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Influence of soil surface manipulation on soil temperature in relation to peanut production

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Abstract: Soil temperature is recognised as one of the most important factors in crop production. Some degree of manual control of soil temperature is possible through regulation of soil surface cover. The effect of eight mulch treatments (rice husk, rice husk incorporated, paddy straw, saw dust, water mulch, transparent polyethylene, black polyethylene and bare) on the soil temperature during various growth phases of peanut crop (*Arachis hypogaea* L.) were investigated on a lateritic sandy loam soil (ultisols). These experiments were conducted for two consecutive seasons. Plastic mulches raised the temperature upto 5 ^{0}C generally during afternoon whereas vegetative mulches depressed the same. Between the plastic mulches, black polyethylene covered field recorded lower soil temperature (upto 2^0 C) than the transparent one. Water mulches due to their high specific heat capacity acted as a heat sink during the day and heat source at night. The vegetative mulches suppressed the soil temperature and did not allow the radiant energy to contact the soil directly and emitted back the energy to the atmosphere. Among the vegetative mulches, rice husk and saw dust proved better than paddy straw and rice husk incorporated. The type and amount of soil cover which modify micro-climate and soil edaphic environment, may help to plan the farming practice for better crop growth and production.

Keywords: Mulch, Peanut, Plastic mulch, Soil temperature, Vegetative mulch

INTRODUCTION

The potentially serious effects of climate change suggest a strong need to introduce a strategy in India to respond to the prospect of future climate variability and change, including extreme climatic events and deal with adverse consequences. Rising temperatures and drier conditions in areas already at the margins of production are expected to come under enhanced agro-climatic as well as human pressure. Crop productivity is well below its potential production (Aggarwal, 2008). Despite tremendous improvements in technology and crop yield potential, food production remains highly dependent on climate. The changes in climate parameters are being felt globally in the form of changes in temperature and rainfall pattern. The global atmospheric concentration of carbon dioxide, a greenhouse gas (GHG) largely responsible for global warming, has increased from a pre-industrial value of about 280 ppm to 387 ppm in 2010. Higher temperatures reduce the total duration of a crop cycle by inducing early flowering, thus shortening the grain fill period. The shorter the crop cycle, the lower the yield per unit area due to poor photosynthesis. Under climate change grain quality may deteriorate as a direct effect of increasing temperature and CO_2 that reduces protein and micronutrient content in grain, which can influence mould growth and mycotoxin production, further affecting quality during storage and transport. Recent IPCC report and a few other global studies indicate a probability of 10 - 40% loss in crop production in India with increases in temperature by 2080 - 2100 (IPCC, 2007).

The favourable soil physical edaphic environment can be achieved by maintaining desired soil surface conditions. Soil surface conditions can be altered by mulching. Mulch can be defined as a material used at the surface of the soil primarily to prevent the loss of water by evaporation. Other soil properties and soil surface conditions that are affected directly or indirectly by mulches are soil water through increased infiltration, favourable water storage, soil temperature through radiation shielding, heat conduction and evaporation cooling, soil temperature moderation, soil nutrient mobility, soil salinity control, soil biological regime through organic matter addition, soil structure improvement, weed control and soil aeration. Mulching also alters soil temperature (Khan, 1998 b). Oxygen diffusion rate (ODR) is temperature dependent and an increase in temperature decreases the solubility of oxygen and increases the diffusion through both gas and liquid (Letey and Stolzy, 1964; Mohsin and Khan, 1977). Research information about the soil oxygen flux under varying mulching conditions are limited. The objective of the experiment reported here was to

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determine the temperature moderation of the soil as influenced by varying mulching treatments during the growth period of peanut, *Arachis hypogaea* L.

MATERIALS AND METHODS

The field study was conducted for two consecutive seasons on lateritic sandy loam soil (typic, acrorthox, kaolinitic, ultisols) in Kharagpur (West Bengal), the coastal belt of eastern India. Experimental soil is well drained, acid (pH 5.50) and has low natural fertility, cation exchange capacity and lime. Three replications of eight mulch treatments were combined in a randomized block design. Erect bunch type peanuts (*A. hypogaea* L.) cultivar SB'XI' was hand dibbled at a spacing of 30 cm x 15 cm. The recommended agronomic practices for the optimum peanut yield in this agro-climatic region for peanut were followed (Khan and Datta, 1982).

Soil temperature was measured at 5, 10, 15 and 20 cm depths in the plant rows by thermocouples. Temperature readings were taken at all the four depths at 8 a.m. and 3 p.m. through out the growth phases of peanut (Viz., from sowing till harvest). Three observations were made for each plot and five readings were taken for each site to avoid variability from location to location. One shaded thermocouple was placed at a height of 100 cm in the centre of the experimental area for measurements of air temperature. Temperatures were measured by instrumentation described by Khan *et al.* (1977). The details of treatments of soil surface are presented in Table 1.

RESULTS AND DISCUSSION

Table 3 to 6 show the mean diurnal fluctuation of soil temperature under various mulching practices during the different growth phases of peanut *Arachis hypogaea* at different depths of soil at Kharagpur. One season data are presented for the sake of brevity and similar trend. The variation in soil temperature under different mulches is not much at 8 a.m., whereas the variation is higher at 3 p.m. In the morning, bare plots show in general, a higher temperature followed by polyethylene mulch, but at noon, the temperature under polyethylene mulches was found significantly higher. With the increase in soil depth, the amount of temperature fluctuations and also the temperature differences between the treatments tend to decrease.

While soil temperature was higher under polyethylene

Table 1. Details of treatments of soil of the area at Kharagpur (West Bengal).

Treatment symbol	Description of treatments of soil
M_1	Rice husk spread on the soil surface @ 6 tons per hectare
M_2	Rice husk mixed into the surface soil (5 cm) @ 6 tons per hectare before sowing
M_3	Paddy straw spread on the soil surface @ 6 tons per hectare
M_4	Saw dust spread on the soil surface @ 6 tons per hectare
M_5	Layers of water (upto a height of 15 cm) contained in polyethylene envelopes placed between the rows and plants on the soil surface
M_6	Transparent polyethylene (thickness 30 gauge) spread on the soil surface
M_7	Black polyethylene (thickness 30 gauge) spread on the soil surface
M_8	Bare (control) Normal cultivation practice followed

Table 2. Relationship between soil temperature and soil depth during the different growth stages of peanut crop at varying time.

Variables	R (correlation coefficient value)	Regression equation
I. Seedling emergence stage		
A. Morning (8 a.m.)	0.197*	$Y= -0.081d-0.006d^2+0.0004d^3$
B. Noon (3 p.m.)	0.506**	$Y= -1.217d+0.080d^2-0.002d^3$
II. Flowering stage		
A. Morning (8 a. m)	0.256**	$Y= -0.731d+0.069d^2-0.002d^3$
B. Noon (3 p.m.)	0.470**	$Y= -0.605d+0.036d^2-0.0007d^3$
III. Pegging stage		
A. Morning (8 a.m.)	0.198**	$Y= -0.241d+0.021d^2-0.0005d^3$
B. Noon (3 p.m.)	0.334**	$Y= -0.316d+0.010d^2-0.0007d^3$
IV. Pod formation and at harvest		
A. Morning (8 a.m.)	0.338**	$Y= -0.023d+0.011d^2-0.0004d^3$
B. Noon (3 p.m.)	0.087	$Y= -0.174d+0.018d^2-0.0005d^3$

Table 3. Soil temperature influenced by varying soil surface treatments (M) during seedling emergence stage of peanut crop.

Treatments	Temperature (^{0}C)							
	5 cm depth		10 cm depth		15 cm depth		20 cm depth	
	8 a. m.	3 p. m.	8 a. m.	3 p. m.	8 a. m.	3 p. m.	8 a. m.	3 p. m.
M_1	28.00	30.00	27.90	29.90	27.50	29.75	27.83	29.75
M_2	29.50	32.50	28.50	32.90	28.90	31.50	30.00	31.60
M_3	27.50	31.75	27.90	30.50	28.00	30.00	28.10	30.25
M_4	26.50	31.25	27.00	30.00	27.50	29.00	28.00	29.40
M_5	27.50	34.50	28.10	32.00	29.90	31.50	29.10	31.75
M_6	28.10	36.00	28.00	34.00	28.90	32.50	30.00	32.50
M_7	27.50	32.50	29.00	32.00	28.00	31.50	28.10	31.40
M_8	29.00	35.00	27.50	33.10	28.00	33.00	28.25	33.00
L.S.D. (P=0.05)	1.811	1.813	1.809	1.812	1.812	1.813	1.753	1.810

Table 4. Soil temperature influenced by varying soil surface treatments (M) during flowering stage of peanut crop.

Treatments	Temperature (^{0}C)							
	5 cm depth		10 cm depth		15 cm depth		20 cm depth	
	8 a. m.	3 p. m.	8 a. m.	3 p. m.	8 a. m.	3 p. m.	8 a. m.	3 p. m.
M_1	29.00	30.75	29.75	31.10	29.00	30.25	29.00	30.25
M_2	29.10	32.33	30.25	33.03	30.10	32.10	30.10	32.25
M_3	29.10	32.50	29.25	32.00	30.50	32.17	30.75	32.00
M_4	29.00	32.50	29.50	31.50	29.75	30.75	30.10	30.60
M_5	29.10	34.57	30.00	33.50	31.50	33.25	31.60	33.25
M_6	29.25	32.90	30.50	33.50	31.25	33.40	31.40	33.50
M_7	30.00	33.50	30.90	33.75	30.75	33.30	31.00	33.57
M_8	30.74	34.00	29.10	32.25	30.00	32.75	30.10	33.00
L.S.D. (P=0.05)	1.808	1.833	1.811	1.815	1.813	1.799	1.807	1.780

Table 5. Soil temperature influenced by varying soil surface treatments (M) during pegging stage of peanut crop.

Treatments	Temperature (^{0}C)							
	5 cm depth		10 cm depth		15 cm depth		20 cm depth	
	8 a. m.	3 p. m.	8 a. m.	3 p. m.	8 a. m.	3 p. m.	8 a. m.	3 p. m.
M_1	29.90	33.10	30.50	32.75	31.00	32.27	31.10	31.60
M_2	30.25	33.25	31.00	33.20	31.10	32.00	31.25	33.00
M_3	30.10	33.50	30.90	32.60	31.25	32.40	31.40	32.40
M_4	29.00	33.75	29.90	32.25	30.67	31.90	30.82	33.00
M_5	30.00	34.25	30.10	38.00	31.00	32.40	31.10	32.40
M_6	30.75	33.50	30.90	32.00	31.10	32.40	31.25	32.40
M_7	30.33	33.50	31.00	33.40	30.75	33.50	31.00	32.40
M_8	31.50	35.10	30.00	32.50	30.50	33.40	30.50	32.60
L.S.D. (P=0.05)	1.745	1.812	1.809	1.807	1.846	1.708	1.845	1.808

sheets at all the stages of peanut crop, the vegetative mulches, in general, suppressed the same. Amongst the polyethylene sheets transparent polyethylene recorded the highest soil temperature upto 2-3^{0}C in comparison to black polyethylene and water mulch. Soil temperature differences between the treatments tended to narrow down as shading effect of the plant canopy started developing with crop growth. The same effect was also reported by Burrows and Larson (1962) and Fairbourn (1974).

Vegetative mulches like paddy straw and rice husk treatments do not allow the radiant energy to contact the soil directly due to which most of the energy is emitted back to the atmosphere. The combined effects of radiation interception and evaporative cooling were responsible for lower soil temperature under vegetative mulches. The materials like straw and other plant waste products like

Table 6. Soil temperature influenced by varying soil surface treatments (M) during pod formation stage and at harvest of peanut crop.

Treatments	Temperature (^{0}C)							
	5 cm depth		10 cm depth		15 cm depth		20 cm depth	
	8 a. m.	3 p. m.	8 a. m.	3 p. m.	8 a. m.	3 p. m.	8 a. m.	3 p. m.
M_1	29.50	31.10	30.25	31.50	30.00	30.95	30.10	30.75
M_2	30.50	31.80	31.25	32.40	31.00	30.93	31.25	31.75
M_3	30.10	31.40	31.00	31.80	30.75	29.17	30.90	30.50
M_4	29.90	31.10	29.10	30.10	29.00	31.00	30.10	31.00
M_5	30.50	32.25	30.25	31.50	31.25	32.00	30.03	31.90
M_6	30.25	32.25	31.43	32.50	31.25	32.00	31.25	31.90
M_7	30.50	32.00	31.25	33.40	31.00	32.00	31.25	38.10
M_8	31.50	32.90	30.00	30.80	30.80	31.60	31.08	31.75
L.S.D. (P=0.05)	1.812	1.787	1.844	1.808	1.813	1.965	1.813	1.813

saw dust and rice husk could reduce soil temperature was demonstrated by Adams (1965), Webster *et al.* (1967) and Nanda *et al.* (1999). The temperature of surface soil at 3 p.m. was 34^{0}C due to straw mulching whereas temperatures of non-mulched plots were as high as 42^{0}C (Nanda *et al.*, 2000).

Soil warms up faster under transparent plastic since the incident short wave radiation is transmitted through it and absorbed directly by the soil. Transparent polyethylene mulches increased soil temperature improving seedling emergence and soil moisture conditions in the seed zone and reduced the nematodes (Singh *et al.*, 2007). Khan *et al.* (2003) used the transparent polyethylene to raise the soil temperature to a level lethal for many soil borne pathogens and weed seeds, thus killing weeds before its germination through solarization. Soil warming is slower under black plastic since most of the incident solar radiation is absorbed by the film. Black plastic lost heat by emitting long wave-infrared radiation from both the upper and lower surface of the film. Thus, soil under black plastic receiving only a portion of incoming energy absorbed by the film from the incoming incident radiation, *i.e.* the one emitted from the lower surface of the black plastic. The heat from the plastic has to be conducted through a still air space to the soil. Air space between the black polyethylene and soil may have an insulating effect and as a result the soil temperature remained lower under the black plastic mulches. Khan *et al.* (1997) found the same effect for smothering of weeds. Water mulches due to their high specific heat capacity act as a heat sink during the day and heat source at night. The water mulch restricts energy loss by absorbing all long wave radiation from the soil and re-radiating at a lower temperature. Therefore the effect is a dampening of the diurnal fluctuations of soil temperature (Bowers, 1968 and Khan, 1998 a). The relationship between soil temperature and soil depth at varying time during the growth stages of peanut crop are presented in Table 2.

Production of peanuts and water use efficiency (mean of two seasons) are presented in Fig. 1. The higher pod

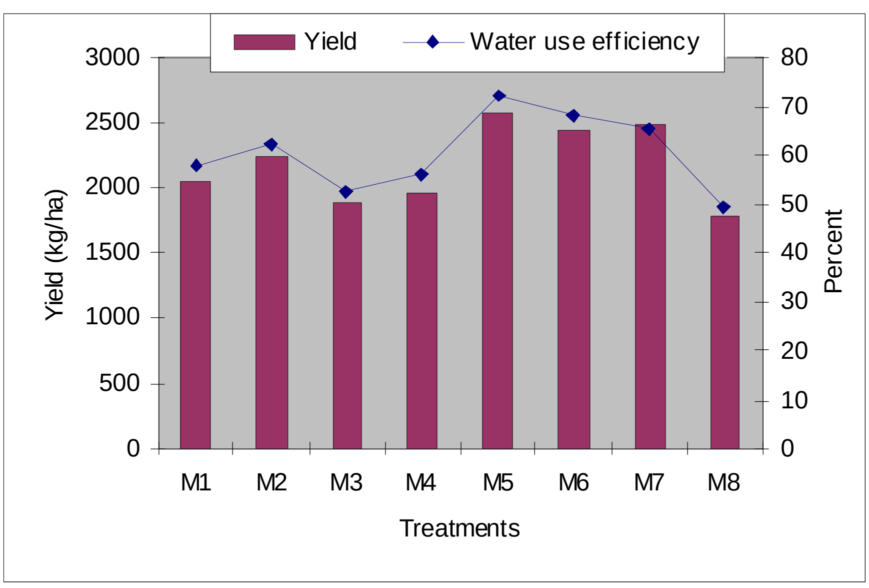

Fig. 1. *Pod yield of peanut crop and water use efficiency at varying soil surface (mulch) treatments.*

yield and water use efficiency was observed under plastic mulch followed by vegetative mulches. Experimental findings relating crop production to soil temperature have caused wide acceptance of the value of mulches for providing a favourable crop environment for increasing crop yield in cold temperate climates. Warmer temperature may increase the absorption of nutrients and water as well as the production and translocation of carbohydrates. Soil temperatures affect other factors which influence growth, such as nitrification, P-mineralization, uptake of water, transpiration and respiration. Increasing seed bed soil temperatures during the growing season accelerated growth rates and plants development sufficiently to hasten maturity and increase the pod yield. Reduced soil water evaporation from soil surface under plastic mulch may be the probable explanation for higher water-use efficiency.

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