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# Studies on the Thermal Regime of Maryout Soil 2. Effect of Shading and Mulching with Bituminous Emulsion on Total Heat Retention in the Soil Profile

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THE CURRENT work was carried out during the summer season 2004 in agricultural experimental station of the Desert Research Center at Maryout , some 40 km South West of Alexandria City, Egypt, to study the influence of mulching using bituminous emulsion and shading using porous black plastic sheets on the thermal regime of Maryout soils . Measurements were carried out under two soil moisture conditions and two heating/cooling cycles throughout four soil layers of 0 – 2.5, 2.5 – 7.5, 7.5 – 15 and 15 – 20 cm. To attain the dry and wet soil moisture conditions, measurements were achieved before irrigation on 1/8/2004 and after irrigation on 4/8/2004. Total heat retained ($T_H$), heat content of soil ($H_S$) and heat absorbed by soil moisture content of water ($H_W$), were calculated. The experiment was conducted in a split plot design with three replicates. The main plots were assigned for 60% shading using porous black plastic sheets (Saran) laid at 2.5 m above soil surface and non-shading treatments. Meanwhile, the sub main plots were assigned for mulching using three application rates of bituminous emulsion. All experimental plots were cultivated with cowpea. The results indicated that:

1. Actual soil temperature of the studied soil depths in the two measurement times decreased gradually with depth and increased from the early morning ( at 7.00am) to reach their maximum values at 3.00 pm for the two upper soil layers ( 0-2.5 and 2.5-7.5 cm) and 9.00 pm and12.00 (mid night) in the two bottom layers (7.5-15 and 15-20 cm) respectively. After that soil temperature decreased gradually till 4.00 am (dawn).This indicates that the time lag periods required for occurring the maximum temperature in the two bottom layers were 6 and 9 hr, in the same sequence.
2. Actual soil temperature of the dry soil without shading (before irrigation) was higher than that obtained under shading for the same treatment. The maximum soil temperature took the same trend as that mentioned above indicating the some time lag required for the temperature of the bottom layers to reach its maximum.
3. Regardless the effect of shading treatments, it is evident that the temperature of the wet soil ( after irrigation ) at different times were lower than those of the dry one (before irrigation).
4. Bituminous emulsion combined with shading increased soil moisture and total heat storage through different soil layers. This may be beneficent for preserving good media for seed germination, root growth, activity of soil fauna in cold periods and consequently plant growth and production.

**Keywords:** Soil temperature, Thermal regime, Total heat content, Shading, Mulching bituminous emulsion.

Temperature is one of the most important dynamic properties of the soil. Though its daily and seasonal changes, it has several effects on soil properties, such as moisture retention and movement, root growth as well as micro-organisms activity, availability and uptake of nutritive elements. Temperature of the soil surface responds mainly to the radiant energy through day - time heating mainly short wave radiation mostly shorter than 2 microns coming from both the sun and the sky. Night-time cooling results from the loss of energy by emission from the surface of the soil as long wave radiation which is mostly longer than 4 microns.

In addition to such external climatic variables, soil temperature and its thermal regime depend on the properties of soil itself including the temporary variations in soil surface reflectivity, heat capacity, heat conductance and alternating wetting and drying of soil as well as the alteration of these properties with depth. In this context, Awadalla (1977) found that the values of specific heat of soil particles decreased from coarse to fine sand, and progressively increased in the clay fraction. He also found that the volumetric heat capacity of soil "Cv" increased with increasing soil moisture content. Horton (1989) indicated that there was an increase in thermal conductivity of the soil with the increase in water content. Ghali & Mohamed (2003), showed that heat flow through soils was controlled by its apparent thermal conductivity and temperature gradient.

Due to the fact that the surface of soil is easily to manipulate and treating, therefore most of the methods and management practices aimed at modifying soil temperature are performed on the surface. Among of these methods are mulching using either synthetic or natural materials, tillage, shading, irrigation...etc. As to , mulching and shading and their effects on soil surface temperature, Nobel & Geller (1987) found that maximum soil surface temperature was markedly influenced by short wave radiation, wind speed and air temperature. They showed also that when the soil was shaded, simulated maximum soil surface temperature decreased by about 2°C for every 10% increase in shading, indicating that nurse plant can have a substantial effect on the local microclimate. Rosenberg *et al.* (1983) mentioned that mulching materials, *e.g.*, synthetic non-organic mulches as plastic sheets, black or white opaque, polyethylene powders, aluminum foil and petroleum refining products and natural materials such as natural plant residues, were used for moisture conservation and/ or soil temperature modification. El-Sersawy & Awadalla (1993) .They found a positive effect on soil total heat content, which is generally affected by soil heat capacity.

This work is an attempt to clarify the effect of soil mulching with bituminous emulsion as a synthetic soil conditioner and 60% shading with Seran on temperature and total heat retained in the soil profile under different soil moisture conditions throughout heating and cooling cycle.

## Material and Methods

An experiment has been conducted during the summer season of 2004, in the Agricultural Experimental Station of the Desert Research Center, at Maryout ; some 40 km South West of Alexandria, Egypt. The soil is sandy loam, highly calcareous, saline (EC= 5.6 dS/m ) and non-alkaline(pH=7.79).

The experiment was performed in split plot design with three replications for each treatment .Cowpea seeds ( *Vigna Unguiculata* ) was chosen as the indicator crop. The main plots were designated for shading treatments, viz., the control, *i.e.*, non shading and 60% shading using porous black plastic sheets (Seran). Meanwhile, the sub-plots were devoted to mulching using three application rates of bituminous emulsion 55± 5% active material ( B.E.) namely; 0.1, 0.3 and 0.5 L/m$^2$. Bituminous emulsion was sprayed on the soil surface after two days of the first irrigation .

Soil thermal regime under the applied treatments was followed up at two runs; the first was carried out under dry conditions, *i.e.*, immediately before irrigation on the 1$^{st}$ of August, 2004 and the second was under wet conditions *i.e.*, immediately after irrigation on the 4$^{th}$ of August, 2004. For each treatment in each run, soil temperature was measured at the mid depths of the studied layers, *i.e.*, 0.0 – 2.5, 2.5 – 7.5, 7.5 – 15 and 15 – 20 cm, using digital thermometer (accuracy $\pm$ 0.1 °C). Soil temperature at each run was undertaken at 7.00 am, 9.00am, 12.00 pm ( noon time ), 3.00 pm, 9.00 pm, 00.00 am (mid-night) and 4.00 am (dawn), respectively. At each temperature measurement, soil moisture content was determined at the same depths.

For each depth, the amount of heat gained during heating period and that lost during cooling one, was calculated in cal g$^{-1}$ soil. The amount of heat energy retained by solid particles ($H_S$) was obtained via multiplying the weight of the oven-dry soil particles by its volumetric heat capacity, cal g$^{-1}$. Meanwhile, the amount of heat energy absorbed by the soil moisture ($H_W$) was calculated via multiplying the volumetric water content of each soil layer by the heat capacity of water. Thereby, the total heat content ($H_T$) was obtained for each layer ( $H_T = H_S + H_W$). Afterwards, the total amounts of heat retained in each layer in each treatment were obtained via multiplying ($H_T$) by the recorded soil temperature at the considered time.

The main properties of the soil under study were determined according to the standard methods ( Page *et al.*, 1982 and Klute, 1986 ) (Table 1 ).

**TABLE 1. Properties of the studied depths.**

| Depth (cm) | Particle size distribution (%) | | | | T.C. | $CaCO_3$ (%) | ρb | Ps | O.M. (%) | Moisture % at | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | C.S. | F. S.. | Silt | Clay | | | ton $m^{-3}$ | | | 0.1 bar | 15.0 bar |
| 0-2.5 | 2.61 | 53.52 | 29.43 | 14.44 | SL | 36.4 | 1.32 | 2.40 | 0.80 | 19.11 | 8.29 |
| 2.5-7.5 | 2.96 | 53.66 | 31.02 | 12.36 | SL | 36.7 | 1.38 | 2.31 | 0.86 | 17.85 | 7.66 |
| 7.5-15 | 2.78 | 54.83 | 24.39 | 18.00 | SL | 36.45 | 1.30 | 2.31 | 0.75 | 19.87 | 8.9 |
| 15-20 | 2.65 | 54.27 | 28.27 | 14.81 | SL | 36.51 | 1.30 | 2.43 | 0.68 | 18.48 | 8.43 |

C.S. = Coarse sand, F.S. = Fine sand, T.C=Textural class, SL = Sandy loam, ρb = Bulk density, Ps = Solid phase density, O.M. = Organic matter.

## Results and Discussion

*Actual soil temperature*

Table 2 shows that the values of the actual temperature of the dry soil (before irrigation) in the absence of shading were higher than the corresponding values of the same treatment under shading. The values of maximum soil temperatures in the absence of shading were, 35°C and 30°C in the two top soil layers at 3.00 pm, while they were 29.5°C and 29.5°C in the two bottom soil layers at 00.00 am (midnight). But under shading these values were 26.2°C and 26.3°C in the two top soil layers, while they were 25.3 and 25.5°C in the two bottom soil layers at the same recording times. On percentage basis, the decrease of maximum temperature of the soil before irrigation due to shading ranged between 16.6 to 33.6%.Nevertheless such trend is vanished and becomes negligible during the period from late night to the onset of morning (7.00 am ). It is also evident that there were lag periods for approaching the maximum soil temperature at 9.00 pm and 00.00am in the bottom soil layers (7.5 – 15 cm and 15.0 – 20.0) cm), respectively compared to the top soil layers(0 – 2.5 and 2.5 – 7.5 cm). This may be due to the relative increase in the soil moisture content of the bottom soil layers compared to the top ones. Another reason can be rendered to the fact that a temperature gradient must be developed before heat begins to flow to the lower depths, and thus a time lag before the maximum temperature occur at the lower depths and the resistance to heat conduction through soil tends to damp the temperature cycle at greater depths. These findings are in concordance with those of Hanks & Ashcroft (1980).

Regarding the mulching treatments Table 2 shows that the maximum soil temperature upon applying 0.1L/$m^2$ B.E. in the absence of shading ranged between 29.1°C and 31.8°C , meanwhile they were between 28.8 and 32.5°C under 0.3 L/$m^2$ and between 28.7 and 33.0°C under 0.5 L/$m^2$ treatments. This indicates that the higher application rate of B.E. (0.5 L/$m^2$) resulted in higher soil temperature compared to the lower ones. It is also noticed that upon applying B.E. at rates 0.1 and 0.3 L/ $m^2$ the lag period for attaining maximum temperature in the bottom layers reached 6 hr , nevertheless it required 9 hr upon using 0.5L/ $m^2$.

This behavior may be explained on the basis that B.E. especially upon using higher application rate has resulted in a positive impact on conserving soil water. The obtained data of soil moisture reveal that soil moisture content under B.E. was appreciably higher than the corresponding values of the non mulched soil.

As for the influence of shading (Table 2) reveals that the values of actual temperature of shaded soil, under all the application rates of B.E., were relatively lower than those observed under non-shading conditions. The data elucidate that when the soil was treated with 0.1,0.3 and0.5 L/$m^2$ B.E. the values of maximum temperature of the most upper layers of shaded soil were 28.0, 28.2 and 28.9° C, respectively, compared to 26.2, 26.6 and 26.6° C in the bottom layer in the same sequence . Apparently such decrease in the maximum soil temperature upon applying B.E. can be explained on basis that soil mulching by B.E especially under shading treatment slowed down the evaporation rate from soil surface and hence increased the soil moisture content and consequently heat capacity of the soil and its temperature.

Considering the temperature along the wet soil profile (after irrigation), Table 3 reveals, in the absence of shading that they varied from 23.45 to 25.15°C at 7.00 am (early morning ), 27.4 to 30.7°C at 3.00pm ( afternoon ) and from 24.25 to 26.9°C at 4.00 am ( dawn ). The reverse was true under shading treatments. Data also point out that under wet conditions; the differences between soil temperatures under the various application levels of B.E. were not pronounceable due to increasing soil moisture content.

It is striking to notice that the mean values of moisture content of the non-shaded treatment throughout the soil profile before irrigation at 7.00 am and 3.00pm, were 17.24 and 14.56 %, respectively. Meanwhile the corresponding values under shading conditions were 18.10 and 18.65 %, in the same sequence. This means that shading has resulting in increasing and thereby saving 4.99 and 28.09 % of the soil moisture content at early morning and 3.00pm (afternoon time) as compared to the non-shading one.

Regarding B.E., Tables 2 & 3 reveal that spraying the soil surface with the applied rates, in absence of shading did not significantly affect moisture content throughout the soil profile, compared to the (non mulched) soil. Whereas when B.E. treatments were combined with shading, soil moisture content sharply increased. These findings may be attributed to the low evaporation under shaded-mulched treatments (Hillel, 1998).

**TABLE 2. Actual temperature°C and moisture content of soil before irrigation as affected by shading and mulching with B.E.**

| Treatments | | Depth (cm) | Soil temperature °C | | | Soil moisture w/w | | |
|---|---|---|---|---|---|---|---|---|
| | | | at7.00am | at Max Temp | at4.00am of the next day | at7.00am | at Max Temp | at4.00am of the next day |
| Non Shading | B.E 0.0 L /m² soil | 0-2.5 | 23.0 | 35.0* | 24.3 | 11.69 | 12.56 | 10.62 |
| | | 2.5-7.5 | 23.8 | 30* | 24.1 | 18.8 | 13 | 14.4 |
| | | 7.5-15 | 25.3 | 29.5*** | 24.2 | 17.9 | 15.1 | 15.6 |
| | | 15-20 | 25.9 | 29.5*** | 24.1 | 17.4 | 16.3 | 15.9 |
| | B.E 0.1 L /m² soil | 0-2.5 | 24.5 | 31.8* | 26.4 | 11.47 | 11.74 | 8.81 |
| | | 2.5-7.5 | 24.9 | 29.4* | 27.4 | 15.4 | 13.4 | 13.9 |
| | | 7.5-15 | 25.5 | 29.5** | 28.2 | 15.6 | 14.6 | 13.3 |
| | | 15-20 | 25.6 | 29.1** | 28.5 | 15 | 15.4 | 13 |
| | B.E 0.3 L /m² soil | 0-2.5 | 24.2 | 32.5* | 26.2 | 12.37 | 10.84 | 7.93 |
| | | 2.5-7.5 | 24.5 | 30* | 27 | 16.9 | 14 | 13 |
| | | 7.5-15 | 25.4 | 29.2** | 27.7 | 16 | 14.9 | 14.1 |
| | | 15-20 | 25.4 | 28.8** | 28.2 | 15.9 | 14.7 | 13.8 |
| | B.E 0.5 L /m² soil | 0-2.5 | 24.1 | 33* | 26.7 | 10.94 | 9.05 | 8.91 |
| | | 2.5-7.5 | 24.1 | 30.3* | 27.4 | 16.7 | 14.1 | 15 |
| | | 7.5-15 | 25.1 | 28.7*** | 28 | 16.7 | 16.3 | 13.3 |
| | | 15-20 | 25.4 | 29.00*** | 28 | 17.5 | 16.3 | 13.1 |
| Shading | B.E 0.0 L /m² soil | 0-2.5 | 23 | 26.2* | 23.6 | 17.74 | 19. | 16.01 |
| | | 2.5-7.5 | 23.4 | 26.3* | 24.5 | 18 | 19 | 17.7 |
| | | 7.5-15 | 23.6 | 25.3** | 24.4 | 17.9 | 18.4 | 16.8 |
| | | 15-20 | 23.6 | 25.5*** | 25.1 | 18.7 | 18.5 | 16.8 |
| | B.E 0.1 L /m² soil | 0-2.5 | 24.1 | 28* | 24 | 23.38 | 21.54 | 22.66 |
| | | 2.5-7.5 | 24.2 | 27* | 24.6 | 23.2 | 22 | 21 |
| | | 7.5-15 | 24.4 | 26.2** | 25.2 | 21.7 | 21.9 | 20.6 |
| | | 15-20 | 24.3 | 26.3** | 26 | 20.9 | 20.5 | 20.2 |
| | B.E 0.3 L /m² soil | 0-2.5 | 24.3 | 28.2* | 24 | 21.81 | 21.84 | 22.94 |
| | | 2.5-7.5 | 24.5 | 27.3* | 25.2 | 22.4 | 20.8 | 20.6 |
| | | 7.5-15 | 24.8 | 26.6** | 25.5 | 21.2 | 21.1 | 21 |
| | | 15-20 | 24.8 | 27** | 26 | 20.2 | 19.7 | 20.3 |
| | B.E 0.5 L /m² soil | 0-2.5 | 25.2 | 28.9* | 23.6 | 23.44 | 24.8 | 20.27 |
| | | 2.5-7.5 | 24.8 | 28.1* | 24.3 | 22.6 | 21.2 | 19.7 |
| | | 7.5-15 | 25.1 | 26.6** | 25.2 | 22.8 | 21.4 | 21.2 |
| | | 15-20 | 25.2 | 26.6** | 26.2 | 21.1 | 20.4 | 20.3 |

B.E. = Bitomenous emulsion.
* : Maximum soil temperature at 3.00pm.
** : Maximum soil temperature at 9.00pm.
*** : Maximum soil temperature at 12.00am.

**TABLE 3. Actual temperature° C and moisture content of the soil after irrigation as affected by shading and mulching with B.E.**

| Treatments | | Depth (cm) | Soil temperature° C | | | Soil moisture w/w | | |
|---|---|---|---|---|---|---|---|---|
| | | | at 7.00 am | at Max temp. | at 4.00am of the next day | at 7.00 am | at Max Temp | at 4.00am of the next day |
| Non Shading | B.E 0.0 L /m² soil | 0-2.5 | 23.95 | 30.7* | 24.45 | 25 | 21.38 | 18.17 |
| | | 2.5-7.5 | 23.45 | 29.3* | 24.25 | 21.52 | 21.74 | 19.01 |
| | | 7.5-15 | 24.2 | 27.4** | 25.95 | 20.97 | 20.17 | 20.08 |
| | | 15-20 | 25.15 | 27.45** | 26.9 | 21.9 | 21.5 | 17.9 |
| | B.E 0.1 L /m² soil | 0-2.5 | 25.1 | 29* | 24 | 30.66 | 24.52 | 29.44 |
| | | 2.5-7.5 | 23.45 | 27.25* | 24 | 25.59 | 21.55 | 21.99 |
| | | 7.5-15 | 23.85 | 26.4** | 25.25 | 23.77 | 21.17 | 20 |
| | | 15-20 | 24.5 | 26.8** | 26 | 24 | 21.5 | 19.7 |
| | B.E 0.3 L /m² soil | 0-2.5 | 24.8 | 29.8* | 24.1 | 32.49 | 25.51 | 26 |
| | | 2.5-7.5 | 23.35 | 28.25* | 24.1 | 26.28 | 24.27 | 22.89 |
| | | 7.5-15 | 23.75 | 26.1** | 25.4 | 24.64 | 23.88 | 23.02 |
| | | 15-20 | 24.4 | 26.55*** | 26.1 | 23.4 | 21.4 | 22 |
| | B.E 0.5 L /m² soil | 0-2.5 | 25 | 29.05* | 24.25 | 33.02 | 26.03 | 26.3 |
| | | 2.5-7.5 | 23.3 | 28* | 24.3 | 27.74 | 24.53 | 23.9 |
| | | 7.5-15 | 23.75 | 25.9** | 25.35 | 23.1 | 21.84 | 22.4 |
| | | 15-20 | 24.6 | 26.4*** | 26.1 | 23.7 | 22.5 | 22 |
| Shading | B.E 0.0 L /m² soil | 0-2.5 | 24.95 | 28.05* | 24 | 26.85 | 25 | 22.25 |
| | | 2.5-7.5 | 23.8 | 26.2* | 23.75 | 22.81 | 22.45 | 22.35 |
| | | 7.5-15 | 24.05 | 25.5* | 24.55 | 21.14 | 21.95 | 21.58 |
| | | 15-20 | 24.45 | 25.35*** | 25 | 22.4 | 24.9 | 22.8 |
| | B.E 0.1 L /m² soil | 0-2.5 | 26 | 29.25* | 24.05 | 30.97 | 24.67 | 26.31 |
| | | 2.5-7.5 | 23.3 | 27.55* | 23.9 | 25.26 | 24.27 | 24.69 |
| | | 7.5-15 | 23.35 | 26.4* | 24.4 | 23.95 | 23 | 22.99 |
| | | 15-20 | 23.65 | 25.5** | 24.9 | 26.9 | 25.2 | 22.6 |
| | B.E 0.3 L /m² soil | 0-2.5 | 25 | 28.65* | 23.9 | 33.66 | 25.81 | 24.37 |
| | | 2.5-7.5 | 23.2 | 27.45* | 23.85 | 27.95 | 24.84 | 23.25 |
| | | 7.5-15 | 23.25 | 26* | 24.45 | 26.86 | 24.21 | 23.72 |
| | | 15-20 | 23.6 | 25.4*** | 24.95 | 27 | 23.4 | 22.98 |
| | B.E 0.5 L /m² soil | 0-2.5 | 24.3 | 28.6* | 23.4 | 36.77 | 28.97 | 26.22 |
| | | 2.5-7.5 | 23.3 | 27.25* | 24 | 29.81 | 24.69 | 23.99 |
| | | 7.5-15 | 23.35 | 26* | 24.5 | 28.89 | 25.26 | 24.25 |
| | | 15-20 | 23.65 | 25.6*** | 25.05 | 26.6 | 24.8 | 24.13 |

B.E.= Bitomenous emulsion.
*: Maximum soil temperature at 3.00pm.
**: Maximum soil temperature at 9.00pm.
***: Maximum soil temperature at 12.00am.

*Total heat content ( $H_T$ )*

Tables 4 & 5 present the values of total heat content as affected by the applied treatments .The data in Table 4 show in case of non shaded, non mulched soil that total heat content of dry soil increases with increasing soil depth. The magnitudes of the total heat content varied from 347.1 to 1128.9 cal $g^{-1}$ at 7.00 am,466.88 to1250 at (midnight) and 332.14 to 1056.3 cal.$g^{-1}$ at 4.00 am (dawn) . Also, the data reveal that the gain of heat in the non-shaded non mulched dry soil, during the period from 7.00 am to 3.00 pm in the two upper soil layers ranged between 22.11 and 34.51% and between 10.73 and 12.6% in the bottom soil layers. While the loss of heat ( cooling ) from 3.00pm to 4.00am ( dawn ) in the upper soil layers varied from 29.99 to 40.57%.It is evident that surface soil layer ( 0-2.5 cm) displayed the highest gain and loss of heat compared to the bottom soil layers. The relatively high absorbed heat in the surface layers of the dry soil could attributed to their higher temperature gradient. Meanwhile during cooling period, such situation, *i.e.* their higher temperature result in higher heat losses by back radiation. The same table also point out under shading treatment that the values of total heat content and the amounts of gain and loss of heat by the different soil layers were lower than those under non-shading conditions . This could be due to the fact that shading diminishes the incoming solar radiation to the soil(Russell, 1973).

In the case of wetted soil, *i.e.*, after irrigation Table 5 clarify that the values of total heat content in the different layers of non- mulched and non- shaded soil ranged between 428.47 and 820.83 cal $g^{-1}$ at 7.00 am, 512.55 and 1030.06 cal $g^{-1}$ at 3.00pm in the upper soil layers, while ranged between 835.61 and 1186.5 cal $g^{-1}$ and 904.89 and 1321.95 cal $g^{-1}$ in the bottom soil layers at the same recording time. Considering the non-mulched treatment, under shading conditions the values of total heat content ranged between 461.59 and 854.28 cal $g^{-1}$ at 7.00 am and 501.81 and 933.91 cal $g^{-1}$ at 3.00 pm in the upper soil layers, whereas, they were between 820.3and 1183.19 cal $g^{-1}$ and 891.69 and 1274.77 cal $g^{-1}$ in the bottom soil layer for the same times respectively .As for the values of heat content under wetted soil conditions, *i.e.*, after irrigation Table 5 indicate they were appreciably higher than those corresponding values of the dry soil. As mentioned before the moisture content leads to the increase in the absorbed latent heat and to the increase in the thermal conductivity of soil, thereby heat conductance through soil. This confirms the finding of Seidhom (2001) reported that mulching using organic or synthetic material increased soil moisture content and slowed down evaporation from soil.

**TABLE 4. Total soil heat content ( cal/g of the soil ) before irrigation as affected by shading and mulching with B.E.**

| Treatments | | Depth (cm) | at. ( 7.00 am ) | | | at max. Temp. | | | at. ( 4.00 am ) of the next day | | | gain% | loss% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Hw | Hs | $H_T$ | Hw | Hs | $H_T$ | Hw | Hs | $H_T$ | | |
| Non Shading | B.E 0.0 L /m² soil | 0-2.5 | 96.44 | 250.7 | 347.1 | 136.57 | 330.3 | 466.88 | 86.04 | 246.1 | 332.14 | 34.51 | 40.57 |
| | | 2.5-7.5 | 303.54 | 471.7 | 775.19 | 291.53 | 655.1 | 946.6 | 240.45 | 487.77 | 728.22 | 22.11 | 29.99 |
| | | 7.5-15 | 428.46 | 700.4 | 1128.9 | 425.48 | 824.5 | 1250 | 367.32 | 689.02 | 1056.3 | 10.73 | 18.33 |
| | | 15-20 | 289.54 | 511.5 | 801.08 | 312.55 | 589.5 | 902.03 | 249.59 | 533.06 | 782.65 | 12.6 | 15.25 |
| | B.E 0.1 L /m² soil | 0-2.5 | 98.03 | 259.6 | 357.65 | 121.84 | 315.3 | 437.1 | 72.39 | 249.61 | 322 | 22.21 | 35.75 |
| | | 2.5-7.5 | 262.46 | 498 | 760.48 | 282.94 | 616.8 | 899.71 | 257.99 | 542.19 | 800.18 | 18.31 | 12.44 |
| | | 7.5-15 | 390.9 | 733.2 | 1124.1 | 419.22 | 840.2 | 1259.5 | 360.5 | 793.15 | 1153.7 | 12.04 | 9.17 |
| | | 15-20 | 249.11 | 510.6 | 759.66 | 293.29 | 585.5 | 878.77 | 239.56 | 566.5 | 806.06 | 15.68 | 9.02 |
| | B.E 0.3 L /m² soil | 0-2.5 | 105.11 | 258.1 | 363.24 | 111.79 | 313.3 | 425.05 | 66.34 | 254.13 | 320.47 | 17.02 | 32.63 |
| | | 2.5-7.5 | 283.94 | 490.8 | 774.02 | 301.88 | 629.9 | 931.76 | 238.6 | 536.15 | 774.75 | 20.38 | 20.27 |
| | | 7.5-15 | 396.24 | 724.7 | 1120.9 | 416.94 | 818.8 | 1235.8 | 375.99 | 780.25 | 1156.2 | 10.25 | 6.88 |
| | | 15-20 | 262.51 | 507.5 | 770.05 | 277.09 | 579.5 | 856.57 | 250.71 | 557.5 | 828.21 | 11.24 | 3.42 |
| | B.E 0.5 L /m² soil | 0-2.5 | 94.59 | 262.6 | 357.23 | 94.37 | 316.8 | 411.14 | 75.27 | 256.62 | 331.89 | 15.09 | 23.88 |
| | | 2.5-7.5 | 277.7 | 485.8 | 763.46 | 307.92 | 637.9 | 945.85 | 279.97 | 545.22 | 825.19 | 23.89 | 14.62 |
| | | 7.5-15 | 407.88 | 714.7 | 1122.6 | 448.96 | 806 | 1254.9 | 359.2 | 790.3 | 1149.5 | 11.79 | 9.17 |
| | | 15-20 | 287.22 | 504.5 | 791.76 | 305.67 | 576.5 | 882.15 | 238.42 | 559.5 | 797.92 | 11.42 | 10.56 |
| Shading | B.E 0.0 L /m² soil | 0-2.5 | 147.23 | 252.1 | 399.34 | 176.5 | 282.2 | 458.69 | 124.42 | 236.07 | 360.49 | 14.86 | 27.24 |
| | | 2.5-7.5 | 288.14 | 467.6 | 755.76 | 337.58 | 519 | 858.59 | 293.72 | 484.74 | 778.46 | 13.61 | 10.29 |
| | | 7.5-15 | 411.88 | 673.3 | 1085.2 | 448.5 | 713.3 | 1161.8 | 400.49 | 697.21 | 1097.7 | 7.05 | 5.84 |
| | | 15-20 | 286.86 | 471.6 | 758.44 | 303.03 | 503.6 | 806.58 | 270.2 | 494.56 | 764.76 | 6.35 | 5.47 |
| | B.E 0.1 L /m² soil | 0-2.5 | 195.59 | 262.6 | 458.23 | 204.36 | 288.2 | 492.56 | 179.84 | 241.09 | 420.93 | 7.49 | 17.02 |
| | | 2.5-7.5 | 386.59 | 468.8 | 855.36 | 417.45 | 554.3 | 971.73 | 352.11 | 489.8 | 841.91 | 13.6 | 15.42 |
| | | 7.5-15 | 521.53 | 673.3 | 1194.9 | 554.09 | 740.4 | 1294.5 | 500.12 | 710.41 | 1210.5 | 8.34 | 6.93 |
| | | 15-20 | 330.79 | 436.6 | 767.34 | 349.78 | 524.5 | 874.32 | 336.13 | 511.54 | 847.67 | 13.94 | 3.14 |
| | B.E 0.3 L /m² soil | 0-2.5 | 188.57 | 262.6 | 451.21 | 202.52 | 281.7 | 484.2 | 179.04 | 237.07 | 416.11 | 7.31 | 16.36 |
| | | 2.5-7.5 | 377.13 | 491.8 | 868.93 | 398.27 | 559.3 | 957.59 | 349.66 | 495.84 | 845.5 | 10.2 | 13.26 |
| | | 7.5-15 | 512.62 | 707.6 | 1220.2 | 544.12 | 754.6 | 1298.8 | 519.04 | 723.27 | 1242.3 | 6.44 | 4.54 |
| | | 15-20 | 325.62 | 495.6 | 821.17 | 343.17 | 522.5 | 865.68 | 339.77 | 514.53 | 854.3 | 5.42 | 1.33 |
| | B.E 0.5 L /m² soil | 0-2.5 | 206.53 | 267.7 | 474.18 | 234.47 | 287.2 | 521.67 | 158.87 | 238.07 | 396.94 | 10.02 | 31.42 |
| | | 2.5-7.5 | 389.85 | 503.9 | 893.74 | 446.9 | 574.5 | 1021.4 | 295.55 | 582.73 | 878.29 | 14.28 | 16.29 |
| | | 7.5-15 | 554.64 | 711.8 | 1266.5 | 570.66 | 780.3 | 1351 | 511.58 | 706.14 | 1217.7 | 6.67 | 10.94 |
| | | 15-20 | 345.62 | 503.6 | 849.17 | 352.05 | 530.5 | 882.57 | 339.11 | 513.54 | 852.65 | 3.93 | 3.51 |

B.E.= Bitomenous emulsion .

% 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 absorbed by soil moistur.$H_S$=Heat content of soil particles .$H_T$= Total heat content of soil body.

**TABLE 5. Total soil heat content ( cal/g of the soil ) after irrigation as affected by shading and mulching with B.E.**

| Treatments | | Depth (cm) | at. ( 7.00 am ) | | | at max. Temp. | | | at. ( 4.00 am ) of the next day | | | gain% | loss% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Hw | Hs | $H_T$ | Hw | Hs | $H_T$ | Hw | Hs | $H_T$ | | |
| Non Shading | B.E 0.0 L/m² soil | 0-2.5 | 197.59 | 230.88 | 428.47 | 216.6 | 295.95 | 512.55 | 146.6 | 235.7 | 382.3 | 19.62 | 34.07 |
| | | 2.5-7.5 | 348.2 | 472.63 | 820.83 | 439.52 | 590.54 | 1030.06 | 318.08 | 488.76 | 806.84 | 25.49 | 27.67 |
| | | 7.5-15 | 497.32 | 689.22 | 1186.5 | 541.6 | 780.35 | 1321.95 | 510.65 | 739.06 | 1249.71 | 11.41 | 5.78 |
| | | 15-20 | 358.01 | 477.6 | 835.61 | 383.61 | 521.28 | 904.89 | 312.98 | 510.83 | 823.81 | 8.29 | 9.84 |
| | B.E 0.1 L/m² soil | 0-2.5 | 253.96 | 241.96 | 495.92 | 234.66 | 279.56 | 514.22 | 233.16 | 261.36 | 464.52 | 3.69 | 10.7 |
| | | 2.5-7.5 | 414.06 | 472.75 | 886.81 | 405.19 | 549.36 | 954.55 | 364.15 | 483.84 | 847.99 | 7.64 | 12.57 |
| | | 7.5-15 | 555.58 | 677.82 | 1233.4 | 547.71 | 751.87 | 1299.58 | 494.9 | 719.12 | 1214.02 | 5.37 | 7.05 |
| | | 15-20 | 382.2 | 465.26 | 847.46 | 374.53 | 508.93 | 883.46 | 332.93 | 493.74 | 826.67 | 4.25 | 6.87 |
| | B.E 0.3 L/m² soil | 0-2.5 | 265.9 | 239.07 | 504.97 | 250.87 | 287.27 | 538.14 | 206.78 | 232.32 | 439.1 | 6.57 | 22.55 |
| | | 2.5-7.5 | 423.41 | 470.74 | 894.15 | 473.08 | 569.52 | 1042.6 | 380.64 | 485.86 | 866.5 | 16.6 | 20.32 |
| | | 7.5-15 | 573.5 | 676.4 | 1249.9 | 610.8 | 743.33 | 1354.13 | 573.01 | 723.39 | 1296.4 | 8.34 | 4.45 |
| | | 15-20 | 371.12 | 463.36 | 834.48 | 369.31 | 504.18 | 873.49 | 373.23 | 495.64 | 868.87 | 4.67 | 0.53 |
| | B.E 0.5 L/m² soil | 0-2.5 | 272.42 | 241 | 513.42 | 249.54 | 280.04 | 529.58 | 210.47 | 233.77 | 444.24 | 3.15 | 19.21 |
| | | 2.5-7.5 | 445.98 | 469.73 | 915.71 | 473.92 | 564.48 | 1038.4 | 400.73 | 489.89 | 890.62 | 13.4 | 16.6 |
| | | 7.5-15 | 537.65 | 676.4 | 1214.05 | 554.34 | 737.63 | 1291.97 | 556.48 | 721.97 | 1278.45 | 6.42 | 1.06 |
| | | 15-20 | 378.96 | 467.15 | 846.11 | 386.1 | 501.34 | 887.44 | 373.23 | 495.64 | 868.87 | 4.88 | 2.14 |
| Shading | B.E 0.0 L/m² soil | 0-2.5 | 221.07 | 240.52 | 461.59 | 231.41 | 270.4 | 501.81 | 176.22 | 231.36 | 407.58 | 8.71 | 23.12 |
| | | 2.5-7.5 | 374.59 | 479.69 | 854.28 | 405.85 | 528.06 | 933.91 | 366.26 | 478.68 | 844.94 | 9.32 | 10.53 |
| | | 7.5-15 | 498.25 | 684.94 | 1183.19 | 548.53 | 726.24 | 1274.77 | 519.19 | 699.18 | 1218.37 | 7.74 | 4.63 |
| | | 15-20 | 355.99 | 464.31 | 820.3 | 410.29 | 481.4 | 891.69 | 370.5 | 474.75 | 845.25 | 8.7 | 5.49 |
| | B.E 0.1 L/m² soil | 0-2.5 | 265.72 | 250.64 | 516.36 | 238.13 | 281.97 | 520.1 | 208.81 | 231.84 | 440.65 | 0.72 | 18.03 |
| | | 2.5-7.5 | 406.11 | 469.73 | 875.84 | 461.36 | 555.41 | 1016.77 | 407.16 | 481.82 | 888.98 | 16.09 | 14.37 |
| | | 7.5-15 | 548.05 | 665.01 | 1213.06 | 595.06 | 751.87 | 1346.93 | 549.74 | 694.91 | 1244.7 | 11.04 | 8.21 |
| | | 15-20 | 413.52 | 449.11 | 862.63 | 417.69 | 484.25 | 901.94 | 365.78 | 472.85 | 838.63 | 4.56 | 7.55 |
| | B.E 0.3 L/m² soil | 0-2.5 | 277.7 | 241 | 518.7 | 244.02 | 276.19 | 520.21 | 192.21 | 230.4 | 422.61 | 0.29 | 23.09 |
| | | 2.5-7.5 | 447.42 | 467.71 | 915.13 | 470.48 | 553.39 | 1023.87 | 382.61 | 480.82 | 863.43 | 11.88 | 18.58 |
| | | 7.5-15 | 612.01 | 662.16 | 1274.17 | 616.87 | 740.48 | 1357.35 | 568.35 | 696.34 | 1264.69 | 6.53 | 7.33 |
| | | 15-20 | 414.18 | 448.16 | 862.34 | 386.33 | 482.35 | 868.68 | 372.68 | 473.8 | 846.48 | 0.74 | 2.62 |
| | B.E 0.5 L/m² soil | 0-2.5 | 294.86 | 234.25 | 529.11 | 273.43 | 275.72 | 549.1 | 202.47 | 225.58 | 428.05 | 1.85 | 25.35 |
| | | 2.5-7.5 | 479.09 | 469.73 | 948.82 | 464.23 | 549.36 | 1013.6 | 397.27 | 483.84 | 881.11 | 6.83 | 15.04 |
| | | 7.5-15 | 661.09 | 665.01 | 1326.1 | 643.62 | 740.48 | 1384.1 | 582.24 | 697.76 | 1280 | 4.37 | 8.13 |
| | | 15-20 | 408.91 | 449.11 | 858.02 | 412.67 | 486.14 | 898.81 | 392.9 | 475.7 | 868.6 | 4.75 | 3.48 |

B.E.= Bitomenous emulsion.

% 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 absorbed by soil moistur,$H_S$=Heat content of soil particles ,$H_T$=Total heat content of soil body.

Values of total heat content under wetted soil, *i.e.*, after irrigation were higher than those of the corresponding dry soil, *i.e.*, before irrigation. This behavior could partly due to its relatively higher albedo with consequent higher reflection of the incoming radiation and partly to the higher adsorbing latent heat. Horton (1989). Table 4 also illustrates that the values of heat content when B.E. was combined with shading, were increased compared to the corresponding values under non – shading. Also, it is obvious that the percentages of gain and loss of total heat content for B.E. under non- shading treatment were lower than those of the corresponding of control.

It is striking to notice that the values of the total heat content ($H_T$) shown in Tables 4 & 5 reveal that ($H_T$) at 4.00am (dawn) of the studied soil layers, under the different B.E. treatments were higher than those of the non mulched one. This up rise of recorded soil temperature upon applying B.E. may be attributed to its black color which increases the absorption of incident solar radiation during the day-time (Hillel, 1998). Such beneficial effect of B.E. on worming soil could enhance seed germination, growth and proliferation of roots, seedling emergence and activity of organisms especially during the transition periods cultivation, *i.e.*, early spring and autumn.

Finally, it is found that shading and mulching using B.E. tend to increase soil moisture content and total heat storage with depth. Therefore, it should recommend applying B.E. after plantation to warm the soil root zone, and improve plant growth, consequently increasing total yield and crop production.

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# دراسات على السلوك الحرارى للتربة في مريوط ٢. تأثيرإضافة البيتومين والتغطية على المحتوى الحرارى الكلى خلال طبقات التربة

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أجريت تجربة حقلية بنظام القطع المنشقة ذات ثلاثة مكرارات لكل معاملة خلال الموسم الصيفي سنة ٢٠٠٤ بمحطة بحوث مريوط التابعة لمركز بحوث الصحراء، وذلك لدراسة أثررش سطح التربة بمستحلب البيتومين بتركيزات مختلفة والتغطية (بالثيران) على المحتوى الحرارى الكلى للتربة.

وتم قياس درجات الحرارة خلال شهر أغسطس فى يومين ٢٠٠٤/٨/١ قبل الرى و ٢٠٠٤/٨/٤ بعد الرى وخلال دورتين للحرارة، دورة تسخين (Heating) ودورة تبريد (Cooling) .

وقد دلت النتائج المتحصل عليها على :-

١. أن الحرارة الفعلية على مستوى كل المعاملات تقل مع العمق كذلك لوحظ وجود Lag period مع الزمن فدرجة الحرارة تزيد من ٧ صباحا إلى أن تصل إلى الدرجة القصوى وذلك الساعة ٣ مساء وذلك للطبقتين الأولى والثانية (صفر – ٢،٥ ، ٢،٥ – ٧،٥ سم) ، أيضا تصل إلى أقصى درجة الساعة ٩ مساء ، عند منتصف الليل للطبقتين الثالثة والرابعة (٧،٥– ١٥،١٥– ٢٠ سم) ، ثم تقل درجة الحرارة مرة أخرى عند الفجر ٤ صباحا.

٢. لوحظ ان درجة الحرارة تحت المعاملة بدون تظليل بالثيران فى ٢٠٠٤/٨/١ (قبل الرى) كانت أعلى من نفس المعاملة تحت التظليل.أيضا لوحظ أن درجات الحرارة على مستوى كل المعاملات بعد الرى فى ٢٠٠٤/٨/٤ كانت أقل من درجات الحرارة قبل الرى فى ٢٠٠٤/٨/١.

٣. أدى رش مستحلب البيتومين على سطح التربة إلى زيادة محتوى التربة من الرطوبة.كذلك وجد أن المحتوى الحرارى الكلى للتربة $H_T$ يزيد بزيادة العمق وبزيادة معدل اضافة مستحلب البيتومين المستخدم .

٤. أدت التغطية بالثيران وإضافة البيتومين بعد الرى إلى زيادة المحتوى الرطوبى للتربة وبالتالى زيادة التوصيل الحرارى والإنتشار الحرارى للتربة أكثر من الملاحظ قبل الرى.