MAUSAM, 49, 3 (July 1998), 383-386

631.671 : 631.559 : 634.58 (213.52) (540)

Water use pattern and yield response of groundnut (*Arachis hypogaea* L.) in semi-arid areas of India

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(Received 25 July 1994, Modified 13 January 1998)

सार — भारत के अर्ध-शुष्क क्षेत्रों में मूंगफली बड़े पैमाने पर उगाई जाने वाली एक प्रमुख खाद्य फली है। खरीफ मौसम के दौरान तीन स्थानों अर्थात् बेलारी, राहुरी और आनन्द में 3 से 5 वर्षों के दौरान उगाई गई मूंगफली की फसल के लिए जल की आपूर्ति, जल की मांग और उपज की मात्रा के संबंध में अध्ययन किया गया है। राहुरी में आर्द्रता दबाव के कारण मूंगफली की उपज की मात्रा में काफी कमी पाई गई है जहां पर अपेक्षाकृत कम समय में तैयार होने वाली फसल चिकनी मिट्टी में उगाई गई थी। आनन्द में बेलारी और राहुरी की अपेक्षा कुल जल की अधिकतम आपूर्ति की गई थी। जल का उपयोग क्रमशः 660, 460 और 410 मि.मी. किया गया था। फसल के सूत्र (पेग) बनने की अवस्था से लेकर मूंगफली बनकर तैयार होने की अवस्था तक फसल द्वारा वाष्पोत्सर्जन सभी स्थानों पर अधिकतम था। बेलारी में आनन्द और राहुरी की अपेक्षा जल की मांग अधिकतम थी। फसल तैयार होने की पूरी अवधि में सापेक्षिक वाष्पोत्सर्जन अनुपात ETc/ETo आनन्द, बेलारी और राहुरी में क्रमशः 0.97, 0.63 और 0.92 था। फसल की उपज कुल जल की आपूर्ति के काफी अनुरूप थी।

ABSTRACT. Groundnut, an important food legume, is extensively grown in semi-arid regions of India. Water use, water use efficiency and yield response of groundnut grown at three locations, *viz.*, Bellary, Rahuri and Anand during kharif season have been studied for 3 to 5 years. Reduction in pod yield due to moisture stress was found greatest at Rahuri, where a relatively short duration crop was grown in a clayey soil. Total water use was highest at Anand, followed by Bellary and Rahuri. The water use was 660, 460 and 410 mm respectively. At all locations evapotranspiration by the crop was maximal at peg formation to pod development stage of crop growth. The water use efficiency was highest at Bellary followed by Anand and Rahuri. The relative evapotranspiration ratio ET_c/ET_o for the entire growing season was 0.97, 0.63 and 0.92 at Anand, Bellary and Rahuri respectively. Pod yield showed good correspondence with total water use.

Key words — Yield response, Evapotranspiration, Water use efficiency.

1. Introduction

Groundnut (*Arachis hypogaea* L) is widely grown in sandy soils in semi-arid India. Nearly 45% of the cropped area under oilseeds and 55% of the oilseed production comes from groundnut (ICAR 1988). The average yield in India is approximately 925 kg/ha, which is approximately the world's average unit area yield of the crop (India 1995). As a crop with high rate of photosynthesis, the potential for increasing its production is great. Groundnut is sensitive to water deficits, particularly at pod formation stage of growth. Understanding of water needs of the crop at different growth phases, and identification of varieties which can withstand stress, would go a long way in enhancing productivity of this cash crop. Naveen *et al.* (1992) studied the effect of drought on yield of groundnut and found that moisture stress during flowering and pegging resulted in a lower oil content and a reduction in pod yield per unit area. They also found that stress in early pod formation also resulted in a lowered seed number and, consequently reduced yield. Ramachandrappa *et al.* (1992) observed that moisture stress 10-40 days after sowing is beneficial in increasing the pod yield of groundnut. It helps in a synchronous pod development. Sahu and Sastry (1992) determined the water availability pattern and water requirement of groundnut in Saurashtra region by evaluating water requirement satisfaction index in each of the pheno-phases of the crop.

This study attempts to determine water requirement and water use efficiency of groundnut in relation to soil water status during different phases of its growth. Growth stages, at which the groundnut crop is sensitive to moisture deficits, have been determined for efficient irrigation scheduling for increasing the productivity.

2. Materials and methods

Three stations, namely Bellary (15° 9′ N, 76° 51′ E), Rahuri (19°24′N, 74°39′ E) and Anand (22°35′ N, 72°55′E), were chosen for the study. Details of experiment, variety

TABLE 1
Groundnut yield and water use

Station	Variety	Year	Duration (weeks)	RF (mm)	Irrigation (mm)	Total water	Total ET(mm)	Mean weekly ET(mm)	PE (mm)	Yield (kg/ha)	WUE (kg/ha/mm)
Bellary	S-206	1985	19	92	249	341	509	30	799	3333	6.55
	Do	1987	16	230	212	442	459	29	744	3055	6.65
	Do	1988	17	506	171	677	414	24	706	3669	8.86
	Do	1989	23	324	265	589	540	32	750	3379	6.26
	Do	1990	18	282	368	649	378	21	836	1775	4.70
Rahuri	Phulepragati	1980	14	234	279	513	356	25	418	1656	4.65
		1981	11	343	319	662	442	32	648	1740	3.90
		1982	12	087	275	362	426	30	683	1933	4.54
Anand	JL-24	1985	21	472	343	815	795	38	712	2393	3.01
		1986	16	223	359	582	588	34	671	1955	3.32
		1987	18	283	492	775	792	42	768	2810	3.55
		1988	20	806	060	866	447	23	580	1330	2.96

TABLE 2
Phasewise water use of groundnut (ET)

Station	Year	Vegetative phase	Flowering to peg formation	Peg formation to pod development	Pod maturity	Total
Bellary	1985	108(21)	157(31)	133(26)	111(22)	508
	1987	114(25)	159(35)	120(26)	66(14)	458
	1988	67(16)	106(25)	162(39)	79(19)	413
	1989	105(19)	146(27)	141(26)	148(27)	539
	1990	138(37)	67(18)	111(29)	61(16)	377
Rahuri	1980	78(22)	113(32)	95(27)	69(19)	356
	1981	108(23)	113(26)	146(33)	75(17)	442
	1982	99(23)	102(24)	132(31)	92(21)	425
Anand	1985	159(20)	215(27)	308(39)	107(13)	790
	1986	115(20)	129(22)	192(33)	152(26)	586
	1987	160(20)	172(22)	283(36)	177(22)	792
	1988	61(14)	157(35)	163(36)	66(15)	447

Note: Figures in the parenthesis represent percentage of the total WU.

used, soil type, amount of irrigation etc., are given in Table1. The water applied was measured through gravimetric lysimeter while meteorological data were collected from Agromet Observatory located near the lysimeter tank. Soil moisture was measured to a depth of 67.5 cm of the soil profile. The crop was sown during early July in Rahuri and Anand, and during late July in Bellary.

3. Results and discussion

3.1. *Water Use (WU)*

Rainfall during the groundnut growing season varied within narrow limits at Rahuri. The amount was rather low at Rahuri and Bellary both located in typically semi-arid, arid zone of the Deccan plateau. The range and the mean rainfall at Anand is rather large. At all stations, average rainfall is not adequate to meet the potential evapotranspiration (PE) demand and hence supplemental irrigation has to be provided for optimized crop production. Singh *et al.* (1968) at Hissar reported that groundnut crop sown in *kharif* season required four irrigations. Large temporal and spatial variability in evapotranspiration (ET) is due to microclimatic conditions and soil differences.

The data (Tables 1 & 2) show that at the same location, with the same groundnut cultivar, the water loss varied from year-to-year. The mean total evapotranspiration at Bellary and Rahuri was 460 and 410 mm respectively. It is slightly higher than the amount reported by Saini *et al.* (1973) for groundnut in Ludhiana but lower than the ET loss computed by Ghadekar and Patil (1989) for the Nagpur region. The figure of 660 mm for Anand, though large compared to the other two stations, compares favourably with 620 mm observed by Venkataraman *et al.* (1981) for Hyderabad, and 500- 700 mm determined by Kakade (1985).

It is seen from Table 2 that the duration of growth period has varied across stations and years. The total water use, therefore, cannot be compared objectively. Comparison of mean weekly water use to an extent helps to solve this problem (Table 1). It is observed that S-206 grown at Bellary uses 27 mm of water per week, while Phule-Pragati at

Rahuri used 29 mm per week. At Anand, JL-24 used about 32 mm per week. The average daily water used has varied between 3 and 5 mm which is similar to the values obtained by Metochis (1993) for groundnut grown in the Mediterranean environment.

Analysis of the evapotranspiration demand (PE) *vis - a - vis* the water supply revealed that this is invariably not met in full at Bellary and Rahuri. Even at Anand, out of every four years, PE exceeds the cumulative ET (ET_c) in two years. On an average, at Bellary 60% of the demand is met, however, at Rahuri and Anand over 70% and 95% of the demand is satisfied respectively.

Cumulative ET_c and PE for selected years indicate that total demand is hardly met in any year at any of the three selected stations. At Anand, however, in the year 1987, ET_c was fully met between weeks 32 and 38 (Aug - Sept). In most parts of its growth cycle, groundnut is exposed to drought of various magnitudes, particularly after the seedling stage. Initially the rate of water use by groundnut has been observed to be of similar order at all places, but it increased steadily thereafter. During this period PE was low due to the associated low radiation load. At this stage of growth, the crop has LAI of less than 1 and soil cover is greater than 20%. As such, evapotranspiration was mainly due to soil evaporation. Thereafter, as crop canopy developed and soil cover increased, ET became increasingly dependent on plant factors (Ritchie 1971). After 70-80 days of sowing the crop canopy fully covered the soil. At this stage ET increased substantially till about 100 DAS at Anand and Bellary, and till about 80 DAS at Rahuri.

In controlled lysimetric studies, Kassam *et al.* (1975) observed that the peak ET of groundnut occurred shortly before peak LAI. Though different varieties tested in this experiment have different maturity durations, the average consumption of water was observed to be substantially higher at Anand compared to Bellary and Rahuri. The rainfall at all the test locations is clearly not able to meet ET_c in full, except in some years. In order to sustain groundnut production, recourse has to be taken to irrigate the crop. It is also observed that water input (*i.e.*, rainfall + irrigation) at Anand and Rahuri, the amount of water supplied far exceeded the seasonal PET. Lenka and Mishra (1973) reported that water requirement of groundnut has 830 mm out of which 690 mm were met through irrigation. At Bellary, inspite of additional irrigation, ET_c was never met in full. Inspite of this, Bellary recorded highest pod yield exceeding 3000 kg/ha. On the other hand, though sufficient irrigation was provided the yield of groundnut at Rahuri was low. These data suggest that groundnut S-206 at Bellary uses water more efficiently as compared to JL-24 at Anand, or Phule-Pragati at Rahuri.

3.2. *Phasewise water consumption and water use efficiency*

Table 2 contains phasewise WU by groundnut at the 3 test locations during various years. Considerable variation is noted in WU. Large year-to-year variations are seen at the same location. However, water requirements are comparable in different phases across locations. It is observed, in general, that the plant uses the largest, *i.e.*, nearly 30% of its total water use between pod formation and pod development stages of growth.

The water use efficiency (WUE) has been computed as the ratio of pod yield to the water consumed. The data are shown in Table 1. WUE is low, *i.e.*, 3kg/ha/mm at Anand followed by Rahuri (>4 kg/ha/mm). Water use efficiency at Bellary is the highest at 6.4 kg/ha/mm. Thus groundnut S-206 is, perhaps, ideally suited for dry farming tracts of Bellary region.

3.3. *Soil water use*

The relative contribution of soil evaporation to ET decreases with an increase in crop canopy. The ratio ET_c/PE depends largely upon soil moisture status in the root zone. At Bellary, there was hardly any event when the SM depleted to less than 50%. At Rahuri, the sample size was too small to merit consideration. It is evident that the enhancement of soil moisture (SM) does directly influence ET. The correlation between SM below 50% of field capacity (FC) and the corresponding ET was r=0.55 at Anand. The soil moisture depleted significantly from emergence to peg formation of the crop.

Sarma and Sivakumar (1990) also observed reduced evapotranspiration during emergence to peg initiation stage at Patancheru (Andhra Pradesh).

Normally ET_c is conditioned by soil moisture after occurrence of critical level of water extraction. The ET_c/PE ratio has been computed for Anand and Bellary, it remains nearly constant for different values of SM. This is confirmed by the insignificant correlation observed between these two parameters.

3.4. *Yield - ET relationship*

Water is the most critical factor in determining plant survival, development and production. Crop growth is related to availability of soil moisture during growing season. The first report to establish relationship of biomass with ET was published by DeWit (1958) who assessed the value of the "*m*" co-efficient for a dryland crop at about 290 kg/ha/day in the great plains of USA. The dry matter production is influenced by the choice of cultivar and soil. The sample size was relatively small (3 stations) in this study. Therefore, a pooled analysis was conducted. A linear rela-

tionship exists between the WU and yield. Blanchet *et al.* (1977) found that soyabean grain yield and production of total dry mass are linearly related to amount of water consumed. The linear relationship observed in our study is given below:

$$Y = 1.9WU + 1297$$

where Y denotes yield (kg/ha).

The correlation coefficient between WU and yield was 0.50 and signifies the dependence of yield on the water use in groundnut production in marginal lands of semi-arid tropics.

4. Conclusions

The following conclusions can be drawn from the study:

(*i*) The peak period of soil water use occurs between peg formation and pod development stages of groundnut. During this period the relative evapotranspirative rate (*i.e.*, ET_c/PE) is also the highest.

(*ii*) The water use efficiency in groundnut crop varies temporally and spatially. It is highest at Bellary followed by Anand and Rahuri.

(*iii*) Pod yield was found to bear a linear relationship with seasonal evapotranspiration.

(*iv*) The relative evapotranspiration remains nearly constant for different soil moisture regimes, when the soil moisture is below 50% of the field capacity, the ET_c/PE ratio is significantly correlated with the soil moisture.

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