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**Research Article**

# Modification of Hydrothermal Regimes through Soil Management Practices

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**ABSTRACT**

To observe the influence of agronomical management practices on soil hydro-thermal regimes, a field experiment was conducted during *kharif* season of 2008 at IARI, New Delhi on bare soil in split-split plot design with three manure types as main treatments (green manure, compost + charcoal and no manure), two land configuration (bed and flat system) as sub treatment and two mulch types (transparent polythene 175 µm thickness –TP and no polythene-NP) as sub-sub treatment. Results of field study showed that irrespective of manure type and mulch application, conventional planting system had significantly lower surface temperature (ST) (1-2 °C) and higher soil water content (SWC) (1.5 to 2 % w/w) than bed planting system. It also revealed that surface ST of bed covered with TP in compost +charcoal treatment had highest magnitude and conventional system covered with NP in green manure treatment had lowest magnitude all throughout the day. Modification of hydrothermal regimes by application of extraneous material or by adopting suitable management practice can result in optimizing crop production through soil solarisation.

**Key words:** Bed planting, Soil solarisation, Soil temperature, Soil water content

## Introduction

Mulching is known to positively affect the soil plant system: soil temperature, reducing evaporative humidity, good weed control, and earliness effects on yield with better quail-quantitative traits (Candido and Miccolis, 2003). Mulch helps to achieve higher soil temperatures as compared with the uncovered ridges (Graefe, 2005). Mulches by modifying the soil thermal regime and above ground temperature may affect plant growth, development, and crop production (Likatas *et al*., 1986). Soil moisture and soil temperature conditions in the seedbed zone (top 5 cm) can promote or delay seed germination and plant emergence (Kasper *et al.,* 1990). Mulches modify soil hydrothermal regimes in crop root zone, conserve soil moisture, keep weeds under control and promote soil productivity. Plastic mulches are highly effective in conserving soil and in alleviating sub optimal temperature conditions (Chaudhary and Prihar, 1974). Different kind of mulches vary in their ability to conserve soil moisture, regulate soil temperature, weed control, soil salinity control, nutrients availability and soil physical properties leading to variations in crop plant yield (Anderson and Jensen, 2001; Dommelen, 1989).

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The indirect lethal heat generated by the sun through orchard fruit trees such as olive trees and strawberries, clear or black polyethylene sheets cause soil solarization (Horowitz *et al.,* 1983). It refers to covering the soil with transparent sheets, usually transparent polyethylene, during hot summer months for capturing solar energy to heat the soil in the open field or in glasshouse. Solarization is a hydrothermal process, which brings about thermal and other physical, chemical, and biological changes in the moist soil during, and even after mulching (Stapleton and DeVay, 1986). Objectives of this investigation were to determine the effectiveness of transparent polythene, compost + charcoal, green manure and ridge bed planting system in moderating soil temperature and moisture.

## Materials and Methods

### *Study Area*

To achieve the objective of the research study, a field experiment was conducted in the main block of experimental farm of IARI, Delhi (28°37' N latitude, 77°11' E longitude and at an altitude of 228.7 m). The climate of the area is semiarid and sub tropical with hot summer and cool winters. The mean monthly maximum and minimum temperature during the year ranges from 21.3 °C to 40.5 °C and 7.3 °C to 28.7 °C, respectively. The annual rainfall is 708.6 mm of which on an average 597 mm (84 %) is received from June to September months. Land use was maize–wheat rotation. Variation of soil temperature (ST) and soil water content (SWC) under different manure types (compost +charcoal, green manure- GM and no manure), land configurations (bed and flat/conventional system) and mulch (transparent polythene (TP) and no polythene (NP)) was studied on bare sandy loam soil during *kharif* season of 2008 (July- October).

Treatments were laid out in a split plot design in 5 m x 5 m plots, with incorporation of organic manure [Compost mixed with charcoal (4:1) @ 10t/ha, Green manure (dhaincha; @ 10t/ha), No manure] as main treatment, land configuration- (bed system and flat system) was used as sub-treatment and mulch (transparent polythene and no polythene) were taken as sub-sub treatment, with three replications. Both (Compost + charcoal) mixture and *dhaincha* were incorporated into the soil by 2-3 passes of tractor.

### *Observations Recorded*

Hourly soil temperature from each treatment at 0, 5, 10, 15 and 20 cm depth was recorded from 10 AM to 7 PM at weekly interval by using digital thermometer. Soil moisture content was determined gravimetrically.

## Results and Discussion

Maximum aerial temperature during mid July to mid October varied between 30.5°C to 35.2°C. ST and SWC observations were recorded on various dates so as to obtain variable aerial temperatures and SWC conditions.

### *Variation of Soil Temperature at Maximum Air Temperature*

Results indicated that for all types of manures under mulch treatment (TP), surface soil water content (SWC) was lower by 1.5 to 2% under bed system as compared to conventional flat system (Fig. 1). It was also observed that during the period of study, SWC under different manure treatments were in the order; GM >charcoal + compost > no manure. Irrespective of manure type, conventional flat system had lower surface ST (1-2°C) than bed system. By using TP as mulch in all manure treatments, surface soil temperature increased by 7-12°C over ambient temperature. During the period of study, soil temperature under different manure treatments were in the order; charcoal + compost > no manure > GM. Range of variation of surface ST in charcoal + compost, green manure and no manure treatments were 42.5-47.6°C, 39.5-46.2°C and 40.5-47.4°C, respectively under bed system and 41.1-46.1°C, 38.3-43.1°C and 38.8-45.6°C, respectively under flat system. On an average, ST was higher by 1-2°C in charcoal + compost than in other two treatments.

On an average, at 5 cm soil depth ST was higher by 2°C under bed as compared to flat system and also by 1-2°C in charcoal + compost

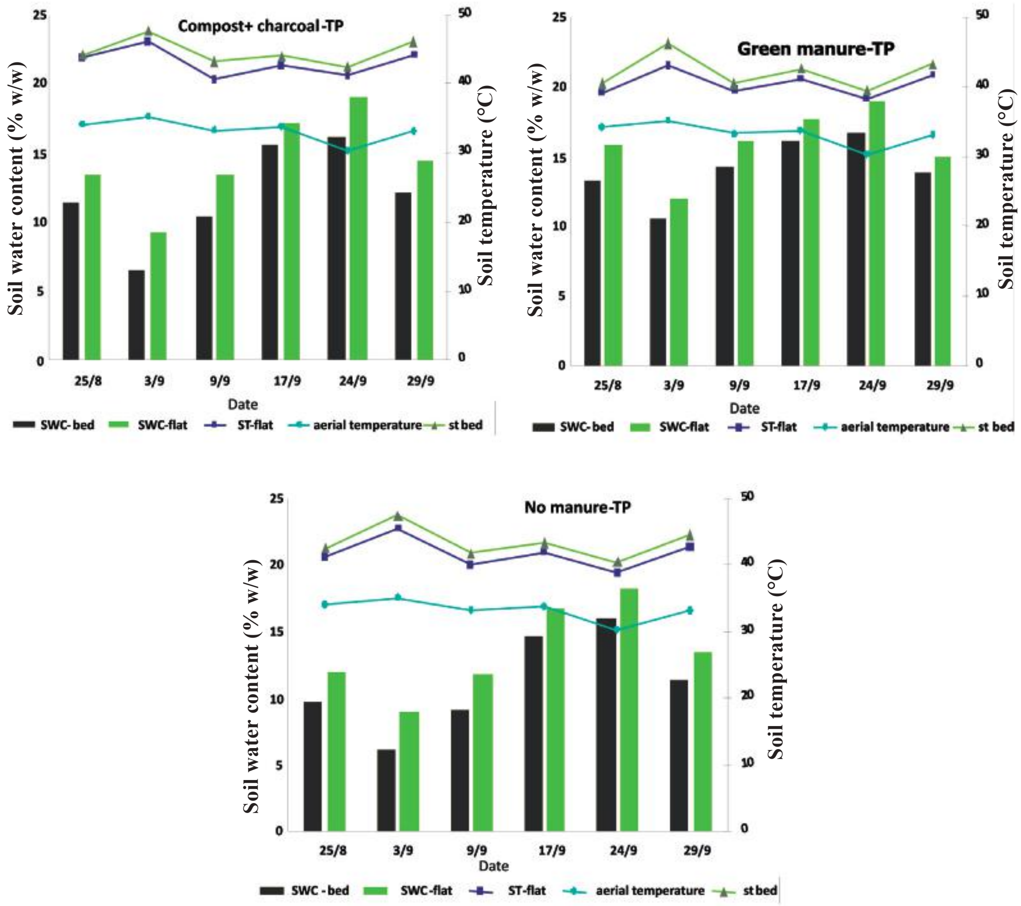


**Fig. 1.** Temporal variation of surface soil temperature in different manure treatments and land configuration under mulch condition

as compared to other two treatments (Fig. 2). Average ST at 5cm depth in all treatments was higher by 7-9° C over ambient temperature.

Difference in SWC at 10 cm soil depth between bed and flat system were nearly 2 % in charcoal + compost and GM treatments but were <1% in no manure treatment (Fig. 3). Average ST of charcoal + compost, and no manure treatments at 10m soil depth under TP were similar and were marginally higher than that under GM treatment. Average ST at 10 cm soil depth was marginally higher (0-4° C) than AT throughout the observation period. Similar trend had been found for 15 and 20 cm of soil layer.

The average SWC under no mulch was 1.3 % lower under bed than under conventional flat system and also was 0.9 % and 1.6 % higher in GM than those in charcoal + compost, and no manure treatments (Fig. 4). Similarly, range of variation of surface ST in charcoal + compost, green manure, and no manure treatments were 35-42.9° C, 33.4-39.4° C and 34-40.5° C, respectively under bed system and 33.5-41.4° C, 31.9-37.5° C and 32.7-39° C, respectively under flat system. Surface ST of bed under NP was higher than that of flat system by 1 to 2°C. However, irrespective of land configuration system, under no mulch condition, average surface ST of compost+ charcoal treated plots showed an increase of 2°C over green manure treated plots and 1.5°C over no manure treated plots. The differences between the surface ST and AT were 3-5°C.

Fig. 5 indicated average ST of compost+ charcoal treated plots at 5cm depth showed an

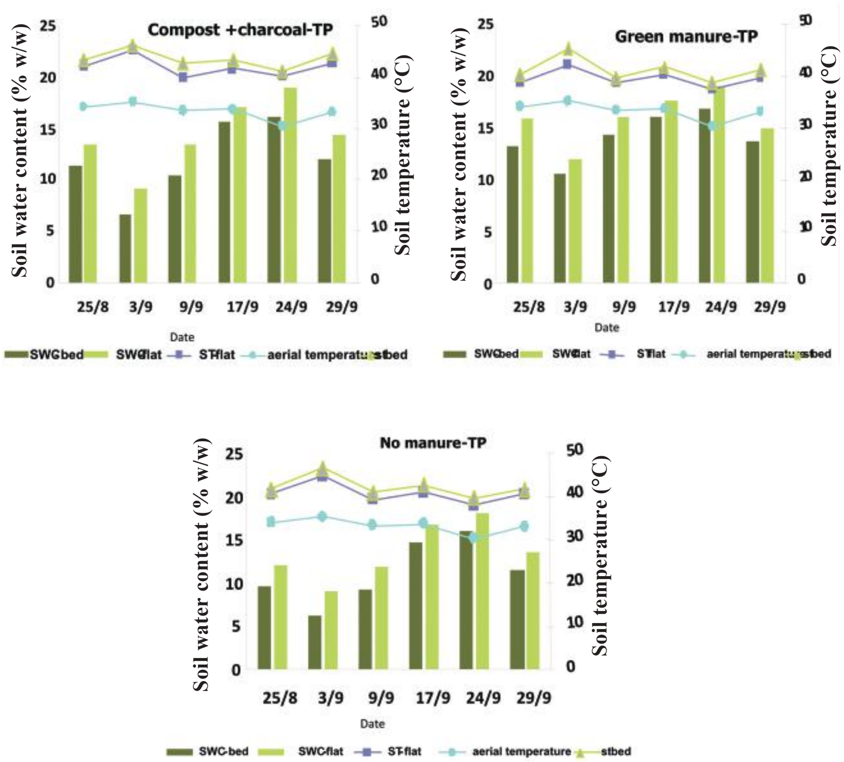


**Fig. 2.** Temporal variation of soil temperature at 5 cm depth in different manure treatments and land configuration under mulch condition

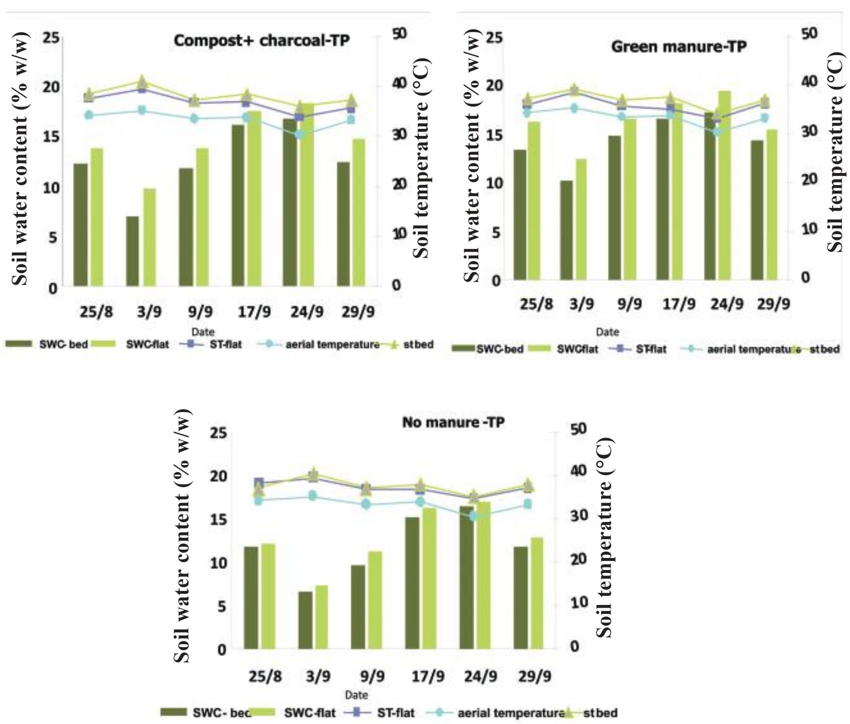


**Fig. 3.** Temporal variation of soil temperature at 10 cm depth in different manure treatments and land configuration under mulch condition

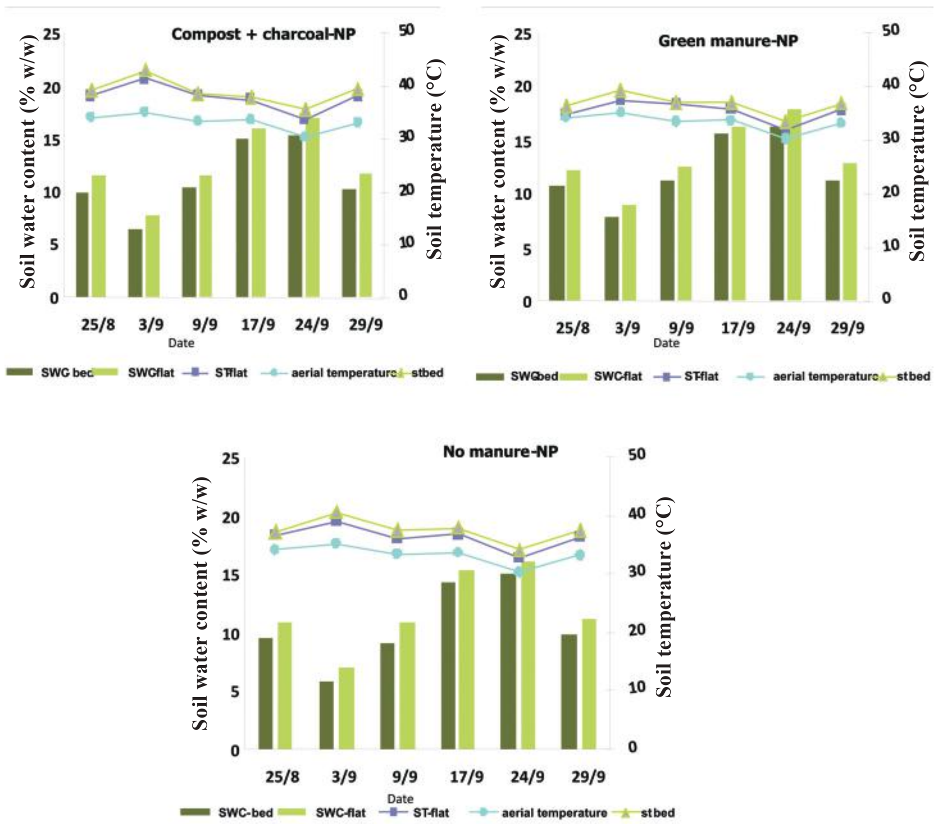


**Fig. 4.** Temporal variation of surface soil temperature in different manure treatments and land configuration under no mulch condition

increase of 2.5°C over green manure treated plots and 1.5°C over no manure treated plots. Similarly, ST of bed under NP was higher than that of flat system by 1.2°C. Average ST at 5cm depth was 1-3 °C higher than AT.

At 10 cm soil depth under NP treatment, SWC of bed was 1.3% lower than in flat system and was 1.3% and 2.1% higher in GM than in charcoal +compost and no manure treatments (Fig. 6). Similar to trends in upper layers, ST of bed at 10cm was 1.2°C higher than in flat and 2.3 °C and 0.8 °C higher in GM than in charcoal +compost and no manure treatments. Average ST at 10 cm depth was 0-1 °C lower than AT. At 15 cm and 20 cm soil depths under NP treatment, variation of SWC and ST followed same trend upper layers; however the differences in their magnitude narrowed down.

The above results thus clearly indicated that all throughout the observation period, flat system retained 1-3% more moisture than in bed system at all depths. Similarly, among manure treatments, on an average SWC retained by GM were nearly 2% and 3% more than in charcoal + compost and no manure treatments. In addition to this, on an average TP retained 1-3% more moisture than NP treatment. These results are in agreement with those reported earlier (Aggarwal and Goswami, 2003; Li *et al.,* 2001). The results on variation of soil temperature at all depths also indicated 1-3 °C higher values on bed over flat. Similarly ST of different manure types were of the order; charcoal + compost > no manure >GM. ST of surface under TP had 5-6 °C higher value over NP but these differences narrowed down with increase in depth. Again, ST of surface under TP was higher by 9-10°C over AT during the period of study. Surface ST on bed in charcoal + compost treatment under TP had highest temperature among all treatments. Above trends on variation of ST due to addition of manure in

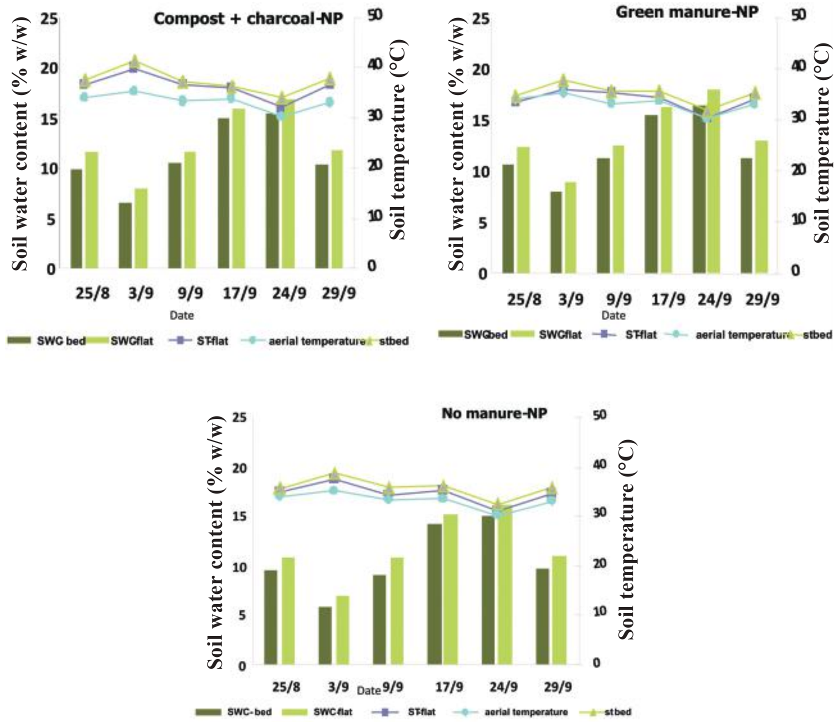


**Fig. 5.** Temporal variation of soil temperature at 5 cm depth in different manure treatments and land configuration under no mulch condition

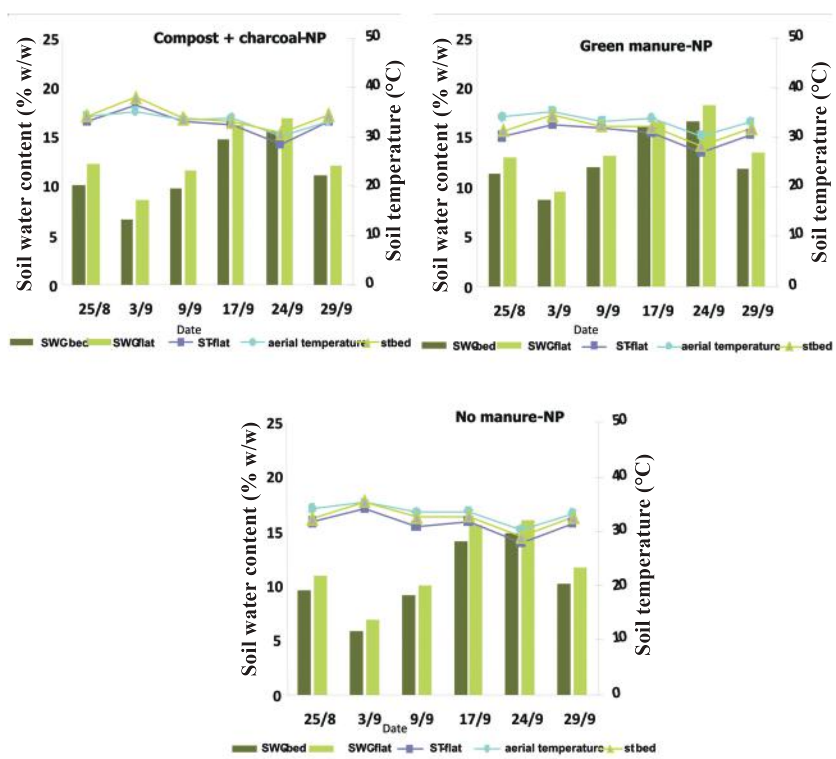


**Fig. 6.** Temporal variation of soil temperature at 10 cm depth in different manure treatments and land configuration under no mulch condition

plough layer or application of transparent polythene as mulch or making of beds for sowing of crops were similar to those reported earlier (Zhang *et al.,* 2005; Wilson and Jasa, 2007).

### *Hourly Variation of Soil Temperature during Daytime*

The purposes of monitoring the soil temperature at hourly interval was to capture the movement of heat in soil profile during day under various soil management practices with variable SWC and ambient temperatures. It is important to quantify the effectiveness of soil management practices alone or in combination for increasing the soil temperature of plough layer, which is desirable on few occasions during different seasons of the year (e.g. during summer for solarisation and during early growth of wheat in December and January when temperatures become sub optimal).

Results of hourly variation of surface soil temperature during day time (dry soil profile condition) showed that under green manure during daytime showed that, the peak magnitudes of bed-TP, bed-NP, flat-TP and flat-NP were 43.3°C, 36.8°C, 41.7°C and 35.6°C, respectively and in all cases peak arrived around 14:30 hours (Fig. 7**).** If conventionally tilled green manure plot are covered with transparent polythene mulch, one can raise surface ST by 1.2-6°C but if beds are made first and plots are then covered with polythene the temperature could be increased by

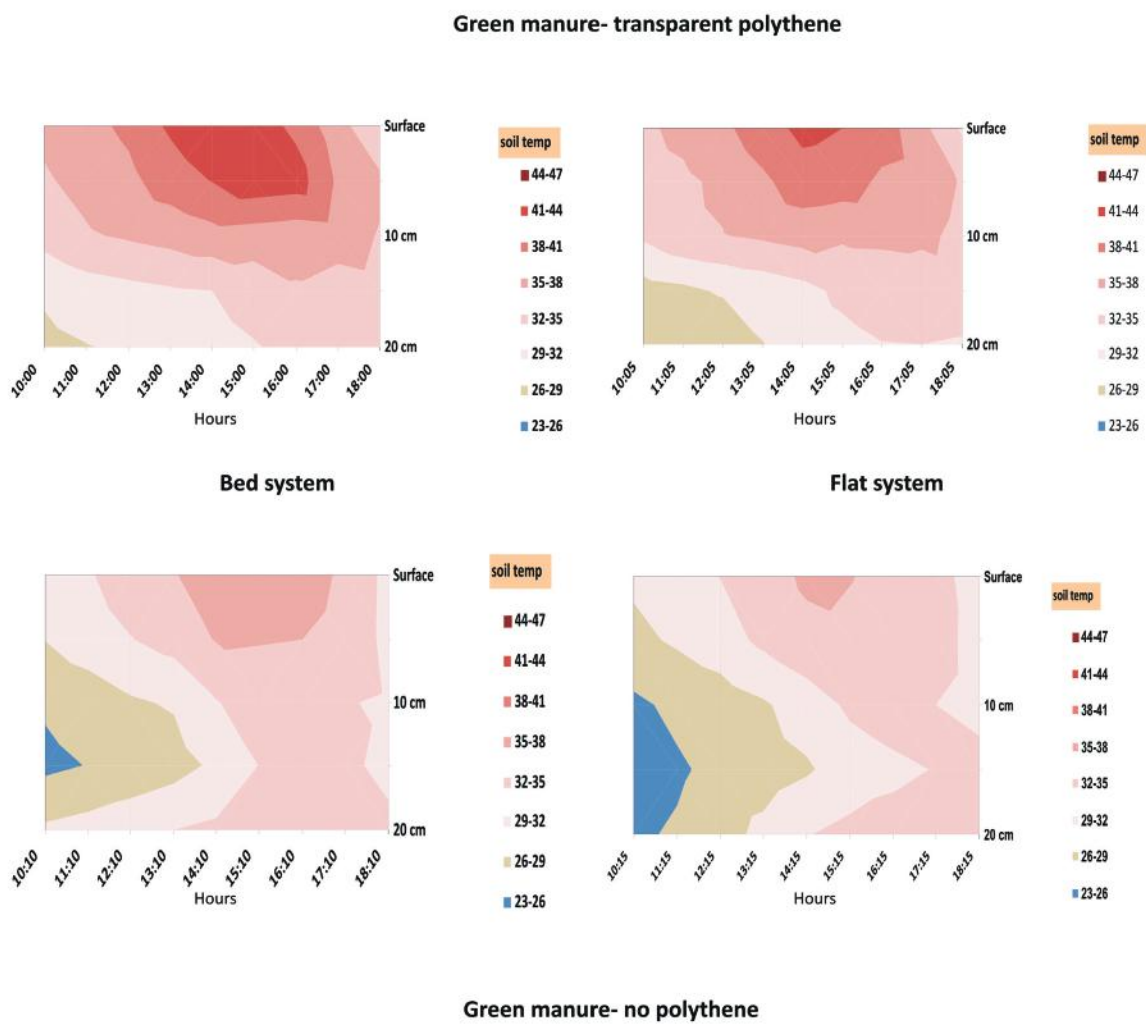


Fig. 7. Hourly variation of temperature during day time in dry SWC conditions under mulch and no mulch conditions in green manure treatment

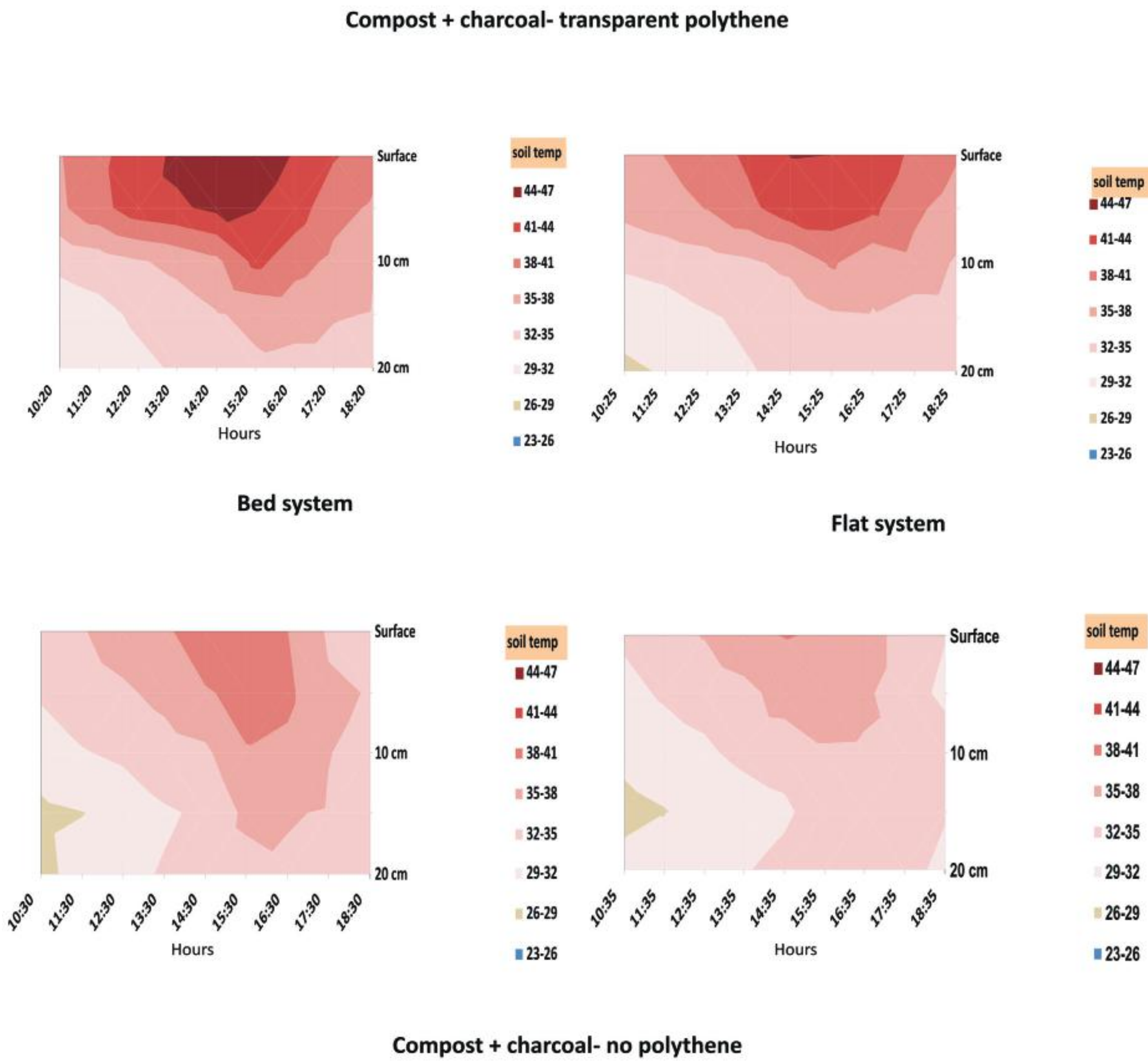


**Fig. 8.** Hourly variation of temperature during day time in dry SWC conditions under mulch and no mulch conditions in compost + charcoal treatment

2-8°C. It was observed that addition of GM alone will reduce the temperature by 0.7 °C whereas, the GM +bed+TP combination could increase the soil temperature by 2-7 °C.

Hourly variation of surface soil temperature under charcoal + compost as manure treatment during day time showed that the peak magnitudes of bed-TP, bed-NP, flat-TP and flat-NP were 46.2°C, 39.4°C, 44.1°C and 38.1°C, respectively and in all cases peak arrived around 14:30 hours (Fig. 8). It is clear from the results that by covering charcoal + compost plot with transparent polythene mulch alone, one can raise surface ST by 5-6°C but if beds are made and plots are then covered with polythene, the temperature could further be increased by 1.5-2°C. It was observed that addition of charcoal + compost alone increased the temperature by 2 °C whereas, the charcoal + compost +bed + TP combination increased the soil temperature by 10 °C.

Similarly, hourly variation of surface soil temperature during day time (dry soil profile condition) showed that under no manure treatment, the peak magnitudes of surface layers of bed-TP, bed-NP, flat-TP and flat-NP treatments were 44.7°C, 37.5°C, 42.7°C and 36.3°C,

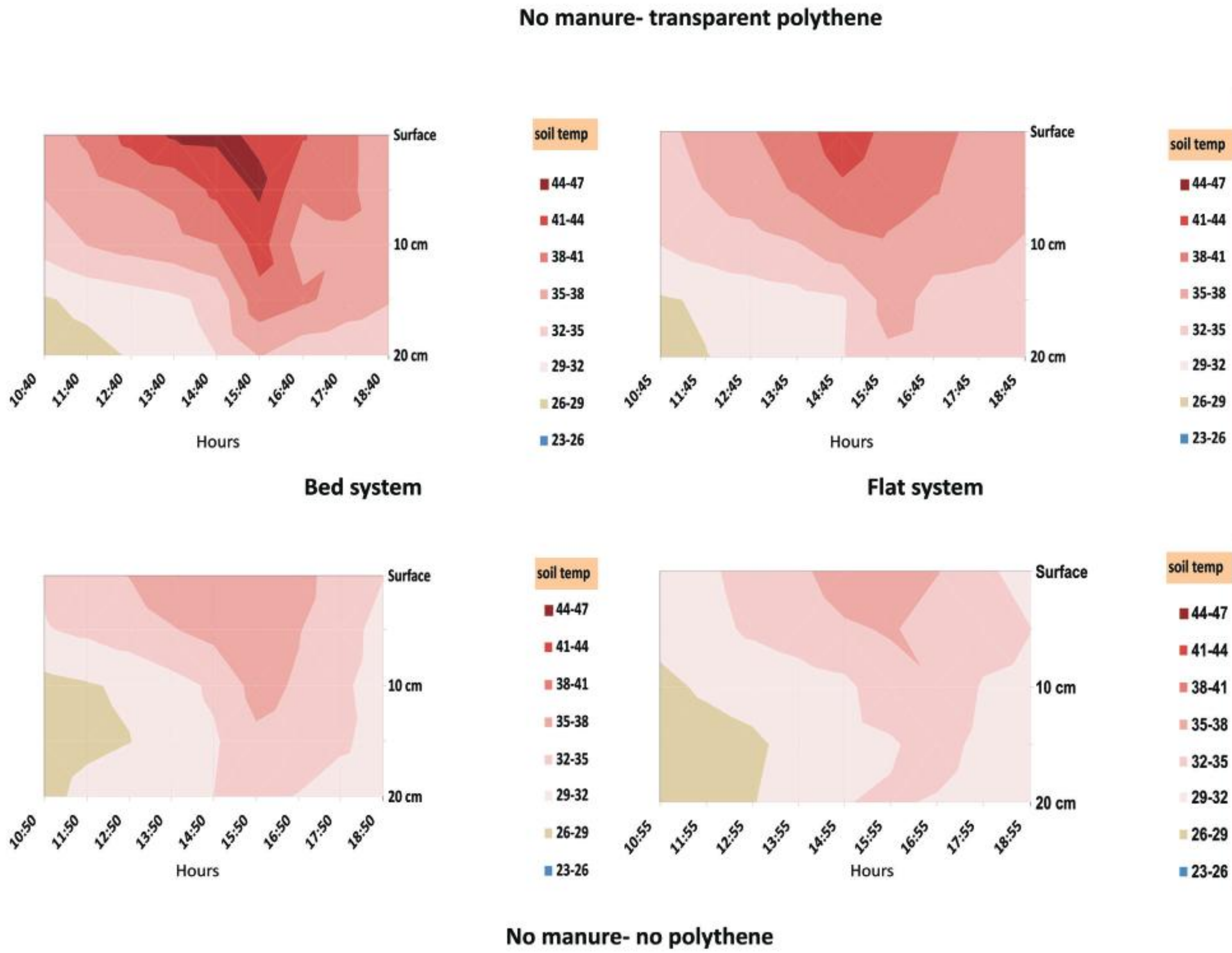


**Fig. 9.** Hourly variation of temperature during day time in dry SWC conditions under mulch and no mulch conditions in no manure treatment

respectively (Fig. 9). The surface temperature of conventional plots could be raised by 4.5-6.4 °C by covering no manure plot with transparent polythene mulch, but if beds are made and plots are then covered with polythene the temperature could further be increased by 2°C.

## Conclusions

Soil surface temperature can be enhanced to different extents by using different soil management practices. For example, an increase of 1.0-2.0° C, 1.5-2.5°C and 4.5-6.5 °C could be obtained by making beds, incorporating compost + charcoal in plough layer or applying transparent polythene on bare soils. Incorporation of charcoal in plough layer followed by making of beds and application of thick transparent polythene could raise the surface soil temperature of bare soil by 10 ° C without affecting nutrient absorption by plant. In field, charcoal should always be applied with FYM. The regulation of soil temperature by polyethylene mulching is governed by varying optical properties which affect the degree of soil warming owing to entraption and reflection of energy. Covering soil with transparent polythene sheeting during hot periods can control soilborne diseases. The technique can be commercially exploited for growing high-value cash crops in diseased soils in environments with a hot summer (maximum daily air temperatures regularly exceeding 35°C). Modification of hydrothermal regimes by application of extraneous material or by adopting suitable management practice can result in optimizing crop production through soil solarisation.

## References

Aggarwal, P. and Goswami, B. 2003. Bed planting system for increasing water use efficiency of wheat grown on Inceptisol. *Indian Journal of Agricultural Sciences,* **73**: 422-425.

Andersen, M.K. and Jensen, L.S. 2001. Low soil temperature effects on short-term gross N mineralisation–immobilisation turnover after incorporation of a green manure. *Soil Biology and Biochemistry*, **33** (4-5): 511-521

Candido, N. and Miccolis. V. 2003. Greenhouse melon response to plastic mulch. *ACTA Horticulture,* **458**: 263-267.

Chaudhury, M.R. and Prihar, S.S. 1974. Root development and growth responses of corn following mulching, cultivation or intern compaction. *Agronomy Journal,* **66**: 412-421.

Dommelen, C.V. 1989. Black film in autumn, problem free planting in spring. *Groenten en Fruit*, **45:** 67-74.

Graefe, J. 2005. Simulation of soil heating in ridges partly covered with plastic mulch, Part 1: Energy Balance Model. *Biosystems Engineering,* **92**(3): 391-407.

Horowitz, M.; Rege, Y. and Herzlinger, G. 1983. Soil solarization for weed control. *Weed Science*, **31**: 170-179.

Kasper, T.C.; Erbach, D.C. and Cruse, R.M. 1990. Corn response to seed- row residue removal. *Soil Science Society of American Journal,* **54**: 1112-1117.

Li, X.Y.; Gong, J.D.; Gao, Q.Z. and Li, F.R. 2001. Incorporation of ridge and furrow method of rainfall harvesting with mulching for crop production under semiarid conditions. *Agricultural Water Management.,* **50**: 173-183.

Likatas, A.; Clark, J.A. and Monteith, J.L. 1986. Measurements of the heat balance under plastic mulches. *Agricultural and Forest Meteorology*, **36**: 227-239.

Stapleton, J.J. and DeVay, J.E. 1986. Soil solarization: a non-chemical approach for the management of plant pathogens and pests. *Crop Protection,* **3**: 190-198.

Wilson, R. G. and Jasa, P.J., Ridge plant system: weed control. University of Nebraska- Lincoln Extension, Institute of Agriculture and Natural Resources. 2007.

Zhang, X.F., Wang, D.Y. and Shao, G.S. 2005. Effects of rice ridge cultivation on grain yield and quality and its physiological and ecological mechanisms. *Chinese Journal of Rice Science,* **17**(4): 343-348.