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Soil Water Dynamics in Alley Cropping Systems in the Dry Zone of Sri Lanka

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ABSTRACT. This study was conducted to evaluate the competition for soil water between the hedgerow and intercrop in alley cropping systems in Rhodustalfs in the Dry Zone of Sri Lanka. Two alley cropping systems; 2 m and 6 m wide, established using gliricidia as the tree component were tested with sole gliricidia alleys. Cowpea in yala 98 and yala 99 seasons, and blackgram in maha 98/99 and maha 99/00 seasons were cultivated as associated food crops in alley cropping systems. The food crops were also grown as mono crops with no mulch, mulch equivalent to the gliricidia yield of 2 m and 6 m wide alley systems. Gliricidia trees were pruned at the beginning and the end of each season. Soil water content in the profile down to 200 cm depth at various distances from the hedgerow in alley cropping and sole gliricidia systems, and at the centre of mono crops was measured. The soil water content in 0-15 cm layer was highly variable with frequent recharging after every rain. Recharge of deeper layers occurred frequently in maha, and only once in yala. Soil water contents in other layers fluctuated in relation to rainfall with less variability. Higher water consumption was observed in 2 m wide alley cropping followed by 2 m sole gliricidia, 6 m wide alley cropping and mono crops. The lowest soil water consumption was recorded for 6 m wide sole gliricidia. The food crop in monoculture extracted water from shallow soil layers while gliricidia hedgerows extracted water from deeper layers also. Soil water content within 2 m wide alleys was uniform across the alley, while there was an increase of water content towards the centre of 6 m wide alleys. The soil water extraction patterns showed that extraction was less at the centre than on the hedgerow in 6 m wide alleys. It was observed that soil water contents during crop growing seasons remained close to the field capacity with no apparent competition for water between two components.

INTRODUCTION

Alley cropping is a production system where food crops are grown in between hedgerows formed by leguminous trees. It has been evaluated and promoted for a long period as a sustainable farming system in the Dry Zone of Sri Lanka (Keerthisena, 1995). Introduction of trees into annual cropping can result in differences in resources utilization, especially soil water. Therefore, understanding soil water dynamics is very crucial in order to undertake proper management practices aiming at increasing productivity of this system. Research results on alley cropping under semi arid conditions elsewhere have shown that competition for moisture between the hedgerow species and the intercrops could be a major

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factor causing yield depressions of crops near hedgerows (Ong *et al.*, 1991; Sing *et al.*, 1989). Chirwa *et al.* (1994) reported that 5.25 m wide double hedgerows depleted the same amount of water as depleted by the maize crop from shallow soil layers in alley cropping systems in Zambia. During dry conditions there was higher soil moisture under the hedgerows than in maize rows, indicating that there was no apparent competition for moisture between hedgerows and maize plants. Mc Intyre *et al.* (1997) showed that opportunity for increasing water uptake in 2 m wide hedge-intercrop system with Senna in semi-arid environment is marginal.

However, information on soil water dynamics under alley cropping in the Dry Zone of Sri Lanka is not available. Therefore, this experiment was conducted with the objective of studying the soil water dynamics in alley cropping systems under rainfed condition in the Dry Zone of Sri Lanka.

MATERIALS AND METHODS

This experiment was conducted during April 1998 to February 2000 at the Field Crops Research and Development Institute, Mahailluppallama in the central Dry Zone of Sri Lanka. The area selected was in the mid aspect of catena with 2% slope in the undulating landscape. The soil of the area is classified as Rhodustalfs according to USDA (1975) and as Reddish Brown Earths according to local classification (Alwis and Panabokke, 1972). Two alley cropping systems, namely 2 m (AC-2) and 6 m wide alleys (AC-6) were compared with sole gliricidia alleys of the same spacings (SG-2 and SG-6). The food crops were also grown as mono crops with addition of different rates of gliricidia mulch, for evaluating the root effect by hedgerows. The mulch rates were equivalent to the gliricidia biomass yield in 2 m wide alleys (SC-2) and 6 m alleys (SC-6), and no gliricidia mulch (SC-0). All treatments were assigned according to a randomized complete block design with 3 replicates. All plot interfaces were separated by a thick vertical polythene barrier; 50 cm deep preventing any lateral water flow and separating root systems in each treatment.

Alleys were established using 3-months old gliricidia (*Gliricidia sepium*) seedlings with within row spacing of 0.5 m in *yala* 97. The gliricidia trees were pruned at the beginning and at the end of each season starting in *yala* 98. The prunings were applied as mulch in the alleys. Cowpea variety MI-35 in *yala* 98 and *yala* 99 seasons, and blackgram variety MI-1 in *maha* 98/99 and *maha* 99/00 seasons were cultivated as food crops in alley cropping treatments and mono crop treatments. They were seeded at 50 cm inter-row spacing parallel to hedgerows, where the first row was 25 cm away from hedgerow. Within row spacing was 15 cm with 2 plants per hill. A mixture of 16N:60P_2O_5:45K_2O kg ha^{-1} at seeding and 14 N kg ha^{-1} at flowering stage as mineral fertilizer were applied for each crop. Plots were kept weed free throughout the growing period. The mono crops were mulched at each gliricidia pruning occasions with respective amount of gliricidia prunings obtained from a nearby tree stand planted and managed similar to trees in the experiment.

The soil profile was characterized and major horizons were identified. Soil texture was determined for each major horizon using the Pipette method (Gee and Bauder, 1986). Particles larger than 2 mm were reported as gravel content. Bulk density was determined using core samples of 5 cm diameter and 5 cm in height. Four soil cores were obtained from the centre of each horizon as replicates. The field capacity and permanent wilting point were determined at 10 and 1500 kPa respectively by pressure plate apparatus using the core samples.

The biomass yield of gliricidia was measured at each pruning *i.e.*, at the beginning and end of each season. Ten adjacent trees of the centre row of each plot were sampled and weighed. A sub sample was removed in order to determine the dry matter content. Neutron moisture metre (make CPN) was used to determine the volumetric water content at different depths of the soil profile. Neutron moisture metre was calibrated for each soil horizon. Access tube positions varied for different treatments. An access tube was placed between two trees in the hedgerow and 100, 200 and 300 cm away from hedgerow in SG-6 and AC-6 plots. Access tube positions in SG-2 and AC-2 plots were in the hedgerow and 100 cm away from hedgerow. Two access tubes were installed in every SC-0, SC-2 and SC-6 plots. Measurements were taken from 23 cm to 188 cm depth at 15 cm intervals. Volumetric water content of 0-15 cm layer was determined by gravimetric method.

RESULTS AND DISCUSSION

Climate

According to rainfall records at Mahailluppallama, the month of May was relatively drier in 1999 received 42 mm of rain compared to 143 mm in 1998. However, both *maha* season rainfalls were similar in the two years except in the month of October, which received 337 mm in 1999 and only 52 mm in 1998. In both years, unusual high rains were received during January and February against the monthly average of 60 and 65 mm respectively in the past 20 years.

Soil physical characteristics

Six major soil horizons were identified namely Ap, AB, B2, B21t, B22t and C. The depth of each horizon and the soil physical characters are listed in Table 1. The texture of the horizons ranges from Sandy Clay Loam to Clay Loam. Bulk density values showed that Ap and AB horizons were more compacted than the horizons below. The bulk density values of Ap and AB horizons given by Joshua (1988) for Rhodustalfs are lower than that observed in this site while the values of B2 and gravel horizon are comparable. However, Mapa and Yapa (1992) reported a bulk density of 1.82 Mg m^{-3} in Bt horizon, where the gravel content was very much higher than that observed in this site. According to the data on field capacity (FC) and permanent wilting point (PWP) presented in Table 1, the 200 cm deep profile can hold 625 mm of water at field capacity and 411 mm at PWP. Accordingly, the profile had 214 mm of available water within 200 cm depth.

Gliricidia biomass yield

The average gliricidia biomass yield obtained from alley cropping and sole gliricidia treatments and applied to all treatments at the beginning of the season are given in Table 2. The biomass yield at the end of each season was not significantly different to that of the beginning of the season. Accordingly, AC-2, SG-2 and SC-2 received approximately 3 t ha^{-1} of dry matter per pruning while AC-6, SG-6 and SC-6 received approximately 1 t ha^{-1} of dry matter.

Table 1. Important soil physical characteristics of the experimental site.

Horizon		Ap	AB	B2	B21t	B22t	C
Depth (cm)		0-15	15-40	40-70	70-115	115-150	>150
Bulk density (Mg m^{-3})		1.61	1.66	1.57	1.49	1.51	1.41
Texture	% sand	60.5	53.9	46.7	37.8	45.5	49.6
	% silt	18.9	18.1	15.9	27.5	15.9	25.2
	% clay	20.6	28.0	37.4	34.7	38.6	25.2
	class	SCL*	SCL	SC**	CL***	SC	CL
Gravel % (by weight)		1.1	1.1	0.5	1.0	16.4	8.9
Field capacity (m^3 m^{-3})		0.24	0.28	0.33	0.34	0.32	0.30
Permanent wilting point (m^3 m^{-3})		0.16	0.18	0.22	0.22	0.20	0.22
Available water (mm m^{-1})		81.7	94.2	116.8	129.5	119.1	80.5

* - Sandy clay loam ** - Sandy clay *** - Clay loam

Table 2. The gliricidia biomass yield (t ha^{-1}) and amount applied (t ha^{-1}) to each treatment at the beginning of each season.

Treatment	*yala* 98	*maha* 98/99	*yala* 99	*maha* 99/00	Average
AC-2 and SG-2*	2.85	2.75	3.0	3.45	3.0
AC-6 and SG-6*	1.1	0.95	0.9	1.0	1.0
SC-2**	2.85	2.75	3.0	3.45	3.0
SC-6**	1.1	0.95	0.9	1.0	1.0
SC-0	0	0	0	0	0

* - gliricidia obtained and applied ** - gliricidia applied

Effect of cropping system on soil water content

Soil water content (SWC) varies with time as influenced by the rainfall and water uptake by the vegetation. Although different mulch rates were added and differences in crop dry matter production towards the end of the seasons were observed among three mono crop treatments (SC-0, SC-6 and SC-2), no difference in soil water content among three treatments at any given soil layer was observed throughout the study period suggesting that mulch effect on soil water dynamics is minimal. Seasonal fluctuation of soil water was higher in upper soil layers than in deeper layers in responding to rainfall and evaporation under mono crop treatment (Fig. 1). The SWC at 0-15 cm layer ranged from 0.11 m³ m⁻³ during dry period to 0.27 m³ m⁻³ during wet periods. However duration of high water contents was shorter in *yala* seasons compared to that in *maha* seasons. Fluctuation of SWC was lowest in 150-200 cm layer.

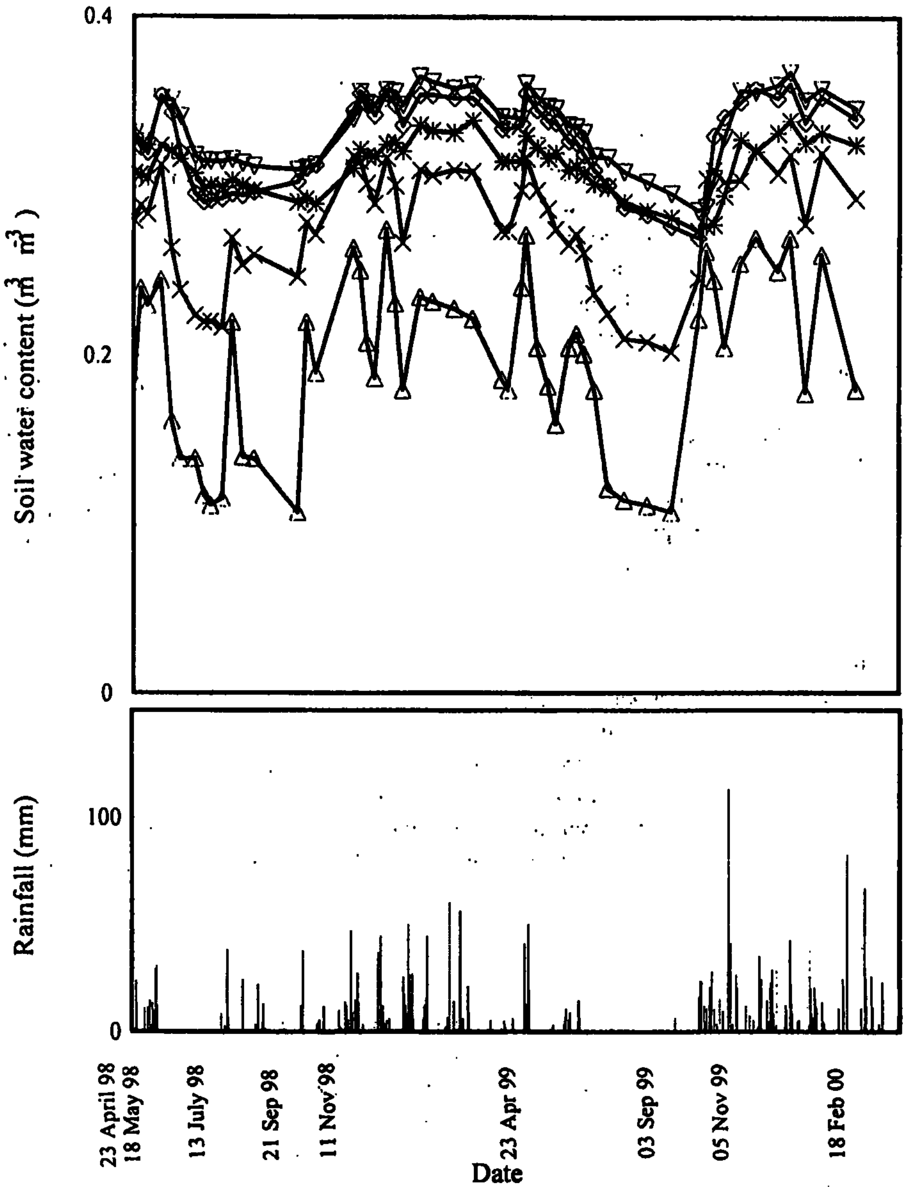

Fig. 1. **Change of average soil water content in 0-15 am (Δ), 15-60 cm (×), 60-105 cm (◇), 105-150 cm (✻) and 150-200 cm (▽) layers in relation to daily rainfall distribution in mono crop treatments.**

Seasonal behaviour of SWC under SG-2 and SG-6 treatments was found to be somewhat similar to mono crop treatments with few exceptions. The average SWC in the profile in mono crop, SG-2 and SG-6 treatments on 3 occasions during *yala* 98 where the highest differences in SWC among treatments were observed is given in Fig. 2. Variation of SWC under mono crop, AC-2 and AC-6 treatments for the same occasions is illustrated in Fig. 3. This period extended from 18 May 1998 to 18 June 1998 which coincided with just after peak rainfall in the season and active crop growth period. There was no rainfall received during the period concerned. At the beginning of the dry period, the SWC at all depths under all treatments was near field capacity. The profile water storages (PWS) were 661 + 18.3, 636 + 29.7, 654 + 27.8, 651 + 44.6, 670 + 32.7 mm in mono crop, SG-2, SG-6, AC-2 and AC-6 treatments respectively. At the end of the respective period, considerable reduction in SWC occurred up to 150 cm depth in mono crop and SG-6 treatments while reduction of SWC at all depths could be observed in other treatments. The SWC at all depths of all cropped plots were lower than that of non cropped plots irrespective of alleys. The depletion was higher in 2 m wide alleys than in 6 m wide alleys irrespective of crop. These results suggest that the crop uptake water from shallow soil layers while hedgerows uptake water from both shallow and deeper soil layers. Extraction of water down to 150 cm depth by cowpea crop could be expected because deep rooting was possible in this site as the gravel layer was thin and deeply situated. Nayakekorala (1991) observed cowpea root activity even at 120 cm depth in a similar soil under irrigated conditions. The PWS and the standard deviations of these treatments at the end of the period were 554 + 17.7, 520 + 14.7, 571 + 31.9, 498 + 26.1, 538 + 46.5 mm respectively. Therefore, the depletions of PWS were 107 ± 6.1, 115 ± 15.0, 82 ± 9.5, 153 ± 18.5, 132 ± 13.9 mm. These results clearly show that intercropping gliricidia with cowpea does not increase water use to an extent of the cumulative water use of individual components. However, when 6 m wide alleys were intercropped, the increase of water use was more than in the 2 m wide alleys. This may be due to either extraction from layers deeper than the depth considered or reduction of water use by the crop component in 2 m wide alley cropping treatment due to the gliricidia canopy. This effect was milder in wide alley system (AC-6), therefore the increase of its water use was higher compared to AC-2. Extraction from deeper layers was evident as soil water content in 150-200 cm layer was lower in AC-2 than in SG-2 treatment, and SG-2 than in mono crop. Mc Intyre *et al.* (1997) showed that alley cropping does not increase water use in semi arid environments but these results prove that there is a possibility of improving water use by alley cropping in semi humid Dry Zone of Sri Lanka.

Effect of hedgerows on soil water content

The variability of SWC within an alley field represents the effect of hedgerows on SWC. Soil water content observed with respect to the distance from hedge indicated various patterns depending upon the treatments. SWC at the hedgerow and centre of alley (100 cm away from the hedgerow) was not different in both SG-2 and AC-2 treatments at all depths during the study period. Similarly, PWS at both positions in each treatment was same throughout the period. It appears that the effect of hedgerow is uniform in 2 m wide alleys irrespective of crop.

Variation of SWC with positions, layers and time in SG-6 and AC-6 treatments are shown in Fig. 4 and Fig. 5. In SG-6, temporal variation of SWC at the hedgerow and centre of alley in 15-60 cm layer was similar throughout the study period. However, in all other

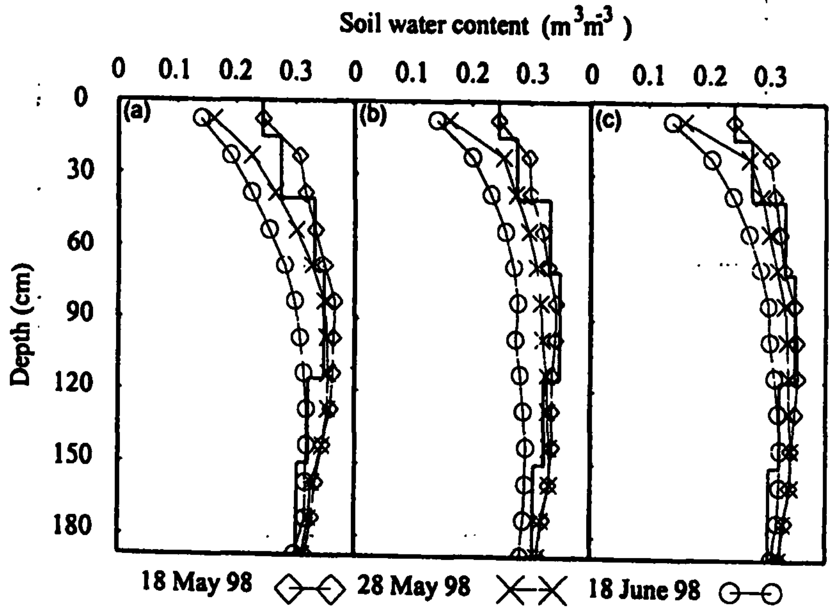

Fig. 2. Change of soil water content averaged over all; access tube positions with depth in relation to FC (_) in (a) mono crop, (b) SG-2 and (c) SG-6 treatments in *yala* 98.

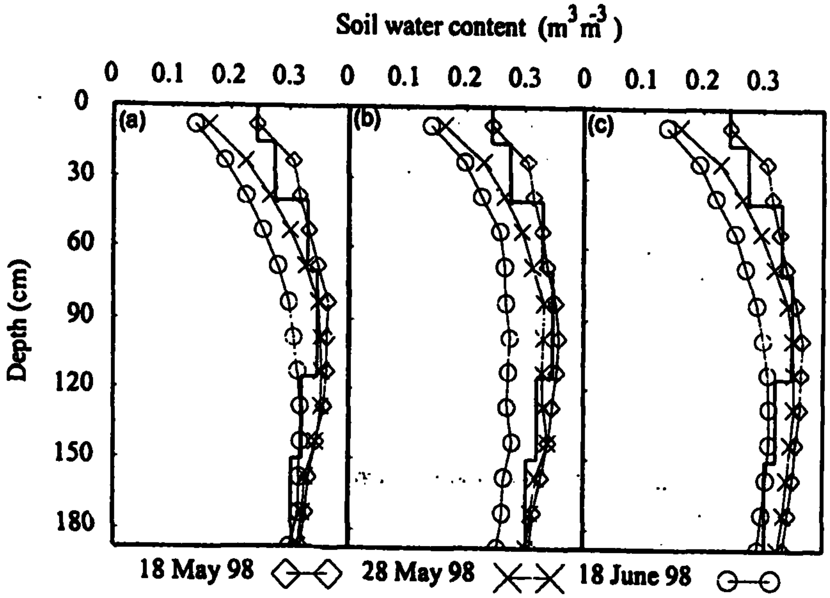

Fig. 3. Change of soil water content averaged over all; access tube positions with depth in relation to FC (_) in (a) mono crop, (b) AC-2 and (c) AC-6 treatments in *yala* 98.

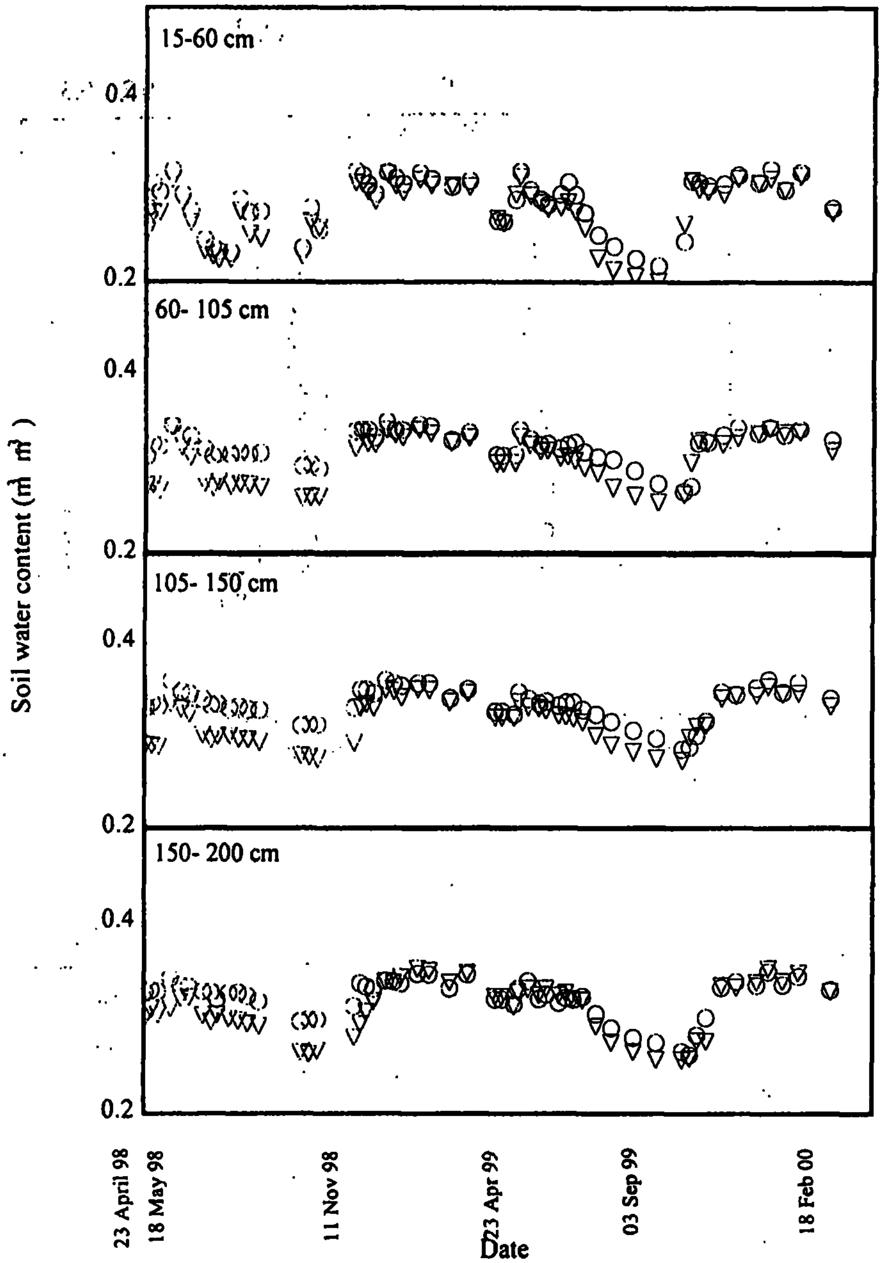

Fig. 4. Change of average soil water content in different soil layers at the hedgerow (v) and the centre (O) of SG-6 treatment.

deeper layers, differences were distinct during the period from 18 May to 11 November 1998 and 23 April to 3 September 1999, where there was no considerable rainfall. This suggests that water uptake by hedgerows is uniform across the alley in 15-60 cm layer and restricted to areas closer to hedgerows in deeper layers. However the SWC in 15-60 cm layer in SG-6 was higher compared to that in AC-6, suggesting that water uptake by hedgerows is mainly from deeper layers. In AC-6 treatment, the trend was slightly different. The SWC at the hedgerow and at the centre of the alley in 15-60 cm and 60-105 cm layers were similar as well as same with mono crop treatments. As extraction by the crop during the growing period was prominent, SWC across the alley became similar. However, in deeper layers, higher SWC were seen at the centre of alley than at the hedgerow (Fig. 5).

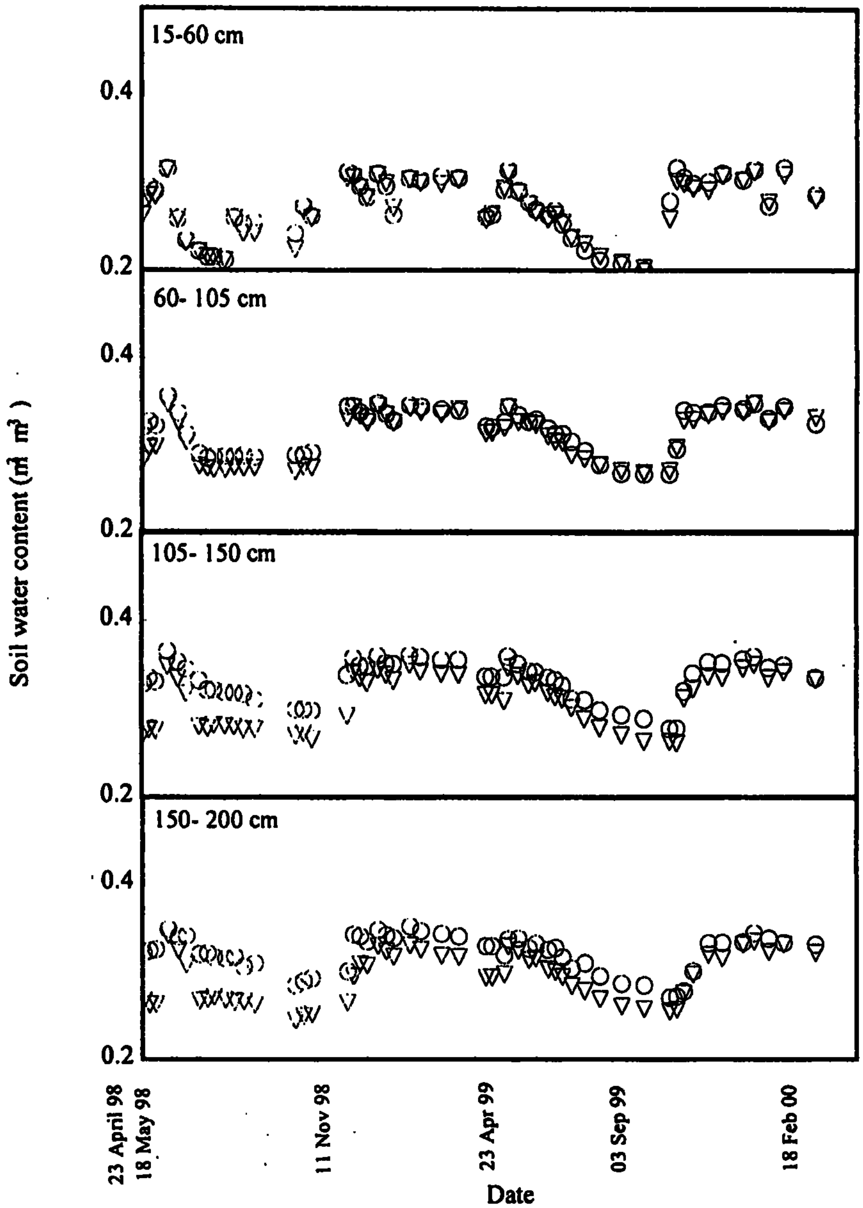

Fig. 5. Change of average soil water content in different soil layers at the hedgerow (▽) and the centre (O) of AC-6 treatment.

CONCLUSIONS

SWC and PWS at any given time indicate the pattern of water use by the plant stand. Because of the differences in plant densities under different treatments, changes in SWC and PWS were more pronounced when there was limited rainfall.

In *maha* seasons, frequent replenishment of the soil profile by heavy rains reduced the differences in soil water content and therefore there was no change in PWS among the treatments considered. The SWC of 0-15 cm layer was highly variable due to rainfall and evaporation rather than root extraction. The effect of mulch was also minimal on soil water content.

Intercropping gliricidia with food crops increased the water use of the total system than as mono crops. While crop used water at shallow depths of 15-150 cm, hedgerows extracted water from both shallow and deeper layers, and even beyond 200 cm depth. Further, with frequent replenishment of soil water due to heavy rains in *maha* seasons and SWC remaining around field capacity, there was no competition for moisture. In *yala* seasons, even though the profile was replenished to its full capacity only once, the SWC remained above PWP where chances for competition for water was minimal. Further, within the alley, chances for competition for water were lighter at the centre than near hedgerow in 6 m wide alleys while the chances were uniform across the 2 m wide alleys.

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