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EFFECT OF PLANT POPULATION ON WATER USE OF MATURE CLONAL TEA

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The evapotranspiration and bush characteristics of clones with different growth habits (TRI 2024, DT 1 and TRI 777) and drought tolerant characters were studied in a long term trial planted at different population densities. The results show that ET rates, LAI, bush spread and root distribution change with population density depending upon the growth habits of the clones.

INTRODUCTION

Tea (*Camellia sinensis*) in Sri Lanka is grown as a rain-fed crop. During prolonged dry weather there is reduction in yield and under extreme conditions casualties are more frequent. The intensity of drought effects can vary from clone to clone. One method to alleviate the drought effects and to obtain maximum production is to manipulate the planting density (Gardner and Gardner, 1983). A number of plant population experiments with various clones have been conducted by the Tea Research Institute of Sri Lanka since 1961 at various agro-ecological regions (Manipura, 1974); population tested ranged from 6000 to 24,000 plants per hectare. In most of these studies, yield was the criteria for evaluating the optimum plant population density. Little attention was paid to study water use patterns of clonal materials with different drought tolerant characteristics at different plant population densities. At present a population density of 12,500 plants per hectare is recommended for all the clonal materials irrespective of their growth habits and drought tolerant characteristics. It is felt that information on water use pattern would help to give location specific recommendations on population density for various clonal materials. The following study was undertaken to investigate the effect of plant population density of different clones on water use pattern during dry periods.

MATERIALS AND METHODS

The investigation was carried out in a long term field trial on plant population density with various clones at Fields No. 8, of St. Coombs Estate (1385 m amsl; lat. 9.40; long 80.40 E). In this experiment, three clones (TRI 2024, DT1 and TRI 777) with different growth habits were planted at three different densities (7936, 11,905 and 23,809 plants per hectare). The presently recommended planting density is 12,500 plants per hectare, irrespective of the growth habit of clones. We have therefore included a low and high population density to study the performance of vigorous clones such as TRI 2024 and DT1 with that of a less vigorous clone such as TRI 777.

Evapotranspiration (ET) measurements

ET rates were determined by applying the following water balance equation to the root zone (Hillel, 1980).

$$ET = RF - D - \Delta M$$

where,

(1)	ET	evaporation rate
(2)	RF	rainfall
(3)	D	deep drainage
(4)	Δ M	change in soil moisture storage

During dry periods RF = O and when soil moisture is below field capacity D can be considered as negligibly small compared to M. Therefore a change in soil moisture storage is equal to ET.

Crop characteristics

(a) Leaf Diffusion Resistance

The leaf diffusion resistance in the mother leaf was measured around 10.00 hours using an auto-porometer (Li-cor model) both during dry and wet periods of the study.

(b) Stomatal characteristics

Stomatal density was estimated from an epidermal impression on cutex on five leaves from each clone at each density using a microscope equipped with a calibrated graticule in the eye-piece. The stomatal size was estimated by measuring the maximum length and width of stomatal aperture.

(c) Leaf Area Index (LAI)

All leaves in a representative bush were stripped and leaf area was determined by measuring the length and width and multiplying by 0.625 (Pethiyagoda and Rajendram, 1965). The leaf area index was determined by dividing the total leaf area by land area.

(d) Bush spread

The bush spread was determined by measuring the length and width of three bushes and finding the average area by multiplying length by width.

(e) Root distribution

A quadrat of 30 cm x 30 cm was used to sample soil at 15 cm intervals in the middle of the inter-row between two plants up to a depth of 60 cm. The samples were washed through a 0.5 mm sieve and roots were separated into fibrous (< 3.0 mm) and non-fibrous (> 3.0 mm) roots (Nagarajah and Ratnasuriya, 1981). The separated samples were oven dried at 80° C and the weight noted.

(f) Characteristic dimension

The maximum width of the mother leaves was measured with a meter ruler under each treatment, since average leaf width is a satisfactory estimate of characteristic dimension (Campbell, 1977). There were 25 measurements taken for each treatment.

RESULTS AND DISCUSSION

ET rates

Of the three clones studied, DT 1 had the highest mean ET rate and TRI 777 had the lowest (Table 1). Also, ET rates were lowest at the highest population density and increased with progressively low population density. The ET rates include the transpiration by canopy and evaporation from the soil surface.

Clone TRI 2024 being a vigorously growing clone depleted soil moisture to a greater extent than the other two clones at the highest density. Therefore, moisture availability for TRI 2024 during dry periods is low. In addition, being relatively shallow rooted (Nagarajah and Ratnasuriya, 1981) the moisture available from the root volume is also limited. As a result, at the highest population density ET rates are relatively lower than the other two densities. Clones DT 1 has a deep feeding root system and it can explore moisture to a greater depth than TRI 2024 or TRI 777. Therefore, during dry periods DT 1 showed higher ET rates even at the highest population density. Another reason could be that DT 1 has a semi-erect leaf angle which helps radiation to penetrate into the canopy thus increasing transpiration rates. The relatively smaller leaf dimension of DT 1 keeps the leaf temperature lower than that of broad leaved clones without getting overheated (Campbell, 1977). As a result transpiration goes on unhindered. Further due to the inclined nature of the leaf there is relatively more radiation passing through the canopy and reaching the soil surface at the lowest population density. This increases the evaporation rate from the soil surface thereby increasing ET rates at the lowest population density. In general TRI 777 being a less vigorous clone and being characterized with horizontal leaf pose and larger leaf dimension than DT 1 had lower ET rates than DT 1 at the highest and the lowest population densities tested.

TABLE 1 – *Mean evapotranspiration rates (mm/day)*

Clone	*Density (plants/ha)*			
	23,809	11,905	7,936	*Mean*
TRI 2024	3.34	4.42	4.16	3.97
DT 1	4.61	4.09	4.44	4.38
TRI 777	3.84	3.52	3.63	3.66
Mean	3.93	4.01	4.08	

Water Depletion Curves

The water depletion curves for the 3 clones at various population densities for the period 23.12.87 to 09.01.88 are presented in Fig. 1. For clone TRI 2024, the surface soil was relatively dry on 9.01.88 at the highest population density studied. It is to be noted that the moisture extraction was greater at this density when compared to the other two densities. This is due to greater competition for moisture at the highest population density. Similar observations were reported for tea by Atkinson (1978) and Alemar and Maestri (1986). In the case of DT 1, at the highest population density the surface soil was relatively dry and the roots extracted moisture from deeper layers. However, at the other two densities, the depth of extraction was almost similar. A trend similar to TRI 2024 and DT 1 was observed for TRI 777 at the highest population density. On the other hand, depth of extraction was similar and not affected by other population densities studies.

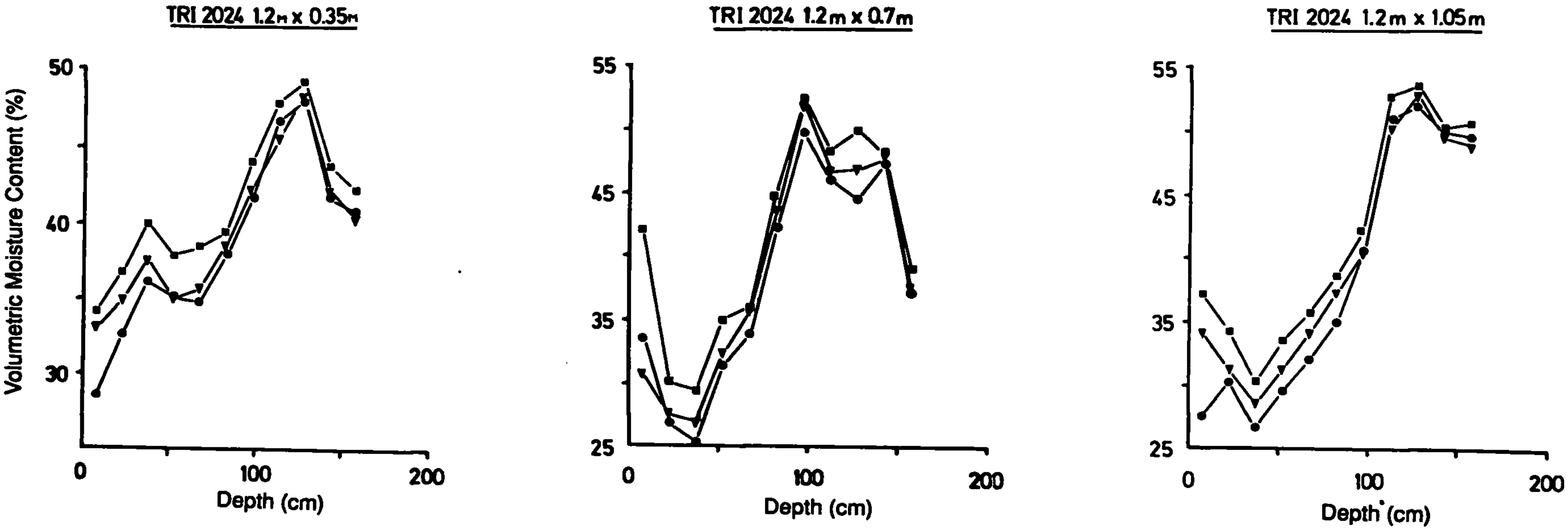

Fig. 1 – Water depletion curves for 3 clones at 3 planting densities

■ – ■ Moisture content of the profile on 23.12.87

▼ – ▼ Moisture content of the profile on 31.12.87

● – ● Moisture content of the profile on 9.1.88

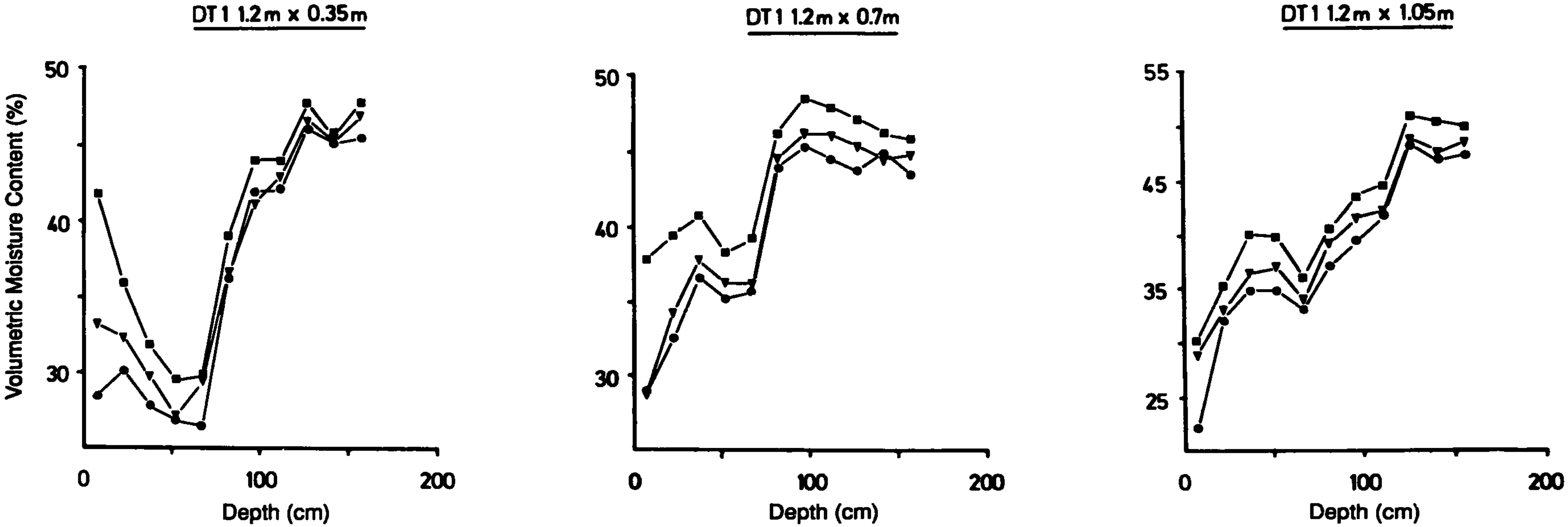

Fig. 1 – continued

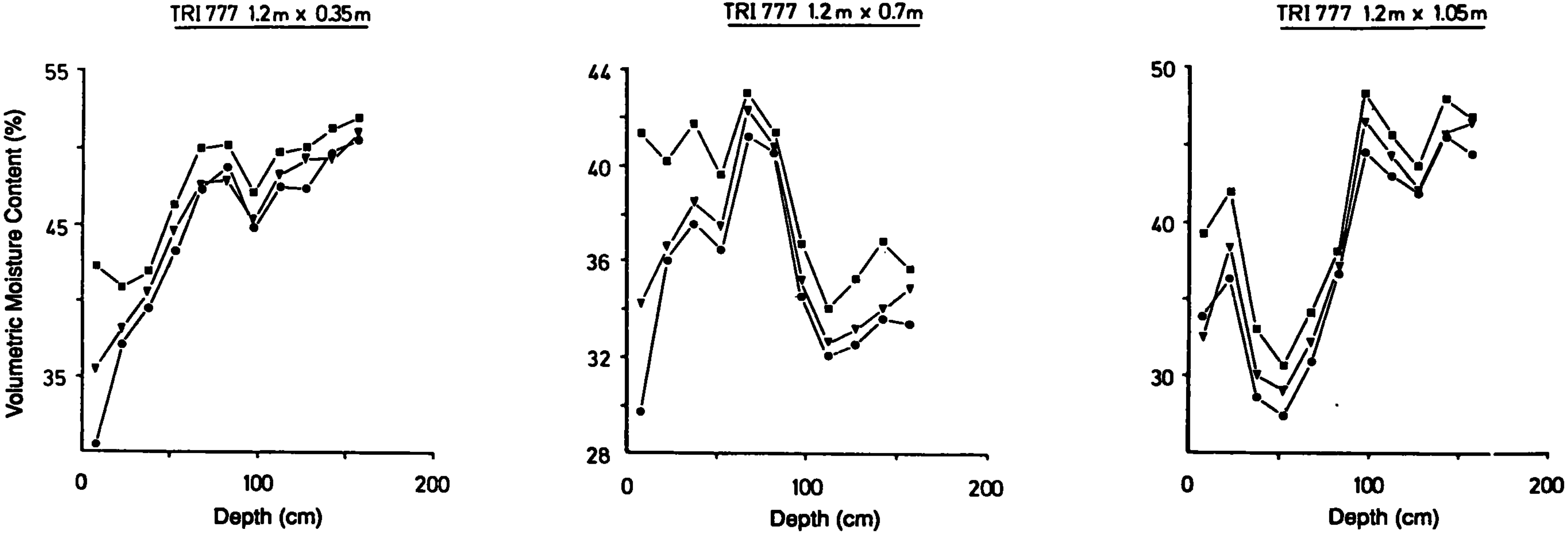

Fig. 1 – continued

Leaf Diffusion Resistance

Table 2 presents the leaf diffusion resistance measured. The leaf diffusion resistance depends on the radiation, vapour pressure deficit, leaf water potential and soil moisture availability. Since the experimental plots are at the same location the variation in the leaf diffusion resistance could be explained by soil moisture availability and leaf water potential. The leaf diffusion resistance during wet periods are less than that of dry periods due to unlimited availability of moisture. During dry periods, the leaf diffusion resistance of TRI 2024 was the highest of all the clones tested. This is expected because of its shallow rooting habit and limited availability of moisture in the rooting zone. As population density decreased the leaf diffusion resistance too decreased. During the wet period an opposite trend was observed. Since moisture was freely available, diffusion resistance was low at the highest population density and it increased with decreasing population density. The leaf diffusion resistance is independent of leaf water potential over a wide range. However, above a critical value it changes rapidly. Unfortunately, we have not measured the leaf water potential in this experiment. Otherwise this would have given a better picture of the leaf diffusion resistance. On the other hand, during dry periods, DT 1 had shown relatively low diffusion resistance compared to TRI 2024. This may be due to its deeper root system which could extract moisture from a larger soil volume and therefore, moisture is not limiting. DT 1 also followed the same pattern as the clone TRI 2024, with the decrease in population densities. During the dry period, TRI 777 had the lowest diffusion resistance among the three clones studied, which could be due to its lowest growth rate compared to the other two. Further, in clone TRI 777 the diffusion resistance values did not show any change with planting density. However, no clear trend was seen during the wet period.

TABLE 2 – *Leaf Diffusion Resistance (s/m)*

Clone		*Population density (plants/ha)*		
		23,809	11,905	7936
TRI 2024	dry	3.59	3.08	2.93
	wet	1.08	1.19	2.22
DT 1	dry	2.49	2.42	2.14
	wet	1.44	1.29	1.32
TRI 777	dry	2.21	2.20	2.22
	wet	1.39	1.49	1.21

Crop characteristics

(a) Leaf Area Index (LAI)

The leaf area index for various treatments, presented in Table 3 shows that in general, when population density increases, LAI tends to decrease. This was more pronounced with clones TRI 2024 and TRI 777. However, the decrease in LAI was not so marked with clone DT 1. Lower LAI of clones TRI 2024 and TRI 777 could be explained by the increased competition for nutrients and water by the clones at the highest plant population density. Therefore, one way to reduce the competition is to decrease the total leaf area which reduces the LAI. However the competition for moisture and nutrients is not so high in clone DT 1 which has a relatively deeper root system. Therefore, LAI does not change markedly with change in population density. It is to be noted that the high LAI of DT 1 is also due to the posture of its leaves which are maintained at an acute leaf angle. This results in less light interception compared to the relatively flatter type of leaves of clones TRI 2024 and TRI 777. Thus, DT 1 has a higher LAI to intercept more radiation.

TABLE 3 – *Leaf Area Index*

Clone	*Population density (plants/ha)*		
	23,809	11,905	7936
TRI 2024	7.30	8.80	10.43
DT 1	8.29	8.42	8.81
TRI 777	7.95	8.00	9.39

(b) Stomatal density

In all the three clones studied, stomatal density increased as plant population density decreased (Table 4). This was more pronounced in clones TRI 2024 and DT 1 when plant population density decreased from 11,905 to 7936 and in TRI 777 when the density decreased from 23,809 to 11,905 plants/ha. For TRI 2024 and DT 1, size of stomatal aperture was affected by the plant population density.

TABLE 4 – *Distribution and size of stomatal aperture*

Clone	*Population density (plants/ha)*	*Distribution (per 2800 sq. microns)*	*Size (sq. microns)*
TRI 2024	23,809	52.2	0.44
	11,905	54.2	0.56
	7,936	73.0	0.38
DT 1	23,809	35.6	0.63
	11,905	34.8	0.69
	7,936	45.0	0.25
TRI 777	23,809	47.8	0.37
	11,905	64.8	0.37
	7,936	65.4	0.37

(c) Bush spread

The bush spread increased as the population density decreased (Table 5). This could be due to greater availability of space. At the highest plant population density TRI 2024 showed the highest bush spread followed by TRI 777 and DT 1.

TABLE 5 – *Bush spread (m^2)*

Clone	*Population density (plants/ha)*		
	23,809	11,905	7,936
TRI 2024	1.09	1.45	1.64
DT 1	0.83	1.48	1.60
TRI 777	0.86	0.89	1.90

(c) Root distribution

The root distribution of the three clones at the three population densities are presented in Table 6. For TRI 2024, as plant population density decreased both fibrous and non-fibrous root weight increases. This may be due to its vigorous growth habit and limited availability of space at the highest population density. On the other hand for DT 1 an opposite trend was observed. For TRI 777, a trend similar to TRI 2024 was observed but the amount of fibrous and non fibrous roots present were low partly due to its less vigorous growth habit.

TABLE 6 – *Root weight (g per 0.09 m^2)*

Clone	*Population density (plants/ha)*		*Depth (cm)*			
			0-15	15-30	30-45	45-60
TRI 2024	23,809	NF	20.6	20.4		
		F	47.0	156.2	9.2	2.1
	11,905	NF	35.2	17.2		
		F	38.9	184.0	24.6	1.6
	7,936	NF	38.2	32.6		
		F	175.9	96.3	2.7	1.6
DT 1	23,809	NF	64.0	54.0		
		F	117.4	81.3	2.4	1.8
	11,905	NF	23.5	48.2		
		F	110.5	21.2	4.7	3.6
	7.936	NF	24.9	12.5		
		F	103.6	21.4	1.5	1.1
TRI 777	23,809	NF	29.1	25.1		
		F	155.8	63.2	6.5	2.5
	11,905	NF	14.2	25.6		
		F	71.7	30.9	16.6	8.6
	7,936	NF	13.8	24.5		
		F	46.6	5.4	3.3	1.1

NF – Non-fibrous roots
F – Fibrous roots

Characteristic dimension

Out of the three clones studied, DT 1 had the lowest characteristic dimension which reduces the resistance to heat and mass transfer. This results in lowering of leaf temperature and increased transpiration. However, the effect of cooling the leaf by increased loss of heat tends to result in lower transpiration rate (Cowan, 1972).

TABLE 7 – *Characteristic dimension (cm)*

Clone	*Population density (plants/ha)*			
	23,809	11,905	7,936	*Mean*
TRI 2024	4.3	4.4	4.5	4.4
DT 1	3.6	3.6	3.5	3.48
TRI 777	3.5	3.9	3.9	3.78

CONCLUSIONS

This study shows that ET rates of clones with different growth habits change with population densities. TRI 2024 has its maximum ET rate around the currently recommended population density whereas clone DT 1 has its maximum at about twice the recommended population density. For TRI 777, ET rates were not very much affected by the population density. Bush characters are also affected by population densities depending on the type of clone. This study broadly indicates the possibility of recommending different population densities for clones with different growth habits and drought tolerant characteristics.

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