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Hydrothermal regimes of an oxisol under coconut (*Cocos nucifera* Linn.) canopy

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सार — वर्ष की सभी ऋतुओं के लिए एक आर्द्र उष्ण कटिबंधीय जलवायु में नारियल में मृदा नमी (आर्द्रता) और मृदा तापमान के अन्तरों का विश्लेषण किया गया है ।

मृदा आर्द्रता संग्रहण में क्रमशः शुष्क और आर्द्र अवधि के लिए 75 सें. मी. से 90 सें. मी. तक की गहराई के लिए क्रमशः 10 सें. मी. से 24 सें. मी. तक की भिन्नता होती है । शुष्क अवधि के दौरान मृदा तापमान पर वितान प्रभाव 15 सें. मी. की गहराई तक 1° से 6° सें. की पराम में होता है । मृदा आर्द्रता और मृदा तापमान के बीच तथा पवन और मृदा तापमान के बीच सांख्यिकीय सम्बन्ध स्थापित किए गए । फसल योजना के लिए वर्ष की विभिन्न अवधियों को निरूपित करने के लिए मृदा आर्द्रता, मृदा तापमान और जल ऊष्मीय विभिन्नताओं के घातांकों का पता लगाया गया । मृदा आर्द्रता, मृदा तापमान और जल उष्मा से संबंधित घातांक क्रमशः 0.37 से 1.00 तक, 0.77 से 1.00 तक और 0.70 से 2.40 तक है ।

ABSTRACT. An analysis of soil moisture and soil temperature variations under coconut in a humid tropical climate have been made for all seasons of the year.

The soil moisture storage varies from 10 cm to 24 cm for 75 to 90 cm depths for dry and wet periods respectively. The canopy effect on soil temperature is in the range of 1° to 6° C up to 15 cm depth during dry period. Statistical relationships were established between soil moisture and soil temperature and between air and soil temperatures. Indices of soil moisture (SMI), soil temperature (STI) and hydrothermal variations (HTI) were worked out for delineating different periods of the year for crop planning. The indices ranges from 0.37 to 1.00, 0.77 to 1.00 and 0.70 to 2.40 for SMI, STI and HTI respectively.

1. Introduction

Soil moisture and soil temperature influence crop production in humid tropics which experience well defined wet and dry periods. These factors assume special importance in intercrops grown under perennial tree crops like coconut.

Soil water storage and its estimation by indirect methods using climatic variables or field water balance components have been reported (Las Cano and Van Bavel 1983, Varadan and Raghunath 1983).

Use of organic mulches for management of soil temperature has been well brought out by number of workers (Lal and Greenland 1979, Varadan and Rao 1983). Indirect estimation of soil temperature for shallow depths based on air temperature values have also been attempted (Persaud and Chang 1983, Bauham and Fue 1970 and Ghuman and Lal 1982).

The present analysis gives seasonal variations of soil moisture and soil temperature and establishes simple relationships between the two and that of air temperature. Further, indices have been worked out to define climatic periods for planning of intercrops in coconut gardens. Intercropping is a common practice in this region.

2. Materials and methods

The site is located at the Kottamparamba campus of the centre in a typical midland laterite area (11° 15′N, 75° 52′E, 70 m a.m.s.l.) and has 15 to 20 per cent slope with northern aspect. The soil type is classified as isohyperthermic, kaolinitic eutrorthox of the order oxisol and belong to Kunnamangalam series. The depth to water table from an observational well near the site varies from 5.5 to 6.0 m for the entire year except for June-July when it ranges from 1.5 to 2.0 m. The coconut trees cv. west coast tall is about 25 years old with a spacing of 7 m.

Weather — The mean annual rainfall of the area is about 3300 mm with a well defined dry period from December to May. The duration of sunshine varies from 3 to 10 hr d^{-1} and the insolation from 100 to 600 Wm^{-2} and the higher values were confined to peak dry period. The mean maximum and mean minimum air temperatures range from 28° C to 33° C and 22° C to 26° C respectively. The mean relative humidity ranges from 69 to 90 per cent.

Observations — The soil moisture was determined by gravimetric method along with the use of neutron moisture gauge. The observations were replicated six times

TABLE 1

Physico-chemical properties of soil

Depth (cm)	pH	Organic carbon (%)	Dry bulk density (gcm^{-3})	Gravel >2 mm (%)	Sand >0.02 mm (%)	Silt >0.002 mm (%)	Clay <0.002 mm (%)
0-15	5.5	0.90	1.17	41.3	46	19	35
15-30	4.9	0.55	1.18	41.7	46	19	35
30-45	4.9	0.37	1.02	34.9	44	18	38
45-60	4.7	0.72	1.01	54.4	44	18	38
60-75	5.2	0.60	1.14	64.8	45	17	38
75-90	5.2	1.08	1.13	62.4	37	18	45
90-105	5.0	0.42	1.24	56.8	38	20	42

and the results are the mean for each depth. Observations for 90 cm depth were taken only from 27th Std. Met. week onwards.

The soil temperature was recorded using mercury in glass soil and earth thermometers for various depths inside the canopy and the results are mean values of three replications (1430 IST observations). Air temperature and relative humidity were recorded using thermohygrometer under standard exposure conditions in the open field (without trees) along with soil temperature observations.

Both soil moisture and soil temperature were recorded in between the coconut trees, and hence reflects the canopy and rooting effects. All the results are reported for standard meteorological weeks to enable them to be useful for crop planning.

Evaporimeters were used for evaporation measurement inside and outside the experimental field and the mean of three replications is reported.

Regression analyses were carried out between soil moisture and soil temperature for depths of 15, 30, 45 and 60 cm and 5, 10, 15, 20 and 30 cm respectively and between air and soil temperature for 5, 15 and 30 cm depth. But statistically significant relationships are only discussed.

Soil temperature index (STI) has been computed as the ratio of air to soil temperature at 5, 10 and 15 cm depths.

Soil moisture index (SMI) were calculated as the ratio of actual to potential storage.

Hydrothermal index (HTI) has been computed as the ratio between STI and SMI at 15 cm.

3. Results and discussion

The basic physical chemico-characteristics of the soil are given in Table 1. The seasonal hydrothermal variations for different depths are depicted in Fig. 1.

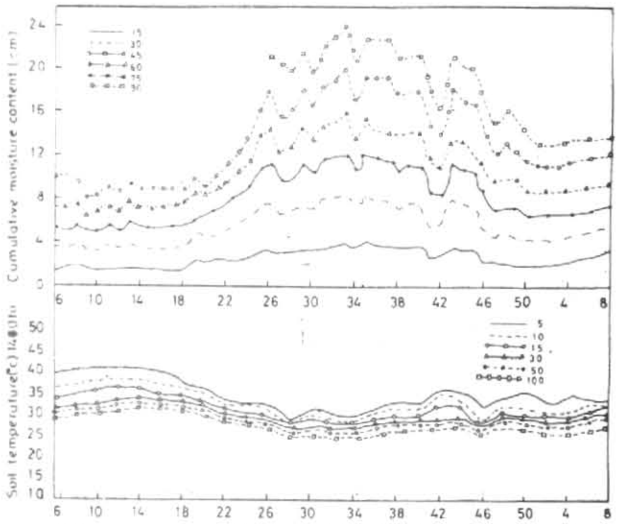

Fig. 1. Seasonal hydrothermal regimes under coconut canopy

Soil moisture regime — During the dry period (1–19th week) the SM storage up to 75 cm depth is about 10 cm and between 20 & 22nd weeks it increases up to 11 cm. This storage increases further to a maximum of 18 cm during 23rd to 26th weeks. However, greater accumulation is observed between 27th and 40th weeks even up to 25 cm for 90 cm depth. The SM storage decreases from 41st week onwards. During this period the lower range of SM up to 60 cm is similar to that observed during 20-22nd weeks while at lower depths, *viz.*, 75 cm and 90 cm there is higher accumulation during the same period. This is a significant aspect for soil moisture availability for deep rooted crops.

The cumulative SM for each depth is of the order of 2 cm up to 22nd week and it increases to as high as 4 cm after the onset of southwest monsoon. The rate of soil moisture storage ranges from 3 to 4 cm during the transition period, *i.e.*, 41-52nd weeks.

Soil moisture index — The soil moisture indices are given in Table 2. The range of SMI (Table 2) for 45 and 60 cm depth are higher compared to SMI 15 and SMI 30 for the periods, *viz.*, 1-19th weeks and also 41-52nd weeks. This means that these soils are able to retain more moisture at lower depths and this may be due to higher clay content at the lower depths and reduced loss of moisture due to evaporation. This may also be corroborated with the soil temperature influence on soil moisture loss up to 15 cm depths. These indices are useful criterion for taking up crops of varying rooting depths.

Soil thermal regimes — The difference in ST between open field (Fig. 3) and coconut canopy (Fig. 1) is of the order of 1° to 6° up to 15 cm depth and it ranges between 1° & 3°C for lower depths up to 100 cm. The differences between open field and coconut canopy ST at 15 cm depth was 1°-6°C for the period 1-22nd weeks and this narrows down to 1°-4°C for the rest of the period. Thus, it can be seen that the canopy effect on ST is apparent only up to 15 cm depth and it is marginal for lower depths up to 100 cm.

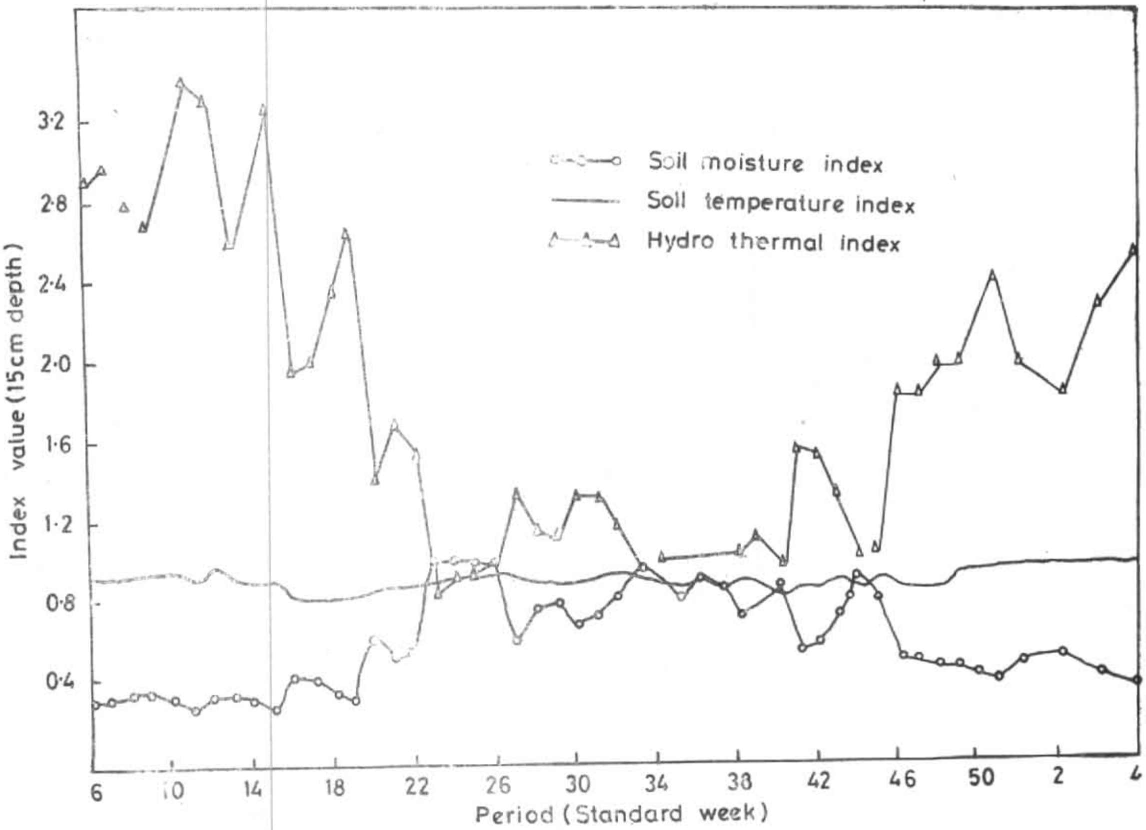

Fig. 2. Indices of hydrothermal variations under coconut canopy

TABLE 2

Soil profile moisture variability under coconut canopy

Period (standard weeks)	Soil moisture indices for					
	15 cm	Σ30 cm	Σ45 cm	Σ60 cm	Σ75 cm	Σ90 cm
1–19	0.28–0.43	0.37–0.55	0.42–0.54	0.42–0.57	0.38–0.47	—
20–22	0.57–0.62	0.50–0.60	0.55–0.60	0.55–0.62	0.41–0.53	—
23–26	1.00	0.65–0.85	0.73–0.97	0.70–0.95	0.60–0.85	—
27–40	0.63–0.91	0.80–0.97	0.95–1.00	0.83–1.00	0.78–0.90	0.70–0.90
41–52	0.43–0.57	0.43–0.64	0.57–0.75	0.53–0.77	0.50–0.70	0.50–0.70

Σ – Cumulative

Soil thermal index — The soil thermal indices (STI) reflect the soil thermal property in relation to air temperature. Lower the index, higher is the ST value and *vice versa*. It ranges from 0.77 to 1.00 (Fig. 2). These indices show marginal changes. These are calculated only up to 15 cm depth since apparent differences in ST are observed only up to that depth. These ratios can be used to calculate ST under canopy by knowing air temperature. Further, the presence of higher percentage of moisture in the lower layers decreases the soil temperature variations beyond 15 cm depth.

Hydrothermal index — In order to delineate different seasons for crop planning, an hydrothermal index (HTI 15) has been proposed (Fig. 2) as a ratio of STI 15 and SMI 15 wherein ambient temperature, soil temperature and soil moisture are all considered. Based on the range of values of these indices the periods may be classified as dry summer (1st to 19th week); pre-monsoon period (20th to 22nd week); onset of south-west monsoon (23rd to 26th week); monsoon period (27th to 40th week) and wet to dry transition period (41st to 52nd week). HTI is computed for 15 cm depth

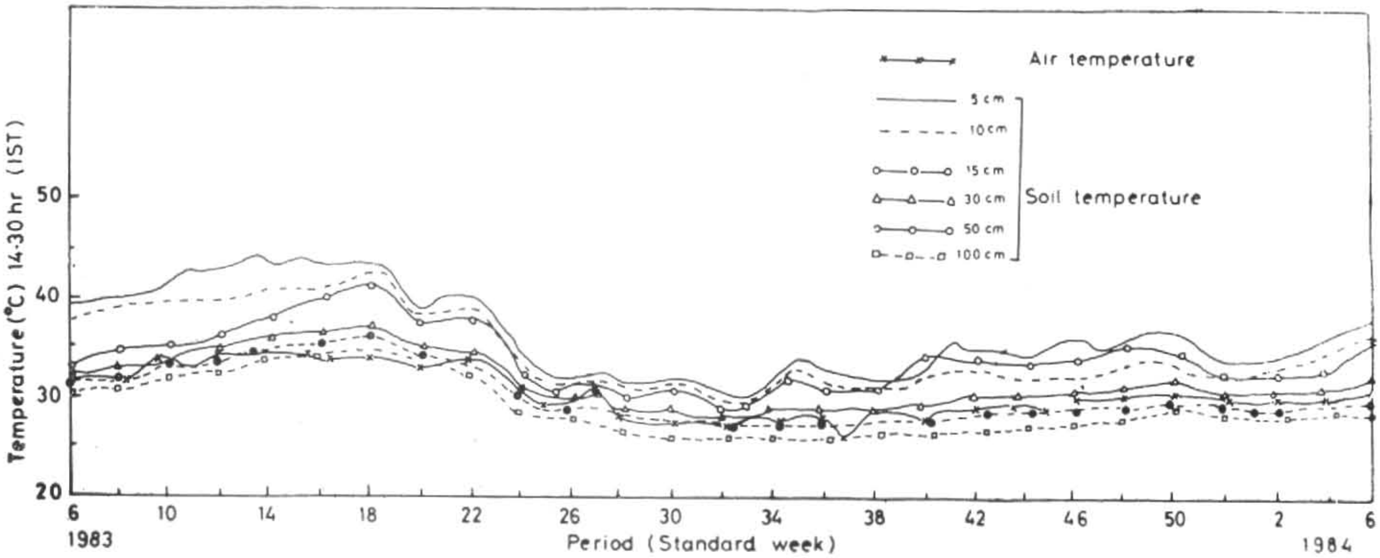

Fig. 3. Seasonal air thermal profile in the open field

only because of the observed fact that ST and SM variations are maximum at that depth and also that there is no significant change in ST after 15 cm depth.

The indices STI 15, SMI 15 and HTI 15 are all depicted in Fig. 2 for different periods of the year. STI 15 do not show much variations while SMI 15 and HTI curves are clear indicators of the seasonal changes.

Soil moisture and soil temperature relationships — For estimation of SM from ST values, regression analyses were done between SM at 15, 30, 45 and 60 cm depth with ST at 5, 10, 15, 30 and 50 cm depth for various periods, *viz.*, dry period (1st to 19th week); wet period (23rd to 35th week) and transition period (41-52nd week). Statistically significant relationships are presented and discussed. The number of observations used were 57 for dry period and 36 each for wet and transition periods. Three sets of observations were taken for each week and, therefore, 57 observations for 19 weeks (dry period) and 36 observations for 12 weeks (transition period).

For dry period SM at 15 cm depth is related with ST_5, ST_{10} and ST_{15} as follows :

$$SM_{15} = 4.04 - 0.04\ ST_5 + 1.00\ ST_{10}\ (r = 0.78,\ r^2 = 0.61, \text{ significant at } 0.01 \text{ p level}) \quad (1)$$

$$SM_{15} = 10.12 - 0.243\ ST_{15}\ (r = 0.691,\ r^2 = 0.48, \text{ significant at } 0.01 \text{ p level}) \quad (2)$$

and for the transition period :

$$SM_{15} = 13.84 - 0.31\ ST_5\ (r = 0.97,\ r^2 = 0.94, \text{ significant at } 0.01 \text{ p level}) \quad (3)$$

It is clear from the above equations that SM_{15} is significantly related to ST_5, ST_{10} and ST_{15} for dry and transition periods only and these equations can be used for prediction of SM at that depth. Management of soil temperature at shallow depths by use of natural mulch materials will be an useful practice to maintain soil moisture during those periods.

Air-soil thermal profile — Fig. 3 shows soil thermal variations (1430 IST observations) with reference to air temperature. The curves for $ST_{5,\ 10,\ 15}$ cm depth differ from others for the dry and transition periods. The air temperature is always lower than ST at 5, 10 and 15 cm depth.

For indirect computation of ST, regression analysis were done with air temperature. Of the various computations, ST at 5 cm during dry period is significantly related to AT as :

$$ST_5 = 28.3 + 2.0\ AT\ (r = 0.952 \text{ and } r^2 = 0.91, \text{ significant at } 0.01 \text{ p level}) \quad (4)$$

Since air temperature data are normally available in meteorological stations the above equation can be used to estimate ST at 5 cm. Further by knowing the thermal diffusivity coefficients it is possible to compute ST up to 15 cm depth.

The above relationships (Eqns. 1 4) show that SM, ST and AT are significantly related for shallow depths only and that too for dry and transition periods.

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