Lysimetric studies on the effect of soil moisture tension on growth and yield of groundnut

(*Arachnis hypogaea L*)

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(Received, July 1977)

INTRODUCTION

THE experiment reported in this paper is a continuation of the investigation commenced by Vivekanandan and Gunasena into the water requirement of some important field crops grown in the Dry Zone of Sri Lanka. In the earlier work (Vivekanandan, Gunasena and Sivanayagam, 1974), the effect of three different soil moisture tensions on water use, growth and yield of maize (*Zea mays* L) was studied. Small differences in soil moisture tension did not show significant differences in daily water use of maize in early growth stages, but the effect was later reversed. At all soil moisture tensions highest daily water use was recorded between 50-60 days after crop emergence. The soil moisture stress decreased grain and total dry matter yield of maize. The reduction in grain yield at higher soil moisture tensions was due to a reduction in grain number per cob, through a reduction in cob size. This paper reports the effect of soil moisture tension on the growth and yield of groundnut (*Arachis hypogaea L*).

MATERIALS AND METHODS

The experiment was carried out in catchment 'C' at the Agricultural Research Station, Maha Illuppalama during March-June (Yala season) 1971. The soil belonged to the great soil group of Reddish Brown Earths and has been described by Panabokke, (1958).

Treatments consisted of 3 soil moisture regimes approximating to 330, 530 and 730 millibars (mb) of soil moisture tension at the depth of maximum root intensity (17 cm) and these moisture tensions refer to the maximum extent to which the plants in the different treatments were stressed.

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2—A 28849 762 (77/07)

The design and layout of experiments, installation of lysimeters and irrigation practices followed were similar to that described for the earlier experiments (Vivekanandan *et al.* 1974).

After land preparation, ridges were made 60 cm apart and 3 seeds per hill of the groundnut variety A 92 were dibbled on the top of the ridge at a spacing of 30 cm, on 9 March, 1971.

All plots received a basal dressing of concentrated super phosphate (42 P_2O_5) and muriate of potash (50 K_2O) at the rate of 60 and 40 kg/ha respectively. Nitrogen as ammonium sulphate (20% N) was applied at the rate of 40 kg/ha, of which 15 kg/ha was applied as a basal dressing and the remainder was top dressed 4 weeks after sowing.

The crop was sequentially sampled at 14 day intervals commencing from the day of complete emergence. At each sampling 10 plants from 5 randomly selected hills from each plot were removed and dry matter yield and leaf area were estimated. Leaf area was estimated by the disc method (Watson and Watson, 1953).

Measurement of the extent of stomatal opening and relative turgidity were made at 35, 55, 73 and 85 days after crop emergence to include various stages of crop growth. The extent of stomatal opening was measured by the infiltration technique using mixtures of kerosene and medical paraffin in different proportions. Eleven graded solutions were prepared with a 10% increase in concentration of kerosene to paraffin. Six fully emerged unshaded leaves from the top were selected for the measurement of stomatal opening and the measurements were made on clear bright days.

Relative turgidity, the ratio of the moisture content of the leaf at any time to the maximum that the leaf could contain under fully turgid conditions, expressed as a percentage (Weathely, 1951) was measured at the same times of the day when the stomatal opening measurements were made. In this measurement 25-30 leaf discs having an area of 1.05 cm^2 were puniched using a cork borer and their fresh weights were recorded. They were then floated in distilled water for 4 hours and the turgid weights were recorded. Subsequently they were dried in an oven and the relative turgidity was determined.

CLIMATIC DATA

Climatic data are given in Table 1. During the growing season the crop received very little rain and generally the weather conditions were similar to that of any dry season in the dry zone.

RESULTS AND DISCUSSION

The results have been subjected to a detailed analysis of variance. The least significant differences refer to a probability level of 0.05. As in maize, cumulative evapotranspiration (Et) increased with a decrease in soil moisture tension (Table 2). Significant differences between treatments occurred 35 days after crop emergence when the wet treatment recorded a higher value of Et, compared with the intermediate and dry treatments. The maximum values of Et recorded at final harvest taken at 105 days after crop emergence were 506, 374 and 320 mm for wet, intermediate and dry treatments respectively. This indicates that moisture became progressively more limiting to groundnut plants with increase in soil moisture tension and this could be attributed to the high rates of potential evaporation which exceeds 6 mm on hot sunny days during April to June. Low available water storage capacity of Reddish Brown Earths which approximates to 3.6 cm per 30 cm of soil depth, and the unique moisture-energy relationship of the soil where 50% depletion of available moisture occurs at 330 mb soil moisture tension.

As reported for maize, such strong dependence of total water use on prevailing weather conditions makes generalization of water use by groundnut extremely difficult. The above data confirm the results of the previous experiment and also agree with the findings of Robins and Rhodes (1958) and Doss *et al* (1962).

Values of daily Et for fixed periods computed from records of evaporation for each irrigation cycle are presented in Table 3. Similar to that of cumulative Et, daily evapotranspiration increased at low soil moisture tensions but in spite of it considerable differences in daily Et existed between the different treatments. The daily evapotranspiration recorded a peak level from 50-80 days in the wet moisture regime while in the intermediate and dry moisture regimes, the duration of peak level of water use lasted only from 50-65 days from emergence and then declined. This pattern resembled that of maize, but the period of peak water use was longer in groundnut. However, unlike in maize the daily Et never exceeded the potential evaporation (Eo) in groundnut. The maximum daily Et recorded for the wet regime (6 mm) was 27% and 47% higher when compared with the intermediate and dry moisture regimes. During the early stages of growth crop cover was sparse and root development may have been shallow and Et from the surface soil will be high. The development of a dry soil layer in addition to a reduced amount of transpiring surface viz leaf area had resulted in a lower Et during the early stages of growth. In the wettest regime that was maintained near field capacity, daily Et during the peak period was almost equal to that of potential evaporation and this supports Penman's (1948) contention that evaporation from a wet bare soil will be equal to that of evaporation from a crop covered surface. The increase in Et during the subsequent period could be associated with the root penetration to deeper layers of soil and the rapid expansion of leaf area (Table 4). Under all soil moisture regimes, daily Et decreased after the peak period when the leaf area index (L) commenced to decline. The pattern of water use over different growth stages suggests that groundnut plants required more water at certain stages of growth for maximum performance. The pattern of daily water use did not resemble that of potential evaporation and this suggests that factors other than potential evaporation were partially responsible for causing variations in daily Et.

Estimates of open pan evaporation (Eo) as an index of crop evaporation has been widely used to determine irrigation requirements both under limiting and non-limiting conditions of soil moisture (Monteith, 1961 ; Hudson, 1962). Sivanayagam (1971) also reported the dependence of Et upon Eo in maize crop grown in a green house under non-limiting soil moisture conditions. As reported for maize no correlation was found between daily Et and Eo in groundnut. Under limiting conditions of soil moisture and where the atmospheric demand is so high, it is unlikely that such a correlation could exist and under such situations open pan evaporation will be an unreliable guide for scheduling irrigations.

Significant differences in the leaf area index (L) were recorded at samplings made at 40, 70 and 112 days after crop emergence (Table 4). Maximum value of L recorded for the wet moisture regime was 6.25 followed by 4.75 and 3.81 for the intermediate and dry treatments respectively. Thereafter, L declined, the rate of decline being faster with each increment of moisture tension. As in maize, leaf persistence was greater at lower than at higher moisture tensions and at the final harvest taken 112 days after emergence, the wet treatment recorded an increase in L of over 83% compared with other treatments. Eventhough, dry matter and leaf area were reduced at higher soil moisture tensions the reduction in leaf area was greater than that of dry matter. Zelith (1969) found that turgor determines the responses of stomata and this to be involved with cell enlargement while Boyer (1968) reported cell enlargement to be reduced at lower leaf water potentials. The results of this investigation supports the above evidence in that marked differences in leaf area were associated with small differences in relative turgidity. This could possibly account for the relatively less reduction in dry matter production than leaf expansion at higher soil moisture tensions.

An examination of daily Et in relation to L shows an increase in daily Et with an increase in L and a decrease in daily Et when L commences to decline 84 days after crop emergence. Duration of the peak period of water use therefore appears to depend largely on how rapidly the crop achieves complete leaf cover and the persistence of leaves thereafter. This has been emphasised by Laing (1965) and Vivekanandan *et al* (1974 who reported a similarity in the pattern of L and Et/Eo ratio of soyabean and maize respectively. However, a significant correlation did not exist between daily water use and L for any of the moisture regimes tested which suggests that L was only partially responsible for differences in water use between treatments.

The effect of soil moisture regimes on leaf area duration (D) was similar to that of L and D was reduced by increasing soil moisture tension. The D values recorded for the wet, intermediate and dry moisture regimes were 55.6, 42.8 and 33.3 and the intermediate and dry moisture regimes reduced D by 28% and 40 % respectively when compared with the wet moisture regime.

The pattern of stomatal opening (Fig. 1) was similar to that of maize. Under all moisture regimes stomata remained closed at 6.00 a.m. Then they gradually opened until a maximum was reached between 8.00-9.00 a.m. This was followed by a decrease until a maximum mid day closure was reached between 12.00-1.00 p.m. At mid day however, the stomata were not completely closed and the maximum closure even at the highest moisture tension did not exceed 60% at any stage of growth of the crop. After mid day closure the stomatal opening again increased upto 4.00 p.m. followed by a rapid closure after 5.00 p.m. and at 6.00 p.m. the stomata remained completely closed.

Similar to that of maize, the relative turgidity (Fig. 2) indicated that the values were highest for all regimes at 6.00 a.m. and it decreased to the lowest value beween 12.00-1.00 p.m. Threafter relative turgidity increased upto 6.00 p.m. and continued to increase further during the night. This indicates that a greater part of the build up of relative turgidity occurs during the night. Wilson *et al* (1953), Halevy (1960) and Weatherley (1951) have reported similar results. The value of relative turgidity recorded at 6.00 a.m. was always higher than that recorded at 6.00 p.m. for all moisture regimes and the magnitude of difference increased with increase in moisture tension. Although differences in stomatal opening and relative turgidity were caused by difference in soil moisture tensions, no significant difference in the response of both parameters were recorded within the tensions 0-300 mb. In maize also no difference in relative turgidity or stomatal opening existed when the soil moisture tension ranged between 0-300 mb. whereas at higher tensions the differences were significant. Offir *et al* (1968) and Gardner and Ehlig (1962) suggests that a crop factor possibly due to root resistance controlled the uptake and loss of water at tensions near field capacity whereas at higher soil moisture tensions, soil resistance or unsaturated conductivity controlled both stomatal opening and relative turgidity.

Measurements of relative turgidity and stomatal opening were taken at different stages and it is evident from these that at the same soil moisture tension, relative turgidity and stomatal opening both decreased with increase in age of the crop. However, such a decrease was observed to take place only up to 75 days from emergence and it was at higher soil moisture tensions. This could be due to differences in water availability to plants influenced by differences in leaf area and water became more limiting with increase in age of the crop even under similar soil moisture tensions. In the subsequent growth period stomatal opening decreased while relative turgidity increased possibly due to lower leaf area resulting from leaf senescence whereas the presence of a fully developed root system enabled the plants to maintain turgor even under the highest soil moisture tension. The increase in relative turgidity with age observed by Denmead and Shaw (1960) has been attributed to reduced physiological activity associated with leaf senescence.

The total dry matter yield of groundnut increased with a decrease in soil moisture tension but the pod weight per plant and pod/haulm ratio was significantly greater at higher soil moisture tensions (Table 5). Pod number per plant and 100 pod weight increased at lower soil moisture tensions. The increase in pod yields was due to differential distribution of dry matter, which at lower soil moisture tensions favoured the production of excessive vegetative growth rather than pods.

SUMMARY

The effect of three soil moisture regimes on water use, growth and yield of groundnut was studied. The daily evapotranspiration was lower during early stages of growth and this effect was attributed to dry surface soil layer, changes in leaf area and stomatal behaviour rather than to the direct effect of evapotranspiration. The peak period of daily water use was longer in the wet than in the drier moisture regimes and lasted from 50-65 days after crop emergence. The total dry matter yield increased with a decrease in soil moisture tension but the pod yield was greater at higher soil moisture tensions. This was due to the differential distribution of dry matter, which at lower soil moisture tension favoured excessive vegetative growth than pod production.

ACKNOWLEDGEMENTS

The authors greatfully acknowledge the help of Mr. W. M. T. Wanisekera in the preparation of the manuscript and of Mr. T. Thavanesh for help in the field work.

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Table 1.—Climatic Data—1971

	Period	Temperature mini.	(°F) Max.	Relative humidity %	Total rainfall mm.	Sunshine hours
March	9–13	72.0	89.4	86.8	10.4	8.8
	14–18	72.4	90.4	84.2	6.1	8.2
	19–23	70.2	92.2	80.0	—	9.5
	24–28	71.7	94.2	76.8	—	9.7
	29–2	72.0	93.0	79.4	5.0	7.6
April	3–7	74.4	93.7	77.2	35.3	10.3
	8–12	70.8	93.9	75.8	7.9	10.3
	13–17	71.7	92.8	77.6	29.2	9.1
	18–22	72.9	91.7	78.8	78.5	8.6
	23–27	71.9	92.0	82.8	20.5	9.4
	28–2	72.8	90.1	82.0	17.3	7.2
May	3–7	78.8	89.5	80.6	17.3	6.3
	8–12	75.5	91.6	75.4	—	1.3
	13–17	75.9	90.1	72.0	—	5.8
	18–22	73.8	87.8	81.0	35.3	8.6
	23–27	77.5	92.5	79.0	—	9.1
	28–1	76.3	89.0	78.6	0.5	3.5
June	2–6	75.8	89.5	77.4	2.0	5.4
	7–11	75.0	88.6	76.4	0.9	9.4
	12–16	75.7	89.9	74.0	—	9.0
	17–21	74.5	87.4	80.0	28.4	6.1
	22–25	74.4	86.4	85.5	5.6	6.0

Table 2.—Effect of soil moisture tension on cumulative evapotranspiration of groundnut

330 *millibars*		530 *millibars*		730 *millibars*	
Period up to	*Cumulative Et (mm)*	*Period up to*	*Cumulative Et (mm)*	*Period up to*	*Cumulative Et (mm)*
5 days	15	5 days	14	5 days	11
11 days	31	12 days	30	15 days	33
18 days	52	19 days	49	25 days	58
24 days	73	27 days	74	35 days	84
30 days	98	35 days	99	45 days	114
36 days	123	43 days	130	54 days	148
41 days	146	50 days	160	62 days	176
46 days	176	56 days	189	70 days	207
51 days	205	62 days	216	78 days	239
56 days	234	68 days	246	87 days	268
60 days	258	75 days	274	96 days	289
64 days	285	82 days	303	108 days	320
69 days	310	90 days	333		
74 days	345	98 dasy	363		
79 days	366	105 days	374		
84 days	400				
89 days	423				
94 days	451				
99 days	476				
105 days	506				

Table 3.—Effect of moisture tension on daily evapotranspiration of groundnut (mm)

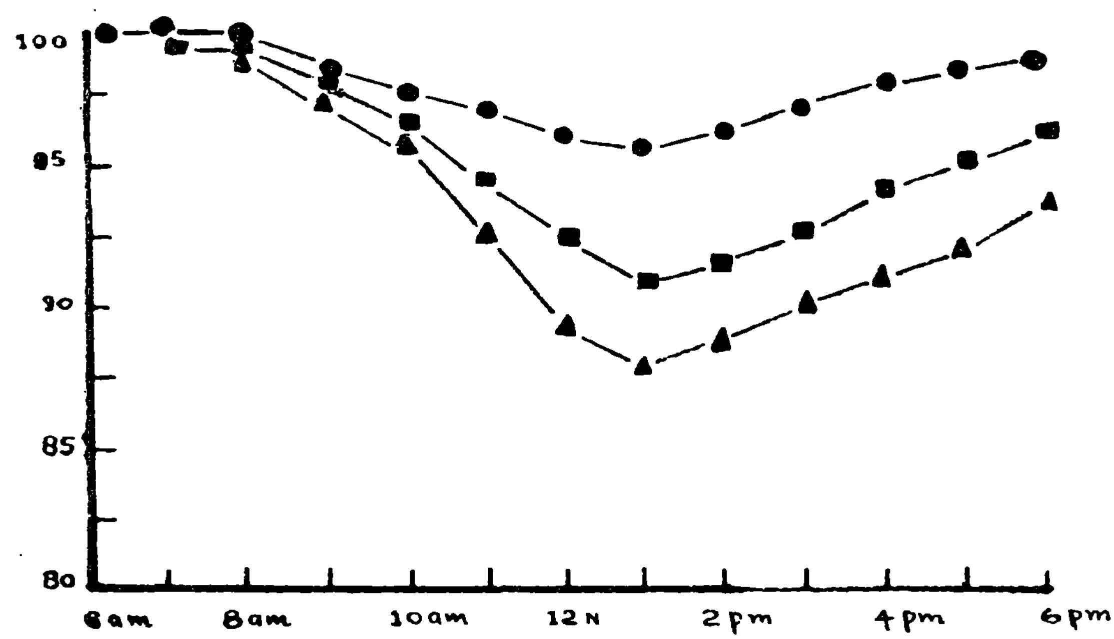
Period in Days	*Soil moisture tension*		
	330 *mb*	530 *mb*	730 *mb*
0–5	2.8	2.4	2.2
5–10	2.9	2.6	2.3
10–15	3.0	2.7	2.3
15–20	3.2	2.8	2.4
20–25	3.4	2.9	2.4
25–30	3.8	3.1	2.5
30–35	4.3	3.3	2.7
35–40	4.9	3.7	2.9
40–45	5.6	4.1	3.2
45–50	5.9	4.5	3.4
50–55	6.0	4.6	3.7
55–60	6.0	4.7	3.8
60–65	5.9	4.6	3.8
65–70	5.9	4.5	3.7
70–75	5.8	4.4	3.5
75–80	5.8	4.2	3.3
80–85	5.7	4.0	3.2
85–90	5.4	3.8	3.0
90–95	5.1	3.7	2.8
95–100	4.7	3.6	2.7
100–105	4.3	3.4	2.5

Table 4.—Effect of soil moisture tension on leaf area index (L) of groundnut

Days after emergence	*Leaf area index, L*		
	330 *mb*	530 *mb*	730 *mb*
14	0.25	0.23	0.21
28	1.02	0.95	0.90
42	2.63	2.25	1.87
56	5.13	4.13	3.25
70	6.13	4.75	3.81
84	6.25	4.63	3.62
98	5.37	3.37	2.37
112	4.00	2.13	1.19

Table 5.—Effeet of moisture tension on yield components and pod yield of groundnut

Yield Components	*Soil moisture tensions*			*L.S.D*
	330 *mb*	530 *mb*	730 *mb*	$P=0.05$
Pod weight per plant (g)	25.3	26.8	35.1	3.80
Pod number per plant	38.0	36.0	30.0	3.26
Number of developed pods per plant	18.0	20.0	26.0	3.82
% developed pods per plants	47.4	55.6	86.7	8.12
Shelling % of developed pods	78.4	75.7	76.9	N.S.
Weight of 100 pods (g)	138.8	134.0	134.0	4.06
Leaf/stem ratio	0.58	0.55	0.56	N.S
Pod/haulm ratio	0.21	0.33	0.71	0.13



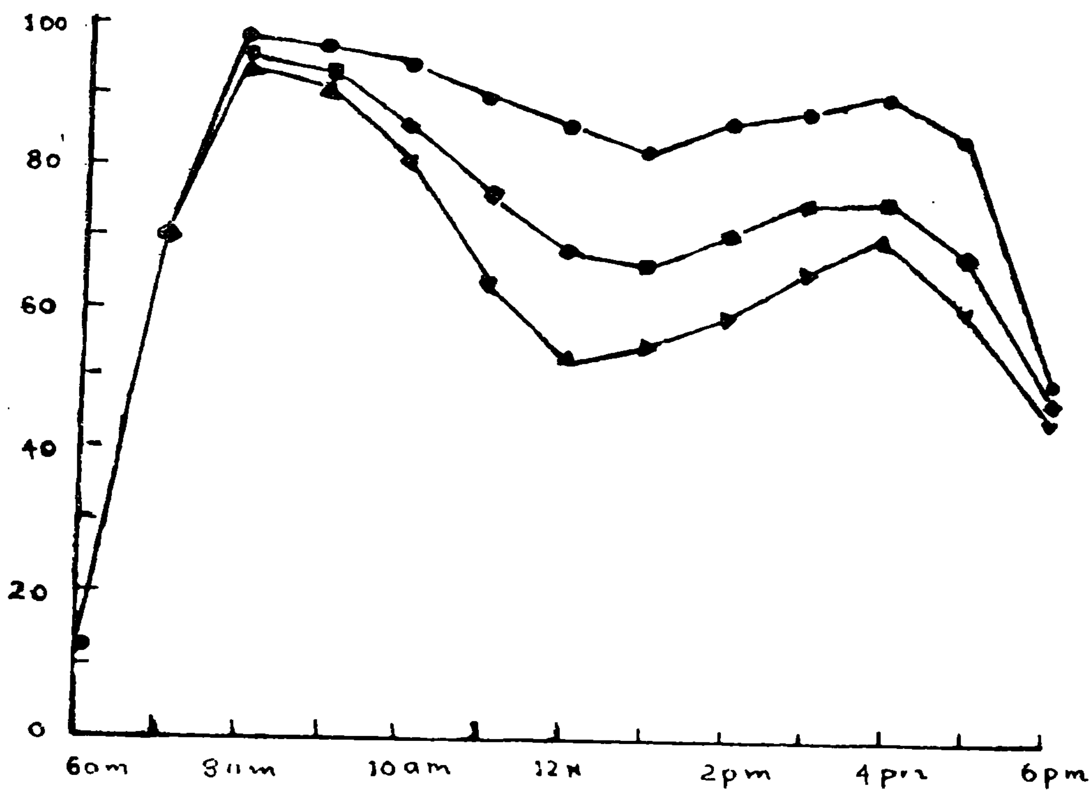


Fig. 1 (above) and Fig. 2 (below)

Legends for Figs. 1 and 2

Fig. 1.—The diurnal pattern of stomatal opening at different soil moisture tensions: groundnut.

Legend :

●————●330 millibar

■————■530 millibar

▲————▲730 millibar

Fig. 2.—The diurnal pattern of relative turgidity at different soil moisture tensions: groundnut.

Legend :

●————●330 millibar

■————■530 millibar

▲————▲730 millibar