Soil & Tillage Research 103 (2009) 350–355

Contents lists available at ScienceDirect

Soil & Tillage Research

journal homepage: www.elsevier.com/locate/still

Effect of deep ploughing on the water status of highly and less compacted soils for coconut (*Cocos nucifera* L.) production in Sri Lanka

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ARTICLE INFO

Article history:
Received 30 April 2008
Received in revised form 29 October 2008
Accepted 29 October 2008

Keywords:
Effective root zone
Mulching
Penetrometer resistance
Soil compaction
Soil water retention

ABSTRACT

Soil compaction limits soil water availability which adversely affects coconut production in Sri Lanka. Field experiments were conducted in coconut (*Cocos nucifera* L.) plantations with highly and less compacted soils in the intermediate climatic zone of Sri Lanka. Soil physical properties of sixteen major soil series planted with coconut were evaluated to select the most suitable soil series to investigate the effect of deep ploughing on soil water conservation. Soil compaction and soil water retention with respect to deep ploughing were monitored during the dry and rainy seasons using cone penetrometer and neutron scattering techniques, respectively. Evaluation of soil physical properties showed that the range of mean values of bulk density (BD) and soil penetration resistance (SPR) in the surface soil (0–10 cm depth) of major soil series in coconut lands was from 1.38 ± 0.02 to 1.57 ± 0.07 g/cm^3 and 55 ± 10 to 315 ± 16.4 N/cm^2 respectively. The total available water fraction increased with clay content of soil as a result of high micropores. However, due to soil compaction, ability of soils to conserve water and to remain aerated was low for those series. Deep ploughing during the rainy and dry periods in highly compacted soils (BD > 1.5 g/cm^3 and SPR > 250 N/cm^2) greatly increased conserved soil water in the profile, while in less compacted soils (BD < 1.5 g/cm^3 and SPR < 250 N/cm^2) conserved water content was adversely affected. Soil water retention in bare soils of both highly and less compacted soil series was higher than that of live grass-covered soil. Amount of water conserved in ploughed Andigama series with respect to bare soils and grass-covered treatments during the severe dry period was 10.4 and 16.9 cm/m, while water storage reduction in the same treatments with ploughed Madampe series was 6.55 and 5.45 cm/m respectively. In addition, deep ploughing even in the effective root zone with live grass-covered highly compacted soils around coconut tree was favorable for soil water retention compared to that of live grass-covered less compacted soils.

1. Introduction

Coconut (*Cocos nucifera* L.) is one of the major plantation crops in Sri Lanka, which covers about 416,000 ha being found on several different soil types with diverse moisture regimes. Amongst soil constraints, soil physical limitations including water deficiency of soils are known to be key factors adversely affecting the physiological and morphological adaptation of coconut roots (Vidhana Arachchi et al., 2000).

Compaction of soil is common in agricultural regions throughout the world and farmers are making progress in dealing with the problem. Soil water deficiency can occur due to low precipitation, while soil compaction could induce low soil water retention due to blocking of capillary fringes (Boone and Veen, 1994) and low infiltration, causing reductions in both crop growth and yield (Rawitz et al., 1983; Boone and Veen, 1994). Compaction may also decrease soil physical fertility through decreasing storage and supply of water and nutrient, which may lead to additional fertilizer requirement and increasing production cost (Hamza and Anderson, 2005). Therefore, deep ploughing in highly compacted soils of Sri Lanka, specially within the Red Yellow Podzolic and Red Yellow Latosols (USDA classification), is one of the options to alleviate soil compaction and enhance water infiltration, increase soil water retention and deep root penetration in drought susceptible crop-lands. Moreover, Tsimba et al. (1999) reported that deep ploughing in soils having bulk density (BD) greater than 1.6 g/cm^3 promoted nutrient and water absorption in the root zone of crops. Although the deep ploughing of sandy loam soils every 2 years was useful, the benefit was reported to be higher when deep ploughing is practiced at four yearly intervals in cotton (*Gossypium hirsutum* L.) cultivation (Arif et al., 2004). Deep ploughing on poorly drained, heavy clay soil promoted deep root penetration, but research studies on the water status of soil profile from deep ploughing are scarce (Chen et al., 2005).

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0167-1987/$ – see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.still.2008.10.025

In addition, the aeration status of soils plays a major role in the growth and activity of coconut roots (Vidhana Arachchi and Somasiri, 1997) and surface ploughing is often practiced in coconut plantations in Sri Lanka on less compacted poorly drained soil, to increase aeration. Excess water in poorly drained soils belonging to Sandy Regosols is a limiting condition for the movement of air through the soil, resulting in reduction of crop growth, directly by impairing root function and indirectly by restricting the availability of plant nutrients due to washing out nutrient through runoff and deep percolation of water (Boone and Veen, 1994; Soane and Van Ouwerkerk, 1994; Gerad et al., 1982). Yavuzcan et al. (2005) reported that deep ploughing in a typical Bavarian soil (Regosol) in Germany, further increased soil compaction and resulted in an increase bulk density and soil strength, and decreased porosity and saturated hydraulic conductivity due to reduction of pore volume with respect to heavy weight of machinery during land preparation. Coconut (*C. nucifera* L.) roots in poorly drained soils tend to proliferate and limit their distribution to top soil layers, resulting root mat formation. However, during the dry period, those surface roots are exposed to heat damage and become inactive for nutrient and water absorption. Excess water in the root zone has a negative impact on root activity by restricting gas exchange in and out of the soil. This keeps spring soil temperature low, forcing new roots to grow just below or even on the soil surface, making the root system more susceptible to attack by soil pathogens and contributing to the well established problem of tree leaning (Fuller, 1999). Moreover, soil drying and compaction have large species-specific effects on the distribution, growth and physiology of roots. Both soil drying and compaction significantly simulated the accumulation of root abscisic acid (Liang et al., 1999). Therefore, coconut farmers in Sri Lanka attempt to harrow/plough these types of lands to cut inactive roots in order to induce new root formation for nutrient and water absorption during rainy seasons (Vidhana Arachchi and Somasiri, 1997).

However, farmers presently misuse these soil management practices without adequate knowledge of their land characteristics specially based on the degree of soil compaction, existing with clay and gravel and, as consequence; these practices may adversely affect the soil water status of their lands. Moreover, deep ploughing could damage to naturally developed pore structure of less compacted soil, thereby low water retention. Therefore, deep ploughing needs to be undertaken with respect to the land characteristics, in order to fulfill the objectives of increasing soil water retention and activate crop root growth. The objective of this study was to evaluate the soil water status of less and highly compacted lands, with respect to deep ploughing.

2. Materials and methods

2.1. Experimental sites and treatments

Based on the visual characteristics of soil profiles and coconut yield, sixteen major soil series in Sri Lanka were classified into low and high productivity soils (Somasiri et al., 1994). Coconut production was mainly limited by high compaction and unfavorable soil water status (Vidhana Arachchi, 1998). Surface (0–10 cm depth) soil physical properties of sixteen major soil series were initially evaluated (Table 1) and based on the results of soil physical characteristics, highly compacted Andigama series from low productivity soil and less compacted Madampe series from high productive soils were selected to evaluate the effect of deep ploughing on soil water status.

Field experiments were therefore conducted for two soil series namely, Andigama and Madampe series. The field experiment conducted in Andigama series was located at Rathmalagara Estate, Madampe in the Low Country (08°02N, 79°E; 35 m altitude) Intermediate climate zone (the annual rainfall and ambient temperature were 1660 mm and 23.8–30.4 °C) of Sri Lanka. Madampe series (light-textured high productive soil) was located in Bandirippuwa Estate, Lunuwila in the low country Intermediate climate zone (08°02N, 79°E, 35 m altitude). Andigama and Madampe soil series belong to the great soil groups Red Yellow Podsolic (Rhodudults/Tropudults; USDA classification) and Latosols and Regosols on old Red and Yellow Sands (Quartzipsamments; USDA classification), respectively.

The coconut plantations at both experimental sites were 45 years old and planted at each corner of square systems (7.7 m × 7.7 m) with a density of 137 trees/ha. The square planting system is generally recommended for monoculture coconut plantations and mid position of the square planting system was named as the centre of square. Grass (*Brachiaria milliformis*) cover was maintained throughout the plantation. Soils of both Andigama and Madampe series at the center square of coconut plants (5 m × 5 m area) and around the base of coconut palm covering 1.75 m radius (effective root zone of coconut) were deeply

Table 1
Soil physical properties in surface of major soil series of coconut lands in Sri Lanka.

Soil series	Bulk density (g/cm^3)	Penetrometer resistance (N/cm^2)	Total available water (vol.%)	Macropores (%)	Micropores (%)	Sand (%)	Silt (%)	Clay (%)
Andigama	1.55 ± 0.08	300 ± 18.5	9.05 ± 1.23	26.40 ± 2.65	15.20 ± 2.45	80.85 ± 6.21	4.80 ± 1.13	14.32 ± 2.13
Kuliyapitiya	1.51 ± 0.06	280 ± 13.3	9.60 ± 1.65	27.21 ± 3.45	16.72 ± 3.12	78.12 ± 4.55	7.76 ± 2.31	14.12 ± 2.44
Kurunagala	1.52 ± 0.07	285 ± 15.7	9.45 ± 1.22	27.88 ± 4.31	16.11 ± 2.76	77.23 ± 3.56	8.21 ± 1.76	13.98 ± 1.99
Boralu	1.57 ± 0.07	315 ± 16.4	8.05 ± 0.98	28.34 ± 3.15	12.67 ± 2.46	80.97 ± 5.76	5.54 ± 2.11	13.34 ± 3.45
Madampe	1.48 ± 0.02	240 ± 16.3	5.71 ± 0.89	34.40 ± 3.21	9.80 ± 1.23	86.10 ± 5.43	2.68 ± 0.97	10.80 ± 2.63
Rathupasa	1.49 ± 0.03	248 ± 12.6	7.54 ± 0.98	32.67 ± 3.34	11.12 ± 0.96	84.54 ± 3.42	3.21 ± 0.67	11.98 ± 3.12
Katunayake	1.43 ± 0.02	225 ± 8.5	5.23 ± 0.87	38.12 ± 2.34	8.90 ± 1.20	88.45 ± 3.21	4.12 ± 0.23	9.87 ± 3.56
Pallama	1.48 ± 0.02	245 ± 10.2	7.89 ± 1.21	33.60 ± 3.70	10.24 ± 3.40	83.70 ± 4.23	4.45 ± 2.10	12.67 ± 2.45
Wariyapola	1.52 ± 0.03	275 ± 14.4	10.00 ± 1.42	25.32 ± 4.65	17.12 ± 3.33	76.12 ± 4.56	10.12 ± 2.10	13.76 ± 3.23
Melsiripura	1.49 ± 0.02	245 ± 16.5	8.92 ± 1.02	31.01 ± 2.10	12.96 ± 1.66	82.67 ± 3.24	5.43 ± 1.65	12.56 ± 2.11
Gambura	1.48 ± 0.01	248 ± 8.5	7.11 ± 1.54	32.10 ± 2.31	11.34 ± 1.32	83.70 ± 2.24	4.88 ± 1.99	12.11 ± 1.99
Wilpattu	1.52 ± 0.05	275 ± 12.2	9.97 ± 0.98	26.21 ± 1.23	16.18 ± 2.45	77.31 ± 4.65	10.21 ± 1.23	12.48 ± 2.12
Mavillu	1.48 ± 0.03	248 ± 8.5	7.23 ± 0.34	33.13 ± 0.98	12.88 ± 1.55	82.73 ± 3.65	4.32 ± 1.65	13.01 ± 2.66
Borupan	1.47 ± 0.01	245 ± 15.0	7.76 ±± 1.20	33.90 ± 2.70	10.90 ± 1.33	83.10 ± 4.31	2.98 ± 0.96	13.13 ± 2.34
Welikatiya	1.38 ± 0.02	55 ± 10.0	1.38 ± 1.01	41.93 ± 2.54	6.82 ± 0.98	96.78 ± 2.43	1.98 ± 0.45	1.55 ± 0.45
Sudu	1.41 ± 0.02	60 ± 15.6	1.41 ± 0.32	40.12 ± 5.66	7.52 ± 1.33	96.12 ± 2.21	2.21 ± 0.98	1.67 ± 0.76
LSD ($p < 0.05$)	0.16	30.8	2.5	5.1	2.2	6.5	2.1	2.8

±SD; n = 10.