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Variation of thermal properties of sandy loam soil under different management practices*

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Seed germination, seedling emergence, root growth and subsequent stand establishment are influenced by the microclimate, which is primarily controlled by soil thermal properties. Information about thermal properties is required for modeling energy, water and nutrient movement in soils. Soil physical properties affecting soil thermal regimes include texture and mineralogical composition of the soil (static properties), soil water content, compaction, organic matter, porosity, etc. (dynamic properties). Abu Hamdeh (2000) showed that thermal conductivity varied with soil texture and tillage. Agustin *et al.* (2000) and Aggarwal *et al.* (2009) reported that bed-planting system was superior to conventional planting system as it improved water and nutrient-use efficiency, modified soil temperature and enhanced root growth of wheat. Objective of the present study was to determine the effect of bed and conventional flat planting system on changes in soil temperature as well as thermal properties of a bare sandy loam soil (Typic Ustochrept).

A field experiment was conducted at IARI Farm, New Delhi in which variation of soil temperature (ST), soil water content (SWC) and soil thermal properties under different manure types, land configurations and mulch were studied on bare sandy loam soil during *kharif* season of 2008 (July–October).

Treatments were laid out in a split-plot design with organic manure incorporation [Compost mixed with charcoal (4:1) @ 10 tonnes/ha, Green manure (GM) (*dhaincha*; @ 10 tonnes/ha), no manure] as main treatment, land configuration-(bed system and flat system) as subtreatment and mulch (transparent polyethylene TP and no polyethylene) were taken as sub treatment, with three replications. 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. Bulk density was determined by core sampler method. Important soil thermal properties namely Cv, D and damping depth of soil were determined by methods given by de Vries (1975), Jackson and Kirkham (1958) and Kirkham and Power (1972).

For all types of manures under mulch treatment (TP), SWC was lower by 1.5 to 2% under bed system as compared to conventional flat system (Table 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. 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 (Table 1). Similar trend for variation in soil water contents for bed and conventional planting was found in earlier studies (Aggarwal *et al*. 2006).

Soil temperature during day time was monitored at an hourly interval to capture the movement of temperature wave in soil profile in various soil management treatments under variable SWC and aerial temperatures, so as to quantify

Table 1 Soil water content of experimental plots

Green manure	Charcoal + compost	No manure
SWC- bed system-transparent polyethylene		
10.46–16.78	6.47–16.13	6.15–16
SWC- flat system- transparent polyethylene		
11.94–18.99	9.2–18.94	9.07–18.25
SWC - bed system- no polyethylene		
7.98–16.35	6.42–15.43	5.86–14.99
SWC - flat system- no polyethylene		
8.91–17.98	7.88–16.94	7.08–16.18

*Short note

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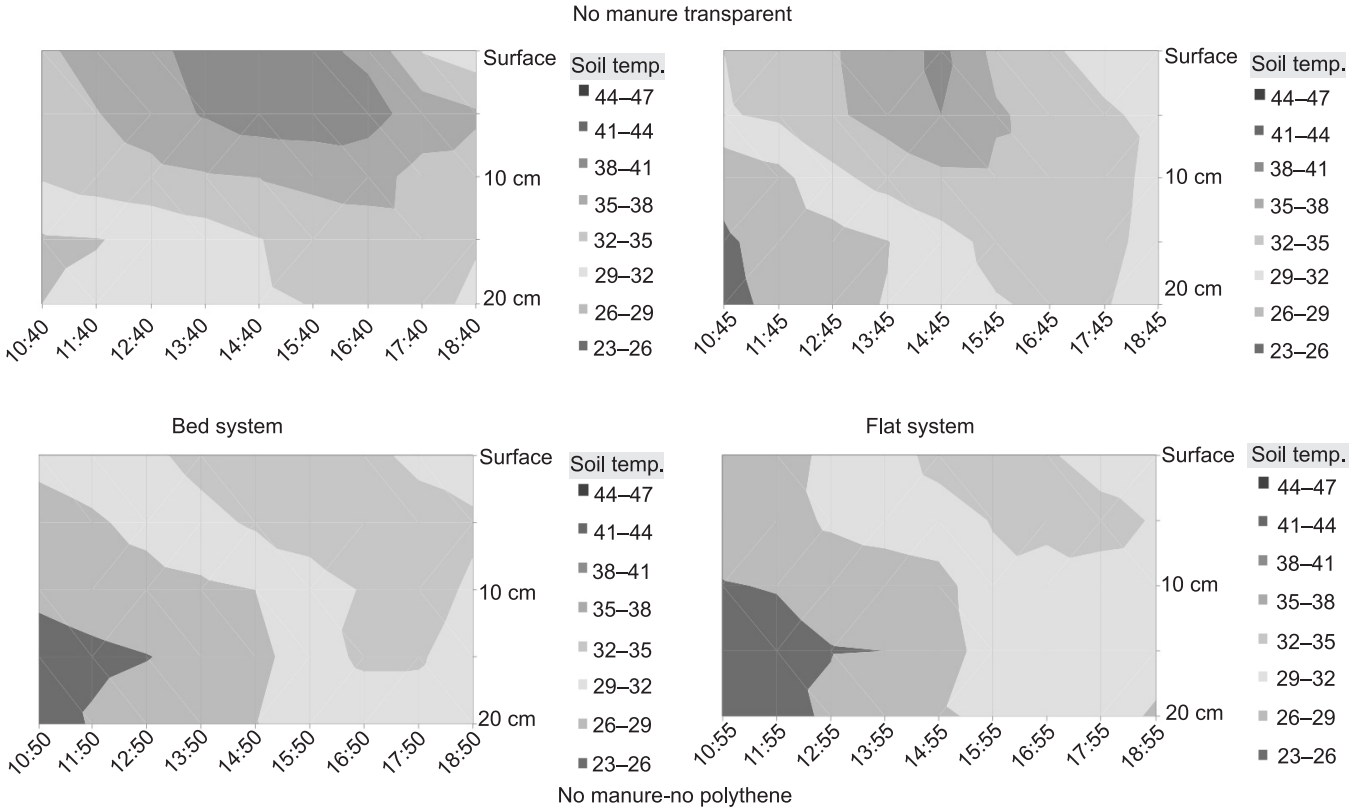

Fig 1 Hourly variation of temperature during day time under mulch and no mulch conditions in no manure treatment

their effectiveness alone or in combination for increasing the soil temperature of plough layer which is desirable on few occasions during different seasons of the year (eg during summer for solarization and during early growth of wheat in December and January when temperatures become sub optimal).

Hourly variation of ST during day time on 24.9.08 (wet 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 40.5°C, 34°C, 38.8°C and 33.1°C respectively (Fig 1). The above results indicated that if beds are made on conventionally tilled soil, the ST could be raised by 0.9–1.8 °C. Alternatively, the surface temperature of conventional plots could also be raised by 1.1–5.7 °C by covering no manure plot with transparent polythene mulch, but if beds are made and plots are then covered with polyethylene the temperature could further be increased by 1.8–7.4°C.

Under charcoal + compost as manure treatment, hourly variation of ST during day time showed that peak magnitudes of bed-TP, bed-NP, flat-TP and flat-NP were 42.5°C, 35.6°C, 41.1°C and 33.6°C, respectively and in all cases peak arrived around 14:30 (Fig 2) .

The results indicated that by covering charcoal + compost plot with transparent polyethylene mulch alone, one can raise surface temperature by 5–7.5°C but if beds are made and plots are then covered with polyethylene the temperature could further be increased by 1.3–2.2°C. On comparing the above results with control (no manure-no mulch – conventional system with temperature range of 28.4–33.1°C during 11:00–18:30 hours, it was observed that the charcoal+compost +bed+TP combination increased soil temperature by 8–9 °C.

Variation of ST at hourly interval under green manure treatment during day time showed that, the peak magnitudes of bed-TP, bed-NP, flat-TP and flat-NP were 39.5°C, 33.4°C, 38.3°C and 32°C, respectively and in all cases peak arrived around 14:30 hours (Fig 3). The above results thus indicated that if beds are made on conventionally tilled green manure plots, the ST could be raised by 0.4–1.0 °C. Alternatively, if conventionally tilled green manure plots are covered with transparent polyethylene mulch, one can raise surface temperature by 2–5°C but if beds are made first and plots are then covered with polythene temperature could be increased by 4.5–6.5°C.

On comparing the time of arrival of peak ST and its magnitude in bed and flat system under no manure- mulch and no manure- no mulch conditions (Table 2), it was observed that peak at surface arrived at same time in both systems but at 5 cm depth it was earlier in flat than in bed. For 10, 15 and 20 cm layers, the time of arrival of the peak temperature was same in both systems. However, the magnitude of the peak

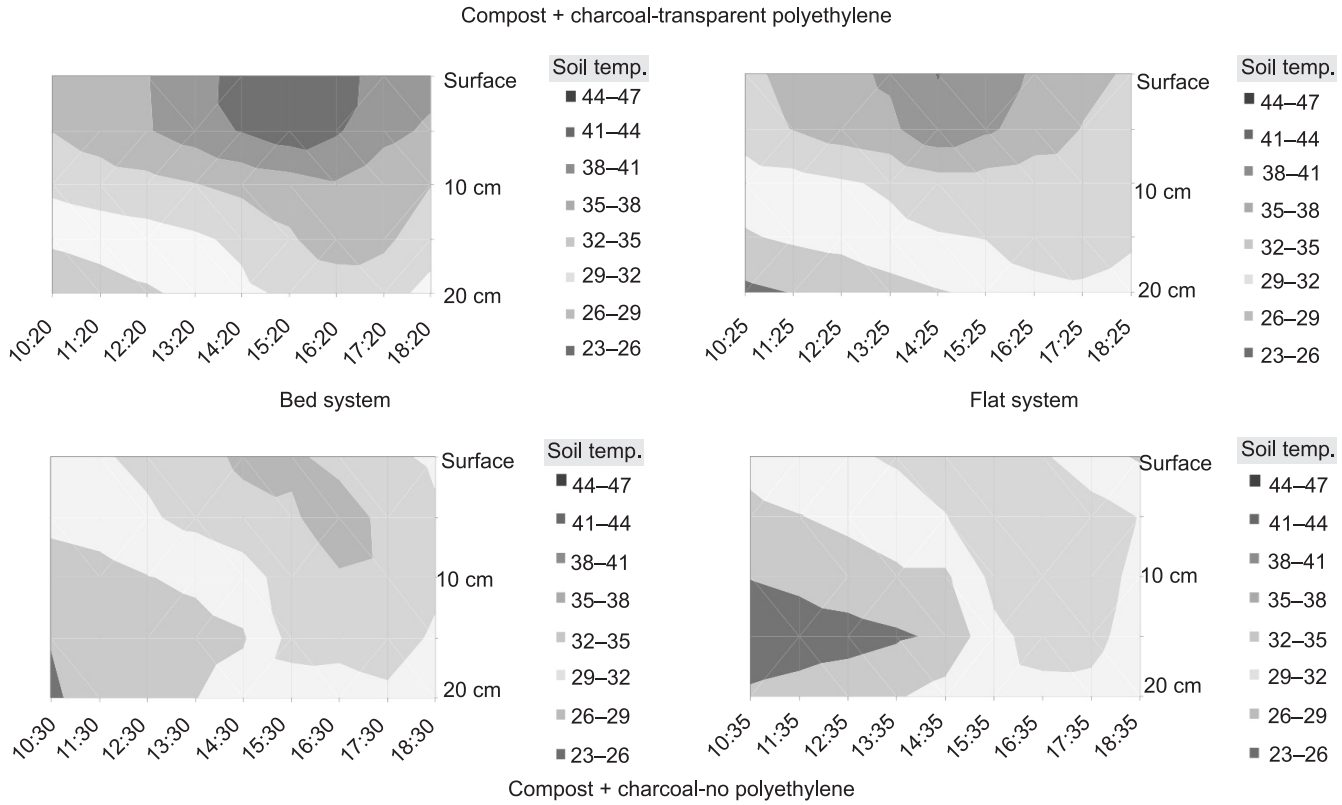

Fig 2 Hourly variation of temperature during day time under mulch and no mulch conditions in compost + charcoal treatment

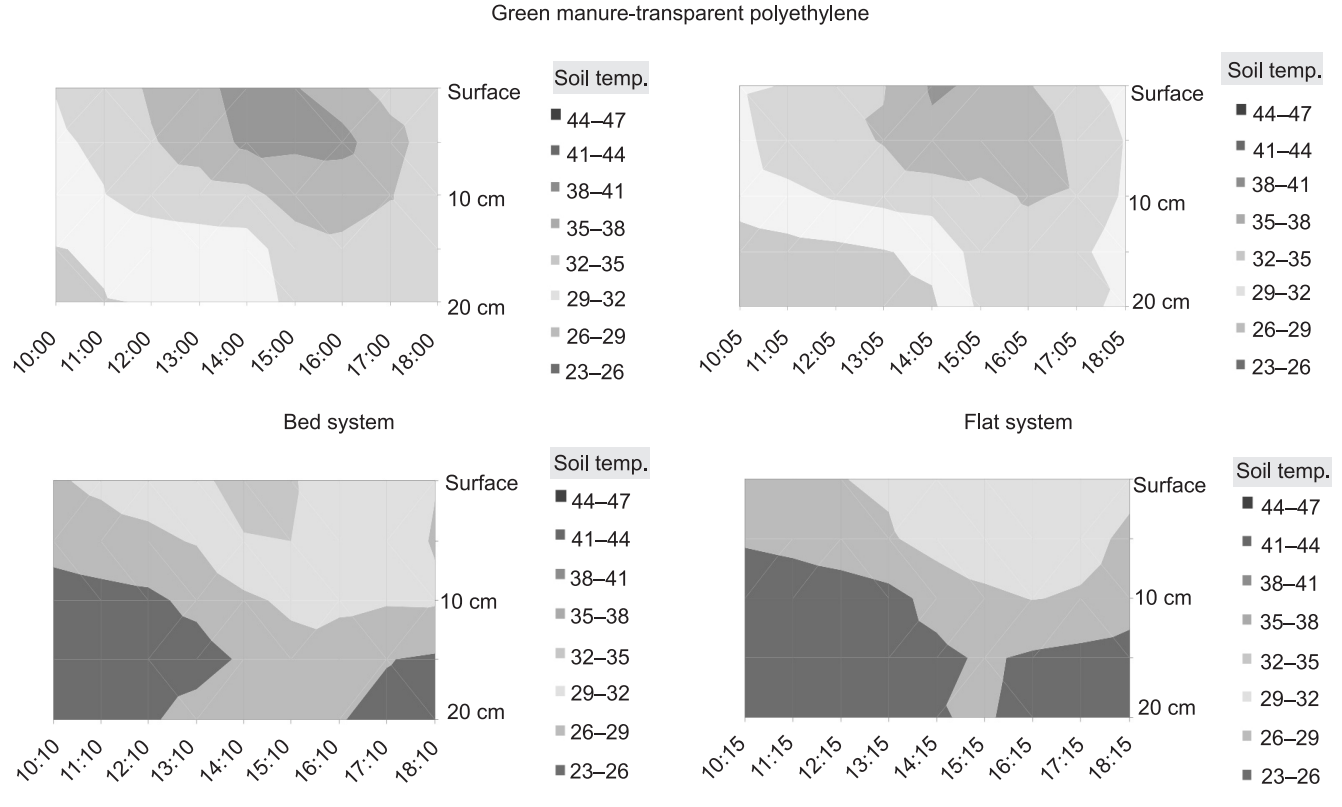

Fig 3 Hourly variation of temperature during day time under mulch and no mulch conditions in green manure treatment

Table 2 Arrival of peak temperature under bed and flat system for no manure- mulch treatment (24/9/08)

				Bed system					
Depth	10:40	11:40	12:40	13:40	14:40	15:40	16:40	17:40	18:40
Surface	34.6	35.9	37.3	39.1	40.5	38.8	37.3	31.8	30.2
5 cm	33.5	34.9	36.4	38.3	39.7	40	39.2	32.1	35.4
10 cm	32.3	33.4	34.2	34.7	35.1	35.6	36.2	34.5	34
15 cm	28.6	28.9	29.5	30.6	31.9	33.5	33.6	33.8	32.4
20 cm	29	29.5	30	30.7	31.5	32.1	32.5	33.4	31.1
				Flat system					
Depth	10:45	11:45	12:45	13:45	14:45	15:45	16:45	17:45	18:45
Surface	32	33.6	34.8	36.3	38.8	34.2	32.5	30.6	29.5
5 cm	31.7	32.6	34.5	36.2	38	35.3	34.2	32.5	31.2
10 cm	26.6	28	31.2	33.1	34.4	34.5	34.3	33.5	30.9
15 cm	25.7	26.7	27.8	28.9	30.8	32.9	33.3	33.2	30.5
20 cm	25.5	26.4	28.4	29.1	30.4	31.8	32.4	32.4	29.6

Arrival of peak temperature under bed and flat system for no manure- no mulch treatment (24/9/08)

				Bed system					
Depth	10:50	11:50	12:50	13:50	14:50	15:50	16:50	17:50	18:50
Surface	29.7	30.3	31.4	32.9	34	33.5	32.7	31.4	30.2
5 cm	27.9	28.6	29.8	31.1	32.4	32.6	33.5	33.1	30.6
10 cm	26.7	27.3	27.9	28.4	29	31.4	32.1	33.7	29.3
15 cm	24.6	25.4	25.9	26.7	27.8	31	32.4	32.4	26.5
20 cm	24	26.3	27.3	28.2	28.9	30.1	30.2	30.3	25.1
				Flat system					
Depth	10:55	11:55	12:55	13:55	14:55	15:55	16:55	17:55	18:55
Surface	27.5	28.4	29.3	30.9	32.7	33.1	32.5	30.3	29.3
5 cm	26.8	27.4	29.5	30.4	31.1	32.1	32.5	32	31.7
10 cm	25.9	26.1	26.8	27.2	27.7	30.5	31	31.4	30.1
15 cm	24.7	25.3	25.9	26	26.5	28.9	29.7	30.1	29.9
20 cm	23.5	24.8	26.5	27.9	28.6	29.6	29.7	30	28.7

temperature was always higher in bed than in flat system. Similar results were reported earlier (Radke 1982).

Thermal properties of all treatments were computed under wet condition (24.09.08). Table 3 shows that the values of volumetric heat capacity (Cv) was higher for flat than for bed system and also higher under TP than under NP condition. The diffusivity value was highest ($D=5.30 \times 10^{-6} m^2/sec$) for green manure with flat system under TP and was lowest ($0.33 \times 10^{-6} m^2/sec$) for no manure with bed system under NP.

Thermal conductivity was highest (12.51/w/m/k) in flat system of green manure treatment under TP and lowest (0.75/w/m/k) in bed system of no manure treatment under NP. Damping depth of green manure treatment with flat system under TP was extended up to 38.18 cm of soil depth but it was confined up to 9.52 cm in bed of no manure treatment under NP. Similar results have been reported by Aggarwal *et al.* 2009. Magnitude of ST was higher in bed system due to lower SWC and hence lower C_V and D which resulted in more increase in temperature for the same supply

Table 3 Thermal properties of alluvial soil of IARI farm

Treatment		Cv ($10^6 \times Jm^{/3}/K$)		D(m^2 /sec) $\times 10^{-6}$		K (w/m/k)		Damping depth (cm)	
		mulch	no mulch	mulch	no mulch	mulch	no mulch	mulch	no mulch
Green manure	Bed	2.198	2.185	1.32	0.59	2.90	1.29	19.05	12.74
	Flat	2.360	2.305	5.30	1.32	12.51	3.03	38.18	19.05
Compost + charcoal	Bed	2.208	2.130	1.32	0.59	2.91	1.26	19.05	12.73
	Flat	2.453	2.303	1.724	0.84	4.23	1.93	21.78	15.19
No manure	Bed	2.245	2.136	0.84	0.33	1.89	0.75	15.19	9.52
	Flat	2.398	2.270	1.32	0.43	3.17	0.98	19.05	10.87

of heat on the surface as compared to flat system. In GM treatments, temperatures were lower as compared to compost + charcoal and no manure treatments mainly because of more moisture retention leading to higher C_V and D and hence less temperature increase. Temperature was higher in compost + charcoal treatment as compared to no manure treatment because of black colour of the surface layer, which has more dominating effect on increase in the temperature because of more heat absorption, even though the SWC was also higher which resulted in higher C_V and D but their effect in moderating the changes in ST were probably less significant.

SUMMARY

To observe the effect of agronomical management practices on soil temperature (ST) and soil thermal properties, a field experiment was conducted during *kharif* season of 2008 at IARI, New Delhi on bare soil in split-plot design with three manure types as main treatment, ie green manure (GM) compost + charcoal and no manure, two land configuration (bed and flat system) as sub treatment and two mulch types transparent polyethylene (TP) and no polyethylene (NP) as sub-sub treatment. Diffusivity (D) values were higher for flat system than for bed system; in GM than in compost +charcoal and no manure treatments and also in TP than in NP. Thermal conductivity (K) was highest (12.51w/m/k) in flat system of green manure treatment under TP and lowest (0.75 w/m/k/) in bed system of no manure treatment under NP. Damping depth of green manure treatment with flat system under TP was extended up to 38.18 cm of soil depth but it was confined up to 9.52 cm only in bed of no manure treatment under NP. The temperatures were higher in compost + charcoal treatment as compared to no manure treatment because of black colour of the surface layer, which has more dominating effect on increase in the temperature because of more heat absorption even though the soil water content (SWC) was also higher in compost + charcoal treatment which resulted in higher C_V and D but their effect in moderating the changes in ST were probably less significant.

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