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AGRONOMY

Effect of Sulphur and different Irrigation Regimes on PAR Distribution, Canopy Temperature, Yield and Water Use Efficiency of Groundnut (*Arachis hypogaea* L.)

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ABSTRACT

A field experiment was conducted to study the effect of different levels of irrigation and sulphur on leaf area index, on distribution pattern of photosynthetically active radiation, consumptive use, water use efficiency, Canopy-Air Temperature Difference as well as yield attributes and yield of summer groundnut (*Arachis hypogaea*) during two consecutive years (2009 and 2010) at the 'C' block farm of Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia, West Bengal during pre-kharif season in a sandy loam soil with 24 treatment combinations (eight irrigation level in main plot and three level of sulphur in sub-plot) in a split plot design replicated thrice. The study revealed that both the levels of irrigation and sulphur significantly influenced all the yield attributing characters and the kernel yield. The highest values of yield attributing characters and kernel yield were recorded when sulphur applied @ 15 kg ha^{-1}. The highest consumptive use, and water use efficiency were recorded under three irrigations applied at flowering, pegging and pod filling stage followed by two irrigations at pegging and pod filling stage. No irrigation treatment recorded lower photosynthetically active radiation absorption percentage value but higher photosynthetically active radiation extinction coefficient and Canopy-Air Temperature Difference value as compare to irrigation treatments, respectively.

Highlights

- Irrigation applied at flowering, pegging and pod filling stage (I8) along with sulphur applied @ 15 kg ha^{-1} (S2) gave the best result with maximum crop water-use efficiency and no irrigation treatment (I1) resulted lower PAR absorption percentage but comparatively higher PAR extinction coefficient.
- The canopy air temperature difference could indicate extreme stress as evident from higher CATD value recorded from no irrigation treatment as compared to other irrigation treatments.

Keywords: Groundnut, irrigation, sulphur, water use efficiency (WUE), PAR absorption percentage, PAR extinction coefficient and CATD

Groundnut (*Arachis hypogaea* L.) is a major oilseed crop after rape-seed and mustard, mostly grown during winter as well as summer seasons under irrigated condition. The ever increasing demand for edible oil calls for in enhanced production of oilseed under limited land and water resource following improved agronomic management. Economic use of water applied at important physiological growth stages during summer seasons can save the water as well as nutrient without hampering the potential yield of groundnut (Patra *et al.,* 1998). The groundnut grown on light textured soils generally suffers from sulphur deficiency due to leaching of SO_4^{2-}. The crop responds significantly to the application of sulphur (Singh *et al.*, 1998) which is involved in the bio-synthesis of primary metabolites such as methionine, cysteine and cystine amino acid, for improving the yield and quality of oil seed crops and obtaining higher yield under balanced fertilization. Therefore, an attempt was made to study the optimum scheduling of irrigation and sulphur for higher groundnut yield under new alluvial zone of West Bengal during summer seasons.

Solar energy plays vital role in crop growth and development by influencing the thermal and light environment for optimizing metabolic processes leading to higher production. The exchange of radiation, water and carbon among soil, vegetation and the surrounding microclimate is the primary factor for growth and production of crop. The amount of photosynthetically active radiation (PAR) absorbed by the crop depends upon the area and distribution of leaf as well as the canopy architecture and cropping geometry. Conversely, the absorption of photosynthetically active radiation is directly related the photosynthesis and consequent crop growth keeping other factors at optimal level. Thus, there exists an auto correlation between plant growth and photosynthetically active radiation absorption in long range. On the other hand, the disposition of solar radiation is linked to the thermal status of crop microclimate.

A plant is sometimes subjected to undue heat load or thermal stress by radiation from its environment. Under such condition, transpiration helps in cooling of crop canopy through latent heat transfer. Hence, the canopy temperature indicates the extent of moisture stress in plant. Canopy under severe moisture stress tends to be warmer than that under unrestricted supply of moisture (Banerjee *et. al.*, 2002). Hence, the distribution of photosynthetically active radiation within crop canopy and the thermal stress of crop in terms of canopy-air-temperature-difference (CATD) as influenced by irrigation and sulphur treatment are studied in the present experiment.

MATERIALS AND METHODS

The field experiment was conducted during pre-kharif season [February to June] in sandy loam soil of Bidhan Chandra Krishi Viswavidyalaya, 'C' block farm, Kalyani, Nadia, West Bengal to assess the crop moisture stress in terms of canopy temperature. The field is situated at the 23°N latitude and 89°E longitude, at an elevation of 9.75 m above mean sea level (approximately). The crop received total rainfall of about 332.9 mm during growing season of 2009 and 307.1 mm during 2010. The maximum and minimum temperatures during that period were 41°C and 16°C, respectively. The experiment was laid out in a split plot design, having eight level of irrigation (I1 – no irrigation; I2 – irrigation at flowering stage; I3 – irrigation at pegging stage; I4 –irrigation at pod filling stage; I5 – irrigation at flowering and pegging stage; I6 – irrigation at flowering and pod filling stage; I7 – irrigation at pegging and pod filling stage; I8 –irrigation at flowering, pegging and pod filling stage) in main plots andthree level of sulphur (S_1 –sulphur @ 0 kg ha^{-1}: S_2 – sulphur @ 15 kg ha^{-1}: S_3 – sulphur @ 30 kg ha^{-1}) in sub-plots. Source of sulphur fertilizer was elemental sulphur (85%).

Groundnut (cv. GPBD – 5) seeds were sown maintaining a plant spacing of 30 cm × 10 cm in experimental plot size of 4 m × 3 m. The recommended dose of fertilizer was 20:40:40 kg ha^{-1} nitrogen (N), phosphorous (P_2O_5) and potash (K_2O), respectively, in form of urea, diammonium phosphate and muriate of potash for N, P_2O_5 and K_2O, respectively.

Water use efficiency (WUE) was computed using the following standard formulae:

$$\text{WUE (kg ha}^{-1}\text{ mm}^{-1}) = \frac{\text{Yield (kg ha}^{-1})}{\text{ET or CU value (mm)}}$$

ET = Evapotranspiration

CU = Consumptive Use

Observation on distribution of photosynthetically active radiation (PAR) in groundnut canopy were recorded using line quantum sensor (Li-Cor: Model: LINE QUANTUM, NO: LQA-2403) at 12:00 hour local time when radiation from sun is maximum. To get the absorbed PAR by the crop canopy, the observation were taken as incident (PAR_{inci}) and out reflected (PAR_{refl}) radiation above the canopy by positioning the sensor in upward and downward directions, respectively. The transmitted

(PAR_{trans}) and soil reflected ($PAR_{soil\ refl}$) radiations were recorded by placing the sensor below the plant canopy but 15 cm above the soil surface in upward and downward directions, respectively. The absorbed PAR percentage is then calculated as:

$$PAR_{abs}\ (\%) = [(PAR_{inci} - PAR_{refl} - PAR_{trans} + PAR_{soil\ refl}) / PAR_{inci}] \times 100 \quad \ldots(i)$$

The line quantum sensor was exposed across the rows at above and below the canopy without disturbing the plant stand.

The PAR extinction coefficient of groundnut crop computed from the PAR measurement and leaf area index following Beer's law as given by Monsi and Saeki (1953).

$$I = I_0\, e^{-k*LAI} \quad \ldots(ii)$$

Where, I = Transmitted radiation (below the crop canopy); I0 = Incident radiation (above the crop canopy); K = Extinction coefficient and LAI = Leaf area index. The LAI (ratio of leaf area and land area) was estimated by destructive sampling from each plot at critical days of observation.

The canopy temperature was measured using Infra-red thermometer (Metravi, Model-MT-2) and air temperature was measured using thermograph kept under shade near the experimental field during 2010 crop season for assessment of impact of water and sulphur treatment on thermal status of canopy microclimate. The canopy-air-temperature-difference (CATD) was computed as:

$$CATD = \text{Canopy temperature} - \text{air temperature} \quad \ldots(iii)$$

The statistical analysis of the observed data was done using the method of Gomez and Gomez (1984) for interpretation.

RESULTS AND DISCUSSION

Leaf Area Index

The leaf area index (LAI) estimated as leaf area per unit land area is an indicator of crop growth. Higher LAI usually represents higher crop growth. In the present experiment, LAI was estimated through destructive sampling from each treatment at 14 days interval from 21 days after sowing (DAS) to harvest. The effect of irrigation regime and level of sulphur on LAI pooled over the years 2009 and

Table 1: Effect of levels of irrigation and sulphur on Leaf Area Index of groundnut (pooled over two years)

Treatment	21 DAS	35 DAS	49 DAS	63 DAS	77 DAS	91 DAS	105 DAS	At Harvest
Level of Irrigation								
I_1	0.090	0.249	0.680	1.53	1.67	1.60	1.53	1.49
I_2	0.102	0.297	0.727	2.00	2.16	2.13	2.10	2.05
I_3	0.109	0.281	0.751	2.13	2.27	2.20	2.17	2.12
I_4	0.094	0.264	0.723	1.88	1.95	1.75	1.72	1.67
I_5	0.115	0.325	0.868	2.59	2.72	2.67	2.63	2.58
I_6	0.111	0.308	0.785	2.41	2.45	2.38	2.35	2.30
I_7	0.124	0.284	0.792	2.49	3.10	3.07	3.04	2.99
I_8	0.129	0.375	0.911	2.83	3.44	3.37	3.34	3.29
$SE_{m\ (\pm)}$	0.012	0.019	0.051	0.17	0.22	0.26	0.25	0.25
CD at 5%	N.S.	0.062	0.165	0.54	0.71	0.85	0.83	0.81
CV (%)	37.31	27.14	27.49	31.43	37.21	40.25	45.60	45.66
Level of Sulphur								
S_1	0.104	0.285	0.680	2.07	2.23	2.22	2.17	2.12
S_2	0.116	0.312	0.861	2.36	2.71	2.61	2.57	2.52
S_3	0.108	0.297	0.798	2.27	2.47	2.37	2.34	2.29
$SE_{m\ (\pm)}$	0.004	0.007	0.019	0.08	0.13	0.10	0.10	0.10
CD at 5%	N.S.	0.019	0.055	0.21	0.36	0.29	0.29	0.28
CV (%)	22.53	15.50	17.30	23.41	36.19	29.23	29.85	30.03

2010 is presented in table 1. It is evident from the table 1 that the LAI increased with the advancement of crop stage upto 77 DAS and decreased slightly thereafter. The peak LAI varied in the range of 1.67 to 3.44 among the different irrigation and sulphur treatments.

The effect of irrigation on LAI was found to be significant at 35 DAS and thereafter till harvest. It is evident from table 1 that application of three irrigations at flowering, pegging and pod filling stages (I8) recorded the highest LAI throughout the growth period whereas no irrigation (I_1) treatment recorded lowest LAI. The treatments I5 (two irrigations at flowering and pegging stages), I_6 (two irrigations at flowering and pod filling stages) and I_7 (two irrigations at pegging and pod filling stages) recorded higher LAI than the other irrigation treatments. At initial stage (35 DAS) I5 and I_6 performed better than I_7 with respect to LAI, whereas, towards later growth phase I_7 has distinct advantage over I5 and I6. This is confirming the result of Mandal *et al.* (2006).

Level of sulphur significantly influenced LAI of groundnut plant at all the dates experimentation 21 DAS (Table 1). Among the sulphur treatments, sulphur applied @ 15 kg ha^{-1} (S2) gave rise better LAI followed by sulphur @ 30 kg ha^{-1} (S3) and they were statistically at par irrespective of different dates of observation. However, the lower LAI was produced under no sulphur (S1) treatment in different dates of experimentation. The significant increase of LAI could be due to optimum dose of sulphur which helped in chlorophyll formation and CO_2 assimilation that attributed to an increase in leaf size of groundnut as reported by Naumba and Edje (1976).

PAR balance components

The incident PAR and the percentage of transmission, absorption and reflection were averaged for the peak period of each observation day (11:00 hrs to 13:00 hrs for location) starting at 55 DAS

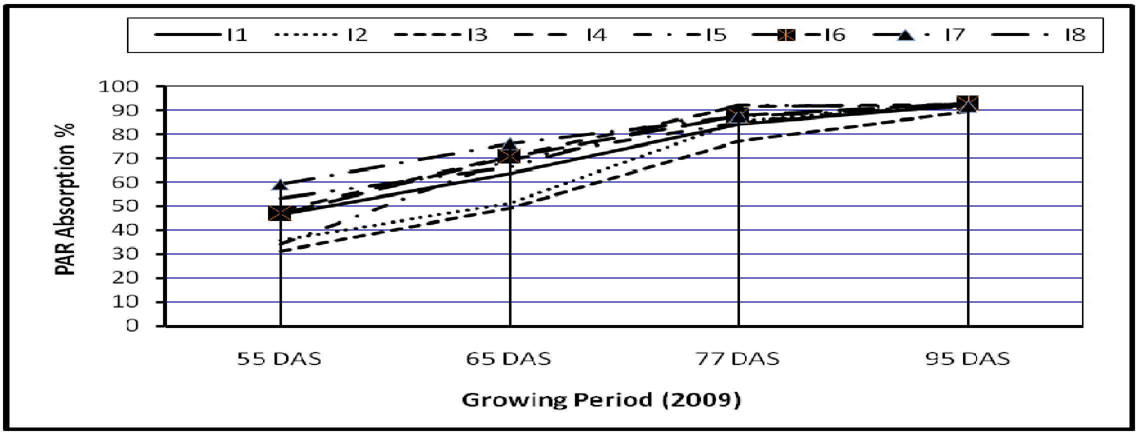

Fig. 1: Effect of level of irrigation on PAR Absorption Percentage of groundnut (2009)

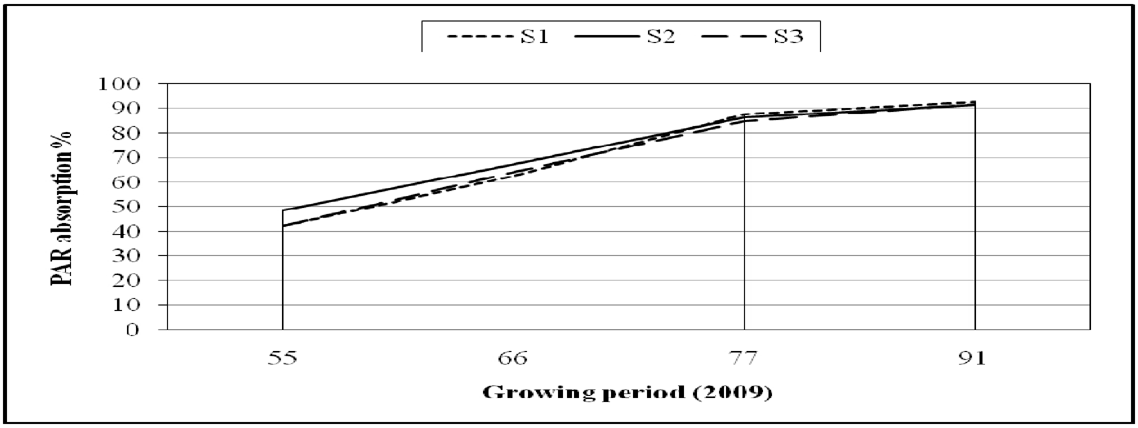

Fig. 2: Effect of level of sulphur on PAR Absorption Percentage of groundnut (2009)

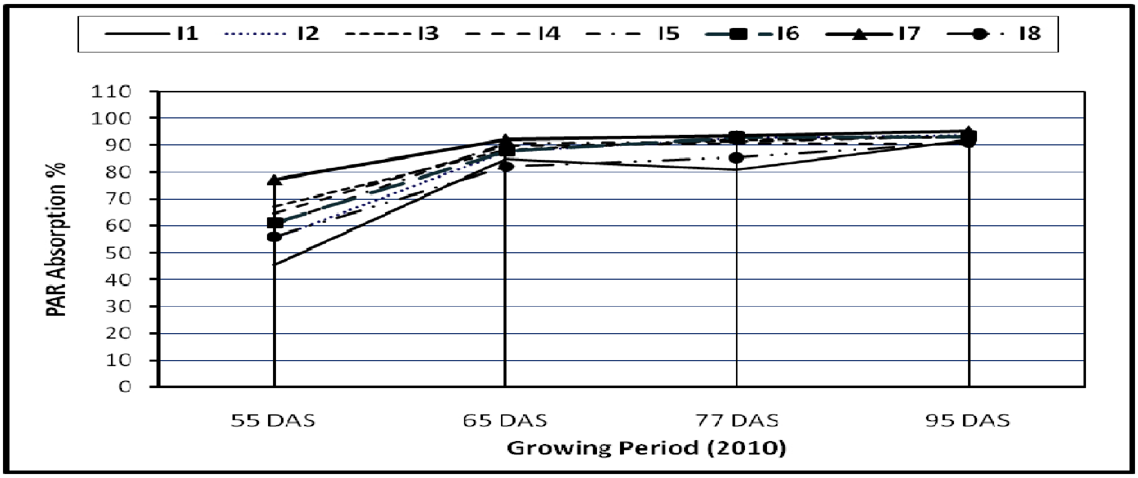

Fig. 3: Effect of level of irrigation on PAR Absorption Percentage of groundnut (2010)

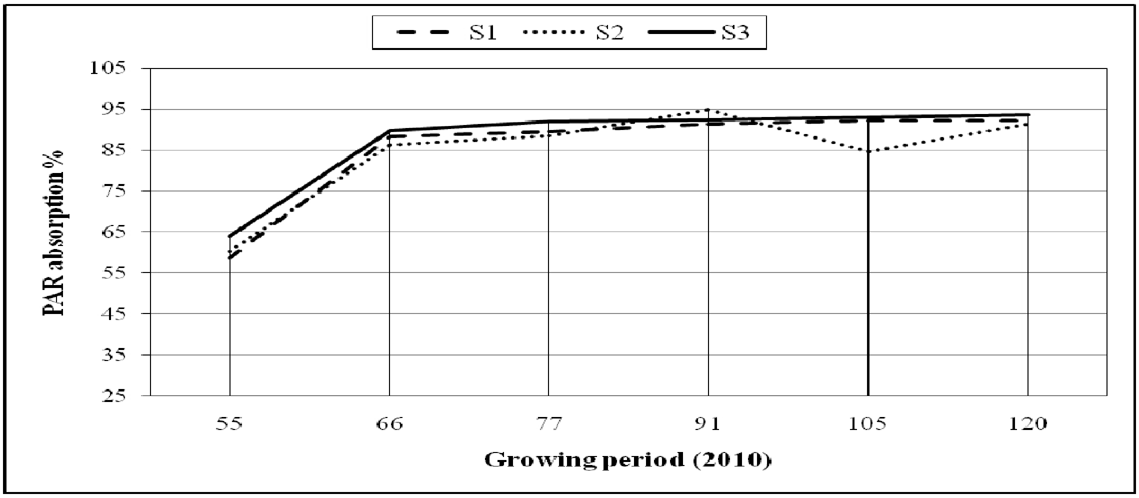

Fig. 4: Effect of level of sulphur on PAR Absorption Percentage of groundnut (2010)

towards maturity at an interval of 14 days and are graphically presented in Fig. 1 to represent the general change in radiative behaviour of groundnut plant with growth stages. As the LAI was very less at the initial stage of the crop, the observations were taken at 55, 65, 77 and 95 DAS during both years of experimentation. Several researchers have studied on PAR absorption and also PAR extinction coefficient (Gonzalez and Calbo, 2002 and Sheehy *et al.*, 2008).

It is evident from the figure (Fig. 1 and 3) that the PAR absorption percentage is fluctuating in the range of 31% at 55 DAS to near 94% at 95 DAS in 2009 and 45% at 55 DAS to near 95% at 95 DAS in 2010 irrespective of irrigation treatments. The PAR absorption percentage by the groundnut crop canopy increased with age of the plant; remains almost constant thereafter towards maturity stage of the crop. The irrigated treatments showed better canopy proliferation that was evident from higher LAI and subsequent increase in PAR absorption percentage.

It is evident from the figure (Fig. 2 and 4) that the PAR absorption percentage is fluctuating in the range of 41% at 55 DAS to near 93% at 95 DAS in 2009 and 58% at 55 DAS to near 94% at 95 DAS in 2010 irrespective of sulphur treatments. The PAR absorption percentage also followed the same trend as like irrigation treatment. The sulphur treated plants showed better PAR absorption percentage.

PAR Extinction Coefficient

The PAR extinction coefficient (k) that describes the horizontal proliferation of canopy structure is a

Table 2: Effect of level of irrigation and sulphur on PAR Extinction co-efficient (k) of groundnut (2009)

Treatment	55 DAS	65 DAS	77 DAS	95 DAS
Level of Irrigation				
I_1	1.03	0.81	1.46	2.44
I_2	0.66	0.42	1.15	1.88
I_3	0.67	0.37	1.23	1.49
I_4	0.98	0.74	1.67	2.31
I_5	0.54	0.54	0.86	1.36
I_6	0.89	0.67	1.11	1.72
I_7	1.23	0.72	0.82	1.13
I_8	0.97	0.46	1.09	0.93
Mean	0.87	0.59	1.17	1.66
SD (±)	0.23	0.17	0.28	0.54
CV (%)	26.12	28.31	24.23	32.44
Level of Sulphur				
S_1	0.95	0.62	1.37	1.84
S2	0.87	0.58	1.07	1.36
S_3	0.80	0.57	1.08	1.77
Mean	0.87	0.59	1.17	1.66
SD (±)	0.07	0.03	0.17	0.26
CV (%)	8.36	4.50	14.59	15.88

critical parameter with respect to the distribution of light in crop canopy and hence the photosynthesis potential of the crop. Lower value of k is associated with more penetration of light towards the lower part of the canopy at a given LAI. The present study indicated that the PAR extinction coefficient varied widely from 0.66 to 1.03 at 55 days after sowing. The k value decreased at 65 DAS to a range of 0.37 to 0.81 implying erect growth during that phase. Again the k-value increased remarkably indicating more horizontal expansion of the canopy towards the later phases (77 and 95 DAS).

It is evident from the table that the PAR extinction coefficient varied in the range from 0.37 to 2.44 in 2009 and 0.89 to 2.27 in 2010 irrespective of the treatments (Table 2 and Table 3). This implies better canopy proliferation at the initial stage during 2010 as compare to the previous year. The PAR extinction coefficient was much higher at the initial stages (55 DAS) when the leaf area was in the process of enlargement followed by a stiff decrease at about 65 DAS which coincided with the pod development stage. This might be the reason for better light penetration during active vegetative stage even at a higher LAI. This could have lead to lower extinction coefficient. Then, the PAR extinction coefficient increased sharply towards pod maturity stage which implied the horizontal proliferation of the existing leaves that did not add to leaf area but attenuated PAR more efficiently to restrict penetration of PAR through the canopy. Among the irrigation treatments, the highest PAR extinction coefficient was recorded in no irrigation treatment (I_1) and the lowest PAR extinction coefficient was recorded in three irrigations applied at flowering, pegging and pod filling stage (I_8) treatment. The lower PAR extinction coefficient might be due to better vertical growth and even distribution of leaves that facilitated efficient light penetration into the crop canopy when appropriate irrigation was applied at critical growth stages.

It is evident from the table that the PAR extinction coefficient varied in the range from 0.57 to 1.84 in 2009 and 1.10 to 1.79 in 2010 irrespective of the treatments (Table 2 and Table 3). The effect of sulphur on PAR extinction coefficient followed the same trend as like the effect of irrigation treatment which was much higher at the initial stages (55 DAS) when the leaf area was in the process of enlargement followed by a decreasing trend at about 65 DAS. Then, the PAR extinction coefficient increased sharply towards pod maturity stage.

Among the sulphur treatments, the highest PAR extinction coefficient was recorded in sulphur @ 0 kg ha^{-1} treatment (S_1) and the lowest PAR extinction coefficient was recorded in sulphur @ 15 kg ha^{-1} (S_2) treatment. The lower PAR extinction coefficient might be due to better utilization of sulphur by the crop.

Soil Moisture Parameter

Moisture depletion pattern of groundnut crop was influenced by irrigation level. The data presented in the table (Table 4) showed that maximum depletion occurred from first layer (0-15 cm) followed by third layer (30-45 cm) and second layer (15-30 cm), respectively, at all the level of irrigation. More amount of soil moisture utilization by the crop from surface (0-15 cm) layer might be due to more root concentration in this layer. Soil moisture depletion was maximum under three irrigations applied at flowering, pegging and pod filling stage (I_8) and the lowest depletion of soil moisture at different depths was found in no irrigation (I_1) treatment.

The highest CU (639.04 mm), and WUE (6.16 kg ha^{-1} mm^{-1}) were recorded under three irrigations applied at flowering, pegging and pod filling stage (I_8) followed by two irrigations at pegging and pod filling stage (I_7) and the lowest CU (387.00 mm), and WUE (4.64 kg ha^{-1} mm^{-1}) (Table 4) were recorded under no irrigation (I_1) treatment. Similar results were observed by Chavan *et al.* (1999).

Canopy Temperature Parameter

The lower canopy temperature is an indicator of higher rate of evapotranspiration from the soil-plant system. Thus, the difference between canopy temperature (Tc) and air temperature (Ta), termed as CATD (CATD= Tc-Ta) is an indicator of the rate of evapotranspiration loss from the system.

It is evident from the figure (Fig. 5) that the CATD of all the irrigation regimes varied widely in the range of -8 ^{o}C to near -4 ^{o}C at the initial stage of crop growth. The figure clearly showed that with the advancement of crop growth phase, Canopy-Air Temperature Difference (CATD) increased which implied that the demand of moisture increased with the advancement of growing period. No irrigation treatment (I_1) resulted positive (more than zero) CATD value throughout the growing period except at 72 DAS and 120 DAS which means rainfed treated plants faced moisture stress almost throughout the crop period. The negative CATD value of rainfed treatment (I_1) at 72 DAS and 120 DAS was due

Table 3: Effect of level of irrigation and sulphur on PAR Extinction co-efficient (k) of groundnut (2010)

Treatment	55 DAS	65 DAS	77 DAS	95 DAS	105 DAS	At harvest
Level of Irrigation						
I_1	1.07	1.29	1.23	1.95	1.74	2.15
I_2	1.30	1.22	1.44	1.72	1.85	1.59
I_3	1.73	1.18	1.46	1.68	1.75	1.28
I_4	1.85	1.56	1.55	2.00	2.27	1.77
I_5	1.26	1.16	1.17	1.50	1.26	1.31
I_6	1.39	1.09	1.43	1.49	1.17	1.75
I_7	2.37	1.54	1.29	1.42	1.43	1.16
I_8	0.93	0.89	0.96	1.00	1.32	1.26
Mean	1.49	1.24	1.32	1.59	1.60	1.53
SD (±)	0.47	0.22	0.19	0.32	0.37	0.34
CV (%)	31.65	18.00	14.73	20.15	23.13	22.30
Level of Sulphur						
S_1	1.63	1.35	1.38	1.50	1.70	1.63
S2	1.27	1.10	1.12	1.79	1.44	1.34
S_3	1.56	1.27	1.45	1.49	1.65	1.63
Mean	1.49	1.24	1.32	1.59	1.60	1.53
SD (±)	0.19	0.12	0.17	0.17	0.14	0.16
CV (%)	12.73	10.04	13.17	10.55	8.73	10.73

Table 4: Effect of level of irrigation on Soil profile moisture depletion (%), CU (mm) and WUE (kg ha^{-1} mm^{-1}) of groundnut (Mean of two years)

Irrigation Treatment	Soil profile moisture depletion (%) Depth of soil (cm)				CU (mm)	WUE (kg ha^{-1} mm^{-1})
	0 - 15	15- 30	30 - 45	45 - 60		
I_1	54.73	50.41	50.54	45.60	387.00	4.64
I_2	62.11	53.73	60.47	47.04	428.98	4.72
I_3	66.15	58.95	62.00	51.84	458.95	4.85
I_4	64.77	50.97	60.56	47.36	428.70	4.65
I_5	79.19	70.41	75.32	64.08	555.48	5.00
I_6	77.78	67.09	73.18	53.74	521.08	4.96
I_7	82.62	77.79	80.64	72.65	604.23	5.94
I_8	87.99	82.51	87.17	74.24	639.04	6.16

Table 5: Effect of levels of irrigation and sulphur on yield attributing characters and kernel yield (q ha^{-1}) of groundnut (pooled over two years)

Treatment	No. of plants m^{-2}	No. of pods plant^{-1}	No. of kernels pod^{-1}	100 kernels weight (g)	Kernel Yield (q ha^{-1})	Percent yield increase
Level of Irrigation						
I_1	18.53	18.48	1.541	22.91	12.18	
I_2	18.61	20.27	1.583	24.44	14.67	20.44
I_3	18.63	21.67	1.600	24.93	16.26	33.50
I_4	18.55	19.92	1.562	24.31	14.46	18.72
I_5	18.89	25.74	1.630	25.66	20.46	67.98
I_6	18.69	24.69	1.619	25.29	18.93	55.42
I_7	19.73	29.68	1.631	27.38	26.42	116.91
I_8	20.78	29.93	1.716	27.65	29.87	145.24
$SE_{m(\pm)}$	0.36	0.96	0.023	0.49	0.93	
CD at 5%	1.17	3.14	0.076	1.61	3.04	
CV (%)	7.98	17.19	6.17	8.25	20.64	
Level of sulphur						
S_1	18.76	20.71	1.544	22.90	14.10	
S_2	19.30	26.40	1.658	27.75	23.74	68.37
S_3	19.10	24.28	1.628	25.32	19.63	39.22
$SE_{m(\pm)}$	0.20	0.42	0.008	0.30	0.42	
CD at 5%	NS	1.19	0.023	0.84	1.20	
CV (%)	7.39	12.22	3.53	8.15	15.28	

to intermittent rainfall during that time. On the other hand, irrigation treatments did not show any positive CATD value in °C throughout the crop growth period which means irrigated treated plants did not face any moisture stress in that year during pre-kharif season. Several researchers have demonstrated the application of canopy air temperature difference for studying the moisture status of different crops (Jackson 1982, Prietro *et al.*, 1994 and Chakravarty 2006).

The figure (Fig. 6) showed that the CATD of all the sulphur treatments varied widely in the range of -5.5 °C to near -2.5 °C at the initial stage of crop growth. All the sulphur treatments resulted negative CATD value throughout the growing period except at 100 DAS. However, sulphur @ 30 kg ha^{-1} (S_3) showed higher CATD value than the other sulphur treatments.

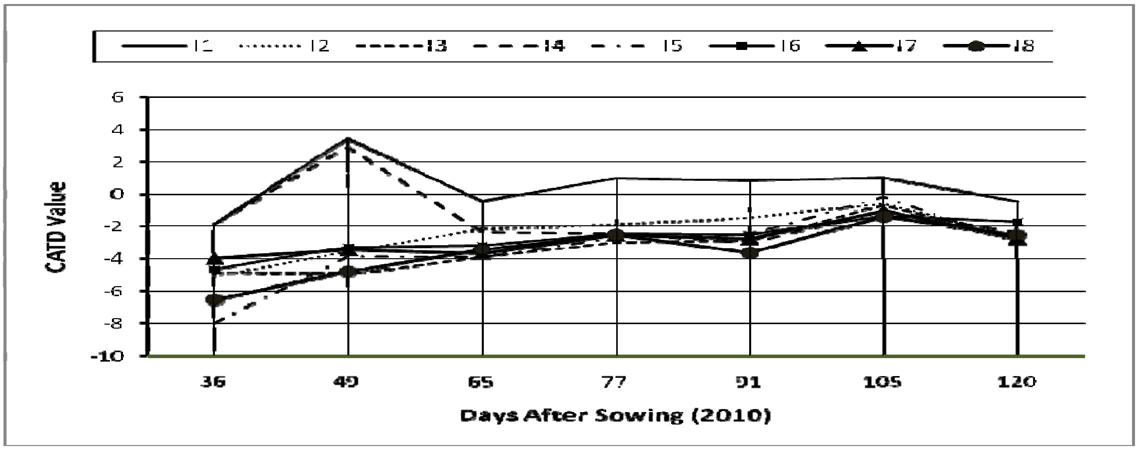

Fig. 5: Effect of irrigation on Canopy-Air Temperature Difference (CATD) (°C) of groundnut (2010)

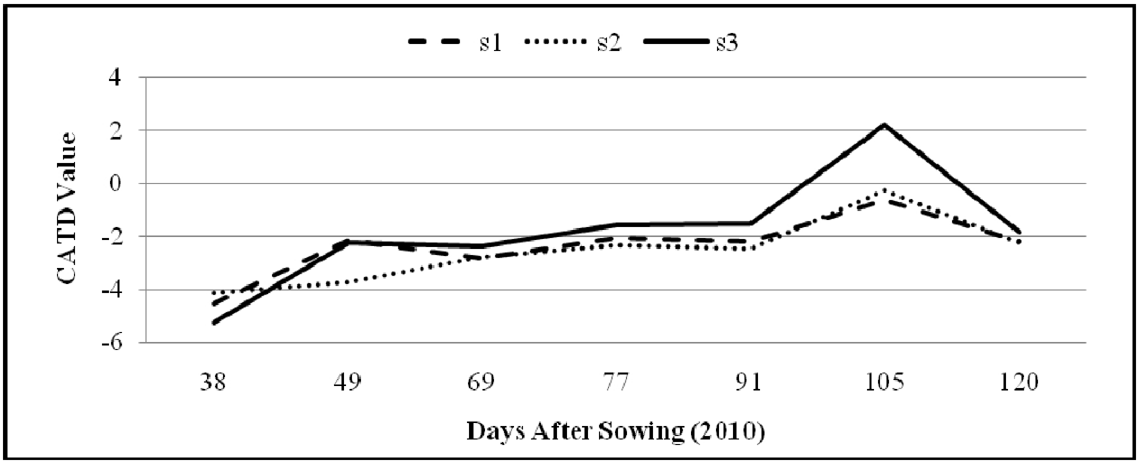

Fig. 6: Effect of sulphur on Canopy-Air Temperature Difference (CATD) (°C) of groundnut (2010)

Yield and Yield Components

Two years pooled data revealed that all the yield attributing characters were significantly influenced by the level of irrigation (Table 5).

The highest values of yield attributing characters [number of plant m^{-2}, number of pods $plant^{-1}$, number of kernels pod^{-1}, 100 kernel weight (g)] were recorded under three irrigations applied at flowering, pegging and pod filling stages (I_8) followed by two irrigations at pegging and pod filling stages (I_7) and they were statistically at par except number of kernels $plant^{-1}$. The lowest values of yield attributing characters were recorded under no irrigation treatment (I_1). This is in conformity with the results of Patra *et al.* (1998), Ghatak *et al.* (1997) and Jana *et al.* (1989).

The kernel yield (q ha^{-1}) was significantly influenced by the level of irrigation. The highest kernel yield (29.87 q ha^{-1}) was recorded under three irrigations applied at flowering, pegging and pod filling stage (I_8) followed by two irrigations at pegging and pod filling stage (I_7) and they were statistically at par (Table 5). The lowest kernel yield (12.18 q ha^{-1}) was recorded under no irrigation treatment (I_1). Irrigations applied at flowering, pegging and pod filling stage (I_8) and irrigations applied at pegging and pod filling stage (I_7) recorded an increase in kernel yield to the tune of 145.24% and 116.91% over control, respectively. This might be due to application of 3 irrigations at important physiologically critical growth stages helps to better utilization of moisture resulting in an increase of yield attributing characters and ultimately yield. Similar results were observed by Jana *et al.* (1989).

All the yield attributing characters were significantly influenced by the level of sulphur. The highest values of yield attributing characters were recorded when sulphur applied @ 15 kg ha^{-1} (S_2) followed by sulphur applied @ 30 kg ha^{-1} (S_3). The lowest values of yield attributing characters were recorded when sulphur applied @ 0 kg ha^{-1} (S_1) (Table 5). Chaplot *et al.* (1991) observed the same results.

The kernel yield (q ha^{-1}) was significantly influenced by the level of sulphur. The highest kernel yield (23.74 q ha^{-1}) was recorded when sulphur applied @ 15 kg ha^{-1} (S_2) followed by sulphur applied @ 30 kg ha^{-1} (S_3) (Table 5). The lowest kernel yield (14.10 q ha^{-1}) was recorded when sulphur applied @ 0 kg ha^{-1} (S_1). Sulphur applied @ 15 kg ha^{-1} (S_2) and sulphur applied @ 30 kg ha^{-1} (S_3) recorded an increase in kernel yield to the tune of 68.37% and 39.22% over control, respectively (Table 5). This might be due to increased photosynthate and their subsequent translocation to storage organ resulted in better fill up of production. This is in conformity with the results of Rathee and Chahal (1977).

CONCLUSION

Thus, it could be concluded that irrigation applied at flowering, pegging and pod filling stage (I8) along with sulphur applied @ 15 kg ha^{-1} (S_2) gave the best result with maximum crop water-use efficiency and no irrigation treatment (I_1) resulted lower PAR absorption percentage but comparatively higher PAR extinction coefficient. This implies that under moisture stress condition the leaf area index decreased appreciably whereas, lower LAI led to more horizontal orientation of leaf that could record comparatively higher PAR extinction coefficient of the crop canopy as a tendency of plant to harvest maximum photosynthetically active radiation under limiting condition. However, the canopy air temperature difference could indicate extreme stress as evident from higher CATD value recorded from no irrigation treatment as compared to other irrigation treatments, respectively.

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