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Studies on the Thermal Regime of Maryout Soil, Egypt 3. Heat Response of Soil as Affected by Shading and Plant Mulching During Heating and Cooling Cycles

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Abstract: The current work was conducted to investigate the influence of mulching and shading on the change of heat content at the different depths of the soil profile. The study was carried out in split plot design and included two main treatments; namely mulching using two types of plant residues, each applied at two rates and shading treatment using porous black plastic sheets laid at 2.5 m above the soil surface. In all treatments, soil temperature were determined at different depths of soil profile up to 20cm depth, under two climatic conditions, represented by chosen two days, viz., the 1st of each of August and October 2004.The rate of change in soil heat content in each soil layer was calculated. The obtained result shows that. The change of heat quantity during heating and cooling periods, i.e. ΔQT_H and ΔQT_C, respectively decreases with increasing soil depth and most of changes were observed in the upper soil layers. Also, it was found that such changes were of less pronounced under shaded plots compared to the non-shaded ones. Heat quantities ΔQT_H at 1/10/2004 were higher than those obtained at 1/8/2004.

Key words: Soil temperature · Total heat quantity · Total heat content · Shading · Mulching · Heat response

INTRODUCTION

In a previous work, Said *et al.* [1] indicated that the maximum actual temperature of the soil profile was attained at 3: pm in the upper soil layers 0-2.5 and 2.5-7.5 cm, at 9: pm and 12: am in the bottom soil layers 7.5-15.0 cm and 15-20.0cm respectively. They found that the time lag periods needed for occurring the maximum temperature in the bottom layers were, 6 and 9hr, in the same sequences. They also arrived at shading and mulching decreased the values of soil temperature as compared to the control due their impact on reducing solar energy and thus heat flow into the soil is low.

Meanwhile, in another study Talaat and Said [2] compared impact of bituminous emulsion as a synthetic black soil conditioner with shading using black plastic porous sheets, on soil temperature profile under both dry and wet soil conditions. They found that temperature of wet soil at different times was lower than the corresponding values of the dry one. The study also indicated that bituminous emulsion combined with shading increased the total heat storage throughout the different soil layers due to their conserving effect on soil moisture.

Due to the fact that the soil energy budget depends on heat exchange with the air and the response of the different soil layers to the heat change, the current study, was conducted to evaluate the impact of plant residues as mulches and shading on total heat content and response of different soil layers for heating / cooling cycles at different times.

MATERIALS AND METHODS

This work was carried out in the Agricultural Experimental station of the Desert Research Center at Maryout region, some 40 Km. South West of Alexandria City, North Egypt, during the growing summer season 2004. The soil of the experimental site is characterized by its sandy loam texture, highly calcareous and saline - non alkali, Said *et al.* [1].

The experiment was conducted in split plot design using plant residues as mulching treatments and porous black plastic sheets at a height of 2.5m above soil surface as shading treatment. In addition to control i.e. non shading non mulched plots. The mulching treatments included, rice straw and sugarcane fibbers, each was applied at two rates, viz., 12 and 24ton/ha. Cowpea seeds

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(Vigna unguiculata) were sown on the 1st of July. Mulch materials were added on soil surface at the beginning of seedling emergence. All plots received the recommended doses of mineral fertilization of NPK at rates of 168, 72 and 168 Kg/ha, respectively.

For all treatments soil temperature were determined at two runs; 1st August and 1st October in the dry soil i.e. immediately before applying the next irrigation.

The changes of heat content (gain and loss) with depth during heating i.e. heat gains (ΔQT_H) and cooling i.e. during heat loss(ΔQT_C) were calculated by subtracting the minimum total heat attained at the deferent depths at 7: am from the recorded maximum total heat attained during the daytime for the same soil layer (heat gain, heating period). Meanwhile, heat loss was obtained by subtracting the maximum total heat of each soil depth from the recorded total heat content at the minimum attained at 4: am (cooling period).

This Can Be Delineated as Follows:

Heat gain $\Delta QT_H = (T_H)_{max} - (T_H)$ at 7: am

Heat loss $\Delta QT_C = (T_H)$ at 4: am $- (T_H)_{max}$

Where,

ΔQT_H is the change of heat quantity (heating period).

ΔQT_C is the change of heat quantity (cooling period).

$(T_H)_{max}$ is the total heat retained calculated at the maximum soil temperature.

(T_H) at 7: am is the total heat retained calculated at the minimum soil temperature.

(T_H) at 4: am is the total heat retained calculated at the dawn.

The rate of change of heat content, or the response for heating / cooling periods, were calculated by dividing the total heat content of each soil layer (heating /cooling period) by the elapsed time.

$\Delta QT_H / \Delta t = T_H$ max- T_H at 7: am/Δt (heating period)

$\Delta QT_C / \Delta t = T_H$ at 4: am - T_H max/Δt (cooling period)

Where,

$\Delta QT_H / \Delta t$ is the response of heat quantity with time (heating period).

$\Delta QT_C / \Delta t$ is the response of heat quantity with time (cooling period).

Data of total heat retained for all treatments under different soil layers and heat change with times were subjected to the analysis of variance (ANOVA and L.S.D.) according to the method described by Snedecor and Cochran [3].

RESULTS AND DISCUSSION

Total Heat Content (T_H): For the 1st of August 2004, data in Table 1 reveal, irrespective of the amount of total heat of shading treatments that the amount of total heat increases with increasing soil depth. It is evident the, temperature of the two upper most soil layers attained their maximum at 3.00 pm, while such maximum reached at 9.00 and 12.00 pm in the bottom two soil layers (7.5-15 and 15-20.0 cm) respectively. However, in all depth soil temperature reached its minimum at 4.00 am (dawn). The data also show that the amount of heat retained in the non - shading plots (i.e. control) is lower than those of the other treatments. The magnitude of heat content of the control plots varies from 347.1 to 1128.89 /Calg at 7.00 am to 466.88 to 1250.01 /Calg at 3.00 pm and 12.00 am, compared with 332.14 to 1056.34 / Calg at 4.0 am (dawn).

Regarding, the values of total heat under rice straw treatment (12 ton/ha) varied between 400.61 to 1202.74 at 7.00 am and 501.27 to 1315.87at $time_{max}$ compared with 401.71 to 1232.71 $Calg^{-1}$ at 4.0 am (dawn). The values of total heat under rice straw (24 ton/ha^{-1}) treatment varied between 431.84 to 1183.11 at 7: am and from 452.71 to 1300.95 at $time_{max}$ compared to 391.11 to 1213.0 $Calg^{-1}$ at 4.0 am (dawn). The data also reveal that sugar cane treatment display quite similar trend, nevertheless with different magnitudes. It is also evident that total heat content under mulching with plant residues, in absence of shading, increases with soil depth up to 15cm depth, then tends to decrease up to 20cm depth, but with descending percentage of gain. Similar behavior was detected under shading condition (Table 2). These results could be attributed to presence of relatively high moisture content in the two upper soil layers due to mulching treatments. These finding is agreement with those obtained by Midmore *et al.* [4] and Horton [5].

The values of total heat under rice straw and sugarcane fibers treatments, declared that the rice straw 24 ton/$ha^{-1}$was lower than the values under 12 ton/ha along the all times. But the reverse is the true for sugarcane fibbers under mulching treatments. In the same time, it was noticed that the values of the total heat

Table 1: Total heat content of the studied depths under the applied treatments (mulching and non shading)

	Soil Temperature °C			Soil moisture (%)			Soil heat content at the indicated time.				
Depth (cm)	7: am	Time at Max Temp	4: am	7: am	Time at Max Temp	4: am	7: am T_H cal/Soil layer	Time at Max Temp T_H cal/Soil layer	4: am T_H cal/Soil layer	Gain %	Loss %
(1/8/2004)Control Without Shading											
0-2.5	23.0	35.0*	24.3	11.69	12.56	10.62	347.10	466.88	332.14	34.51	40.57
2.5-7.5	23.8	30 *	24.1	18.80	13.00	14.40	775.19	946.60	728.22	22.11	29.99
7.5-15	25.3	29.5***	24.2	17.90	15.10	15.60	1128.89	1250.01	1056.34	10.73	18.33
15-20	25.9	29.5 ***	24.1	17.40	16.30	15.90	801.08	902.03	782.65	12.60	15.45
Rice Straw (12 ton/ha)											
0-2.5	24.3	29.8 *	27.1	17.89	19.59	16.47	400.61	501.27	401.71	25.13	24.78
2.5-7.5	24.9	29.2 **	27.7	18.30	16.50	15.00	806.46	909.84	835.86	12.82	8.85
7.5-15	25.8	29.4 **	28.0	19.40	16.80	16.10	1202.74	1315.87	1232.71	9.41	6.75
15-20	26.3	29.5 ***	28.1	16.80	15.50	15.30	805.00	880.68	839.46	9.40	4.91
Rice Straw (24 ton/ha)											
0-2.5	25	29.5 **	27.1	18.00	18.97	15.74	431.84	452.71	391.11	4.83	15.75
2.5-7.5	25.2	29.5**	27.5	17.30	15.80	15.20	805.54	916.20	836.58	13.74	9.52
7.5-15	25.4	29.2**	27.7	18.70	16.20	16.00	1183.11	1300.95	1213.00	9.96	7.25
15-20	25.6	28.7***	27.0	16.10	15.30	16.00	776.40	858.90	823.54	10.63	4.29
Sugar can Fibers (12 ton/ha)											
0-2.5	24.6	31.2 *	25.8	17.39	17.90	14.58	408.25	497.85	368.66	21.95	35.04
2.5-7.5	24.9	28.1*	27.0	17.00	16.00	15.00	801.12	924.96	805.35	15.46	14.85
7.5-15	25.3	27.9**	27.5	15.50	16.00	16.00	1108.53	1218.23	1202.60	9.90	1.30
15-20	25.3	28.7***	27.0	15.90	15.60	15.00	767.03	846.43	810.21	10.35	4.47
Sugar can Fibers (24 ton/ha)											
0-2.5	24.4	30. 0*	26.0	16.69	19.59	18.86	398.41	502.15	407.02	26.04	23.37
2.5-7.5	24.5	28.0*	27.2	20.90	19.70	16.90	845.40	978.73	846.33	15.77	15.64
7.5-15	25.3	27.6***	27.5	18.80	17.70	17.00	1166.84	1256.88	962.16	7.72	30.63
15-20	25.7	27.7***	26.0	17.10	16.40	16.30	797.64	847.26	817.94	6.22	3.58

Table 2: Total heat content of the studied depths under the applied treatments(mulching and shading)

	Soil Temperature °C			Soil moisture (%)			Soil heat content at the indicated time.				
Depth (cm)	7: am	Time at Max Temp	4: am	7: am	Time at Max Temp	4: am	7: am T_H cal/Soil layer	Time at Max Temp T_H cal/Soil layer	4: am T_H cal/Soil layer	Gain %	Loss %
(1/8/2004) Control Shading											
0-2.5	23	26.2 *	23.6	17.74	19.	16.01	399.34	458.69	360.49	14.86	27.24
2.5-7.5	23.4	26.3*	24.5	18	19	17.7	755.76	858.59	778.46	13.61	10.29
7.5-15	23.6	25.3**	24.4	17.9	18.4	16.8	1085.2	1161.76	1097.7	7.05	5.84
15-20	23.6	25.5***	25.1	18.7	18.5	16.8	758.44	806.58	764.76	6.35	5.47
Rice Straw (12 ton/ha)											
0-2.5	24.6	27.2*	25.5	25	27.44	23.62	478.79	542.81	433.90	13.37	25.10
2.5-7.5	24.8	26.5*	25.8	21.6	22	20.5	865.97	948.77	879.82	9.56	7.84
7.5-15	24.7	26.3**	25.3	21.3	21.5	20.7	1222.58	1299.21	1244.60	6.26	4.39
15-20	24.8	26.2**	26	20.5	20.5	19.3	824.35	874.3	834.33	6.06	4.79
Rice Straw (24 ton/ha)											
0-2.5	25.3	26.5*	26.20	29.73	29.87	28.05	534.56	563.64	482.02	5.44	16.93
2.5-7.5	24.9	26.5**	26.10	20.00	22.00	20.70	852.30	931.10	900.58	9.25	3.39
7.5-15	24.9	26.8***	26.20	21.00	21.00	20.80	1220.25	1296.19	1276.40	6.22	1.55
15-20	24.9	26.9***	26.30	20.70	20.8	19.90	832.64	899.52	864.08	8.03	4.10
Sugar can Fibers (12 ton/ha)											
0-2.5	24	27.3*	24.40	21.62	22.85	19.89	438.42	492.70	398.94	12.38	23.50
2.5-7.5	24.2	26.6*	25.30	23.30	22.90	20.90	873.22	969.04	859.24	10.97	12.78
7.5-15	24.	26.2**	26.00	21.50	20.50	20.40	1195.26	1268.74	1205.39	6.15	5.26
15-20	24.1	26.3**	26.00	21.10	20.20	19.40	810.42	869.20	847.38	7.25	2.57
Sugar can Fibers (24 ton/ha)											
0-2.5	24.3	28.4*	24.20	21.92	22.64	23.39	443.52	510.87	436.47	15.19	17.05
2.5-7.5	24.5	28.7*	25.10	23.30	22.20	23.20	884.08	996.82	891.44	12.75	11.82
7.5-15	24.5	26.8**	25.50	21.80	20.50	21.10	1222.23	1324.59	1242.31	8.37	6.62
15-20	24.6	26.8**	26.00	20.40	20.90	19.90	816.09	891.20	847.61	9.20	5.14

Table 3: Total heat content of the studied depths under the applied treatments (mulching and non- shading)

	Soil Temperature °C			Soil moisture (%)			Soil heat content at the indicated time.				
Depth		Time at			Time at		7.00 am	Time at Max Temp.	4.00 am		
(cm)	7.00 am	Max Temp.	4.00 am	7.00 am	Max Temp.	4.00am	T_H cal/Soil layer	T_H cal/Soil layer	T_H cal/Soil layer	Gain %	Loss %
(1/10/2004)Control Without Shading											
0-2.5	21.15	33.85*	22.75	12.73	13.79	13.04	296.09	480.33	317.19	62.22	51.43
2.5-7.5	21.95	30.1*	23.90	17.47	17.81	16.80	706.99	976.56	758.75	38.13	28.71
7.5-15	23.15	27.65**	25.15	16.90	18.21	16.25	1040.80	1278.40	1114.74	22.83	14.68
15-20	24.05	27.2**	26.30	17.99	18.90	17.03	737.86	850.58	790.47	15.28	7.60
Rice Straw (12 ton/ha)											
0-2.5	22.2	30.6*	23.55	19.22	21.53	18.07	354.80	512.37	367.44	44.41	39.44
2.5-7.5	23.45	26.9***	25.80	19.17	19.50	19.18	782.81	904.11	861.44	15.50	4.95
7.5-15	24	27.35***	26.10	18.72	18.09	17.36	1121.60	1261.30	1185.09	12.46	6.43
15-20	24.45	27.25***	26.40	18.31	17.55	17.19	755.21	828.23	798.12	9.67	3.77
Rice Straw (24 ton/ha)											
0-2.5	22.15	30.3*	23.65	20.00	20.25	20.00	359.70	494.55	384.06	37.49	28.77
2.5-7.5	23.35	26.8***	25.50	18.41	20.10	18.50	767.23	911.84	839.46	18.85	8.62
7.5-15	24.2	27.8***	26.25	19.01	20.20	19.80	1137.80	1339.30	1231.31	17.71	8.77
15-20	25.05	27.85***	26.55	18.20	19.41	17.02	771.95	880.14	797.81	14.02	10.32
Sugar can Fibers (12 ton/ha)											
0-2.5	22.3	33.85*	22.25	18.55	19.68	17.44	351.47	546.13	342.52	55.38	59.44
2.5-7.5	22.75	30.1*	23.90	17.42	19.79	18.00	731.98	1017.70	778.54	39.03	30.72
7.5-15	23.6	27.7**	25.45	18.03	18.55	17.60	1089.10	1292.50	1163.78	18.67	11.06
15-20	24.45	27.5**	26.60	18.32	18.46	18.00	755.46	852.20	816.35	12.81	4.39
Sugar can Fibers (24 ton/ha)											
0-2.5	22.35	31.45*	22.15	19.18	19.90	20.56	356.91	509.71	363.81	42.81	40.10
2.5-7.5	22.85	26.55***	24.10	19.92	21.20	20.00	774.61	923.49	818.32	19.22	12.85
7.5-15	23.75	27.00***	25.90	18.57	21.38	19.58	1108.60	1334.70	1234.61	20.39	8.10
15-20	24.55	26.9***	26.35	18.46	19.89	18.31	760.78	858.61	813.99	12.86	5.48

content in the upper layers 0-2.5 and 2.5 - 7.5 cm for sugarcane under mulches treatments at 3.00 pm were higher than the values under rice straw in the same layers. But the reverse is the true in the bottom soil layers.

As to the gain and loss of heat content during heating and cooling periods under non shading conditions (Table 1) clarifies that the response of upper soil layers to such processes was higher than that of deeper soil layers 7.5 - 15 cm and 15 - 20 cm. The data also clearly show that the trend of such response display the following descending order; control treatment, sugar can 24 ton/ha, rice straw 12 ton/ha, sugar can 12 ton/ha and rice straw 24 ton/ha.

It is worthy to mention that the maximum soil temperature was recorded at 3.00 pm in the upper soil layers 0.0-2.5 and 2.5-7.5 cm. compared to at 9.00pm and 12.00am in the bottom soil layers 7.5-15.0cm and 15.0-20.0cm, respectively, indicating a lag period approached 6 and 9hr for the bottom layers, in the same sequence.

Considering the total heat content recorded in 1/10/2004 under shading conditions (Table 3) reveals similar trend to that obtained under non-shading conditions. Nevertheless the values of retained heat, especially under sugarcane fibers, were relatively higher, most probably due to the higher soil moisture content under shading compared to the un-shading conditions. It is also evident that increasing the rate of application of plant residues in has resulted increasing the heat content either under heating or cooling periods. Again, this behavior could be ascribed to the increase of soil moisture content ensuing the higher application of mulching materials [6, 7].

It is also found that the values of heat gain and loss attained their maximum in top soil layer and tend to decrease gradually with depth. It was also observed that the percentage of heat gained during heating period was higher in the top soil layers than those that obtained at the bottom ones.

By comparison the heat gain and loss at the 1st of October 2004 under mulching treatments (Table 3) was higher than the corresponding values under the combined mulching and shading treatments (Table 4). This behavior could be explained on basis that shading diminishes the received solar radiation consequently less heat is absorbed by the soil [8, 9].

Table 4: Total heat content of the studied depths under the applied treatments(mulching and shading)

	Soil Temperature °C			Soil moisture (%)			Soil heat content at the indicated time.				
Depth		Time at			Time at		7.00: am	Time at Max Temp	4.00 am		
(cm)	7.00am	Max Temp	4.00 am	7.00am	Max Temp	4.00 am	T_H cal/Soil layer	T_H cal/Soil layer	T_H cal/Soil layer	Gain %	Loss %
(1/10/2004)Control shading											
0-2.5	22.15	27.75*	22.65	19.32	19.67	18.69	354.75	447.64	358.05	26.18	25.02
2.5-7.5	21.5	26.85*	24.15	17.86	19.11	18.7	698.28	985.2	798.35	41.09	23.40
7.5-15	22.4	25.7**	25	18.47	19.8	16.92	1043.4	1230.6	1126.54	17.94	9.24
15-20	23.1	25.6**	25	17.41	19.6	18	700.08	812.28	767.25	16.03	5.87
Rice Straw (12 ton/ha)											
0-2.5	22.5	29.2*	23.15	24.37	24.27	24.25	397.85	515.36	408.43	29.54	26.18
2.5-7.5	23.1	25.65**	25.00	22.09	23	21.9	817.67	924.05	881.66	13.01	4.81
7.5-15	23.6	25.7***	25.00	20.92	20.09	19.53	1155.97	1237.9	1190.49	7.09	3.98
15-20	24.1	26.4***	25.00	19.25	19.49	19.81	759.21	835.79	796.66	10.09	4.91
Rice Straw (24 ton/ha)											
0-2.5	23.2	27.85*	23.50	25.19	26.49	25.90	416.50	511.93	427.39	22.91	19.78
2.5-7.5	23.4	25.3**	25.00	23.47	23.40	22.70	850.58	918.41	895.46	7.97	2.56
7.5-15	23.7	25.3***	25.00	23.78	22.90	21.85	1227.29	1288.30	1247.33	4.97	3.29
15-20	24.1	25.7***	25.20	22.33	22.48	21.45	807.46	863.57	829.9	6.95	4.08
Sugar can Fibers (12 ton/ha)											
0-2.5	23	28.75*	22.70	23.82	25.26	23.60	402.51	516.80	395.62	28.39	30.63
2.5-7.5	22.95	25.6**	24.90	23.65	22.20	21.90	837.07	908.11	878.12	8.49	3.42
7.5-15	23.4	25.65**	25.15	21.09	21.38	20.15	1150.07	1267.90	1212.91	10.25	4.54
15-20	23.75	25.45**	25.00	22.04	21.74	20.01	791.25	842.93	799.91	6.53	5.38
Sugar can Fibers (24 ton/ha)											
0-2.5	23.2	28.5*	22.85	23.91	21.11	22.07	406.70	473.28	386.69	16.37	22.39
2.5-7.5	22.55	25.15**	24.10	23.16	23.80	22.60	814.86	919.91	861.56	12.89	6.77
7.5-15	23.05	25.3**	25.00	20.08	21.91	20.24	1110.05	1263.80	1207.88	13.85	4.63
15-20	23.65	25.2**	25.00	21.83	20.88	19.19	784.69	820.56	786.59	4.57	4.32

% Gain= The percentage of gain in total heat content from 7.00am to the time of maximum temperature.

% Loss= The percentage of loss in total heat content from 4.00 am(dawn to the time of maximum temperature

H_W= Heat content of water,H_S =Heat content of soil particles, T_H= Heat content of soil body (cal/g soil).

*: Maximum soil temperature at 3.00pm **: Maximum soil temperature at 9.00pm ***: Maximum soil temperature at 12.00am

Table 5: Statistical analysis of total heat retained in the soil profiles under the applied treatments

	ANOVA randomized complete blocks			Duncan's multiple						
	F Test			LSD		Significant of treatments				
Total Heat At	mulch	shading	mulch*shading	mulch	shading	T1	T2	T3	T4	T5
1 / 8 / 2004										
7.0 am	6.81**	9.11**	11.36**	8.35	4.63**	e	b	a	d	c
T_H. 0max	17.74**	13.91**	17.75**	1.84	5.05**	e	c	a	d	b
4.0 am (dawn)	15.79**	18.50**	14.83**	2.13	11.83**	e	b	a	c	d
1 / 10 / 2004										
7.0 am	17.09**	9.3**	32.97**	0.013**	0.006**	e	b	a	d	c
Time at max. Temp.	12.65**	11.13**	34.39**	0.0083**	0.004**	b	c	a	e	d
4.0 am (dawn)	13.35**	11.77**	11.06**	0.047**	0.021**	e	b	a	d	c

** Significant at 1%.T1= Control treatment.T2= Rice straw (12 ton / ha).T3= Rice straw (24 ton / ha).T4= Sugar can fibbers (12 ton / ha).
T5= Sugar can fibbers (24 ton / ha).

Further support of the obtained, results was carried out on basis of statistical analysis. The data presented in Table 5 show that the differences among the studied treatments are highly significant. It is also evident that LSD is lower under treatments in 1st October than in 1st August.

Table 6: The rate of change in heat content under the applied treatments (1/8/2004)

		Heat Quantity					
Treatments	Depth. (cm)	Δ QT_H	Δ QTc	$\Delta QT_H / \Delta t$	Heating period	Δ QTc / Δ t	Cooling period
Non Shading							
Control	2.5	119.78	134.74	16.34	7:40am-3.0pm	-10.36	3:00pm - 4:00am
	7.5	171.41	218.38	23.38	7:40am- 3.0pm	16.80	3:00pm - 4:00am
	15.0	121.12	193.67	7.42	7:40am -12.0am	-48.42	12:00am - 4:00am
	20.0	100.95	119.38	6.18	7:40am -12.0am	-29.85	12:00am - 4:00am
Rice Straw 12 ton / ha	2.5	100.66	99.56	13.73	7:45am -3.05pm	-7.69	3:05pm - 4:02am
	7.5	103.38	73.98	7.76	7:45am - 9.05pm	-10.57	9:05pm - 4:02am
	15.0	113.13	83.16	8.49	7:45am -9.05pm	-11.88	9:05pm - 4:02am
	20.0	75.68	41.22	4.64	7:45am - 12.05am	-10.31	12:05am - 4:02am
Rice Straw 24 ton / ha	2.5	20.87	61.60	1.58	7:55am - 9:16pm	-8.97	9:16pm - 4:08am
	7.5	110.66	79.62	8.40	7:55am - 9:16pm	-11.59	9:16pm - 4:08am
	15.0	117.84	87.95	8.94	7:55am - 9:16pm	-12.80	9:16pm - 4:08am
	20.0	82.50	35.36	5.05	7:55am - 12:15pm	-9.11	12:1pm - 4:08am
Sugar Fibbers 12 ton / ha	2.5	89.60	129.19	12.22	8:00am - 3:20pm	-10.07	3:20pm - 4:14am
	7.5	123.84	119.61	16.89	8:00am - 3:20pm	-9.32	3:20pm - 4:14am
	15.0	109.70	15.63	8.22	8:00am - 9:23pm	-1.99	9:23pm - 4:14am
	20.0	79.40	36.22	4.86	8:00am - 12:20am	-9.47	12:20am - 4:14am
Sugar Fibbers 24 ton / ha	2.5	103.07	95.13	14.21	8:10am - 3:30pm	-7.43	3:30pm - 4:21am
	7.5	133.33	132.40	18.14	8:10am - 3:30pm	-10.34	3:30pm - 4:21am
	15.0	90.04	94.72	5.51	8:10am - 12:30am	-24.73	12:30pm - 4:21am
	20.0	49.62	29.32	3.04	8:10am - 12:30am	-7.68	12:30pm - 4:21am
Shading							
Control	2.5	59.35	98.20	8.09	7:40am -3.0pm	-7.55	3:00pm - 4:00am
	7.5	100.83	78.13	13.76	7:40am - 3.0pm	-6.01	3:00pm - 4:00am
	15.0	76.56	64.06	5.74	7:40am -9.0pm	-9.15	9:00pm - 4:00am
	20.0	48.14	41.82	2.95	7:40am -12.0am	-10.46	12:00am - 4:00am
Rice Straw 12 ton / ha	2.5	64.02	108.91	8.73	7:45am -3.05pm	-8.38	3:05pm - 4:02am
	7.5	82.80	68.95	11.30	7:45am - 3.05pm	-5.30	3:05pm - 4:02am
	15.0	76.63	54.61	5.75	7:45am -9.05pm	-7.80	9:05pm - 4:02am
	20.0	49.95	39.97	3.75	7:45am - 9.05pm	-5.71	9:05pm - 4:02am
Rice Straw 24 ton / ha	2.5	29.15	81.62	3.98	7:55am - 3:15pm	-6.32	3:15pm - 4:08am
	7.5	78.80	30.52	5.91	7:55am - 9:15pm	-4.41	9:15pm - 4:08am
	15.0	75.94	19.79	4.65	7:55am - 12:15am	-5.05	12:15am - 4:08am
	20.0	66.88	35.44	4.09	7:55am - 12:15am	-9.04	12:15am - 4:08am
Sugar Fibbers 12 ton / ha	2.5	54.28	93.76	7.41	8:00am - 3:20pm	-7.26	3:20pm - 4:14am
	7.5	95.82	109.8	13.07	8:00am 3:20pm	-8.50	3:20pm - 4:14am
	15.0	73.48	63.35	5.51	8:00am - 9:2pm	-9.15	9:20pm - 4:14am
	20.0	58.78	21.82	4.41	8:00am - 9:20pm	-3.15	9:20pm - 4:14am
Sugar Fibbers 24 ton / ha	2.5	67.35	74.40	9.19	8:10am - 3:30pm	-5.75	3:30pm - 4:21am
	7.5	112.74	105.38	15.38	8:10am - 3:30pm	-8.14	3:30pm - 4:21am
	15.0	102.34	82.26	7.68	8:10am - 9:30pm	-12.08	9:30pm - 4:21am
	20.0	75.11	43.59	4.60	8:10am - 9:30pm	-6.27	9:30pm - 4:21am

Response of Total Heat with Time and Depth ($\Delta QT_H / \Delta t$ and $\Delta QT_C / \Delta t$): Table 6 represent the time rate of change in the total heat content in the different soil layers, i.e. ($\Delta QT_H / \Delta t$ and $\Delta QT_C / \Delta t$) during heating and cooling cycles at 1st of August 2004. As to the control, i.e. non-shading treatments without mulching, the data elucidates that the maximum time-rate of change occurred in the top two soil layers. It is also evident that such trend except few cases is quite true under the conditions of the applied treatment. Nevertheless, the magnitude of change is less value. On the contrary, during the cooling periods, the time-rate of change in soil heat was generally higher within the bottom layers compared to the heating cycles.

Comparing shading and no shading treatments reveals that the time rate of change under the former is less than the latter [10, 11].This behavior could be attributed to the fact that shading acts as a barrier to the heat losses from soil. Another reason could be ascribed to the relatively higher soil moisture contents under shading relative to non-shading conditions.

Table 7: The rate of change in heat content under the applied treatments (1/10/2004)

	Heat Quantity						
Treatments	Depth. (cm)	Δ QT_H	Δ Qtc	$\Delta QT_H / \Delta t$	Heating period	Δ QTc / Δt	Cooling period
Non Shading							
Control	2.5	273.08	163.14	36.95	7:21am -3.0pm	-12.60	3:00pm - 4:00am
	7.5	269.66	217.81	36.49	7:21am - 3.0pm	-16.75	3:00pm - 4:00am
	15.0	237.63	163.65	17.75	7:21am -9.0pm	-23.38	9:00pm - 4:00am
	20.0	112.72	60.11	8.42	7:21am -9.0pm	-8.60	9:00pm - 4:00am
Rice Straw 12 ton / ha	2.5	157.57	144.93	21.53	7:30am -3.02pm	-11.18	3:02pm - 4:05am
	7.5	121.30	42.67	7.80	7:30am - 12.05am	-10.66	12:05am - 4:05am
	15.0	139.75	76.22	8.50	7:30am -12:05am	-19.06	12.05am - 4:05am
	20.0	73.02	30.11	4.44	7:30am - 12.05am	-7.54	12:05am - 4:05am
Rice Straw 24 ton / ha	2.5	134.85	110.49	18.17	7:43am - 3:08pm	-8.50	3:08pm - 4:11am
	7.5	144.61	72.38	8.76	7:43am - 12:12am	-18.10	12:1am - 4:1am
	15.0	201.51	107.95	12.21	7:43am -12:12am	-26.98	12:12am -4:1am
	20.0	108.19	82.33	6.56	7:43am - 12:12am	-20.60	12:12am - 4:11am
Sugar Fibbers 12 ton / ha	2.5	194.66	203.61	26.31	7:50am - 3:11pm	-15.77	3:11pm - 4:15am
	7.5	285.71	239.15	38.61	7:50am - 3:11pm	-18.40	3:11pm - 4:15am
	15.0	203.34	128.68	15.09	7:50am - 9:15pm	-18.40	9:15pm - 4:15am
	20.0	96.74	35.85	7.18	7:50am - 9:15pm	-5.12	9:15pm - 4:15am
Sugar Fibbers 24 ton / ha	2.5	152.80	145.90	20.82	7:56am - 3:15pm	-11.27	3:15pm - 4:19am
	7.5	148.88	105.17	9.08	7:56am - 12:21am	-26.26	12:21am -4:19am
	15.0	226.05	100.06	13.78	7:56am - 12:21am	-25.05	12:21am - 4:19am
	20.0	97.83	44.62	5.97	7:56am - 12:21am	-11.17	12:21am - 4:19am
Shading							
Control	2.5	92.89	89.59	11.99	7:15am -3:0pm	-6.89	3:00pm - 4:00am
	7.5	196.92	96.85	25.41	7:15am - 3:0pm	-7.45	3:00pm - 4:00am
	15.0	187.22	104.08	13.62	7:15am -9:0pm	-14.86	9:00pm - 4:00am
	20.0	112.20	45.03	8.16	7:15am -9:0pm	-6.43	9:00pm - 4:00am
Rice Straw 12 ton / ha	2.5	117.51	106.93	15.10	7:18am -3.05pm	-8.21	3:05pm - 4:05am
	7.5	106.38	42.39	7.72	7:18am - 9.05pm	-6.07	9:05pm - 4:05am
	15.0	81.96	47.44	4.88	7:18am -12.05am	-11.81	12:05:am - 4:05 am
	20.0	76.58	39.13	4.56	7:18am - 12.05am	-9.80	12:05am - 4:05am
Rice Straw 24 ton / ha	2.5	95.43	84.54	12.52	7:35am - 3:12pm	-6.50	3:12pm - 4:12am
	7.5	67.83	22.95	4.99	7:35am - 9:10pm	-3.28	9:10pm - 4:12am
	15.0	61.03	40.99	3.68	7:35am - 12:11am	-10.26	12:11am -4:12am
	20.0	56.11	33.67	3.38	7:35am - 12:11am	-8.42	12:11am - 4:12am
Sugar Fibbers 12 ton / ha	2.5	114.29	121.18	15.18	7:45am - 3:17pm	-9.30	3:17pm - 4:18am
	7.5	121.04	29.99	8.96	7:45am - 9:15pm	-4.29	9:15pm - 4:18am
	15.0	117.87	55.03	8.73	7:45am - 9:15pm	-7.87	9:15pm - 4:18am
	20.0	51.68	43.03	3.83	7:45am - 9:15pm	-6.17	9:15pm - 4:18am
Sugar Fibbers 24 ton / ha	2.5	66.58	86.59	8.87	7:55am - 3:25pm	-6.66	3:25pm - 4:26am
	7.5	105.05	58.35	7.78	7:55am -9:25pm	-8.33	9:25pm -4:26am
	15.0	153.73	55.90	11.39	7:55am -9:25pm	-7.98	9:25pm - 4:26am
	20.0	35.87	33.97	2.66	7:55am - 9:25pm	-4.86	9:25pm - 4:26am

Table 8: Statistical analysis for the change of heat quantity (heating /cooling period) and responsing with time throughout all treatments

	ANOVA randomized complete blocks			Duncan's multiple						
	F Test			LSD		Significant of treatments				
Response	mulch	shading	mulch*shading	mulch	shading	T1	T2	T3	T4	T5
1 / 8 / 2004										
Δ QT_H	8.3**	12.55**	3.24**	0.039**	0.017**	a	d	e	c	b
Δ QT_C	18.93**	20.73**	15.52**	4.08**	1.83**	a	d	e	c	b
Δ QT_H /Δ t	17.44**	7.39**	4.84**	0.013**	0.006**	a	d	e	c	b
Δ QT_C /Δ t	1.13	0.73	0.89	10.11	5.31	a	c	c	d	b
1 / 10 / 2004										
Δ QT_H	22.13**	10.90**	2.50**	0.052**	0.023**	a	e	d	c	b
Δ QT_C	15.31**	14.72**	6.77**	0.015**	0.007**	a	e	d	b	c
Δ QT_H / Δ t	14.62**	11.53**	10.33**	0.04**	0.018**	a	d	e	b	c
Δ QT_C /Δ t	4.17**	2.00**	1.75**	0.017**	0.007**	c	e	a	d	b

Δ Q $T_{H=Change\ of\ heat\ quantity\ at\ heating\ period}$

Δ Q T_C= Change of heat quantity at cooling period

Δ Q T_H / Δ t = response of total heat with time at heating period

Δ Q T_C / Δ t = response of total heat with time at cooling period

Table 9: Total yield of cowpea under different mulching and shading treatments

	Non- Shading				
	Rice straw			Sugarcane fibbers	
Yield	control	12 ton ha^{-1}	24 ton ha^{-1}	12 ton ha^{-1}	24 ton ha^{-1}
	2.00	4.00	6.00	3.00	5.00
	2.10	3.93	5.15	4.00	5.00
Weight of plants (kg/ plot)	2.00	4.12	6.00	3.75	5.80
Mean weight of plants	2.03	4.02	5.72	3.58	5.27
Total yield	6.10	12.05	17.15	10.75	15.80
	Shading				
	Rice straw			Sugarcane fibbers	
Yield	control	12 ton ha^{-1}	24 ton ha^{-1}	12 ton ha^{-1}	24 ton ha^{-1}
	2.65	5.92	6.50	4.35	5.80
	2.85	4.85	7.32	3.95	6.00
Weight of plants (kg/ plot)	3.10	5.70	6.95	5.00	5.90
Mean weight of plants	2.87	5.50	6.92	4.43	5.90
Total yield	8.60	16.5	20.77	13.3	17.70
L.S.D 0.05	1.5	1.0	2.17	2.32	2.20
Significant at 1%	*	*	*	*	*

Regarding to the data obtained under shading treatments (Table 7) clarifies that the values of time rate of changes in Δ QT_H within the various soil layers were lower than those under non-shading. It is also evident that the time-rate of changes of heat quantity during 1st of October exhibits similar trend to that indicated in the 1st of August. Nonetheless the magnitude of rates was higher in the former compared to the latter. This behavior probably due to the relatively higher recorded air temperature during the1st of October compared to that of the 1st of August.

Furthermore, the data given in (Table 8) proves that the impact of the applied treatments on the change and the time-rate change of heat content within the different soil layers under both heating and cooling cycles is highly significant.

Also the response of heat under heating period is more pronounced compared to cooling period. This finding may be attributed to the influences of solar radiation during day time on the soil [12, 13].

Total Yield: Table 9 shows that 60% shading using seran plastic sheets has increased yield from 6.1 to 8.6 Kg/plot (the plot area = 2*3m). Such behavior can be attributed to the impact of shading on reducing evaporation from soil and plant thereby increasing the soil moisture content with consequent increases of heat retention. This may encourage the plant growth and the obtained yield.

As regard to mulch in the absence of shading, it is clear that the yield of cowpea increases by increasing mulch application. Concerning combined mulches with shading treatment; it is found that the total yield was highly compared to under mulches without shading. The total yield was 16.5 and 20.77 under rice straw 12 and 24 ton/ha, while were 12.05 and 17.15 Kg/plot under non-shading. Also, the results point out that the yield of cowpea under rice straw mulches was higher than those obtained under sugarcane fibbers along all treatments. The differences between shading and non shading treatments were significant.

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