Tropical Agricultural Research and Extension 3 (1): 68-74, 2000

Effect of some soil moisture conservation practices on soil moisture regime during field establishment of black pepper (*Piper nigrum*) in mid country sloping lands of Sri Lanka

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Accepted 16 February 2000.

ABSTRACT

The high degree of plant mortality and slow growth rate are major problems during the establishment phase of black pepper and other perennial crops in the degraded sloping lands of mid country in Sri Lanka. Therefore, several soil water conservation practices adopted in pepper cultivation on a sloping land were compared in terms of soil water balance. Soil moisture regime was monitored using a neutron probe during May 1992 to December 1993 at Matale (70 30' N, 80 07' E and altitude 357m above MSL). The soil moisture content values have been maintained above the permanent wilting point at 30cm beneath the coconut husk mulch placed on the reverse slope basins during both the first and second inter-monsoonal dry spells following the field planting. Surface run-off component was very low though the steepness was greater than 30%. Even though, the total field water balance for the whole period was positive, weekly balance showed a few weeks with negative balance, especially during February, March and mid September. Total profile soil water content reached the Permanent Wilting Point (21.7 vol %) level during such dry spells. Pattern of soil moisture regime revealed that the first inter-monsoonal dry spell i.e. February-March is more severe than the second inter-monsoonal dry spell i.e. August-September for this location. Results suggest that the application of coconut husk mulch in association with run-off concentration basins around plants are beneficial for the successful field establishment of pepper. Furthermore, field planting of pepper on sloping lands in the mid country of Sri Lanka is more appropriate during the early half of south western monsoonal rains, when the soil profile is fully replenished.

Key words: Conservation, moisture regime, mulching, soil moisture.

INTRODUCTION

A large amount of sloping lands are available for cultivation of various perennial species such as coffee, pepper, cacao and forest trees in the mid-country wet and intermediate zones of Sri Lanka. These lands previously cultivated with coffee and subsequently with tea have now become marginal. Agronomic experiments carried out at the Research Station, Matale revealed that even 75% plant mortality could occur in the first inter-monsoonal drought following the field planting of most of the perennial spice and beverage crops. The crop water requirements can not be met with rainfall alone, although the total annual rainfall is much greater than the total annual potential evapotranspiration of the region. Both the erratic nature of rainfall distribution over the time and great spatial variability in soil water storage properties within a short distance are responsible for this plant mortality. Therefore, a run-off concentration farming method with a mulching technique was adopted in view of reducing plant casualties during first and second inter-monsoonal dry spells after the field planting. The main objective of the experiment was to study the effect of soil management practices under pepper on a sloping land for its soil-water regime.

Abbreviations: MSL- Mean Sea Level, PWP- Permanent Wilting Point

MATERIALS AND METHODS

The experiment was conducted at the Research Station, Department of Export Agriculture at Matale (70 30' N, 80 07' E and altitude 357m above MSL) in Sri Lanka and it was field planted in May 1992. The following treatments were included:

T1: Plant pit treatment (60x60x60) cm), soil mixed with organic matter according to the normal practices: "no basin, no mulch" (control) (Bavappa *et al.* 1981).
T2: Same as T1 but with two circles of coconut husk

as a mulch around plant base. Indenting not consistent

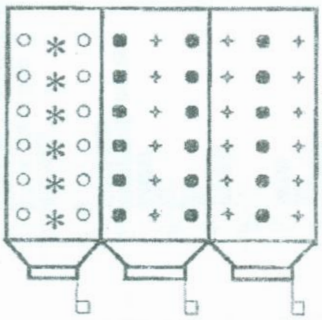
T3: Plant pit treatment as T1 but with a run-off concentration method having a reverse slope circular basin of 75 cm diameter around each planting point.

T4: Same as T3 but basins were covered with two circles of coconut husk as a mulch around plant base.

Soil was undisturbed at the center of four planting points and this area was covered with regularly slashed short grasses.

One gliricidia (*Gliricidia sepium*) stick of 200 cm length was planted 15 cm away from each planting hole at the top left corner as a support tree for pepper vine. Three experimental plots were demarcated with bunds in order to record soil and water run-off.

Pepper was planted in lines consisting of six plant pits. The distance between lines was 2.44 m and the distance between plants within the line was also 2.44 m. Each plot was demarcated by a small ridge and a runoff collecting tank was built at the bottom of the plot. Three representative access tubes were installed for each treatment. The access tubes were installed 10cm away from the base of the pepper vine up to 120m depth, but the tube was located within the plant pit environment. Additionally six access tubes were installed at six center points to represent the natural undisturbed profiles.(Fig.1).



✻	T1	Control
○	T2	Two circles of coconut husk mulch
●	T3	Revers slope basin
✛	T4	Revers slope basin with two circles of coconut husk mulch

Fig. 1. Schematic diagram of experimental layout within run-off plots

The neutron probe (DR 503 Hydroprobe) was field calibrated for both plant pit environment and undisturbed profile of the location (centre area) and calibration lines were established as described by Bell (1987). (Table 1) Moisture content was monitored at 15 cm intervals up to 105 cm at weekly intervals. The 15cm interval was selected to minimize the variability resulting from the effect of sphere of influence of the moisture probe (Bell 1987).

The cumulative storage between the soil surface and different depths was calculated by integrating the soil water content profile. Soil water budget for the root-zone (upper 100 cm) was calculated by a simplified water balance equation for a considered time interval as follows:(Hartmann *et al.* 1988)

$\triangle$ S= P-R- (D+ET) where;

S = change of profile moisture content during the considered time interval over the depth of 100 cm

P = precipitation (rainfall) in mm for the considered time interval

R = surface run-off in mm

D = drainage (+) or capillary rise (-) mm

ET= evapotranspiration (mm)

Physical properties:- Soil physical properties were measured according to K lute (1986). The soil bulk density values were in the range of 1.30-1.42 gmcm^{-3}. The soil texture was sandy clay to sandy clay loam. In general, three depth zones i.e. 0.-22.5 cm, 22.5 cm-67.5cm and soil below 67.5 cm have been identified in terms of soil particle size distribution and bulk density. This observation is comparable with the identification of three separate best fit calibration curves for the respective zones of the profile. Mean steady infiltration rate of the site was 8.8 cmhr^{-1}. Kalpage (1967) categorized reddish brown latasolic soils into the moderate infiltration class. The permanent wilting point of the soil was 21.7 vol. % (undisturbed core samples) and the field capacity was found to be between 31-32 vol. % (on tensiomter basis).

Chemical properties: Cation exchange capacity was 33 milli equivalent/ 100gm, soil nitrogen content was 0.13 mg/100gm and pH was 6.25 for the soil profile upto 90cm.

Table 1. Calibration characteristics obtained for the undisturbed soil profile (082.5 cm) and plant pit environment (0-60 cm depth).

Layer	Calibration curve	Correlation Coefficient	Probability level
Centre area			
0 -22.5 cm	θ = 0.8842 R/Rw - 0.21520.85		0.05
22.5 - 67.5 cm	θ = 0.6304 R/Rw - 0.04770.71		0.05
67.5 - 82.5 cm	θ = 0.5569 R/Rw - 0.04250.66		0.05
Plant pit			
0 - 6 cm	θ = 0.6609 R/Rw - 0.03820.98		0.05

R = neutron probe counts for 256 second period.

Rw = mean of 24 water standard counts for 256 second period

θ = volumetric moisture content

RESULTS AND DISCUSSION

Rainfall distribution pattern

Weekly rainfall distributions for 1992 and 1993 are shown in figures 2A and 2B. Two inter-monsoon dry spells can be identified and they were experienced during February-March and August-September of each year. The February -March inter-monsoonal dry spell was extremely long in 1992 i.e. 90 consecutive dry days (CD). The year 1992 was a relatively dry year. Nevertheless, August-September inter-monsoonal dry spell of 1992 was not very long since there were few intermittent rains. In contrast, there were few intermittent rains during the August-September inter-monsoon period of 1993 (Figure 2A). Moreover, the length of the February-March inter-monsoon dry spell was comparatively longer than the August- September inter-monsoon dry spell in 1993 also.

Total profile moisture regime

Pattern of variation in soil water storage during May -December 1992 is shown in Figure 3. A consistent treatment effect was not observed during the peak of the rainy season i.e. May-July. Soil water storage was in decreasing order towards the third week of September. The total profile moisture content approached the permanent wilting point (PWP) during the inter-monsoonal dry spell i.e. August-September under T1 and T3. The minimum profile depletion was observed at the centre area during the drying cycle and this could be attributed to the presence of very shallow roots of slashed grass. It is important to note that the rate of soil water storage depletion is comparatively low at planting points of T4 when compared to other treatments. Nevertheless, when the total profile (100 cm) was considered as a whole, the differences among treatments could not be clearly seen.

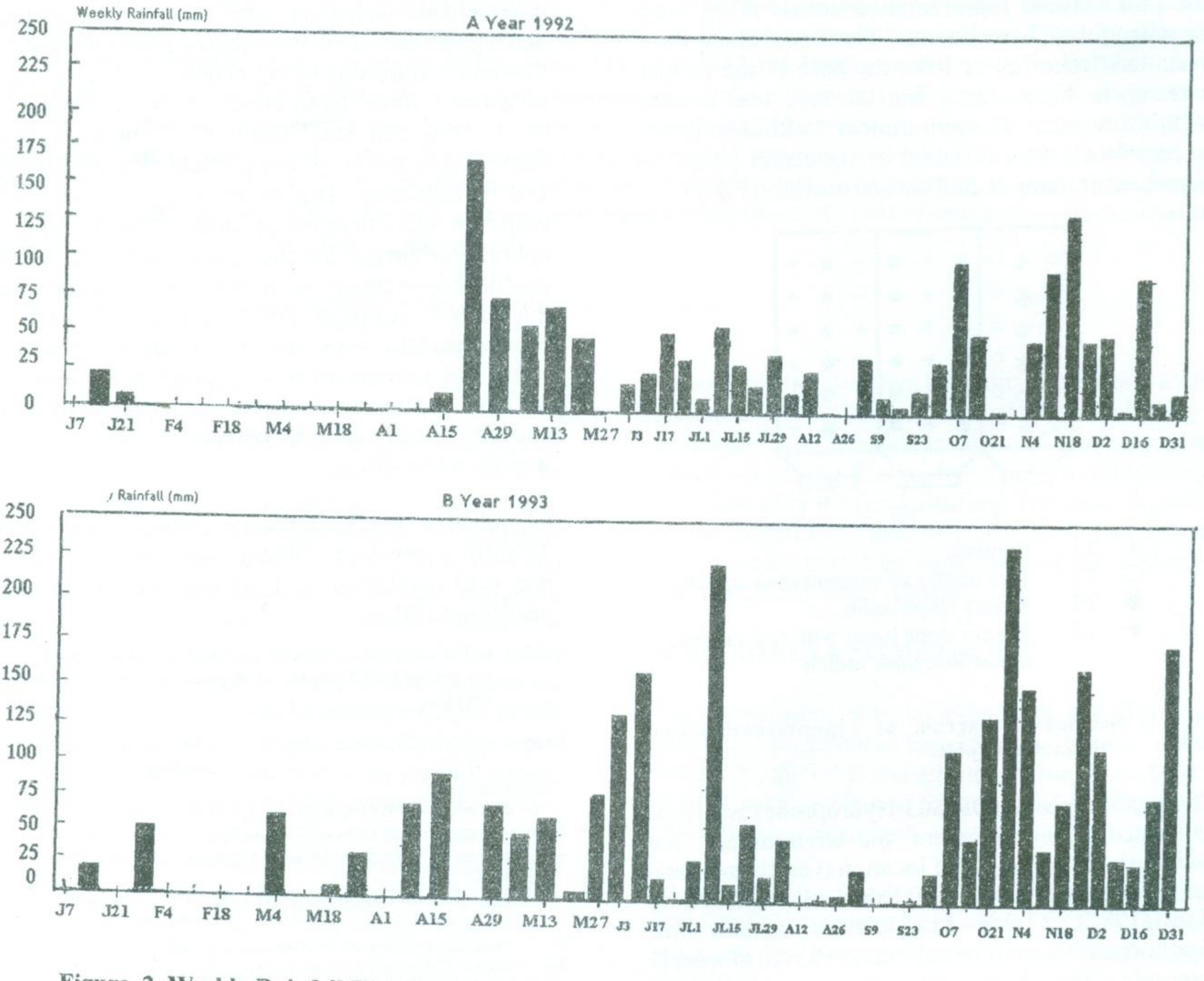


Figure. 2. Weekly Rainfall Distribution

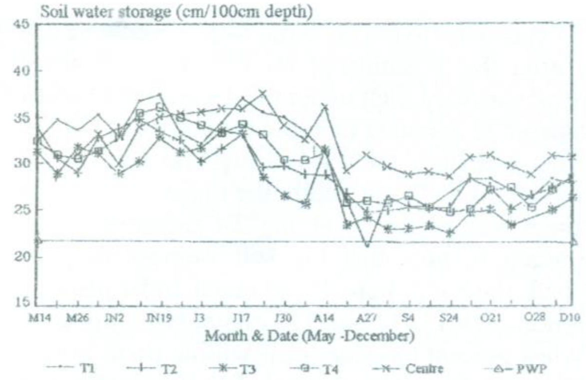


Fig.3. Soil water storage during May-December 1992

Similarly, the pattern of variation in soil water storage for 1993 is shown in Figures 4A and 4B. Almost similar moisture depletion patterns were observed during the second inter-monsoonal dry spell after field planting i.e. January-March 1993. Furthermore, the lowest soil water storage remained at T3 (only reverse slope) until the commencement of monsoonal heavy rains. Although, the profile moisture content at the center remained high in the early months, it also approached the common depletion level in March 22, 1993. Morever, there was no visual difference between treatments during the third inter-monsoonal dry spell after field planting (i.e. August-September 1993) (Figure 4B) The so il water storage level at the center area also approached the planting pit condition towards the third rainy season after field planting (Figure 4B). It is more appropriate to consider regime at 30 cm depth for the comparison of effect of different soil management practices on plant survival of young pepper because active root-zone depth is very shallow (about 30 cm) when compared to the total profile (100 cm).

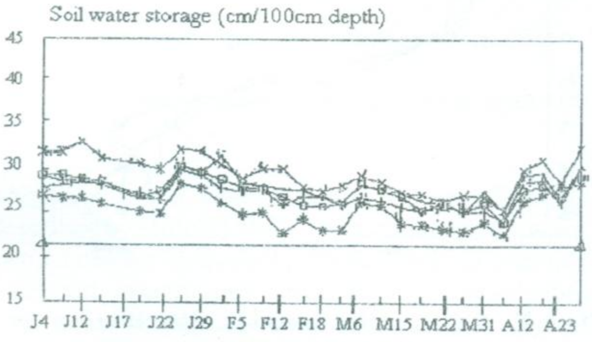


Figure. 4A. Soil water storage during January-April 1993

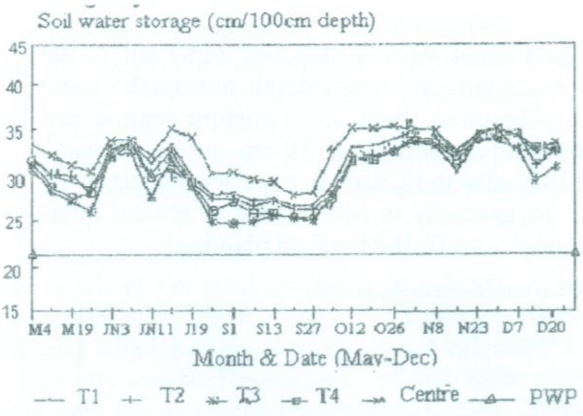


Figure.4B Soil water storage during May-December 1993

Soil moisture regime at 30 cm depth

Figures 5A and 5B show the soil moisture content at 30 cm under different treatments. The soil moisture level dropped below the PWP from the third week of August until the third week of September 1992 under each treatment except for T4. In this treatment the pepper plants were growing under reverse slope basins covered with coconut husk as a mulch and the soil water content during the critical dry period was maintained at higher level. Comparatively higher soil moisture content at the center of the planting points, i.e. 1.22 m away from the pepper plant, was not directly helpful for the survival of the pepper plant during inter-monsoon dry spells.

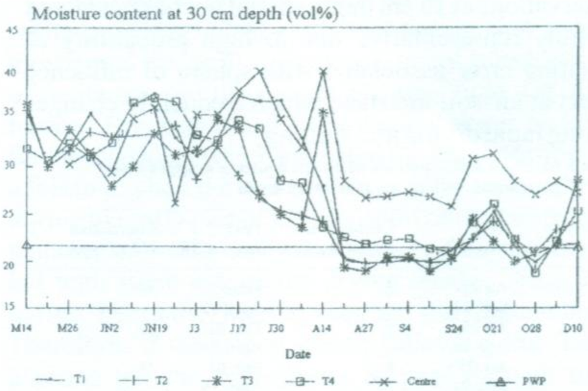


Fig. 5A. Moisture content During May-Decenmber 1992

Moisture deficit periods when soil moisture level dropped below PWP at 30 cm depth are shown in Table 2. The minimum cumulative dry period of only 2 weeks was observed under T4 during May to December 1992. In contrast to August-September dry spell, the moisture deficit periods were longer during January -April 1993. Nevertheless, a break in moisture deficit was observed under T4 during first week of March due to a small shower and this appeared to be a beneficial effect of T4. Such a beneficial effect was not observed under any of the other treatments at 30 cm depth during the same period. Therefore, both soil moisture regime and moisture deficit periods at 30 cm during January-April 1993 also indicated the beneficial effect of T4 treatment, specially in March (end of second inter-monsoon dry spell after the field planting).

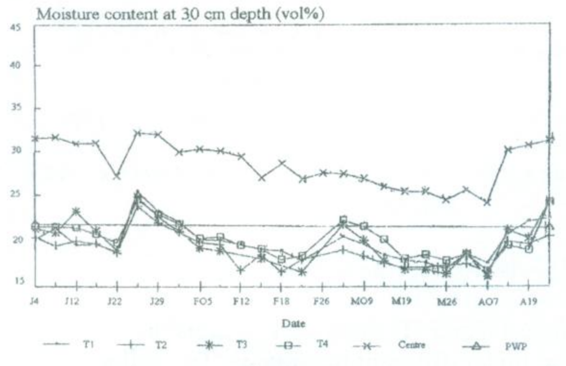


Fig.5.B. Moisture content during January-April 1993

Inter-monsoon dry spell and profile wetness

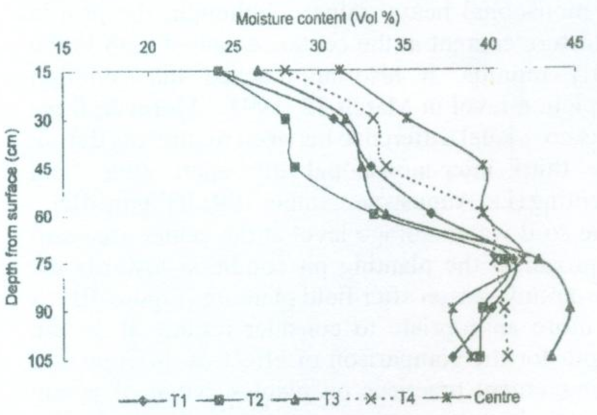
Instantaneous soil wetness distribution through the profile up to 105 cm under different treatments are shown in Figure 6 for July 3, 1992 and August 25 1992 respectively. The profile appeared to be fully replenished on July 3 because there was 236 mm of total rainfall during May-June. The soil moisture observations at 15 cm depth should not be considered as truly representative due to high probability of counting error associated with sphere of influence effect at air-soil interface which frequently changes during rapid drying and wetting.

Table 2. Moisture deficit periods when soil moisture dropped below permanent wilting point at 30 cm depth

Treatments	1992 May - Dec.	Cumulative No. of weeks	1993 Jan. - April	Cumulative No. of weeks
T1 - control	Au 25- Sep. 24	6	Feb.5 - April 12	10
T2	Au 25 - Sep. 24	6	Feb. 01 - April 26	12
T3	Au. 25 - Sep. 24	6	Feb. 01 - April 19	11
T4	Sep. 14 - Sep. 24	2	Feb. 05 - Feb. 26 &	3
			Mar. 09 - April 19	6

Consequently neutron probe base observations are reliable for depths below 30 cm. The maximum soil wetness among planting points was observed up to 60 cm of the profile under T4. It appeared that the application of only coconut husk mulch has not substantially improved the soil water storage at the cessation of heavy rains on July 3.

The profile wetness distribution on August 25, 1992 shown in Figure 6b is the 14th consecutive dry day after the cessation of rainfall. The soil water content was very high under the T4 treatment when compared to the other treatments up to 60 cm of the profile. Although, there was a high variation in the observations at 15 cm depth, the highest remaining wetness was observed at the T4 treatment. It is important to note that the soil wetness dropped beyond the PWP upto 45 cm depth under planting points at each T1, T2 and T3 (Figure 6b). A decline of a few percent moisture near wilting point is very detrimental for plant survival. For this reason life saving supplementary watering for the successful establishment of pepper during the inter-monsoon dry spells is a must. The beneficial effect of T4 (a run-off concentration method having a reverse slope circular basin of 75 cm diameter around each planting point and each basin covered with two circles of coconut husk as a mulch around plant base) as a soil water conservation practice is highly influential from agronomic point of view.



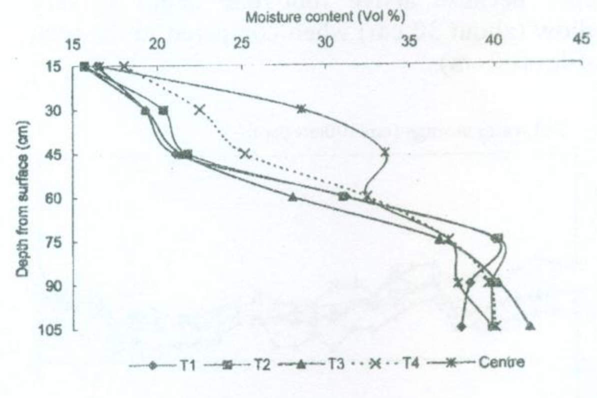


Fig.6.B. Soil profile wetness distribution on August 25, 1992

The second inter-monsoon dry spell following the field planting started from mid-January 1994 onwards. Weekly rainfall graphs (Figure 2) show that there were a number of short dry spells which vary from 8 consecutive dry days (CD) to 19 with a few intermittent showers during January-April 1993. Soil water storage (Figure 4A) shows that there was a successive depletion up to March 27 irrespective of the treatments. Therefore, it was appropriate to study the profile wetness distribution on March 27 (Figure 7b) and it shows that the pattern was almost similar to that of August 25, though quantitatively different.

These observations allow us to conclude that the T4 condition was still beneficial as a soil moisture conservation measure up to 45 cm depth at planting

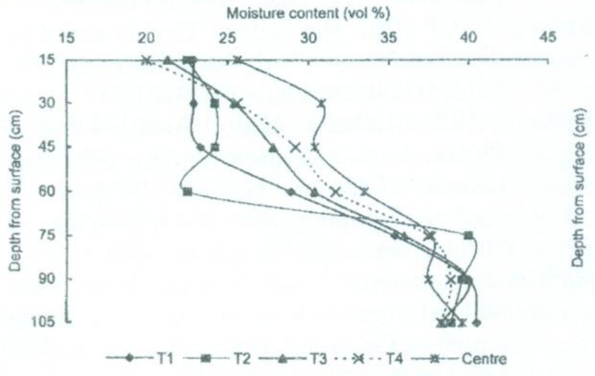


Fig. 7. A. Soil profile wetness distribution on January 04, 1993

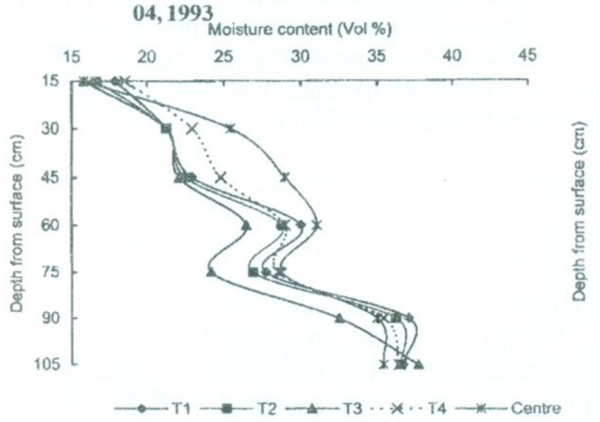


Fig. 7. B. Soil profile wetness distribution on March 27'93

Weekly soil water balance of the profile upto 100 cm

The weekly soil water balance was translated as described by Hillel (1980). It was tabulated between two successive observation times. The time intervals were not exactly one week due to unavoidable difficulties in the collection of field data. It was observed that the surface run-off percentage is very low i.e. less than 5% and it may be attributed to the very high steady infiltration rate in this experimental area. Therefore, run-off component was not tabulated separately for three main plots. Drainage and actual evapotranspiration could not be separated in this experiment due to failure of tensiometers in the mid of short dry spells and absence of evapotranspiration measurements. Therefore, drainage and actual evapotranspiration removal from the profile was considered as a composite (D+ET).

Though the annual soil water balance was positive as a whole i.e. total rainfall is much greater than potential evapotranspiration, there was a number of weeks which had negative soil water balance during short dry spells. The majority of rain water passed through the root-zone (Sumanasena et al. 1984) as downward drainage (Michels *et al.* 1989) during heavy rains irrespective of the treatments. For example, there were 179 mm of rainfall and 10 mm of surface run-off during May 24 - June 3,1993 and only 36 mm of rainfall was stored within the profile under T1. Furthermore, the storage improvement ($\triangle$S) for T2, T3, T4 and center area were 47 mm, 5m, 38 mm and 35 mm respectively. There were 196 mm of rainfall during the following time interval (June 3-7) and $\triangle$ S values for T1, T2, T3, T4 and center area were 13 mm, 8 mm, 5 mm, 14 mm and 1 mm respectively. The soil moisture storage changes among treatments were highly inconsistent and following factors may be the possible reasons:

i. Variable soil moisture re-distribution in the sloping profile
ii. Random counting error
iii. Variations due to effect of the sphere of influence during drying/wetting

There were no plant casualties during first inter-monsoonal dry spell in this experiment irrespective of treatment and the correct planting time was the reason. This was found from the soil water budget for the total year, which indicated the field planting is advisable when the soil profile is fully replenished during the early part of the monsoon rain. During the majority of weeks soil water storage was very high but with some successive drying weeks, specially during February, March, August and September. Therefore, if the young plants following the field planting get the opportunity to pass through the maximum possible number of wet weeks prior to the dry weeks, then success percentage as well as effectiveness of soil moisture conservation practices would be very high. Due to these facts, field planting of pepper on sloping lands in this study area is more appropriate within the early half of the south western monsoon rains i.e, 2nd or 3rd week of May, when the profile is fully replenished. Field planting during the north-east monsoon i.e. October - November is probably not very appropriate since subsequent inter-monsoonal dry spell appeared to be more severe and longer

.CONCLUSION

Observations on soil moisture regime over one and half year suggested that adoption of a run-off concentration method having a reverse slope circular basin of 75 cm diameter around each planting point in association with two circles of coconut husk as a mulch around plant base is beneficial as a soil moisture conservation practice for successful field establishment of pepper on sloping lands in mid country Sri Lanka.

Field planting of pepper is more appropriate within the early half of south-western monsoon rains i.e. 2nd or 3rd week of May, when the soil profile is fully replenished.

ACKNOWLEDGEMENT

This work was funded by International atomic Energy Agency, Vienna under SRL/ 05 / 015 and the Department of Export Agriculture.

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