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Variations in leaf temperature, plant internal resistance, photon requirement and transpiration of pigeonpea under bare and mulched soil conditions

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सार—अरहर के पत्ते के वाष्पोत्सर्जन, उसके तापमान, पौधे की विसरणशील प्रतिरोधकता और मात्रा में परिवर्तन का पता कृषि मौसमविज्ञानिक लक्षणों में लगाने के लिए गुजरात कृषि विद्यालय, आनन्द के कृषि फार्म में अरहर पर 1992 तथा 1993 की फसल के दौरान किए गए प्रयोग के परिणामों को इस शोधपत्र में प्रस्तुत किया गया हैं, यह प्रयोग खरपतवार वाले और खरपतवार रहित खेतों में खड़ी फसल पर तीन स्तरों पर किया गया।

विश्लेषण से पता चला कि पत्ते का तापमान खरपतवार रहित खेतों में अधिक होता है जहां खरपतवार वाले खेतों की तुलना में वाष्पोत्सर्जन कम होता है। दोनों तरह के उपचारों में स्टोमी प्रतिरोधकता तथा मात्रात्मक आवश्यकताओं में काफी समानता है। सुबह तथा शाम को स्टोमी चालकता अधिक होती है।

ABSTRACT. The paper presents the results of an experiment conducted during 1992 and 1993 crop seasons at the farm of Gujarat Agricultural University. Anand on pigeonpea to determine variations in agro-meteorological characteristics of leaf, transpiration. leaf temperature, plant diffusive resistance and quanta were considered at three levels within the crop canopy in mulched and unmulched fields.

The analysis revealed that leaf temperature is more in unmulched field where transpiration rates are lower than the mulched field. Stomatal resistance and the quantum requirements nearly match in both the treatments. Stomatal conductance attains large values in morning and evening hours.

Key words — Pigeonpea. Mulch, Leaf temperature. Stomatal resistance, Transpiration, Quanta.

1. Introduction

Economic production of agricultural crops is a synthesis of two natural resources. *viz.,* light and water and the nutrients. into bio-mass. Efficiency of these resources is largely influenced by management. particularly water management and it influences not only the crop production but helps in the selection of ideal row and plant spacing, plant population density etc. Pigeonpea is an important pulse, largely used in India, to supplement protein deficiency. The plant-stand survival and productivity depends to a large extent on the availability of moisture. As a result, water use efficiency and crop productivity are important factors in pigeonpea production.

Mulch modifies the energy balance near the ground surface. Naturally we can expect it to modify the moisture and energy availability to plants and hence. the water use efficiency. Different mulches have moderating influence of various degree on soil temperature and surface energy balance (Waggoner *et al.* 1960). When moisture becomes a limiting factor, crops under mulch appear to grow well and yield more, particularly in winter climates (Rosenberg *et al.* 1983). As energy absorption and emission properties depend on the nature of the surface, different mulching materials affect plant water and energy use pattern differently. For instance, black plastic mulch has been found to reduce water use in pineapple in Hawai (Ekern 1967), the response being significant in winter. Fairbourn (1973) observed gravel mulch to consume more water than vegetative mulch and improve yields of crops like corn. sorghum and tomatoes except soyabean. Bitumen mulch of 1-2 mm thickness was noted by Phipps and Cochrane (1975) to increase corn yield in England. Increase in sweet corn yield and advance of sulking and harvest by nearly 6 days was also noticed by Andrew *et al.* (1976) in Wisconcin (USA).

Effect of mulch on pigeonpea does not seem to have attracted much attention in India. Pigeonpea is an important long duration pulse crop in India. It is generally sown mixed with maize, sorghum or

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cotton during kharif season. Like any crop, use of mulches modifies the water use efficiency. As such with suitable cropping and mulch practices it may be possible to reduce water use and at the same time increase productivity. With this aim in view the present study has been undertaken.

This has been done by examining the effect of mulching on leaf temperature, stomatal resistance, conductance, quanta requirements and the transpiration rates.

2. Data

An experiment was conducted at the Gujarat Agricultural University, Anand for this purpose, during July to December 1992 and 1993. Using two lysimeters, kept 45 m apart, one lysimeter at the experimental site was covered with single sheet mulch of black polythene material and of 0.5 mm thickness. The other lysimeter was used as a control. Each lysimeter was covered by a single sheet of $5 \times 5\ m^2$ dimensions. Similarly, $3 \times 1.5\ m^2$ adjoining plot was covered with the single sheet mulch and an equal area nearby left uncovered for use as control. Rainfall, temperature, humidity, evaporation etc. data was recorded daily at a nearby observatory. GT-100 variety of pigeonpea was grown in both the years.

Anand belongs to the semi-arid zone having predominantly black, clay soil. It receives normal annual rainfall of 879.6 mm, over 90% of which falls during the monsoon season (June-September). The leaf and air temperature, stomatal resistance, photon requirements and transpiration rates were observed by steady state porometer. These observations were made at three canopy levels, *viz.*, the top, the middle and the bottom. The lysimeter observations were taken daily at 0700 hr. The field was subjected to the same agronomic treatments at the lysimeter tanks. Surface irrigation was provided on 5 occasions in 1992 and 3 in 1992, the amounts ranging from 60 to 120 mm (with a mean of 85 mm per irrigation) and 70 to 95 mm (mean = 80 mm) in these two years respectively.

The leaf temperature, stomatal resistance and photon requirements were measured from flowering to pod formation. This is because these measurements require a fairly well developed canopy. The observations were taken at an interval of 15 days in 1992 when the crop was 72 days' old while in 1993, these observations were taken weekly after 77 days of sowing. The pigeonpea being a long duration crop, its growth and development is rather slow. The analysis for the above elements is thus based on 5 and 9 observations in 1992 and 1993 respectively. Transpiration rates were calculated by taking harmonic average of aboxial and adaxial leaf surfaces. For this purpose fully developed leaves at the top, middle and bottom of the canopy were randomly selected. All these observations were taken after the evaporation of dew from leaf has already occurred, *i.e.*, at 0900 hr and then at 1100, 1400 and 1600 hr.

3. Results and discussion

3.1. *Temperature profile in pigeonpea canopy*

Temperature measurements within any crop canopy are quite different from those above the crop. The profiles are dependent on the availability of moisture and hence different temperature pattern could be expected when the crop is under mulch than when it is bare. The mean temperature in the three layers based on 14 observations in the two years is given in Table 1. The leaf temperatures at each layer, when subjected to χ^2 test, did not reveal any statistical significance within the layer. The root mean square difference between the two trials was 0.5. Maximum temperature occurs near the level where canopy is well developed with highest leaf area index (LAI). It is this level which absorbs maximum radiation load. Below this level as may be seen in the table, there is a temperature inversion, which is more conspicuous in the unmulched treatment. Level to level, the values when the surface is mulched is lower than in the unmulched experiment. In the open (unmulched) field, the leaf temperatures were generally higher at any hour of the day. It is obvious from the table that pigeonpea is very slightly sensitive to environmental temperature.

Night and early morning temperature inversion near the surface is a common feature from October to February in north India. In the study, observations of temperature etc. were taken from 0900 hr IST. Hence the late night/morning temperature inversion could not be confirmed (Table 2). In the diurnal pattern of temperature the minimum leaf temperature is perhaps attained during the morning near sunrise hours. As the radiation load increases during the day, canopy temperature also increases, reaching a peak around 1400 hr, in both the trials and decreases subsequently. In the bare soil conditions, canopy temperature were found higher between 1100 and

TABLE 1

Mean distribution of leaf temperature (°C), stomatal resistance (s/m), transpiration ($\mu g/cm^2/sec$) and quantum ($\mu E_i/cm^2/sec$)

Layer	Temperature		Transpiration		Quantum		Stomatal resistance	
	A	B	A	B	A	B	A	B
Top	30.7	30.9	49.5	41.7	846	807	125	142
Middle	30.6	30.7	40.6	31.2	582	476	130	145
Bottom	30.7	30.8	43.1	35.9	319	298	136	136
Mean	30.7	30.8	45.9	36.1	589	550	130	150

A — Mulched B — Unmulched

TABLE 2

Diurnal variations of leaf temperature (°C), stomatal resistance (s/m), quanta ($\mu E_i/m^2/s$) and leaf transpiration ($\mu g/m^2/s$)

Hours (IST)	Leaf temperature (°C)		Stomatal resistance (s/m)		Quanta ($\mu E_i/m^2/s$)		Leaf transpiration ($\mu g/m^2/s$)	
	A	B	A	B	A	B	A	B
09	29	26	065	080	640	580	36	30
11	30	31	140	180	760	740	45	38
14	32	32	195	215	700	650	55	45
16	31	31	097	125	160	200	42	32

A — Mulched treatment B — Unmulched treatments

1400 hr. The maximum difference between the two cases was 1.6°C at 1100 and 1600 hr. Thus, measurement at 1100 hr perhaps could be used to represent temperature regime for the whole day for pigeonpea in India, unlike 1400 hr observed by Ehrler *et al.* (1978).

On days when irrigation was provided, it was seen that the difference in temperature in the two treatments was, on an average 0.4°C, the higher values of course were seen in the unmulched field. Under prolonged drying conditions, difference between the two treatments tends to increase and it could be as high as 1.0°C.

Though the temperature observations were available after anthesis, it is seen that the canopy temperature increased between flowering and pod formation stages in both cases and declined sharply subsequently. At flowering the crop canopy is fully developed. Leaf senesences sets in only after pod formation. Thus, between the two growth stages maximum amount of water is transpired as vapour by the leaf surface. The latent heat energy of the water vapour perhaps gets trapped in the canopy, thus resulting in increased temperature during reproduction stage.

3.2. *Internal plant resistance*

Plant acts as "wicks" for the transport of the water from soil to air. The manner in which stomates control transpiration is a complex phenomenon. A number of environmental factors like leaf temperature, light, water potential etc. affect stomatal resistance. Considerable efforts have been devoted in recent years to determine how stomates control transpiration. Hansen (1974) showed that transpiration in rye grass is a curvilinear function of stomatal resistance r_s or a linear function of $1/r_s$.

The number of stomata on the bottom and top being unequal, the effective stomatal resistance r_s

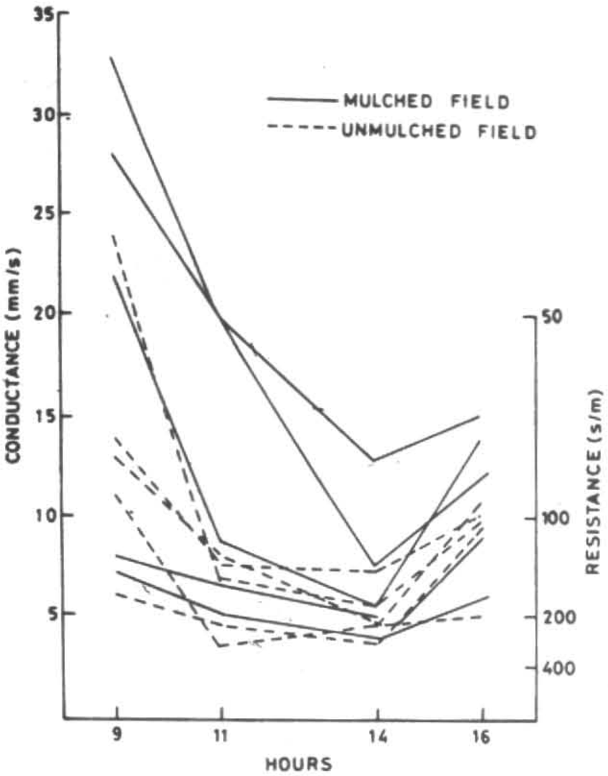

Fig. 1. Hourly values of surface conductance and equivalent resistance values

was determined from the following equation, assuming the stomatal resistance of the top (adaxial) r_{st} and bottom (abaxial) r_{sb} sides to be connected in parallel.

$$1/r_s = 1/r_{sb} + 1/r_{sb} \quad \text{or}$$

$$r_s = r_{st} \cdot r_{sb} \ / \ (r_{st} + r_{sb})$$

Stomatal resistance, in the present experiment, as in case of leaf temperature has been worked out in three layers of the plant, *viz.*, the top, middle and the bottom layers when the field was covered by the mulch and when it was kept open. In the study, r_s was not found uniform within the canopy. In general, the resistance was found to increase from top to the bottom layer. In other words, the leaves in the bottom layer, which are otherwise well guarded from air currents and shielded by direct radiation, offers the maximum resistance. In the lower portion of the canopy the resistance was found more than 8% than at the top canopy in the mulched field and about 15% more in the unmulched field (Table 1). This is in agreement with the result of Tearse and Kanemasu (1972).

The mean daily stomatal resistance in the mulched field was nearly 130 s/m as against about 150 s/m in the control. This suggests that flow of water through the plants gets restricted when mulched. The difference between diffusive resistance to water vapour in the mulched and the unmulched fields was not significant. Increased r_s arise when the rate of water in-take by plants cannot keep pace with the rate of water loss, resulting in partial or total closure of stomates. In other words, in the non-mulched field, the pigeonpea plant takes very little water than the water lost, whereas when the soil is mulched the plants adjust the rate of water loss with water uptake from the soil.

The diurnal variations in r_s is shown in Table 2. Occurrence of minimum resistance within the canopy varies with time of the day. This is due to the presence of different light regimes within the crop canopy. When the sun's elevation is low in the morning and evening, the r_s value are typically low. In both the cases (mulched and unmulched), r_s attains highest value in early afternoon around 1400 hr, the peak radiation time, possibly as a consequence of large saturation vapour deficit. Kumar and Tripathy (1990) also observed that in unirrigated wheat, leaf diffusive resistance increased sharply after 1400 hr.

Correlation coefficients between canopy temperature and leaf resistance were 0.53 and 0.71 for mulched and bare plots respectively.

3.3. *Surface conductance*

Stomatal conductance $1/r_s$ represents flow of water from evaporative surface of the leaf. It is known to respond to changes in quantum (0.4-0.7 μm). irradiance, leaf temperature, soil water potential and ambient CO_2 concentration (Adams *et al.* 1991). Hourly values of surface conductance for selected hours is also shown in Fig. 1, for selected days. For the sake of comparison, a resistance scale is given at the right margin of the diagram. In the morning hours, large variations among different days observed in the figure are possibly a consequence of dew which was observed in varying amounts each day of observation. The canopy became generally dry after 0900 hr, due to occasional influx of sensible heat through clothesline effect. Despite such variability, the results appear remarkably consistent in the pattern they portray. In general, as the sun attains greater elevation, the conductance perhaps increases to attain maximum at 0900/1100 hr for the day and possibly also at sunset. Linvingston and Black (1987) and Price and Black (1989) observed a response in surface conductance to time since sunrise. Munro

(1987) also observed that 0900 hr is the time when conductance appears to be at its maximum value for the day. The gradual decrease in $1/r_s$ after early peak nearly throughout the day perhaps implies some form of control upon surface conductance (Thom 1972, Tan and Black 1976). Surface conductance tends to decrease in the afternoon hours also, apparently in response to increasing saturation vapour deficit. Around noon the conductance was approximately 6 mm/s or a resistance of 165 s/m in mulched field and a little less in the controlled field. The maximum value of conductance observed in the two sample was 3 mm/s.

3.4. *Quanta utilisation*

For the photochemical processes in plant to take place, light energy is essential. The reduction of 1 mole of CO_2 to form carbohydrates theoretically requires 0.469 MJ or 3 quanta of visible light (Rosenberg *et al.* 1983) though CO_2 experiments have shown that 8-12 quanta are needed. The mean quanta requirement for mulched and control, in the present experiment nearly matched each other, with values of 582 and 527 $\mu E_l/m^2/s$ respectively. Perhaps, when the soil is covered, the quanta requirement gets enhanced. The mean values of the quanta for top, middle and lower canopies are given in Table 1. For obvious reasons in both the experiments the photosynthetic efficiency is largest in the topmost canopy. By the time solar irradiance reaches the lowermost canopy, the radiation is reduced by nearly 63%.

As in case of other meteorological parameters, the quanta needs also reveal diurnal variations (Table 2). Large diurnal variation in different days is clearly seen in both the treatments. Another feature not observed in the mean values in the treatments but which is conspicuously brought out in the diurnal analysis, is the large difference between mulched and open fields in different hours. The quantum appears to have fairly high values in both cases at 0900 hr and attain peak values at 1100 hr. Significantly large values are observed even at 1400 hr. With the lowering of the solar elevation there is a drastic fall in the solar incidence when it drops down nearly to 1/4 of its peak value.

3.5. *Leaf transpiration*

The layerwise mean transpiration rate can be seen in Table 1. As may be expected, maximum transpiration occurs from top layer and decreases downward. Luxmoore *et al.* (1971), while computing extinction coefficient (k) in soyabean also observed that maximum k occurred in topmost leaf layer, reached a minimum in the middle layer and then increased again in the lowest leaf layer. Increase in transpiration may be due to increased proportion of diffuse radiation in the lowest canopy.

The diurnal variation for both mulched and bare treatments for leaf transpiration is shown in Table 2. The difference between mulched and bare field conditions was minimum at 0900 hr. In covered treatment, plant water increased rapidly in the forenoon hours resulting in large transpiration. In uncovered field the increase in transpiration rates during forenoon was rather slow. In both cases the peak at 1400 hr was observed as 56.4 and 43.9 $g/cm^2/s$ in mulched and unmulched treatments respectively. The decline in transpiration is faster in both cases. Another noteworthy feature that could be seen from the table is that, in covered treatment, transpiration is nearly 27% higher than in uncovered treatment. Such response was observed by Sarratt *et al.* (1983) and Kumar and Tripathy (1990) in irrigated and unirrigated alfalfa and wheat respectively.

The transpiration rate ceases to increase around 1400 hr though, as seen in the earlier section, the canopy resistance was still increasing. The reduction in transpiration rate ($13.2 \mu g/cm^2/s$) in mulched field is greater than the other field between 1400-1600 hr and is perhaps due to severe water stress. With increased water stress, plant stomata perhaps become rather sensitive but transpiration does not cease completely due to incomplete stomata closure.

An attempt was also made to determine association, if any between leaf transpiration and leaf temperature. In both mulched and bare field experiments, the correlation was poor (*i.e.,* less than 0.20). Lack of a sound relationship between leaf temperature and transpiration may be due to the fact that other environmental factors, particularly, relative humidity, also influence transpiration rates significantly. Temperature affects transpiration only through other weather factors.

From sections 3.1, 3.2, 3.4 and 3.5, it is clear that in the mulched canopy leaf temperature is marginally higher, plant's internal resistance is slightly less and the quanta requirement is nearly the same as compared to the unmulched canopy. The leaf in mulched field also transpires less moisture. These changes in canopy characteristics have been observed to increase the pigeonpea yield by nearly 15%.

4. Conclusions

The following conclusions can be drawn from the analysis :

(*i*) Leaf temperatures are marginally higher in the unmulched field compared to the mulched field. Peak leaf temperatures are attained around 1400 hr in both the trials.

(*ii*) The plant internal resistance in the mulched experiment is slightly less than the unmulched field.

(*iii*) Large values of stomatal conductance are seen in the morning and evening hours.

(*iv*) No significant difference in the quanta requirements is observed in the control and mulched experiments.

(*v*) Largest transpiration loss occurs from the topmost canopy layer followed by that from the lowermost layer. In the unmulched treatment the water loss is less than in the mulched treatment.

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