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SOIL WATER EXTRACTION PATTERN OF COCONUT (*Cocos nucifera* L.) IN RELATION TO SOIL COMPACTION

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ABSTRACT

Effect of soil compaction on the growth and activity of coconut (*Cocos nucifera* L.) roots in two soil series, namely, *Andigama* series (gravelly soil) and *Madampe series* (sandy loam soil) was studied. The effective root zone of coconut in relation to water absorption process under natural soil compaction were also investigated. Soil compaction and soil moisture absorption ability was determined using cone penetrometer and neutron scattering methods, respectively. Coconut root distribution in *Andigama* and *Madampe series* showed that 75%-80% of roots of adult coconut palms were localised in a depth ranging from 20 cm to 100 cm. About 5% of the roots were located beyond the 100 cm depth and 15%-20% was confined to the top layer (0-20 cm) of soil. Root growth of coconut in the two series did not show any significant differences. However, the root activity in the *Madampe series*, with respect to moisture absorption was higher than that of the *Andigama series* due to low compaction of the former. Results also showed that soil compaction higher than 250 N/cm^2 restricted the activity of coconut roots in the *Andigama series* for moisture absorption up to a distance of 2 m away horizontally from the base of the tree and the highest moisture extraction was observed at 1 m distance. High moisture extraction by coconut roots was confined to a depth ranging of 20 to 120 cm and of 20 to 250 cm in soils of *Andigama* and *Madampe series*, respectively, due to differences in soil compaction levels. It was concluded that soil compaction limits the water absorption ability of coconut roots vertically from the base of the tree, rather than coconut root growth and penetration.

INTRODUCTION

Although coconut is presently grown throughout all agro-ecological zones in Sri Lanka, only a few of these environments are suitable for coconut in all aspects. Others have adverse effects on its production, particularly due to unfavourable soil characters and weather conditions (Somasiri *et al.*, 1994;

Vidhana Arachchi, 1996). Among those characteristics, soil physical properties including moisture status play a key role that affects coconut production. Based on soil physical characters, two categories of soils have been identified in the coconut triangle namely low productive and high productive soils (Vidhana Arachchi, 1996). Identification of specific soil physical constraints related to the above two groups are essential, in order to overcome the problems related to coconut production, by adopting suitable management practices.

Crop growth is retarded, when uptake of water, oxygen, or nutrients is less than the actual demand of the crop. This may be caused by the restricted supply from the soil to the root system, a restricted activity of a root system, or a limited length of the growing period (Boone and Veen 1994). Soil compaction has been described as one of the major constraints that limits the above processes (Soane and Van Ouwerkerk, 1994). Information is scanty on root distribution and water extraction by coconut roots in relation to soil compaction. Such information is vital in planning and implementing site-specific soil moisture conservation practices and irrigation techniques in order to improve coconut production. Objectives of the present study were to: (a) evaluate the effect of soil compaction on the growth and activity of coconut roots, (b) define the effective root zone of coconut in relation to water absorption process under existing soil compaction.

MATERIALS AND METHODS

Experimental Site

A survey of the soil physical aspects of major coconut soils in the coconut triangle was conducted to identify soil series as low productive and high productive soils for coconut. On this basis, the *Andigama* and the *Madampe series* were classified into the groups of low productive and high productive soils respectively (Vidhana Arachchi, 1996). Basic soil physical properties of the *Andigama* and the *Madampe series*, according to major horizons, are indicated in Table 1.

Field experiments were conducted at Rathmalagara Estate, Madampe and at Bandirippuwa Estate, Lunuwila located in the Low Country Intermediate Zone (08° 02N, 79° E; 35 m altitude) of Sri Lanka. Soils at the Rathmalagara Estate and Bandirippuwa Estate were classified as the *Andigama series* and the *Madampe series* respectively. The *Andigama series* is classified under the great soil group of the Red Yellow Podzolic soils (FAO classification-Ferric Acrisole) with soft or hard laterite, moderately well-drained, shallow to moderately deep, sandy clay loam mixed with a considerable amount of iron stone gravel. The *Madampe series* is classified under the major soil group Latosol and Regosol on old Red and Yellow sands, imperfectly drained, very deep, sandy to coarse loamy soils (Somasiri *et al.*, 1994). The coconut trees (cv CRIC 60) were 45 years old and planted at each corner of square system (7.7x7.7 m) giving a density of 170 trees/ha. The mean annual rainfall and ambient temperature were 1660 mm and 23.8-30.4°C, respectively.

Table 1: Soil physical properties of Andigama and Madampe series of Sri Lanka

Parameter	Andigama Series			Madampe Series		
Depth	Horizons					
	A	AB	B	A	AB	B
FC (At 10 kPa)	15.86	15.65	17.09	9.87	10.41	10.97
PWP (At 1500 kPa)	6.81	9.29	13.60	4.15	3.73	4.28
TAW (10-1500 kPa)	9.05	6.38	3.54	5.71	6.18	6.70
RAW (10-100 kPa)	6.46	4.55	2.20	3.96	5.30	5.68
Bulk density (g/cm^3)	1.52	1.58	1.62	1.50	1.50	1.51
Macroporosity (%)	27.40	25.19	23.40	38.40	33.50	32.42
Microporosity (%)	15.20	15.21	16.38	9.80	9.90	10.98
Sand (%)	82.85	80.10	70.55	86.10	85.40	84.20
Silt (%)	4.80	5.10	6.40	2.68	1 .90	2.40
Clay (%)	12.32	16.00	23.10	11.00	10.10	10.70

FC-Field capacity (Volumetric %); PWP-Permanent wilting point (Volumetric %); TAW-Total available water (Volumetric %); RAW-Readily available water (Volumetric %)

Soil Physical Properties

At 10 randomly selected centres of coconut squares, soil profiles of *Andigama* and *Madampe series* were exposed for determining the soil physical properties. These soil profiles showed three distinct soil horizons, namely, A, AB and B, corresponding to 0-15, 15-50 and 50-150 cm depth, respectively.

Soil samples were taken at 5 cm intervals up to a depth of 1.3 m to determine the texture. Undisturbed soil core samples, extracted using a steel core of 7.5 cm diameter and 5 cm in height, were used for the determination of bulk density.

Soil water relationships were determined using cores of 4.5 cm diameter and 3.5 cm height, based on the methods described by Mapa and Bodhinayake (1988). In soil water determination, undisturbed core samples of soil were transferred to aluminum rings (4.5 x 3.0 cm). These samples were saturated and water retention measurements were taken using standard pressure plate apparatus for 13 suction intervals ranging from 1 - 1500 kPa. The gravimetric water content at each suction level was estimated and converted to the volumetric water content using the corresponding bulk density values. The mean values of volumetric water content between 10 kPa and 100 kPa suction were used to calculate the percentage of readily available water fraction of all three soil horizons of the *Andigama* and *Madampe series.* Moisture depletion pattern was also estimated as a percentage of available water under different suction increments. The hydrometer method was used for soil texture analysis. Total porosity was obtained using bulk density and particle density values. Particle density was assumed as 2.65 g/cm^3. Volumetric water content at saturation was estimated using porosity values. Water in pores, which drained out at 10 kPa (diameter 0.03 mm) were estimated as macro pores and rest as microprobes. Six replicates were obtained from each depth of all exposed pits to characterize the above soil physical parameters.

Soil Compaction

The degree of soil compaction which is an indication of resistance to root penetration was examined using a cone penetrometer (Penetrograph STIBOKA, The Netherlands) as described by Bradford (1986). A uniform pressure was applied to the hand grips of cone penetrometer and pushed the sounding cone (2 cm, diameter) right angle into the ground at a constant rate of 2 cm/s. Penetrometer readings were then taken up to 1.5 m depth of soil profiles of the *Andigama* and the *Madampe* soil series. Soil pits (1.5 x 1.5 x 2 m) were exposed to facilitate taking penetrometer readings up to 1.5 m depth. Six replicates were obtained for each depth of the two soil types. Measurements were taken in the dry period to minimize the error according to the different antecedent moisture levels and changes of soil moisture in soil profile was observed using the neutron scattering method (Bell, 1987).

Root Measurements of Adult Coconut Palm

Soil core samples of 1000 cm^3 volume were taken at 25 cm intervals, up to a depth of 1.5 m and to a distance of 3 m towards the center of the square of coconut tree grown in *Andigama* and *Madampe series.* Fresh coconut roots in each core sample were separated and their weights taken, after drying at 105 ^{o}C for 24 h, as described by Bohm (1979). The percentage of root mass radiating from coconut bole up to 3 m from the tree was predicted. Six replicates for each series were taken for this study.

Soil Moisture Depletion

Soil moisture measurements were taken using a neutron moisture meter (Troxler Electronic Laboratories Inc. Research Triangle Park, NC 27709 USA., Model 4302 and Serial No. 166). Aluminum access tubes were installed using a steel guide tube up to a depth of 3 m leaving 20 mm exposed at 0.5, 1, 2 and 3 m away from the base of the tree towards the centre square of the diagonal of the square of the coconut tree. The tubes were then sealed with a rubber bung. The area without a coconut tree within the same experimental location was selected as the control area. The neutron probe was calibrated with respect to different horizons of the *Andigama series* and *Madampe series* for precision and accuracy of data.

The measurements of moisture in soil profiles close to the coconut palms were taken during four consecutive dry periods in 1994-1995. Ten years of rainfall data (1983 to 1992) were used to identify dry periods to establish the experiment. The effective root zones of coconut grown in *Andigama* and *Madampe* series were investigated based on the root growth and soil water depletion at different locations away from coconut trees and the control.

RESULTS AND DISCUSSION

Penetrometer Resistance

Penetrometer resistance in relation to depth of soil profiles showed that penetrometer resistance increased with increasing depth of soil profiles (Fig. 1 & 2). Penetrometer resistance in soils of the *Andigama series* were significantly ($p<0.001$) higher than that of the *Madampe series*. The lowest penetrometer reading was observed in the *Madampe series* and it varied from 50 to 225 N/cm^2, whilst the range for the *Andigama series* was from 175 to 500 N/cm^2. The high penetrometer readings of the *Andigama series* was due to the inherent nature of the soil profile. As reported by Vidhana Arachchi (1996) the high amount of clay particles accumulating in the sub-horizon, cemented with gravel particles formed a hard layer in the *Andigama series* of which bulk density was greater than 1.6 g/cm^3. Gerard *et al.*, (1982) also reported that soil strength in a Miles fine sandy loam, Udic Paleustalf, and in an abilene clay loam, Pachic Argiustoll, were influenced by bulk density, voids, and clay content in their soil profiles. Results also showed that soil resistance increased beyond the 100 cm depth in both soil profiles. However, penetrometer readings decreased with distance, away from coconut palm.

Coconut Root Growth

The results indicated that soil strength was negatively correlated ($r = -0.8298$; $p<0.01$) with coconut root growth (Figs. 3 & 4). Gerard *et al.*, (1982) also obtained similar results for cotton. Results showed that 75%-80% of root of adult coconut palms in the Andigama and Madampe series were localized to a depth ranging from 20 cm to 80 cm, about 5% roots beyond 100 cm depth and 15%-20% roots in the top soil layer (0-20 cm) respectively (Figs. 3 & 4).

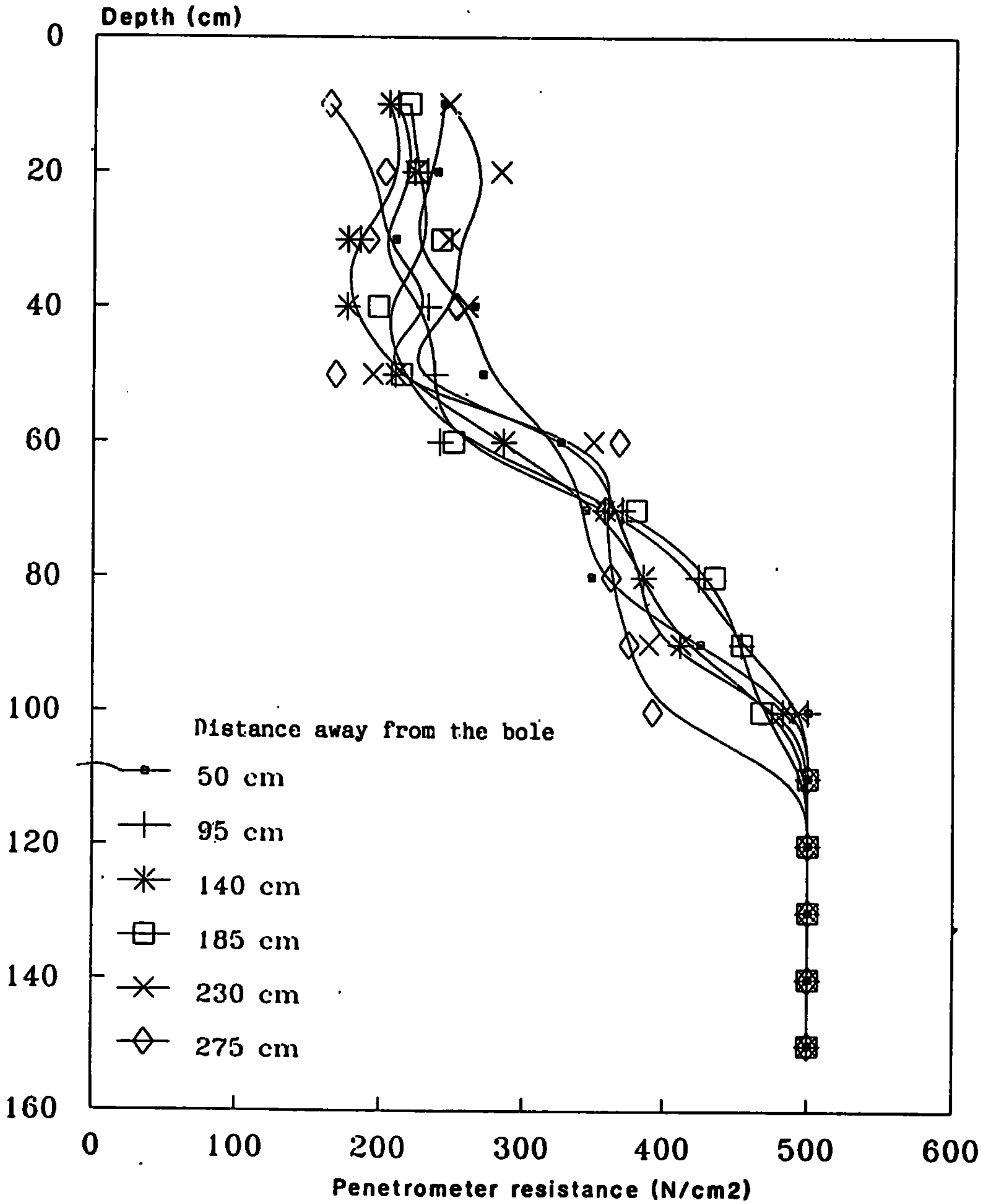

Fig. 1 Penetrometer resistance in Andigama series

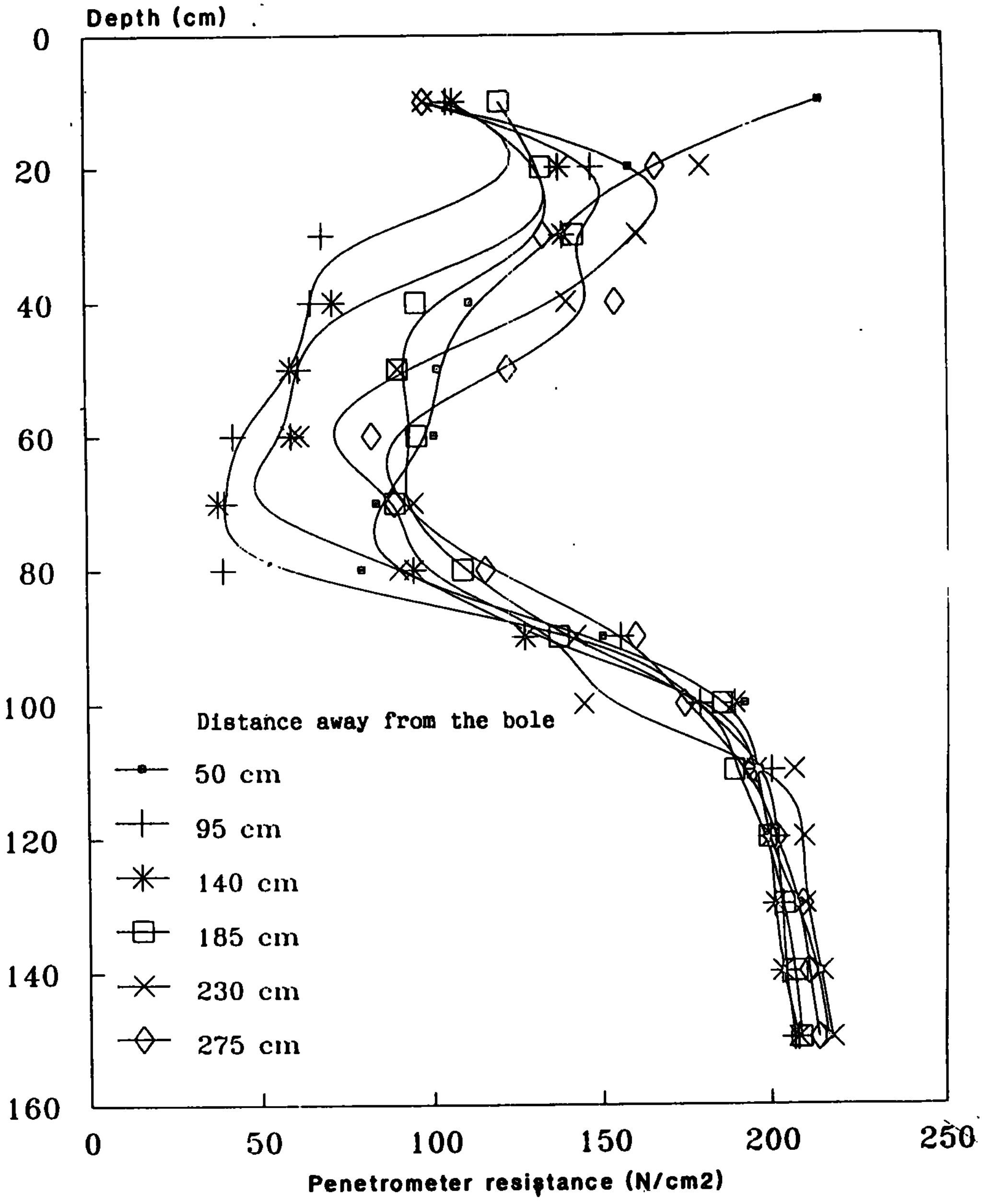

Fig. 2 Penetrometer resistance in Madampe series

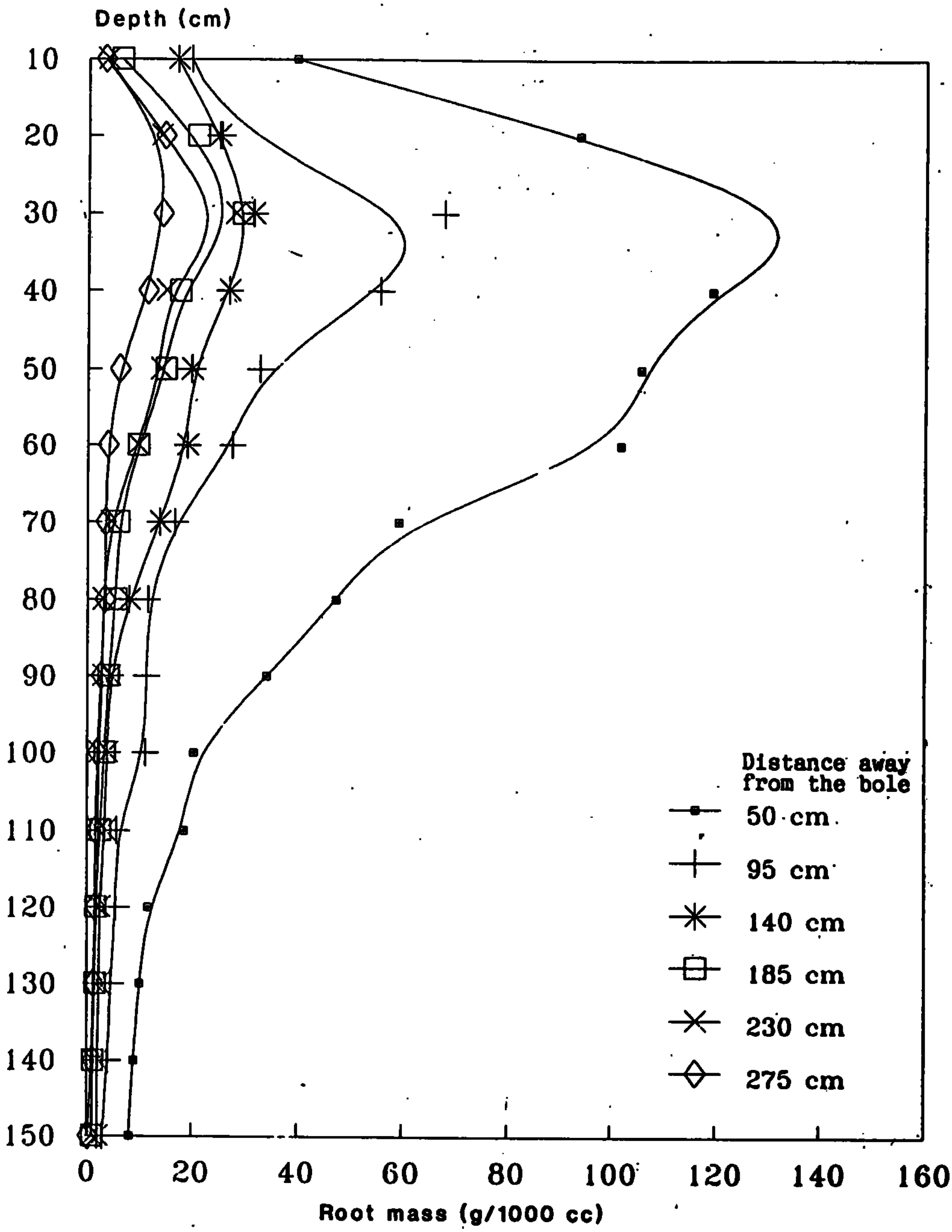

Fig. 3 Root distribution in Andigama series

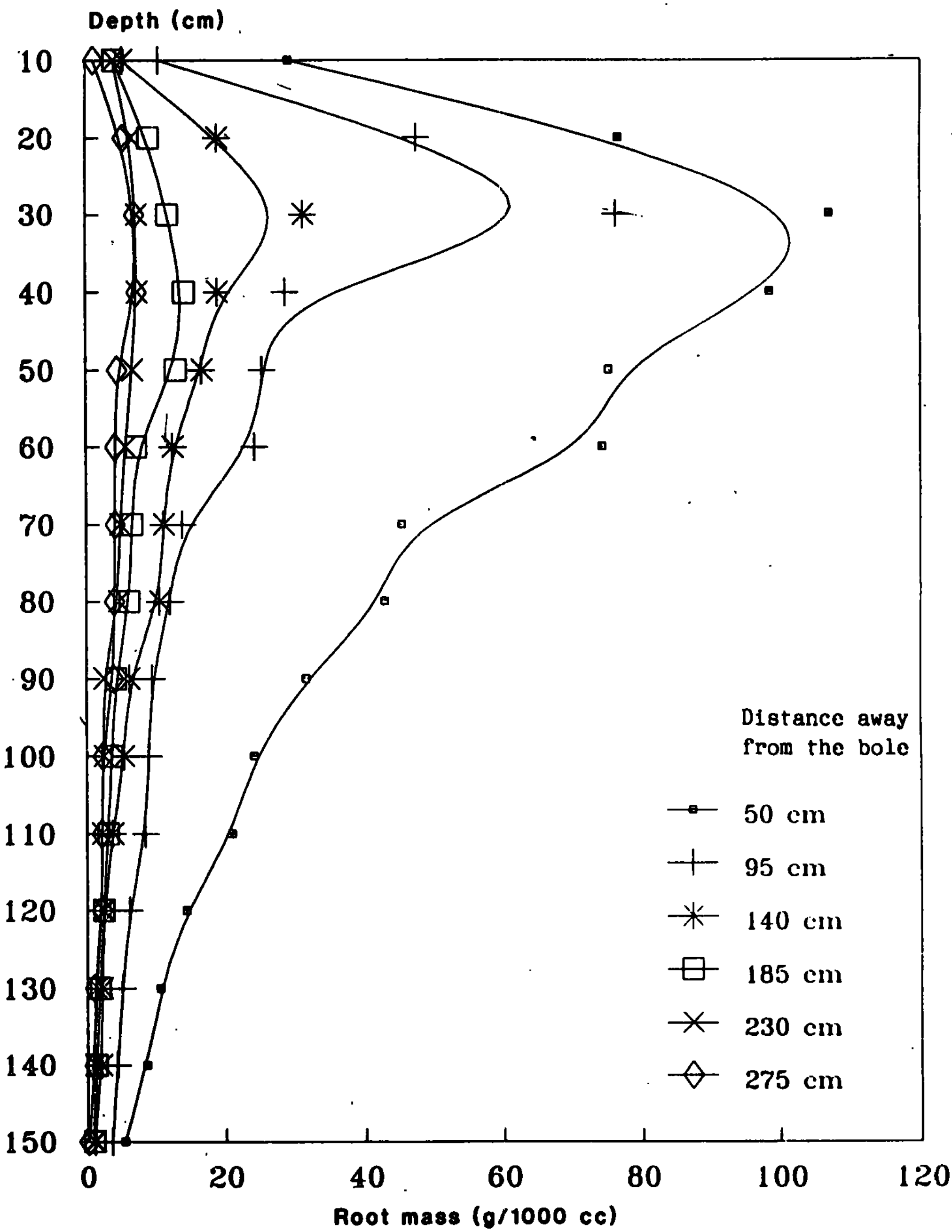

Fig. 4 Root distribution in Madampe series

Further, coconut root growth in both soil series decreased laterally away from an adult coconut palm. However, coconut root mass in the *Madampe series* was higher than that of *Andigama series*, but there was no significant difference throughout the soil profiles, although the penetrometer resistance varied. In contrast, the root distribution pattern of coconut seedlings revealed that gravel compacted with clay soil increased the root diameter whilst root penetration ability was reduced. High compaction also reduced the growth of coconut seedlings due to low availability of water, low infiltration of water, poor aeration capacity, and nutrient absorption dfficiencies (Vidhana Arachchi, 1996). In addition, he also reported that coconut roots in Andigama series tend to re-branch and produce more inactive roots through the process of suberization and dehydration. Therefore, most of the coconut roots in the *Andigama series* become inactive compared to that of the *Madampe series* (refer next section). Overall, results showed that penetrometer resistance lower than 250 N/cm^2 promoted coconut root growth and 75 to 80% coconut roots were localized in a depth ranging from of 20 to 80 cm (Figs. 1, 2, 3 and 4). Atwell (1988) also reported that the compaction of soil and natural high impedance of sub-soils often constitute a major barrier to root growth, especially at low moisture contents.

Water Extractable Ability of Coconut Roots

Water extraction of coconuts grown in the *Andigama* and the *Madampe series* was investigated using the neutron scattering technique. Results showed that in the gravelly, moderately deep, sandy clay loam soils of the *Andigama series*, moisture stored at the depth of 20-120 cm range is significantly ($p<0.01$) mal-extractable by coconut palms compared to the control (Fig. 5). But in deep loamy soils in the *Madampe series*, moisture stored up to 200 cm depth is significantly ($p<0.01$) more extractable than that in the control. Difference of soil moisture levels between the values of soil moisture in profiles of various distances near to the palm and that of the control represents the water extraction by the coconut palm (Figs. 5 & 6). Results also showed that water extraction in the *Andigama series* reaches a maximum at 1-m distance, horizontally from the bole of the palm (Figs. 5) and the extraction ability extended up to 2 m distance away from the palm. Balakrisnamurti (1969) using P^{32} showed that nutrient absorption occurred at 1 m distance from the coconut palm and the efficient nutrient uptake was observed up to 1.75 m in sandy loam soils (Nethsinghe, 1966). However, our study was aimed at investigating the moisture absorption in gravelly soil rather than nutrient absorption. Reports of Alvaro and Key (1996) on water absorption by corn in relation to soil structural quality revealed that corn yield was affected by the least limiting water range (LLWR) of soil which mainly depends on soil compaction.

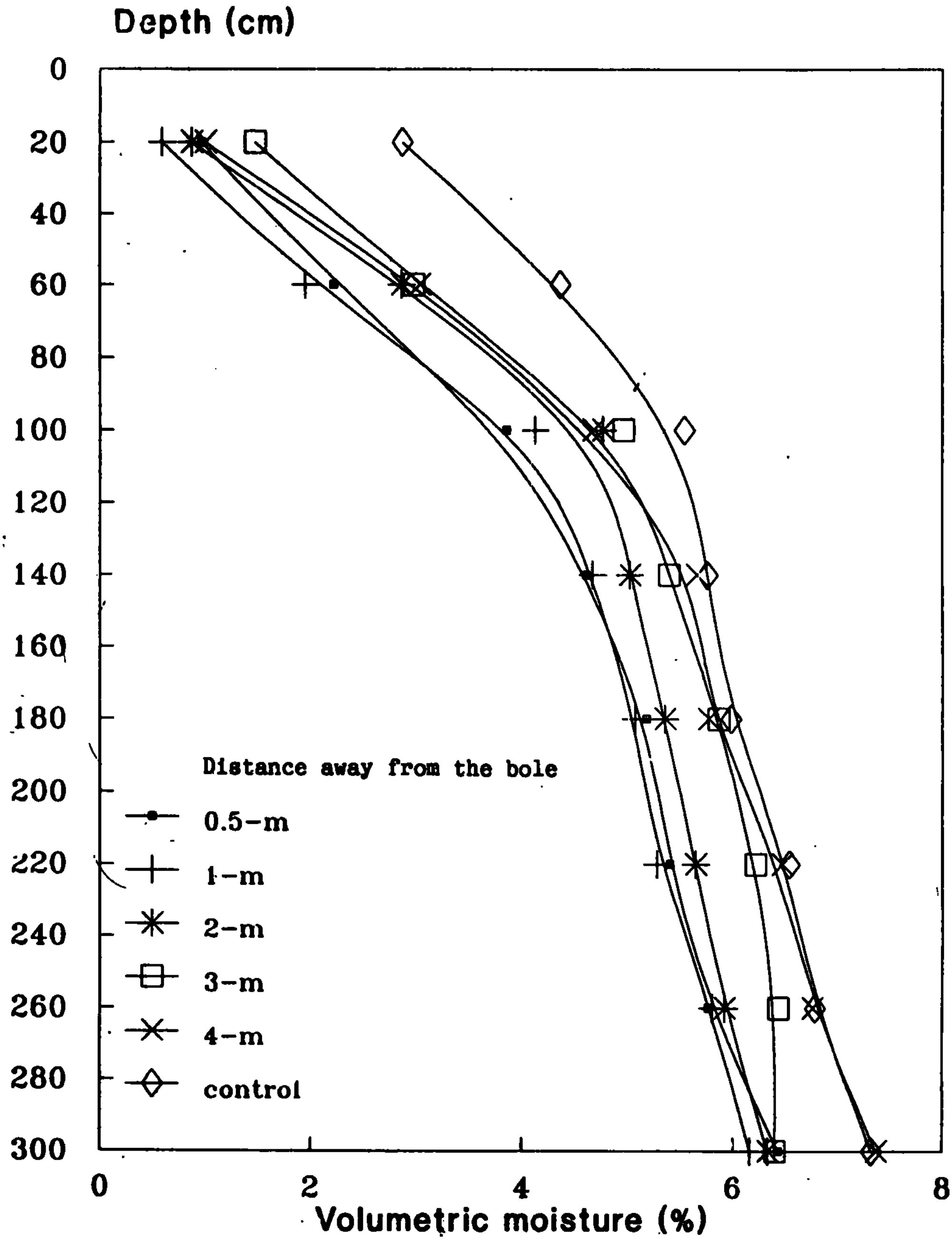

Fig. 5 Water extraction by coconut in Andigama series

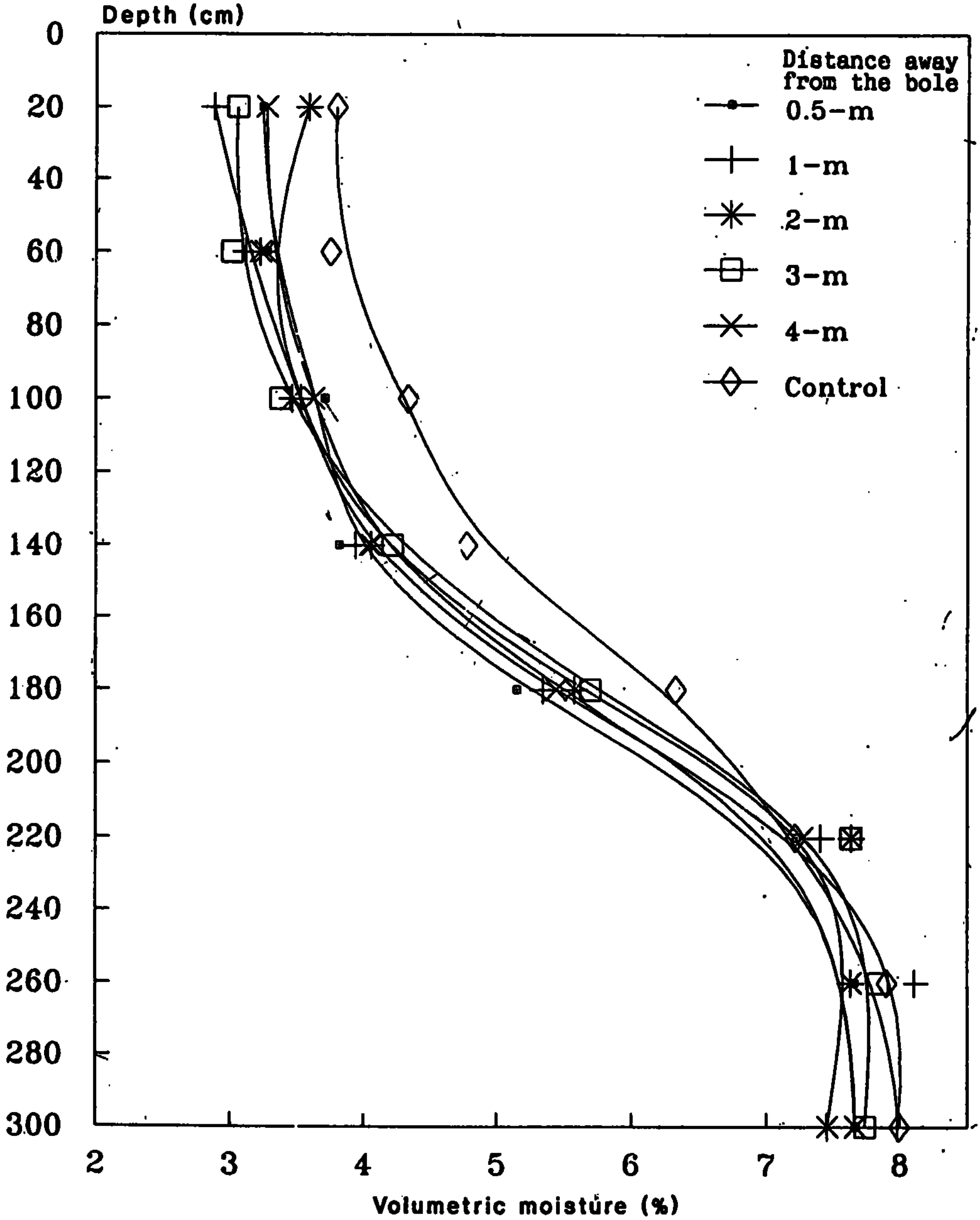

Fig. 6 Water extraction by coconut in Madampe series

In addition, water extraction in horizontal direction by coconut palm grown in the *Madampe series* was not significantly different at depths up to 4 m. Roots of coconut grown in the *Madampe series* are therefore, evidently more active compared to those in the *Andigama series* (Figs. 5 & 6). Vidhana Arachchi (1996) reported that soil compaction and water stress in dry periods adversely affects the normal cellular structure of the absorption cells of coconut seedlings grown in the *Andigama series*, resulting in retardation of growth. Moreover, soil compaction in the *Andigama series* seemed to hinder water absorption and increased upward capillary movement of water in the soil profile (Fig. 5). Boone and Veen (1994) also noted that the most severe limitation to the rate of crop water supply can be expected when root growth in the sub soil is diminished by soil compaction, rainfall, and irrigation or capillary rise from a ground water table are insufficient. Due to upward moisture migration, the shape of the moisture retention curve of the *Andigama series* changed to a concave shape, whilst the shape of this curve for soils of the *Madampe series* was convex due to downward movement of water. Downward movement of water can accelerate due to the sandy nature and lower compaction (<250 N/cm^2) in the Madampe series. Upward and downward movement of water through soil profiles can be decided with understanding of micropores of soils and the moisture depletion pattern of soils (Brady, 1990).

CONCLUSIONS

It is evident from these results that soil compaction adversely affected the activity of coconut roots rather than root growth and penetration. Soil compaction higher than 250 N/cm^2 hindered water absorption of coconut. The effective root zone for water absorption was localized in a depth ranging from, 0 to 120 cm. Furthermore, maximum absorption occurred at a distance of 100 cm away from the bole of the coconut palm and extended up to 200 cm distance away from the palm under high compaction. Moreover, results suggested that soil compaction of less than 250 N/cm^2 promoted moisture absorption by coconut roots up to a depth of 250 cm and up to a distance of 4 m away from the coconut palm. Information generated from this study can be extensively used in generating site-specific recommendations for some cultural practices such as moisture conservation, irrigation and fertilizer application techniques to improve coconut production.

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