membrane supported by the cell wall. Cellular disorganization is one of the signs of stress (Rao et al., 1993). In oil palm seedlings, Figure 3 shows that during moisture stress, the cell membrane suffered some damage that resulted in electrolyte leakage. Damage increased as stress became prolonged attaining between 19 and 25% on the 9th day of stress. In this regard also, different progenies suffered different degrees of cell membrane damage. Significant differences in percentage damage were noticed from about the fourth day. However,

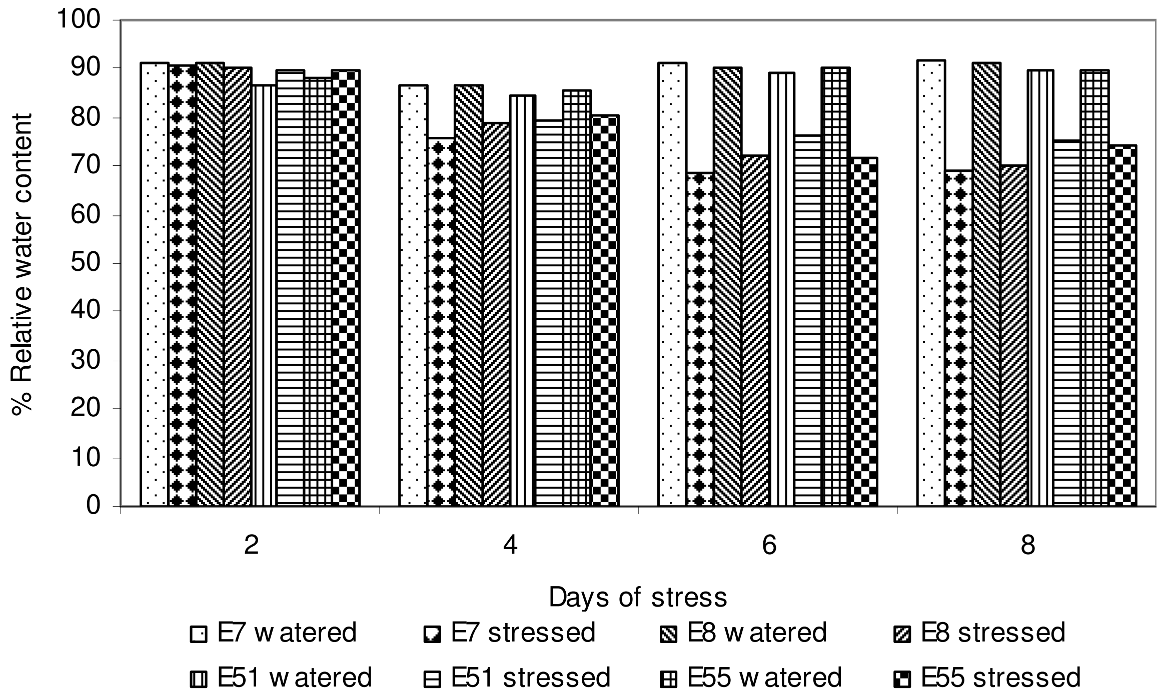

Figure 2b. Changes in relative water content in the leaves of different progenies of oil palm during water stress, comparing well watered with stressed seedlings during a cycle of moisture stress.

Table 1. Treatments and interaction effects on different progenies of oil palm subjected to cycles of moisture stress. [relative water content = (FW-DW)/(SW-DR)x100 FW= fresh weight, DW= dry weight, SW= water saturated weight; while membrane damage is the degree of damage provoked by stress on the cell membranes of stressed plants measured by electrolyte leakage from the cell).

Treatments	Progeny	Parameter		
		Leaf water potential	**Relative water content (%)**	**% membrane damage**
No Stress	E7	0.177	91.857	0
	E8	0.100	91.277	0
	E51	0.150	89.547	0
	E55	0.117	89.770	0
Stress	E7	2.377	68.913	26.20
	E8	2.110	70.113	24.83
	E51	2.070	75.380	19.57
	E55	2.190	74.185	21.43
Significance level (stress/No stress)		**	**	*
Significance level (progeny x treatment))		**	**	ns

while the degree of membrane damage appeared to stabilize relatively in progeny E55, from the fifth day of stress, the other three progenies continued to suffer further membrane damage as stress progressed until the ninth day when measurements were stopped because of termination of the cycle of stress. However, in actual values, progenies E7 and E8 had higher damage while E51 and E55 had less membrane damage due to moisture stress (Table 1).

The responses observed for all three parameters showed the same trend. For each parameter, (Table 1) a 10 day period of complete withdrawal of water significantly

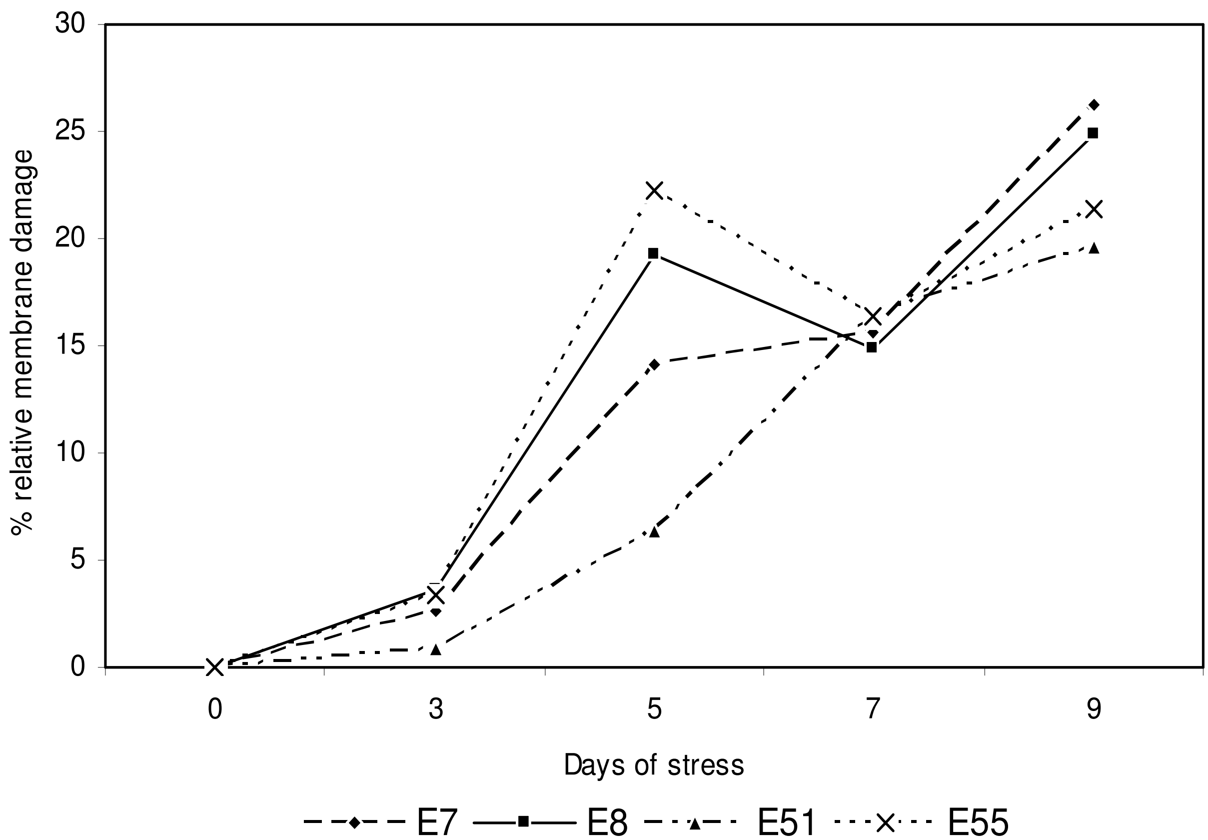

Figure 3: Relative membrane damage, provoked by moisture stress in different oil palm progenies.

affected eighteen months old oil palm seedlings in the nursery. Leaf water potential (ψ) and relative water content of stressed seedlings were significantly ($p \leq 0.01$) different from those of non-stressed seedlings. Stressed oil palm seedlings similarly suffered significant ($p \leq 0.05$) membrane damage in comparison to non-stressed plants. In addition, progenies differed significantly (Table 1) in their leaf water potential changes and leaf water content determinations but no significant differences were noticed between the progenies tested with regards to levels of membrane damage occasioned by the imposed stress. The observed differences between progenies in their response to moisture stress imply that progenies were affected to different degrees by drought. Such differences could, be exploited for selecting possible drought tolerant genotypes from oil palm populations.

This study demonstrates that there are significant variations among progenies for parameters which will be useful for selecting for drought tolerance in the oil palm (Taylor, 1991). Foy et al. (1988) previously reported differential tolerances among plant genotypes of different crops for Manganese in a study on salinity tolerance. A number of options for conserving water are available in oil palm cultivation. These include mulching and reducing the inflorescence and hence bunch load (in the case of female inflorescence), to reduce sink demand. Irrigation could also be considered to reduce drought effects. However, due to the large land requirement for oil palm cultivation, the cost of irrigation infrastructure could be prohibitive. The development of cultivars that are drought tolerant is therefore a promising alternative.

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