Osmotic Adjustments and Associated Water Relations of Clonal Tea (*Camellia sinensis* (L.))

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Abstract

Soil moisture stress associated with high saturation vapour pressure deficits during drought causes adverse impacts on water economy of tea plants. Transpiration rate and stomatal conductance are generally used as indices for screening tea clones for drought resistivity. However, accumulation of osmotically active solutes, leading to osmotic adjustments play a major role in drought tolerance.

Green house studies were conducted to rank recently recommended tea clones for drought tolerance. Feasibility of using osmotic adjustments as a criterion for drought tolerance was studied and identified as a key factor. The treatments consisted of 5 TRI '3000' series clones, 5 TRI '4000' series clones and TRI 2025 which is a well known drought tolerant clones. Artificial induction of drought modified transpiration rates and diffusive resistance resulted in lower leaf water potential at zero turgor, and were higher in most of TRI '4000' series clones while that of TRI '3000' series clones were approximately similar to that of TRI 2025/6. Hence, TRI '3000' series clones can also be considered as drought tolerant clones. Wider osmotic adjustments together with more negative water potential at zero turgor of TRI '4000' series clones revealed more capability to tolerate dry conditions than the other tested clones.

Key words: Tea, osmotic adjustments, drought, transpiration, diffusive resistance

Introduction

Tea (*Camellia sinensis* L.) is primarily grown as a rain-fed crop in tropics. Although monsoonal rains bring in sufficient amounts of rainfall to both wet and intermediate zones, erratic distributions within a year can result in moisture stress on tea plants during the months of January, March and August. Tea lands in the Low Country are especially subjected to moisture stress together with temperature and high saturation vapour pressure deficits during these dry months (Wijeratne and Ekanayake, 1990).

Drought is a serious environmental hazard globally and its damage to cultivated crops has become a frequent phenomenon (Navaratne, 1992). Tea is no exception. Under prolonged dry weather conditions the growth of tea plants is adversely affected by water deficits. This is created by lack of soil moisture and high saturation vapour pressure deficit in the air (Wijeratne and Ekanayake, 1990). Mature tea bushes with well developed root systems withstand drought better than young tea plantations. However, during the first 3-4 years after field planting, bushes are prone to drought effects. Although irrigation during dry periods is a reliable solution, there are practical limitations such as lack of water resources, high costs, etc. Therefore, the use of drought tolerant tea clones with a higher water use efficiency in drought prone regions is of utmost importance.

Transpiration rate and stomatal conductance of leaves are some indices generally used for screening clones for drought tolerance (Sandanam et.al., 1981; Wijeratne, 1986). However, accumulation of osmotically active solutes in plant tissues leading to osmotic adjustments, plays a major role in adapting plants to drought. Moreover, experimental results have shown that the pressure volume curve which explains the relationship between the relative water content and shoot or leaf water potential can be used as a key factor for screening plant species for drought tolerance and shoof or leaf (Wijeratne, 1984).

Most of the clones recommended by the Tea Research Institute of Sri Lanka have been ranked according to their capacity for drought tolerance on the basis of field performance. However, in depth studies have not been conducted on newly released TRI "3000" series and TRI "4000" series clones. Hence a green house experiment was conducted at the Tea Research Institute (Low Country Station) at Ratnapura to rank recently recommended tea clones for the Low Country based on osmotic adjustments and transpiration / diffusive resistance.

Materials and Methods

The experiments were conducted under green house conditions at the Tea Research Institute – Low Country Station, Ratnapura (6^0 40'N, 80^0 25'E and 60m above m.s.L.). A group of eighteen month old vegetatively propagated (vp) plants was selected from the Tea Research Institute nursery (St. Joachim Estate). Eleven clones including TRI 2025 as a control were used for the experiment. They were as follows.

TRI "3000" SERIES CLONES:

a. TRI 3058
b. TRI 3025
c. TRI 3041
d. TRI 3057
e. TRI 3052

TRI "4000" SERIES CLONES:

a. TRI 4042
b. TRI 4052
c. TRI 4049
d. TRI 4033
e. TRI 4014

CONTROL: TRI 2025

These plants were transplanted in plastic pots (41) filled with top soil (Red Yellow Podzolic ultisol). At the beginning of the experiment all the plants were thoroughly watered, and kept for 24 hours to drain out excess water. These potted plants were exposed to moisture stress condition without watering until they were permanently wilted. Plants were arranged in three blocks according to their size. Each block consisted of 33 potted plants (3 plants *11 clones). One month after transplanting, treatments were imposed.

Measurements of relative water content and leaf water potential (pre dawn) were taken between 6.00 am - 8.00 a m daily. For the determination of relative water content 3 mature leaves were excised from three different replicates. Leaves were weighed separately and floated on distilled water for three hours at room temperature under a light intensity of 90 mol/cm^2/s supplied by two 100W bulbs, mounted approximately 30 cm above the water surface (plate 3). After floating, the surface water was removed by placing the turgid leaves between several layers of soft tissues and the turgid weight was recorded. Leaf dry weight was determined by oven drying the leaves at 90^0 c for 24 hours (Sandanam et al., 1981). The relative water content (RWC) was estimated as reported by Weatherly (1950).

$$RWC = (FW - DW) / (TW - DW)$$

where FW, TW and DW are the fresh weight, turgid weight and dry weight respectively,

Leaf water potential was measured on a similar set of mature leaves sampled from the same plants used for relative water content assessments. They were the opposite leaves to that removed for relative water content determination. The leaves were so selected that the effect leaf age on the water relations was minimized (Kozlowski, 1979, Sandanam et al.

1981). The leaf water potential measurements were taken inside the green house using a Pressure bomb (Plant water status Console - Model - 3005, USA). Soil samples were collected at the beginning and at the permanent wilting point of each plant for the estimation of soil moisture. A soil sample of 100g was placed in the oven at 105^0 c for 24 hours and dry weights were recorded (Sandanam et al 1981).

At the end of the experiment fresh and dry weights of leaves, stems and roots (oven dried at 90^0 c for 24 hours) and fresh and dry weights of soils of tagged plants were recorded. The daily soil moisture content was estimated as follows.

$$\text{Soil moisture \%} = [(\text{FW of soil} - \text{DW of soil}) / \text{DW of soil}] * 100$$

where FW of soil in the pot = TW - PW - PMW

and FW = fresh weight, DW = dry weight, TW = total weight of the potted plant, PW = pot weight, and PMW = weight of the plant materials.

Daily minimum and maximum temperatures (using a minimum and maximum thermometer), dry and wet bulb temperatures (Assman Hygrometer) were also recorded inside the green house at 9.00 hrs and 16.00 hrs during the experimental period.

Data were analyzed using SAS statistical package and the means were separated using Duncan's New Multiple Range Test (DNMRT).

Results and Discussions

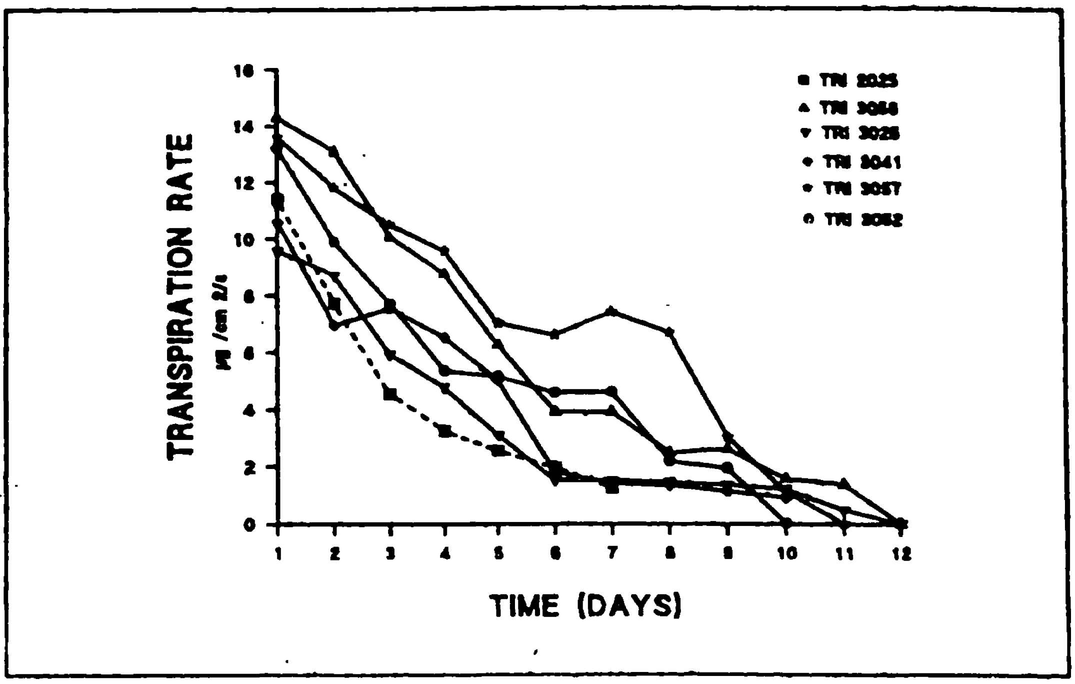
During the drying cycle the sequence of wilting among tea clones was different. Although the age of the plants was the same, the total number of leaves per plant and the leaf area were markedly different among clones. The first signs of wilting was observed in clones having a larger leaf area. TRI 4049 and TRI 4014 started wilting 9 days after withholding watering; on followed by TRI 4033. At the eleventh day of the drying cycle TRI 2025, TRI 4042 and TRI 4052 had wilted. The other clones were wilted twelve days after imposing moisture stress. Moreover, TRI 3025 wilted after 14 days. As wilting depends largely on the leaf area, ranking of tea clones according to their drought resistant capabilities had to be done with utmost care considering the soil moisture content at wilting point and osmotic adjustments.

The variation of transpiration rate of stressed plants is shown in Figure 1. Diffusive resistance recorded an inverse relationship to transpiration. Transpiration rate reduced gradually over the drying cycle (Figure 1) while diffusive resistance increased. A drastic reduction of transpiration up to the sixth day was common for all the clones used in the experiment.

The daily averages of leaf water potential (Figure 2) and relative water content of drying plants show similar patterns of variation. Soil drying has resulted in a reduction of leaf water potential and relative water content. All stressed plants used for assessments were permanently wilted (ie, remained wilted by the morning) by the fourteenth day and recording was stopped.

The pattern of variation of leaf water potential over the drying cycle was similar to that described by other workers. Maintenance of higher water potential may be due to stomata during development of a drought (Kozlowski' 1981). It was evident that TRI '3000' series clones maintained a higher leaf water potential and a relative water content, even at latter stages of the drying cycle (figure 2) due to its moisture conserving ability. Maintenance of higher water potential may be a result of the rapid closure of stomata.

(a)



(b)

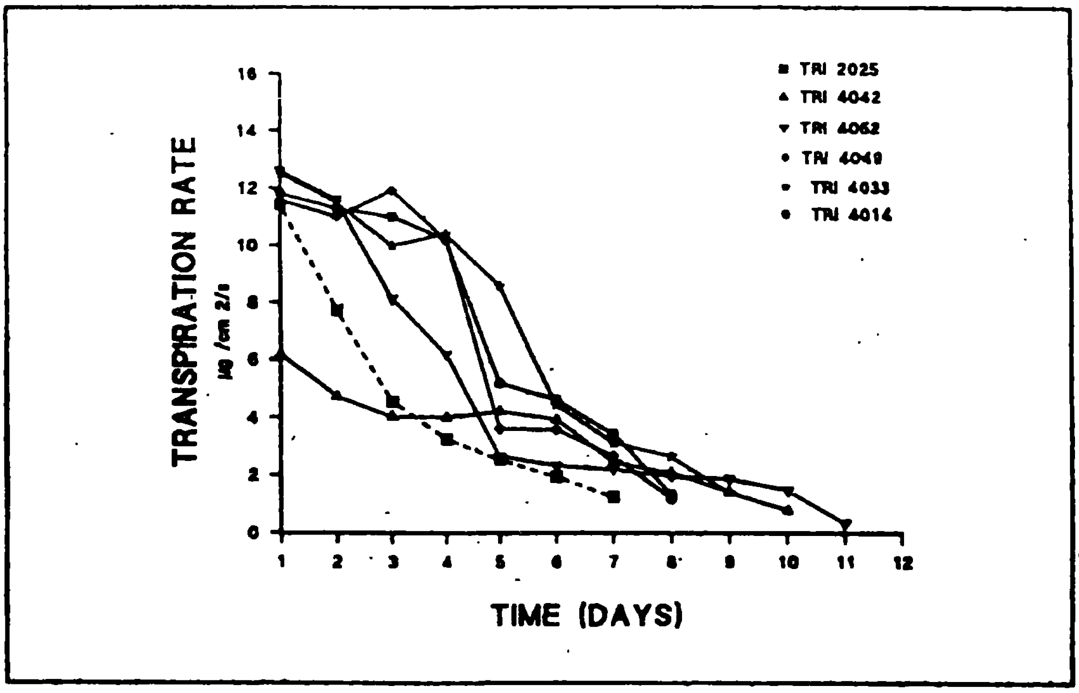
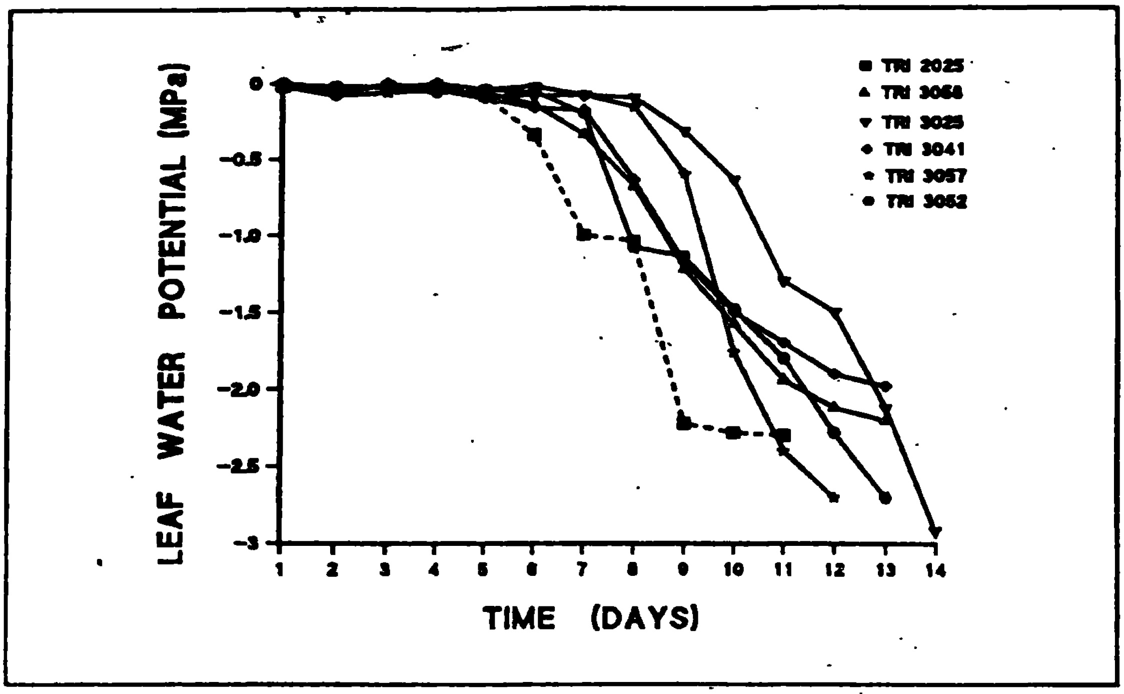


FIGURE 1. The transpiration rate of droughted plants (a) TRI '3000' series clones and (b) TRI '4000' series clones.

(a)



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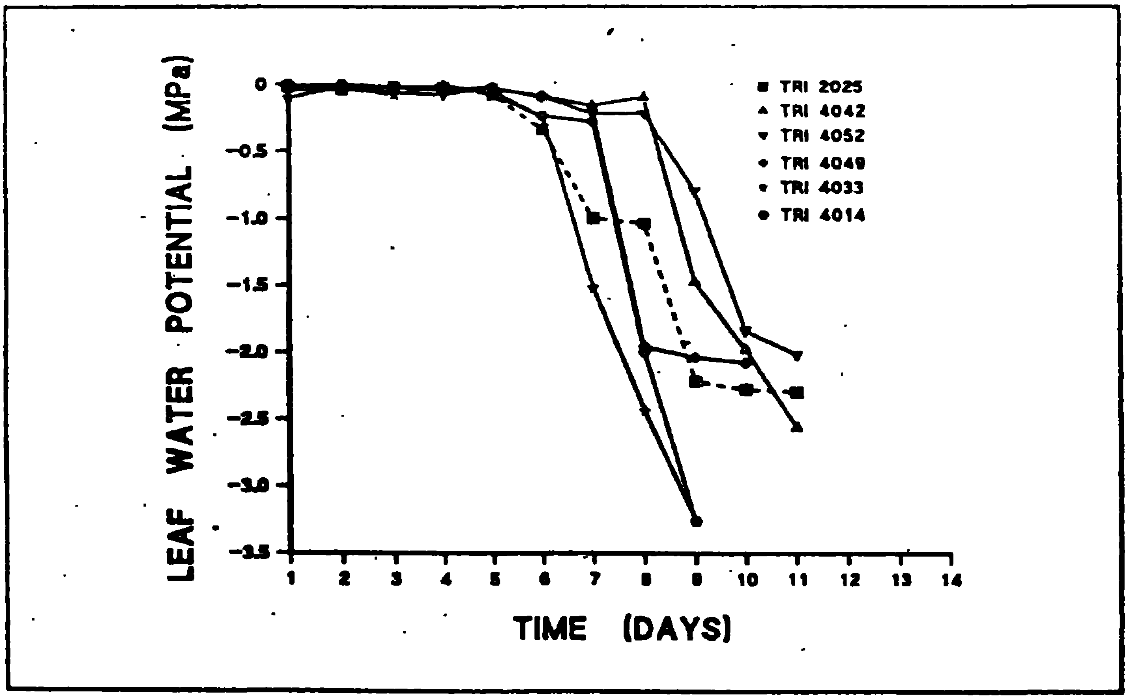

Figure 2. Leaf water potential of droughted plants (a). TRI '3000' series clones and (b). TRI '4000' series clones.

With decreasing soil moisture content, the hydraulic resistance begins to rise (Fitter and Hay; 1983). Consequently, the leaves experience a water stress. Tea plants of this experiment also responded to moisture stress by lowering their leaf water potential and relative water content. With decreasing leaf water potential and relative water content, stomatal conductance reduced thus, lowering the transpiration rate as described by Kozlowski (1981). Therefore, the water relations of the tea plants are mainly governed by the rate of transpiration and diffusive resistance. These two factors contribute to the changes in leaf water potential and relative water content which are the drought resistance properties of plants.

As described by Jones (1992) the difference between leaf water potential at full turgor and turgor loss point was considered as the osmotic adjustments (figure 3 and 4). The osmotic potential at full turgor, zero turgor and appoplastic water content for each clone are shown in Table 1. The osmotic potential at full turgor ranged from -0.75 MPa to -1.32 MPa (Table 1). On average TRI '4000' series clones recorded a higher osmotic potential at full turgor than TRI '3000' clones. The same pattern of variation was characterized by osmotic potential at turgor loss point.

Table 01. Osmotic potential at full turgor, zero turgor and appoplastic water content of tea clones.

Clone	op=full turgor (MPa)	op=zeroturgor (MPa)	Osmotic adjustment (MPa)	Appoplastic water content
TRI 2025	- 0.784	-0.971	0.184	0.48
TRI 3058	-1.010	- 1.114	0.104	0.34
TRI 3025	- 0.754	- 0.860	0.116	0.43
TRI 3041	- 0.985	- 1.098	0.113	0.42
TRI 3057	-0.757	- 0.879	0.122	0.36
TRI 3052	- 0.871	- 0.991	0.120	0.43
TRI 4042	- 1.034	- 1.240	0.206	0.23
TRI 4052	- 0. 828	- 1.039	0.211	0.27
TRI 4049	-1.012	- 1.275	0.263	0.28
TRI 4033	- 0.917	- 1.033	0.116	0.29
TRI 4014	- 1.319	- 1.562	0.243	0.30

Relatively higher values of appoplastic water content were recorded by TRI 2025 and TRI '3000' series clones. Wijeratne (1994) reported that the drought tolerant TRI 2025 had a higher appoplastic water content together with a wider osmotic adjustment than the drought susceptible TRI 2023.

Wijeratne (1994) documented that the drought tolerant clone (TRI 2025) had a higher leaf water potential under well watered conditions and was able to withstand soil drying by lowering its plant water potential to a more negative value than drought susceptible clones (TRI 2023). It was evident with the present results that TRI '3000' series and TRI '4000' series clones can withstand moisture stress to a greater extent through osmotic adjustment than TRI 2025.

Based on these results, it can be stated that higher osmotic potential at zero turgor alone can be used to evaluate drought resistant properties. Observations of field trials in most of low country estates have revealed that TRI '4000' series and TRI '3000' series clones can withstand dry weather conditions better than TRI '2025'. This can be attributed to the ability of

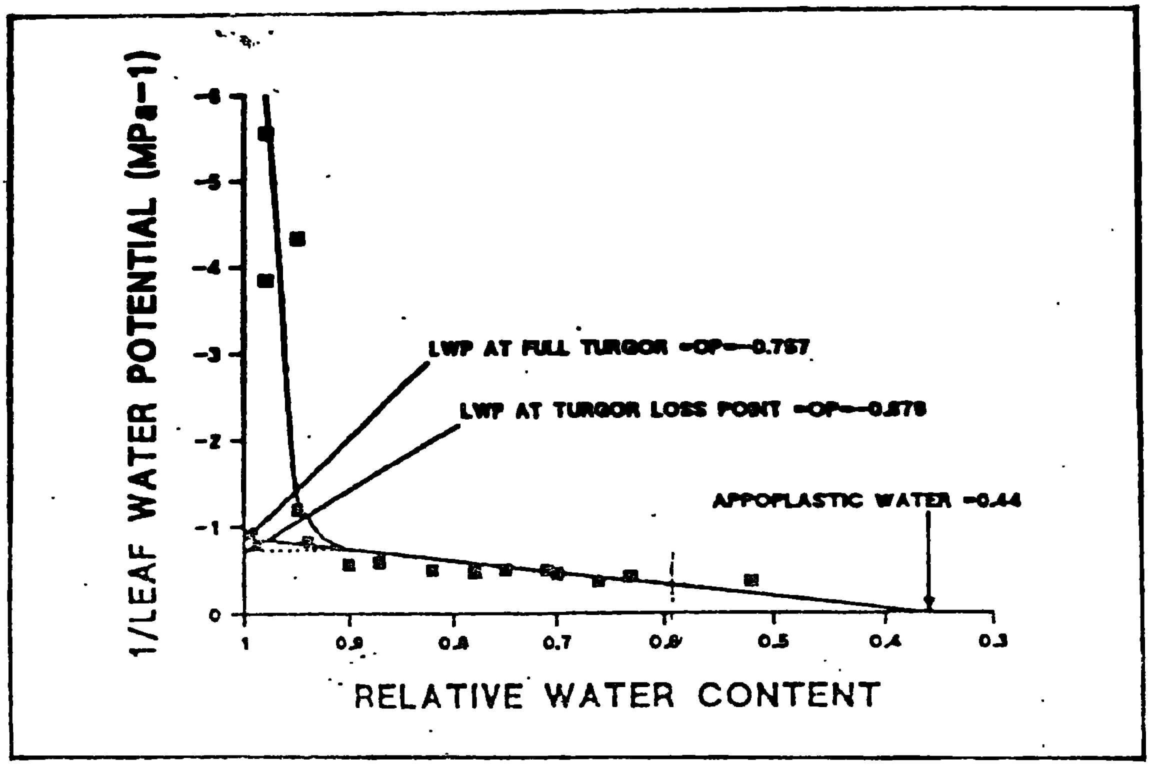

Figure 3. Pressure volume curve of TRI '3057'

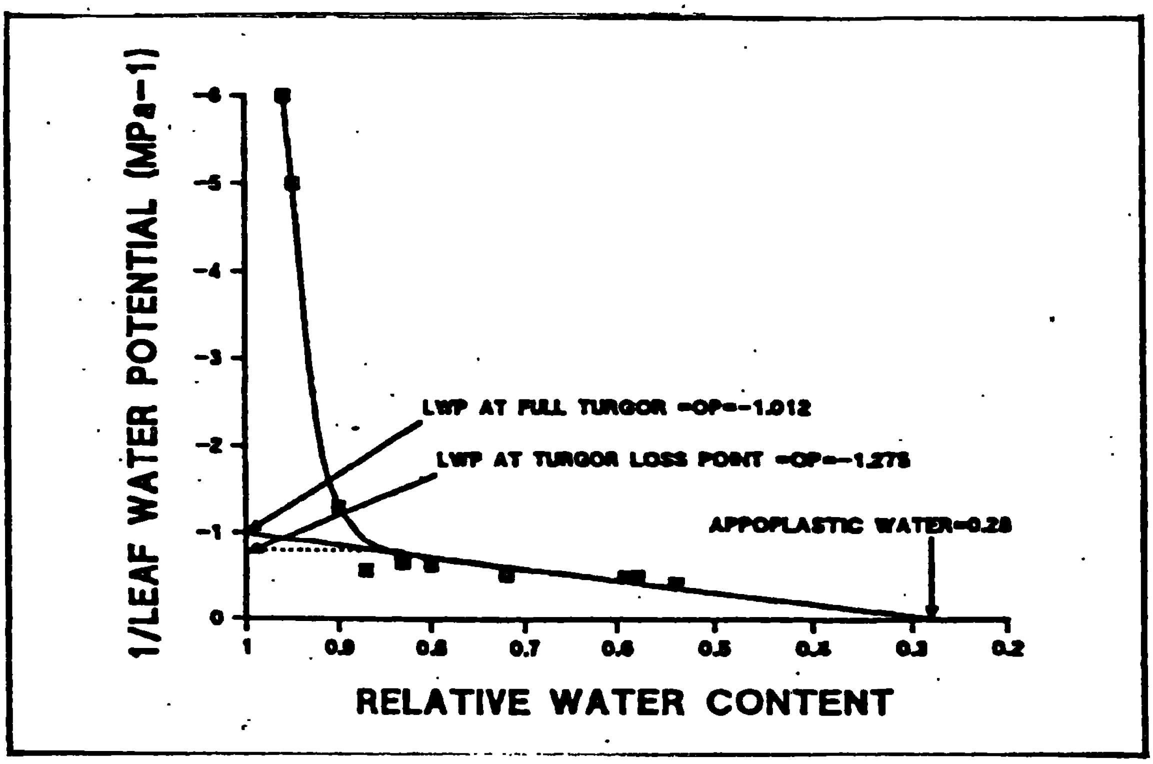

Figure 4. Pressure-volume curve of TRI '4049'

TRI '4000' series clones to reduce the plant water potentials to more negative values and to have wider range of osmotic adjustments. These clones can absorb water from the drier soils than the other clones tested.

Since this was a preliminary experiment conducted under green house conditions, field evaluation will help confirm the methodology for ranking tea clones for drought tolerance successfully. Moreover evaluation of a wider ranger of clones may result in selecting more drought tolerant clones than the tested clones.

Conclusions

This study conducted to evaluate osmotic adjustment and water relationship of tea clones revealed that in comparison with the well known drought tolerant clone TRI '2025', most of the newly released TRI '3000' series clones and TRI '4000' series clones are better adapted to dry weather conditions. Of the two series, the latter appeared to be superior in the content of drought tolerant capabilities with respect to osmotic adjustment. The results of the present study demonstrate that the drought tolerate tea clones tide over periods by conservation of water through efficient stomatal control and effective osmotic adjustment which enable them to absorb soil water at low water potentials.

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