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EVALUATION OF GROUNDNUT RESPONSE TO EARLY MOISTURE STRESS DURING THE RAINY AND THE POST-RAINY SEASONS

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ABSTRACT

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The response of groundnut (*Arachis hypogaea* L.) to early moisture stress (EMS), imposed from emergence to initiation of pegs, was evaluated during the 1982 rainy season at the ICRISAT Research Center, Patancheru, India on a medium deep Alfisol, and was compared with the treatment responses during the 1982–1983 post-rainy season. EMS was imposed during the rainy season by covering the plots with black plastic film to keep off the rain while during the post-rainy season a line source sprinkler irrigation system was used. EMS reduced evapotranspiration with no apparent reduction in LAI, and pod and kernel growth during the rainy as well as the post-rainy seasons. Hence water-use efficiency was substantially higher for the EMS treatment as compared with the control during the two seasons. Despite the contrasting climatic conditions during the rainy and post-rainy seasons, groundnut response to EMS was fairly similar. The implications of these results for developing improved water management strategies for groundnut are discussed.

INTRODUCTION

India is the largest producer of groundnuts accounting for two-fifths of the world acreage and a third of world production (FAO, 1982), but the yields of groundnut in semi-arid tropical India are low and variable due to erratic rainfall and other climatic factors (Kanwar et al., 1983). As competition for limited water supplies increases in the arid and semi-arid regions, irrigation water is becoming increasingly scarce and expensive. Where water is a limiting resource, the objectives of irrigation management may shift from obtaining maximum yield to obtaining maximum economic production per unit of water applied. Development of the capability to predict quantitatively the effects of water deficits will be a key element in rational water management and irrigation scheduling.

In general, water deficits reduce groundnut photosynthesis (Bhagsari et al., 1976) thereby limiting the number of fruits added and decreasing the final yield. For groundnut crop early vegetative growth, flowering, pod development and maturity are the important physiological stages. Early vegetative growth is not sensitive to moisture stress, since the water absorbed during the first month after sowing was found to be small (Su et al., 1964) while the flowering phase (Billaz and Ochs, 1961; Su et al., 1964) and the pod development phase (Joshi and Kabaria, 1972; Pallas et al., 1979) are sensitive.

Previous studies conducted during the post-rainy season at ICRISAT center (Nageswara Rao et al., 1985; Sivakumar and Sarma, 1986) showed that early moisture stress (EMS) — stress imposed from emergence to initiation of pegs — was beneficial while stress imposed at other growth stages reduced growth and yield. However, most of the groundnut crop in India is grown in the rainy season. The ability of the EMS treatment to improve the water-use efficiency of the groundnut crop during the rainy season should be evaluated. The objective of the present investigation was to study the effects of EMS on evapotranspiration, growth and yield of groundnut during the rainy season and compare them with the effects observed during the post-rainy season.

MATERIALS AND METHODS

The experiments were conducted during the 1982 rainy season and in the 1982–1983 post-rainy season on a medium deep Alfisol (fine, clayey mixed, Udic Rhodustalf) at the International Crops Research Institute for Semi-Arid Tropics (ICRISAT), Patancheru, India (17°32′ N latitude, 78°16′ E longitude).

In both the experiments, a basal dose of 100 kg ha^{-1} of diammonium phosphate (18:20 $N:P_2O_5$) was incorporated into the soil at the time of land preparation. The field was prepared as broadbeds (120 cm wide) with furrows (30 cm wide) on either side of the beds. The experiment during the 1982 rainy season included two moisture treatments, i.e. EMS and no EMS (rainfed under the conditions of rainfall received in the season) with cultivar Robut 33-1 in plots measuring 6×13.5 m. Sowing was done on 19 June and emergence occurred by 24 June. EMS was imposed through covering the experimental area with a 4 mm black plastic film soon after the crop emergence to prevent the seepage of rain water into the soil. Bamboo stakes were used at 30-cm intervals to secure the plastic film firmly onto the bed and in the furrows. Rain water falling on the plastic film was guided away from the plots through the furrows. The black plastic was removed at 44 days after emergence (DAE) when 50% of the pegs had been initiated.

The experiment during the 1982–1983 post-rainy season was part of a more comprehensive study dealing with the response of groundnut to moisture stress imposed at different phenological stages using the line source sprinkler irrigation technique (Sarma and Sivakumar, 1989). Only the EMS and the continuous irrigation treatments are described here.

Groundnut was sown on 29 October and emergence was complete by 5 November. Intensive plant protection was provided against leaf miner and leaf spot and the plots were kept weed free.

The line source sprinkler technique used standard impulse sprinkler heads spaced at half their normal spacing along the irrigation line which produced a continuously decreasing rate of water application at right angles to the sprinkler line (Hanks et al., 1976). The amount of water applied varied as a function of the distance from the line source. Generally the maximum amount of water was received at 0–6 m distance from the line source and little or no water was received at 13–18 m from the sprinkler line. Hence the 0–6-m strip from the line source in the treatment which was irrigated at 7-day intervals throughout the season was used as the control treatment. This treatment received 740 mm of water during the season. The crop grown at 13–18 m distance was used as the EMS treatment for comparison with the EMS treatment in the rainy season. From 50 DAE (when the drought stress was released) to maturity this treatment received irrigations through perforated tubes that distributed water uniformly. Net amount of water applied in this treatment was 522 mm.

In both the seasons, the profile water content in the 30–120-cm soil depth was determined at 7–10 days interval with Type I.H.II neutron moisture meter (Didcot Instrument Co. Ltd., Abingdon, Oxon, Gt. Britain) from two access tubes in each plot at 15-cm depth increments. A calibration equation developed from measurements made on the experimental site was used to convert the count ratios from the neutron probe to volumetric water contents. Soil moisture in the top 30 cm was measured by the gravimetric method.

Seasonal evapotranspiration (ET) was computed with the water balance equation

$$ET = (M_i - M_f) + (I + P) - (R + D)$$

where M_i = initial moisture in the 0–120-cm soil profile; M_f = final moisture in the 0–120-cm soil profile; I = irrigation; P = precipitation; R = runoff; D = deep drainage.

Deep drainage below 120 cm was considered negligible based on soil moisture measurements using the neutron probe following each irrigation, which showed little or no increase in the moisture content of the 105–120-cm-deep soil layer after each irrigation.

Growth measurements were made by sampling the whole plants at 7–10 days interval in a 0.75-m^2 area in each replicate. Leaf area of individual leaves was measured with an LI-3100 leaf area meter (LI-COR Ltd., Lincoln, NE, U.S.A.).

Plants were dried to constant weight in a forced draft oven at 65 °C and then weighed. Pod and kernel yields were obtained from a net area of 9 m^2 in each plot.

Thermal time for different developmental processes of groundnut has been calculated using the base temperatures given by Leong and Ong (1983) for the cultivar used in this study.

RESULTS AND DISCUSSION

Seasonal weather

Average maximum and minimum temperatures, wind speed, solar radiation, open pan evaporation, relative humidity and total rainfall during the two growing seasons are shown in Table 1. No rain occurred during the post-rainy season thereby facilitating an effective imposition of the early moisture stress.

Weather data show that the average air temperatures during the post-rainy season for the first 3 months of the crop growth were generally 6–7 °C lower in comparison to those during the rainy season. The rainy season crop matured in 115 days while during the post-rainy season the cycle was 148 days. This delayed maturity during the post-rainy season effectively prolonged the pod filling period which occurred at a time when the solar radiation levels were higher (Table 1) than those during the rainy season.

TABLE 1

Meteorological parameters during the 1982 rainy season (June–October) and the 1982–1983 post-rainy season (November–March)

Month	Rainfall (mm)	Temperature (°C)		Pan evaporation (mm)	Relative humidity (%)		Wind speed (km h^{-1})	Solar radiation (MJ m^{-2})
		Max.	Min.		0717 h	1417 h		
June	193	34.3	24.1	265.5	77.3	49.4	17.2	18.5
July	155	31.2	22.6	212.7	84.5	57.5	16.1	18.5
August	69	30.0	22.5	179.2	86.2	60.5	13.5	16.8
September	180	29.7	21.9	137.9	92.0	65.0	6.4	17.3
October	59	30.3	19.8	148.9	89.4	49.8	5.8	18.2
November	0	28.5	17.3	132.3	90.9	49.1	7.6	16.9
December	0	28.2	13.2	149.2	92.2	40.3	6.4	16.4
January	0	28.8	13.1	169.9	85.8	33.4	6.6	18.7
February	0	32.3	17.0	210.5	75.1	26.6	8.3	20.9
March	0	36.5	19.9	303.9	61.1	22.5	8.2	22.5

Available soil water

Seasonal changes in the available soil water at different soil depths for the rainy season experiment are shown in Fig. 1. Soil water content in the EMS treatment was generally low until 45 DAE, particularly in the surface 0–10- and 11–30-cm soil layers. After the removal of the black plastic film (at 44 DAE), soil water contents in the EMS treatment increased.

During the post-rainy season available soil water (Fig. 2) contents were generally higher than those in the rainy season, specially in the 11–60-cm soil layers. As can be expected, available soil water in the top 60-cm soil layer was lower in the EMS treatment (Fig. 2(a)) in comparison to the fully irrigated control (Fig. 2(b)). From 50 DAE when the crop in the EMS treatment re-

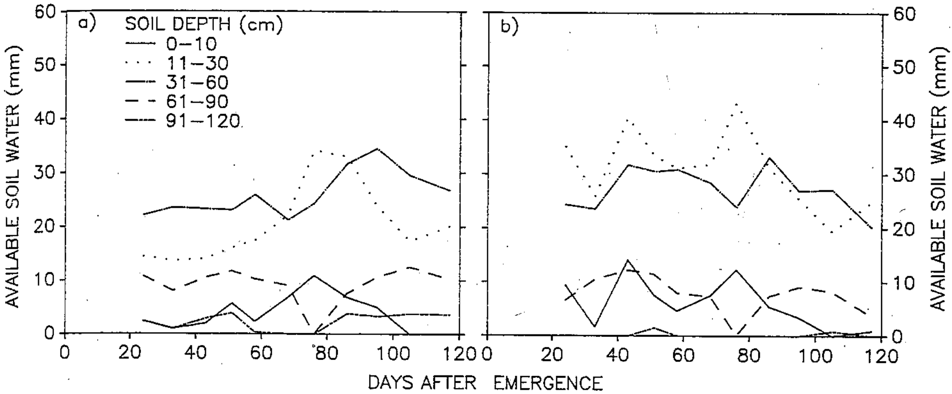

Fig. 1. Seasonal changes in available soil water at different soil depths in (a) the EMS treatment and (b) the rainfed control treatment during the 1982 rainy season.

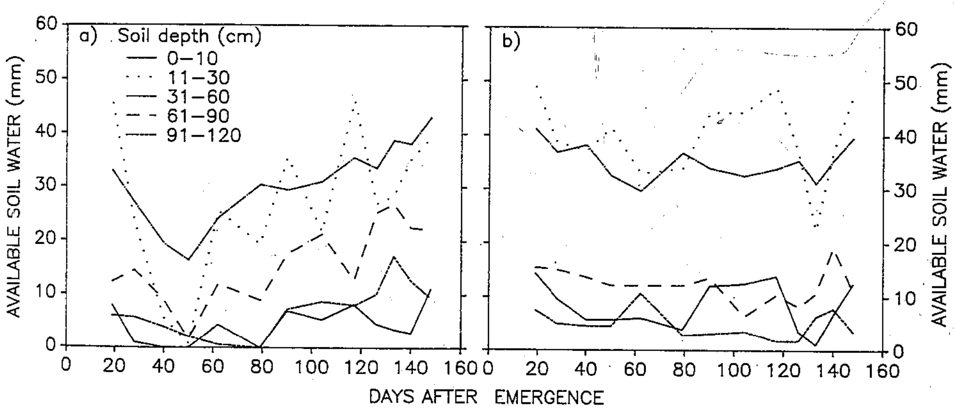

Fig. 2. Seasonal changes in available soil water at different soil depths in (a) the EMS treatment and (b) the fully irrigated control treatment during the 1982–1983 post-rainy season.

ceived irrigations at the same interval as the control treatment, available soil water in the top 60 cm increased but did not reach the levels seen in the control treatment until much later in the growing season.

Available soil water contents during the post-rainy season were generally higher due to the regular frequency of irrigations after the release of EMS. Soil water contents at 19 DAE during the post-rainy season in the EMS and the irrigated control treatment were 105 and 127 mm, respectively. At the corresponding growth stage during the rainy season available soil water contents were 52 and 75 mm in the EMS and control plots, respectively.

Evapotranspiration (ET)

Total ET during and after the period when EMS was imposed for the two seasons is shown in Table 2. EMS reduced the ET by 135 and 174 mm in the rainy and post-rainy seasons, respectively and the reduction, as expected, was large during the period when EMS was imposed, but was still appreciable in the next period.

Lower soil water contents due to the imposition of EMS contributed towards decreased ET in both seasons. During the rainy season, the black plastic film covering the ground kept 233 mm out of a total rainfall of 656 mm received during the growing period from entering the soil. Even after the removal of the polyethylene film, the ET was low. Total ET after the release of EMS in the post-rainy season was higher in comparison to the rainy season (Table 2) due to the increased availability of soil water from the irrigations given at 7-day intervals. These results are in agreement with the conclusions of Vivekanandan and Gunasena (1976) that soil water availability exerts a controlling influence on the total water use by the crop.

TABLE 2

Total evapotranspiration (mm) during and after the period of imposition of early moisture stress during the 1982 rainy season and 1982-1983 post-rainy season

Period	Rainy season			Post-rainy season		
	EMS	Control	SE	EMS	Control	SE
During EMS	32	121	3.7	87	190	15.9
After the release of EMS	162	208	2.5	437	508	8.4
Total	194	329	3.2	524	698	19.9

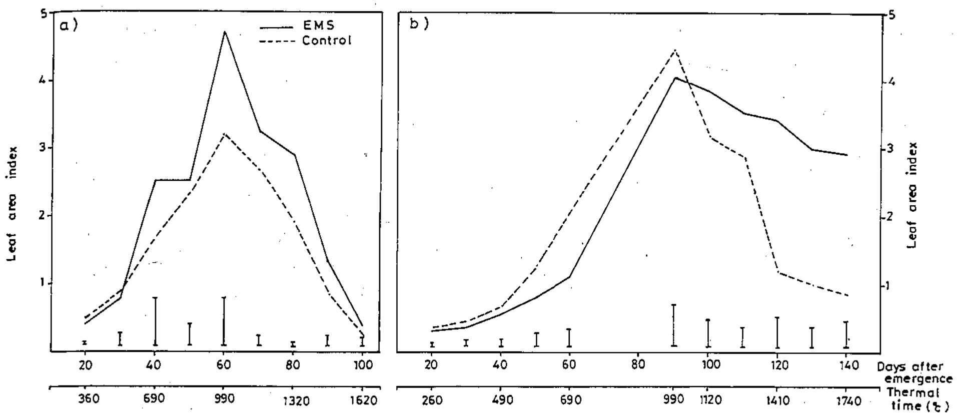

Fig. 3. Seasonal variation in leaf area index of groundnut and thermal time during (a) 1982 rainy season and (b) 1982–1983 post-rainy season.

Leaf area index (LAI)

During the rainy season LAI in the EMS treatment was initially lower than that in the control (Fig. 3(a)). Commencing from 30 DAE, LAI in the EMS treatment was slightly higher. Differences in the LAI between the two treatments were not statistically significant. From the LAI patterns it is obvious that groundnuts have the ability to compensate for EMS. After the release of the water stress, there was considerable stimulus in the leaf growth as was also observed by Billaz and Ochs (1961).

During the post-rainy season LAI in the EMS treatment was lower until 80 DAE (Fig. 3(b)). Afterwards LAI in the control treatment decreased rapidly while in the EMS treatment the rate of decrease in LAI was much slower and was always higher than the control. Lower air temperatures during the first 3 months of crop growth during the post-rainy season (Table 1) could have resulted in slower leaf growth rates. Thermal time (or accumulated temperature above a base temperature of 10 °C) during the two seasons (Fig. 3) was different, explaining the lower LAI values for the first 60 DAE in the post-rainy season in comparison to those in the rainy season. In both seasons, peak LAI was attained at a thermal time of 990 °C i.e., at 60 DAE in rainy seasons and 90 DAE in post-rainy seasons.

Pod and kernel growth

Pod growth during the rainy season showed no significant difference between the two treatments (Fig. 4(a)). During the post-rainy season pod growth was initially lower in the EMS treatment, but starting from 110 DAE, EMS

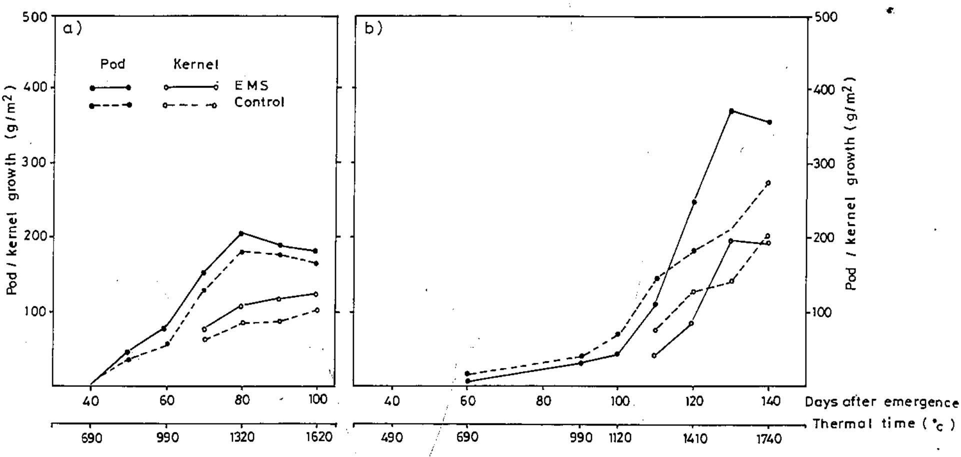

Fig. 4. Seasonal variation in pod and kernel growth of groundnut and thermal time during (a) 1982 rainy season and (b) 1982–1983 post-rainy season.

resulted in increased pod growth over the control. Pod growth rates during the post-rainy season were much higher than those during the rainy season.

Kernel growth pattern during the rainy season (Fig. 4(b)) was similar to that of the pod growth. In the post-rainy season kernel growth rates were much higher than those in the rainy season but there was no significant difference between the treatments.

EMS delayed flower initiation as shown earlier by Ochs and Wormer (1959). The release of moisture stress at the stage of pegging resulted in a reproductive flush leading to synchrony in flowering which increased the number of pegs as well as the pods. Groundnut is reported to have the ability to compensate for flower reduction because of early water deficit (Lin et al., 1963; Ono et al., 1974; Boote et al., 1976) by producing a flush of flowers and fruits when the water stress is relieved (Billaz and Ochs, 1961; Pallas et al., 1979).

Pod and kernel yield and water-use efficiency (WUE)

During both the seasons (Table 3), there was no significant difference in the pod and kernel yields between the EMS and the control treatments with the exception of pod yields in the EMS treatment during the post-rainy season. Nageswara Rao et al. (1985) and Sivakumar and Sarma (1986) also reported higher pod yields under conditions of early moisture stress in the post-rainy season. Because of lower ET, significantly increased WUE was achieved in the EMS treatment in both the seasons.

Results of this study have implications in developing water management strategies for groundnut, especially in the semi-arid regions. Historical rainfall data should permit determination of drought stress periods for groundnut from

TABLE 3

Pod and kernel yields (kg ha^{-1}) and water-use efficiency (kg ha^{-1} cm^{-1}) of groundnut cv. Robut during the 1982 rainy season and 1982–1983 post-rainy season

Season	Pod yield		Kernel yield		Water-use efficiency for kernel yield	
	EMS	Control	EMS	Control	EMS	Control
Rainy	1610	1260	890	810	45.9	24.6
SE (±)	150		100		0.52	
Post-rainy	4390	3258	3100	2530	59.2	36.2
SE (±)	283		400		1.18	

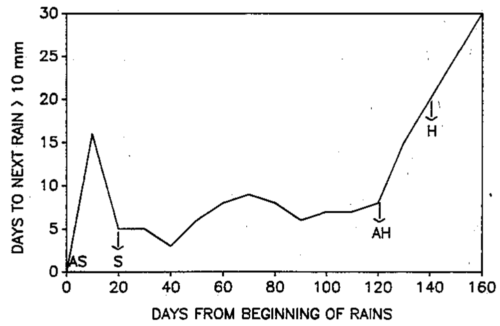

Fig. 5. A hypothetical example of adjustment of sowing dates for groundnut based upon waiting period for rainfall (S and H denote normal sowing and harvesting dates; AS and AH denote adjusted sowing and harvesting dates, respectively).

the beginning of rains. Under rainfed conditions, the date of sowing could be adjusted to allow the crop to grow under early moisture stress and avoid the drought periods during the later growth stages which are more sensitive to water stress.

A hypothetical example of the use of drought stress calculations is shown in Fig. 5. Historical rainfall data could be analysed to calculate the waiting period for receiving a given amount of rainfall for consecutive 10-day periods after the onset of rains (Sivakumar, 1988). Normally sowings would be done when the rains stabilize as indicated by the letter "S" (Fig. 5) at 20 days after the rains begin. A 120-day cultivar would be harvested (indicated by the letter "H") at 140 days after the rains begin. However data shown in the figure suggest that from 120 days onwards the waiting period for rains increases rapidly. Hence the crop would undergo considerable drought stress during the pod filling stage which has been shown to be a very sensitive stage to drought stress (Pallas et al., 1979). Since groundnut could withstand drought stress during the early stages, sowing could be adjusted ("AS" in Fig. 5) to coincide with the beginning of rains. The adjusted harvesting ("AH" in Fig. 5) day indicates that pod filling now occurs during a more favourable rainy period.

Agroclimatic analysis of historical rainfall data could be used in conjunction with knowledge of the phenology of varieties used in a given region, to develop strategies as described above for developing weather advisories for farmers. Under conditions where limited irrigation facilities are available, it should be possible to establish groundnut with irrigations just ahead of the average date of onset of rains. This would enable the crop to reach its peak vegetative growth stage by the time the monsoon is well established in Peninsular India.

CONCLUSIONS

Studies reported in this paper for the rainy season showed that moisture stress during the early stages of groundnut crop causes no apparent reduction in the pod yields. Since it also resulted in a reduction in ET, WUE in the EMS treatment was higher. Climatic conditions during the post-rainy season in Peninsular India are different from those in the rainy season with lower air temperatures in the first 90 days of the crop growing season and higher solar radiation levels during the pod filling phase. Despite these contrasting climatic conditions, there was a good correspondence in the response to EMS for the two seasons. Our results for the rainy season confirm the previously reported responses to EMS during the post-rainy season. These results should help develop improved cropping strategies for increased groundnut production during the rainy season in Pensinular India.

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