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Quantification of soil temperature in sole and intercropped pigeonpea (*Cajanus cajan L. Millsp.*) using meteorological parameters

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सार — गुजरात के मध्य क्षेत्र में विभिन्न मौसम विज्ञान प्राचलों के दृष्टिकोण से तीन वर्षों (1986-87, 1987- 88 और 1988-89) के दौरान दिन में दो बार (0738 और 1438 बजे) अरहर और अरहर-मूंगफली (ऐराकिस हाइपोजिया) फसल पद्धति में पौधों की जड़ के स्तर (5,15 और 30 सें.मी. गहरे) पर मौसम विज्ञान की सप्ताहवार मृदा-जल प्रवृत्ति का अध्ययन किया गया।

फसल वृद्धि अवधि के दौरान तीन अवसरों पर अर्थात् दप मानसून के प्रारम्भ में, वर्षा ॠतु की समाप्ति पर और उप-फसल की कटाई के समय मृदा-जल प्रवृत्ति में आई कमी का पता चला है। केवल अरहर में, मृदा तापमान का माध्य वायु तापमान द्वारा 30 सें.मी. की गहराई तक आकलन किया जा सकता है परन्तु अरहर और मूंगफली दोनों फसलों की प्रणाली में मूंगफली की खुदाई से पूर्व मिट्टी की ऊपरी पर्तों में क्रमशः सुबह और सायं के तापमान के आकलन के दौरान न्यूनतम और अधिकतम तापमान अधिक उपयुक्त पाए गए हैं।

ABSTRACT. The meteorologiçal week-wise soil thermal regime in the root zone (5, 15 and 30 cm depth) of pigeonpea and pigeonpea based groundnut (*Arachis hypogaea*) cropping systems was studied in relation to various meteorological parameters twice a day, 0738 and 1438 hrs (IST) for three years (1986-87, 1987-88 and 1988-89), in the middle Gujarat region.

A decline in soil thermal regime was observed on three occasions during the crop growth period *viz*., at onset of SW monsoon, at the end of rainy season and at the time of harvesting of intercrop. In sole pigeonpea, the soil temperature upto 30 cm depth can be estimated from mean air temperature, whereas in the pigeonpea + groundnut cropping system, before harvest of intercrop the minimum and maximum temperature were found to be more appropriate for estimation of morning and afternoon time respectively, but only in the top layers of the soil.

Key words — Soil thermal regime, Intercropping, Meteorological parameters, Cropping system.

1. Introduction

Area of research pertaining to soil thermal regime under intercropping system is still inadequate and not completely understood yet. It is an established fact that in any agroecosystem, the soil thermal regime is as important as any other environmental factor. The magnitude of soil temperature in the root zone of the crop influences the final yield more in tuber crops than cereals and others. This is also true in case of component crops in intercropping. Large number of researchers have shown that yield stability is greater in intercropping without adverse effect on pigeonpea yield. Further, substantial yield advantages can be achieved by practicing more rapid growing legumes with pigeonpea (Giri *et al*., 1980, Willey *et al*., 1980, Rao and Willey, 1980, Reddy and Willey, 1981). Artificial shading substantially reduces soil temperature relative to the crop grown alone, but has little effect on plant morphology or dry weight at final harvest in groundnut (Stirling, 1990). The microclimate in an intercrop of sorghum and groundnut had lower temperatures resulting from shading, causing a possible intercrop advantage (Harris and Natrajan, 1987). Several forms of organic mulch have been found to have a major influence on soil temperature, soil water status and plant growth (Tripathi and Katiyar, 1984 and Olasantan, 1965).

Data on air temperature are available in plenty, but the data on soil temperature are meagre especially within agroecosystem. Since both soil and air temperatures have profound influence on plant growth and yield, an attempt is made to develop a submodel for soil temperature in sole and intercropping systems of pigeonpea in terms of weather parameters for possible use in crop-weather-models, so that paucity of soil temperature data within the cropping systems is not felt.

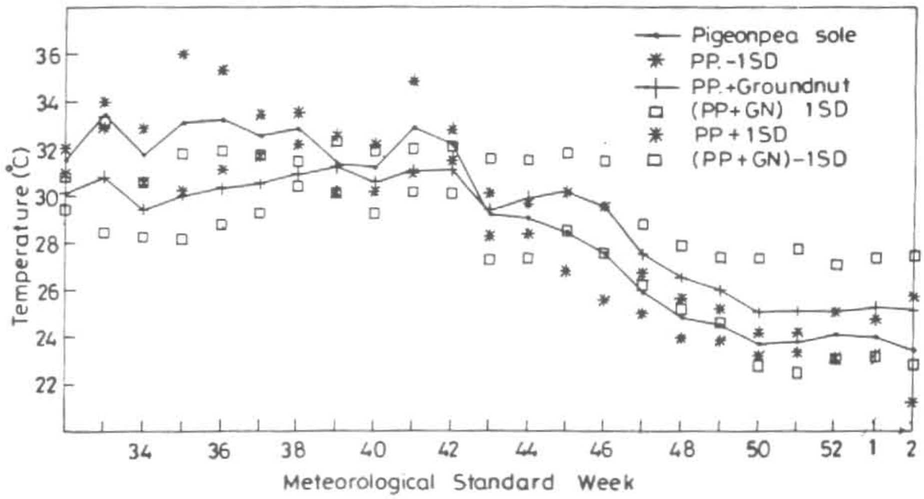

Fig.1. Weekley variation of temperature at 5 cm depth

TABLE 1

Correlation coefficient between soil temperature and weather parameters

Meteorological parameters	Pigeonpea sole			Pigeonpea + Groundnut: Before harvest of groundnut			Pigeonpea + Groundnut: After harvest of groundnut		
	Soil depth (cm)			Soil depth (cm)			Soil depth (cm)		
	5	15	30	5	15	30	5	15	30
0738 hrs									
V.P.	0.93**	0.89**	0.88**	0.82**	0.61*	0.35	0.76**	0.73**	0.72**
Mean V.P.	0.87**	0.82**	0.81**	0.70*	0.47	0.21	0.51	0.48	0.47
Min. Temp.	0.97**	0.95**	0.94**	0.88**	0.69*	0.43	0.96**	0.94**	0.89**
Mean Temp.	0.98**	0.98**	0.99**	0.82**	0.91**	0.89**	0.97**	0.96**	0.91**
1438 hrs									
V.P.	0.55**	0.69**	0.69**	-0.66*	-0.03	0.08	0.02	0.02	0.08
Mean V.P.	0.68**	0.80**	0.80**	-0.59	-0.15	-0.04	0.36	0.41	0.44
Min. Temp.	0.85**	0.79**	0.80**	0.90**	0.64*	0.52	0.84**	0.94**	0.93**
Mean Temp.	0.95**	0.98**	0.99**	0.48	0.90**	0.87**	0.86**	0.95**	0.93**

Note: * & ** significant at 5% and 1% respectively.

2. Materials and methods

Field experiments were conducted on the Agronomy farm of the Gujarat Agricultural University, Anand (22° 35′ N and 72° 55′ E) in the years 1986-87, 1987-88 and 1988-89. The soils at the experimental site are of alluvial origin having sandy loam texture with bulk density 1.5 (g/cc) and pH 8.1. Pigeonpea cv. T-15-15 and groundnut cv. JL-24 were taken as the main and the intercrop respectively for the study. Pigeonpea sole was sown at a distance of 90 x 30 cm. and pigeonpea + groundnut at a distance of 30 x 10 cm (1:2 row ratio) on June 29, *i.e.*, in 22nd meteorological standard week (MSW) in plots of size 5.7m x 5.7m. The plots of sole and intercrop were fertilized at levels of 25 N + 50 P + 0 K and 12.5 N + 25 P + 0 K kg/ha respectively. The harvesting of intercrop and main crop was done in 43rd MSW (October 25) and 4th MSW (January 26) respectively.

Standard bent-bulb soil thermometers were installed at 5, 15 and 30 cm depths between plant rows in plots of both

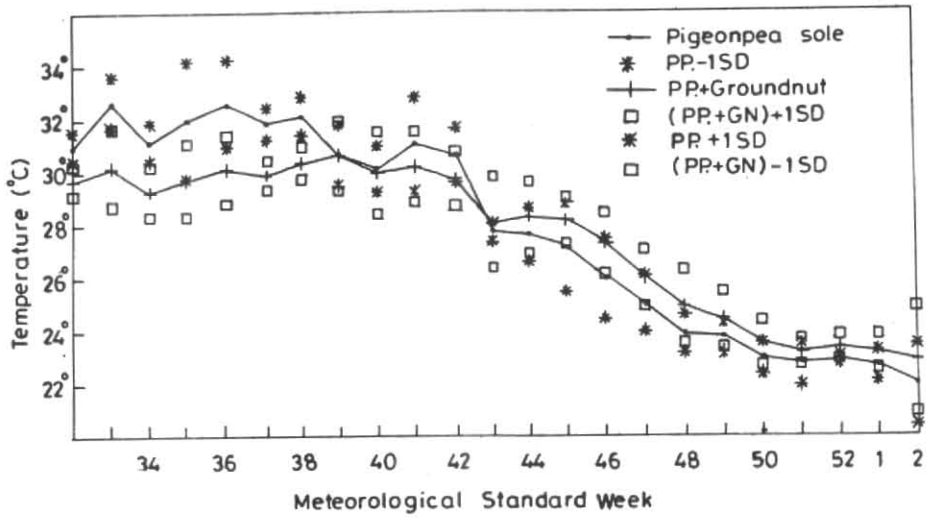

Fig.2. Weekley variation of temperature at 15 cm depth

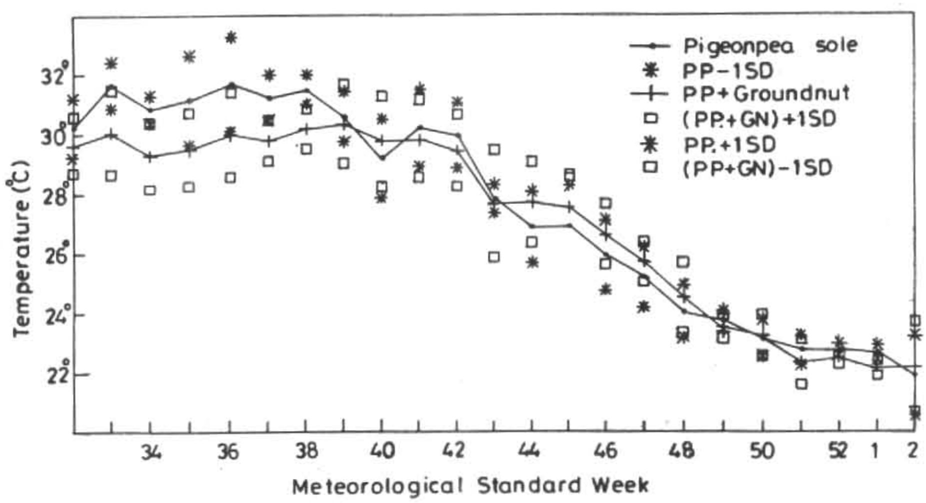

Fig.3. Weekley variation of temperature at 30 cm depth

the cropping systems. Observations were recorded daily at 0738 and 1438 hrs (IST). Data on weekly weather parameters were collected from the records of the Agrometeorological observatory situated adjacent to the experimental field. The weekly soil and weather parameters were averaged for the first two years of the experiment and correlated. Regression models for estimating soil temperature at different depths in both the cropping systems at 0738 and 1438 hrs (IST) were developed using weather parameters for the first two years' data of the experiment, and tested for the third year.

3. Results and discussion

3.1. *Variation of soil temperature in the crop growingseason*

Variation of soil temperature at different depths in the two cropping systems are presented in Figs. 1 to 3. The weekly temperature variations and their standard deviation for three years' data at 5 cm depth in both the cropping systems are shown in Fig.1. The growing habit of pigeonpea in the early growth stage is very slow and hence more soil near stem portion remained exposed to solar radiation, resulting in higher soil temperatures, whereas in the intercrop-

TABLE 2

Regression models for soil temperature

Soil depth (cm)	Equations	Model No.	SEE	R^2
	Pigeonpea sole			
(a) 0738 hrs				
5	Ts=0.37Tn + 0.62Tm + 1.1	1	0.57	0.98**
15	Ts=0.15Tn + 0.79Tm + 2.78	2	0.63	0.97**
30	Ts=0.88Tm + 5.48	3	0.58	0.97**
(b) 1438 hrs				
5	Ts=-0.91 Vp2 + 0.88 Vp + 0.69Tm + 14.5	4	0.86	0.94**
15	Ts=1.04Tm + 1.77	5	0.78	0.96**
30	Ts=0.89Tm + 5.26	6	0.57	0.97**
	Pigeonpea + groundnut (before harvest of groundnut)			
(a) 0738 hrs				
5	Ts=0.35Tn + 0.58Tm + 1.94	7	0.29	0.96**
15	Ts=0.088Vpl + 0.67Tm + 7.05	8	0.33	0.90**
30	Ts=0.66Tm + 10.31	9	0.39	0.80**
(b) 1438 hrs				
5	Ts=-0.63Tx + 10.15	10	0.76	0.80**
15	Ts=-0.07Vp2 + 0.93Tm + 4.68	11	0.42	0.89**
30	Ts=0.74Tm + 7.93	12	0.42	0.89**
	Pigeonpea + groundnut (after harvest of groundnut)			
(a) 0738 hrs				
5	Ts=0.93Tm - 1.73	13	0.59	0.95**
15	Ts=0.78Tm + 4.8	14	0.64	0.92**
30	Ts=0.88Tm + 6.04	15	0.99	0.93**
(b) 1438 hrs				
5	Ts=0.83Tm + 12.72	16	1.36	0.74**
15	Ts=0.81Tm + 8.09	17	0.69	0.91**
30	Ts=0.80Tm + 6.45	18	0.84	0.87**

Ts= Soil temperature, Tx = Max. temp., Tn = Min. temp., Tm = Mean temp., Vpl = Morning time vapour pressure, Vp2 = Afternoon vapour pressure, Vp = Mean vapour pressure

TABLE 3

Goodness of fit for the developed models

Model No.	Degrees of freedom	χ^2 at 0.01	Calculated χ^2	Test
1	21	38.93	0.44	NS
2	21	38.93	0.82	NS
3	21	38.93	1.88	NS
4	21	38.93	5.21	NS
5	21	38.93	2.06	NS
6	21	38.93	1.31	NS
7	10	23.21	0.22	NS
8	10	23.21	0.24	NS
9	10	23.21	0.25	NS
10	10	23.21	1.01	NS
11	10	23.21	0.18	NS
12	10	23.21	0.22	NS
13	9	21.67	0.61	NS
14	9	21.67	0.38	NS
15	9	21.67	0.74	NS
16	9	21.67	0.52	NS
17	9	21.67	0.67	NS
18	9	21.67	0.19	NS

ping system, groundnut achieved sufficient leaf area for covering the soil, thereby preventing the increase in soil temperature. This was true till the harvest of groundnut (43 MSW); thereafter, the temperature was higher in the intercropped system because of removal of the intercepting medium, *i.e.*, intercrop canopy, which caused disturbance of top-soil and resultant aeration through top-soil voids. At 15 cm depth also (Fig.2), similar variations were observed, but with lower magnitude. At 30 cm depth (Fig.3), however, the soil temperature was higher throughout the season in the sole cropping system indicating the low impact of harvest of intercrop on soil temperature at 30 cm depth.

3.2. *Relationship of soil temperature with weather parameters*

Among the various air temperatures, the mean temperature was best correlated with soil temperature at all depths and both cropping systems, except at 5 cm depth in intercropping system before harvest of groundnut (Table 1). In this case, the minimum and maximum temperatures were better correlated at 0738 and 1438 hrs (IST) respectively. A prominent feature of Table 1 is that correlation coefficient is reduced by more than 40% from morning to afternoon. This is attributed again to the insulating effect of the groundnut canopy.

Soil temperature at 5 cm depth within the canopy is correlated with vapour pressure better during morning time than in the afternoon in both the cropping systems. Further, it is higher for sole pigeonpea. However, in the afternoon, the two parameters were negatively correlated in the intercropping system.

The presence of groundnut crop as an insulating and opaque medium caused little variation in soil temperature; this may have caused either no or negative correlation. After the harvest of groundnut, the correlation was positive.

It is interesting to note that, after harvest of the intercrop, the correlation between soil temperature and air temperature & vapour pressure increased positively with soil depth. This may again be attributed to the fact that, harvesting of groundnut led to the disturbance of the upper layer of the soil, and consequent destruction of the compactness of the soil till the harvest of pigeonpea, since no further rainfall occurred. The low '*r*' values for the 5 cm depth are explained by the looseness of upper layer and the aeration provided to deeper layers.

3.3. *Modelling of soil temperature*

Stepwise regression analysis was carried out using the data of first two years of the experiment (1986-87, 1987-88) with soil temperature at different depths, times of day and cropping systems, separately, as dependent variables and morning time vapour pressure ($Vp1$), mean vapour pressure (Vp), minimum temperature (Tn), mean temperature (Tm), afternoon vapour pressure ($Vp2$), and maximum temperature (Tx) as independent variables. Thus, 18 regression models were obtained: six for sole crop and 12 for intercrop systems. The 12 models in intercropping system include six before harvest and six after harvest of intercrop. In model 1 only mean temperature (Tm) covered variation of 96 per cent. It further improved by 2 per cent more *i.e.*, 98 per cent when minimum temperature (Tn) was considered alongwith the mean temperature. In model 2 there is no improvement in R^2 value. Under model 4 mean temperature (Tm), afternoon vapour pressure ($Vp2$) and mean vapour pressure (Vp) were entered in step I, II and III having R^2 value 0.91, 0.93 and 0.94 respectively. Minimum temperature (Tn) was entered at step I with a R^2 value of 0.78 and this was increased up to 0.96 at step II by adding mean temperature (Tm) in model 7. Mean temperature (Tm) at step I with 0.84 R^2 value in model 8 was improved by adding morning time vapour pressure ($Vp1$) up to 0.90 R^2 value. Whereas, in model 11 mean temperature (Tm) was entered at step I having R^2 0.82 and this was improved by adding afternoon vapour pressure ($Vp2$) up to 0.89 R^2. The obtained models are presented as Table 2. The coefficient of determination (R^2) is seen to be highest for sole crop and lowest for intercrop after harvest of groundnut.

The developed models were tested for the data of the third year of the experiment (1988-89) and the results are presented in Table 3. The chi square test for goodness of fit indicates non- significance for all the models developed.

4. Conclusion

(*i*) Soil temperatures at different depths and in differing environments are correlated significantly, with different weather parameters.

(*ii*) The mean temperature is seen to be the most significant parameter to estimate the soil temperature in both the cropping systems. In pigeonpea + groundnut cropping system, before harvest of intercrop the minimum and maximum temperatures were found to be more appropriate for estimation of morning and afternoon time respectively, but only in the top layers of the soil.

(*iii*) Looking to the usefulness of soil temperature in crop-weather-modelling, it is suggested that similar relationships be derived for different cropping systems, so that easily available meteorological data can be used in lieu of soil temperature.

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