



Relationship between soil temperature and soil degree days with pod yield of groundnut (*Arachis hypogaea*) as influenced by different mulches and land configurations

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ABSTRACT

This study was carried out during rainy (*kharif*) season of 2020–2023 at Tamil Nadu Rice Research Institute (Tamil Nadu Agricultural University, Coimbatore), Aduthurai, Tamil Nadu to study the functional relationship between soil thermal indices and crop growth parameters and yield of groundnut (*Arachis hypogaea* L.) under different mulches and land configurations. Field experiment was conducted during south-west monsoon (SWM) with three mulches, viz. No mulch (NM), Organic mulch (OM) and Polyethylene film mulch (PMG) and four land configurations, viz. Flatbed (FB), Broad bed furrow (BBF), Ridges and furrows (RF) and Raised bed and furrow (RBF). The 4-year pooled results indicated that soil temperatures were significantly higher under polyethylene film mulched groundnut in different phenophases from sowing to harvest compared to non-mulch and organic mulches. Similarly, the soil degree-days (SDD) varied significantly among the different mulches and the total accumulated soil degree days in different phenophases were highest with transparent film mulch. The increase in the accumulated soil degree days shortened the crop period and the crop attained maturity six days earlier than no mulch and organic mulch. The soil temperature and soil degree days were lower with organic mulch as compared to no mulch. The coefficient of determination (R^2) at three depths ranged from a value of 0.991–0.996 for pod yield and soil temperature which indicated a strong correlation. The soil warming efficiency of land configurations was in the order of ridges and furrows>raised bed>broad bed and furrow>flat bed. Due to an increase in the growth and yield attributes, the pod yield obtained with transparent plastic mulch was 16.48% higher than the non-mulched control. The raised bed and furrow method of land configuration produced a higher yield of 2500 kg/ha, which was 13.17 % higher than the broad bed and furrow.

Keywords: Land configuration, Mulch, Pod yield, Soil degree days, Soil temperature

Weather variables such as solar radiation, temperature, rainfall, wind, and humidity have pronounced effects on groundnut (*Arachis hypogaea* L.) growth, development, and pod yield (Vinu *et al.* 2020). Soil temperature is considered to be more important than aerial temperature in improving crop growth and the functional activity of roots (Gan *et al.* 2013). Soil temperature influences the nutrient and water uptake, orientation of root growth, leaf area and number of branches (Clarke *et al.* 2015). Heat or energy modification and soil surface water balance are said to be influenced by different kinds of mulches (Pramanik *et al.* 2015). To obtain satisfactory crop yield, it is necessary to conserve soil moisture and modify soil temperature, especially under rainfed conditions.

The practice of mulching with either organic or inorganic materials is done to conserve moisture, regulate

soil temperature, improve soil physical, chemical and biological properties, weed control and soil erosion (Ranjan *et al.* 2017). Organic mulches are those derived from mainly plant materials which help in improving soil organic matter and the population of soil biota (Kasirajan and Ngouajio 2012). The non-availability of adequate quantity of natural materials, poor soil warming and weed control efficiencies, serving as host to insects and temporary immobilization of N were the major constraints in adopting organic mulches (Ranjan *et al.* 2017). It has been further reported that the efficiency of organic mulches was inconsistent in increasing the crop yield across all the seasons. Hence, the trend has been toward the use of plastic mulch in crop production throughout the world due to benefits such as an increase in soil warming efficiency, soil moisture balance, reduced infestation of weeds and pests, soil nutrient mobility and yield enhancement (Kasirajan and Ngouajio 2012).

The soil warming efficiency also varied with different land configurations in combination with mulches (Tang *et al.* 2022). Since the podding depth is usually less than

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6 cm, surface soil temperature plays a crucial role in the translocation of photo-assimilates to growing pods (Subrahmaniyan *et al.* 2018). Hence, the present study was conducted to study the functional relationship between the soil temperature and crop growth parameters and yield under different mulches and land configurations.

MATERIALS AND METHODS

This study was carried out during rainy (*khari*) season of 2020–2023 at Tamil Nadu Rice Research Institute (Tamil Nadu Agricultural University, Coimbatore), Aduthurai, Tamil Nadu. The mean annual rainfall (average of 40 years) of 1069.9 mm is distributed as 25.7 mm (2.4%), 75.4 mm (7.1%), 396.5 mm (37.1%) and 571.5 mm (53.4%), respectively during the cold weather period (January–February), hot weather period (March–May), south-west monsoon period (June–September) and north-east monsoon period (October–December).

The experiment was conducted in split plot design (SPD) with three mulches, namely sugarcane trash mulch @5 t/ha (M_1), transparent plastic mulch (M_2) and no mulch (M_3) and four land configurations, viz. Flatbed (L_1), Broad bed furrow with a dimension of 1 m width and 50 cm furrow (L_2); Ridges and furrows (L_3) and Raised bed and furrow with a dimension of 60 cm width and 30 cm furrow (L_4). All the treatments were replicated three times. The soil was red sandy loam, low in available N (165 kg/ha), moderate in available P (8.2 kg/ha) and available K (128.0 kg/ha) with a pH of 7.1. The experimental plot size was 4.5 m × 6.0 m having 15 rows of groundnut. In the broad bed and furrow method, the beds were formed at a width of 100 cm, leaving 25 cm on either side and three beds were formed in a plot. In ridges and furrows and raised bed and furrows, the ridges and beds were formed at a width of 60 cm leaving 15 cm on either side for the furrows. In a plot size of 4.5 m × 6.0 m, five raised beds and ridges were formed. A uniform fertilizer schedule of 25:50:75 kg NPK/ha was applied. The required quantity of fertilizers and pre-emergence herbicide pendimethalin @1.0 kg a.i/ha was applied to the soil surface just prior to laying the mulches. Neither fertilizers nor herbicides were used in the undisturbed beds of transparent plastic mulch (groundnut), whereas herbicides were used for controlling weeds and fertilizers applied in the undisturbed beds of non-mulched control. Polyethylene sheets of 7 µm thickness with holes at the required spacing of 30 cm × 10 cm was spread over the soil in the mulched plots and seeds of the groundnut variety 'VRI 6' were dibbled in the holes. In a plot size of 4.5 m × 6.0 m, the population maintained was 900 plants in all the treatments. No after-cultivation was done in the mulched plots, whereas in the non-mulched plots, two hand-weeding at 20 and 40 days after sowing (DAS) was carried out.

Soil temperature was recorded at 0600, 0800, 1000, 1200, 1400, 1600 and 1800 hours at 10, 20 and 30 cm depths using Indian Meteorological Department (IMD) approved soil thermometers fixed at 45° angles for the individual

treatment and expressed as degree centigrade. The mean soil temperature corresponding to different phenological phases of groundnut, viz. sowing to emergence (0–6 days), emergence to beginning of flowering (7–22 days), beginning of flowering to beginning of peg (23–29 days), beginning of peg to beginning of pod formation (30–35 days), beginning of pod formation to full pod formation (36–42 days), full pod to formation beginning of seed development (43–48 days), beginning seed development to full seed development (49–57 days), full seed development to beginning of maturity (58–67 days) and beginning of maturity to harvest (68 days to harvest) was worked out.

The Growing Degree-Days (GDD) or accumulated degree-days also called as “effective heat unit”, is an arithmetic accumulation of daily mean temperature above threshold temperature. The soil degree days were computed using the formula very similar to GDD, where soil temperatures were used instead of air temperatures

$$SDD = \frac{1}{2} \times (T_{Max} + T_{Min}) - T_{base}$$

Where T_{Max} , T_{Min} , and T_{base} are the daily maximum and daily minimum soil temperatures and the base (10 °C) temperatures, respectively (Ngouajio and Ernest 2005).

Analysis of variance (ANOVA) was used to detect the significance of treatment effects on different parameters studied. Critical difference (CD) was used to separate the mean whenever the treatment means were significantly different (Steel *et al.* 1997). The regression analysis and figures were done by using Microsoft Excel.

RESULTS AND DISCUSSION

Soil degree days: The data on heat accumulation measured in terms of soil degree days (Table 1 and 2) indicated that the transparent plastic mulch had a higher accumulation of SDD as compared to organic mulch and no mulch as well at 10, 20 and 30 cm soil depths at all the phenophase. Since the SDD were derived from soil temperature, the SDD accumulated at 10 cm depth was also higher than 20 and 30 cm depth. The SDD accumulated with transparent plastic mulches was 2077.4, 2058.5 and 2020.9 at 10, 20, and 30 cm, respectively as compared to organic mulch (1930.0, 1911.7 and 1874.9 at 10, 20, and 30 cm) and no mulch (1949.8, 1929.2 and 1892.0 at 10, 20, and 30 cm). The total accumulated SDD was numerically higher with transparent plastic mulch as compared to organic and no mulch though the crop maturity was attained 6 days earlier than organic and no mulch. In other words, as the required soil degree days was achieved in 93 days in transparent plastic mulch, the crop attained maturity earlier as compared to organic and no mulch. Earlier, Ibarra-Jimenez *et al.* (2011) reported that SDD had a higher correlation with early harvest to the crop. The clear plastic mulch is transparent to the incoming short-wave radiation, opaque to the outgoing long-wave radiation and hence most of the heat is retained inside the film and an increase in soil temperature has been observed. Whereas much of the heat is lost to the

Table 1 Soil degree days as influenced by mulch and land configurations from sowing to full pod stage (Pooled mean of 4 years)

Treatments	Growth stages of groundnut														
	Sowing to emergence			Emergence to beginning bloom			Beginning bloom to beginning peg			Beginning peg to beginning pod			Beginning pod to full pod		
	Depth (cm)			Depth (cm)			Depth (cm)			Depth (cm)			Depth (cm)		
	10	20	30	10	20	30	10	20	30	10	20	30	10	20	30
Mulch															
No mulch	138.0	136.5	133.8	317.6	314.6	308.0	138.0	136.5	133.8	144.1	142.5	139.8	136.4	134.8	132.2
Organic mulch	138.3	136.7	133.9	310.8	307.2	300.8	137.0	135.5	132.7	140.8	139.3	136.6	134.7	133.3	130.6
PMG	146.7	145.3	142.5	342.8	339.6	333.2	153.0	151.6	148.8	147.1	145.5	142.7	147.1	145.9	142.8
Mean	141.0	139.5	136.7	323.7	320.5	314.0	142.7	141.2	138.5	144.0	142.4	139.7	139.4	138.0	135.2
CD ($p=0.05$)	2.6	3.2	4.4	8.2	10.1	9.6	10.4	11.4	12.6	2.8	3.4	4.2	6.8	8.2	7.4
Land configurations															
BBF	141.2	139.4	136.7	323.2	319.5	313.1	143.0	141.3	138.8	144.7	142.7	140.2	139.7	138.3	135.5
RB	141.2	139.8	137.0	326.9	323.7	317.3	142.6	141.2	138.5	143.5	142.0	139.3	138.8	137.6	134.5
R and F	140.9	139.5	136.7	322.1	318.9	312.5	142.8	141.5	138.5	144.3	142.9	140.1	140.0	138.4	135.9
FB	140.6	139.2	136.4	322.7	319.7	313.1	142.2	140.8	138.0	143.5	142.1	139.2	139.1	137.8	134.9
Mean	141.0	139.5	136.7	323.7	320.5	314.0	142.7	141.2	138.5	144.0	142.4	139.7	139.4	138.0	135.2
CD ($p=0.05$)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

BBF, Broad bed furrow; RB, Raised bed; R and F, Ridges and furrow; FB, Flat bed.

Table 2 Soil degree days as influenced by mulch and land configurations from full pod to harvest stage (Pooled mean of 4 years)

Treatment	Growth stages of groundnut											
	Full pod to beginning seed			Beginning seed to full seed			Full seed to beginning maturity			Beginning maturity to harvest		
	Depth (cm)			Depth (cm)			Depth (cm)			Depth (cm)		
	10	20	30	10	20	30	10	20	30	10	20	30
Mulch												
No mulch	138.0	136.5	133.8	317.6	314.6	308.0	138.0	136.5	133.8	144.1	142.5	139.8
Organic mulch	138.3	136.7	133.9	310.8	307.2	300.8	137.0	135.5	132.7	140.8	139.3	136.6
PMG	146.7	145.3	142.5	342.8	339.6	333.2	153.0	151.6	148.8	147.1	145.5	142.7
Mean	141.0	139.5	136.7	323.7	320.5	314.0	142.7	141.2	138.5	144.0	142.4	139.7
CD ($p=0.05$)	3.8	4.6	6.2	11.2	6.8	12.6	8.4	7.6	3.8	3.4	2.8	2.6
Land configurations												
BBF	141.2	139.4	136.7	323.2	319.5	313.1	143.0	141.3	138.8	144.7	142.7	140.2
RB	141.2	139.8	137.0	326.9	323.7	317.3	142.6	141.2	138.5	143.5	142.0	139.3
R and F	140.9	139.5	136.7	322.1	318.9	312.5	142.8	141.5	138.5	144.3	142.9	140.1
FB	140.6	139.2	136.4	322.7	319.7	313.1	142.2	140.8	138.0	143.5	142.1	139.2
Mean	141.0	139.5	136.7	323.7	320.5	314.0	142.7	141.2	138.5	144.0	142.4	139.7
CD ($p=0.05$)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

BBF, Broad bed furrow; RB, Raised bed; R and F, Ridges and furrow; FB, Flat bed.

atmosphere from the bare soil (non-mulched). Wang *et al.* (2024) also reported that the intensity of soil heat by interms of soil temperature has been increased due to plastic mulch as the heat is trapped by the greenhouse effect. The interesting observation made in the study was the reduction of soil degree days due to organic mulch at all three depths. The decrease in soil temperature in organic mulch (sugarcane trash) might have been due to its low thermal conductance and heat retention capacity and high reflectance of incoming solar radiation. A similar observation was made by Kader *et al.* (2017) in soybean, which indicated the unsuitability of organic mulch for improving soil warming. As the soil depth increases,

the amplitude of soil temperature tends to decrease. No significant variation between 10 cm and 20 cm depth was observed for soil degree days, while a marked reduction in soil degree days was noticed in 30 cm depth (upto 0.5⁰ C) irrespective of the mulches and land configurations. Earlier, Singh and Sharma (2017) reported diurnal variation of soil temperature upto 40 cm depth. Similarly, irrespective of the land configuration, the soil degree days were lowest in the flatbed method of land configuration though it was non-significant. The order of increment in the soil degree days irrespective of the depth was ridges and furrows>raised bed>broad bed and furrow>flat bed. The ridges and furrow or bed method with film mulching would have provided

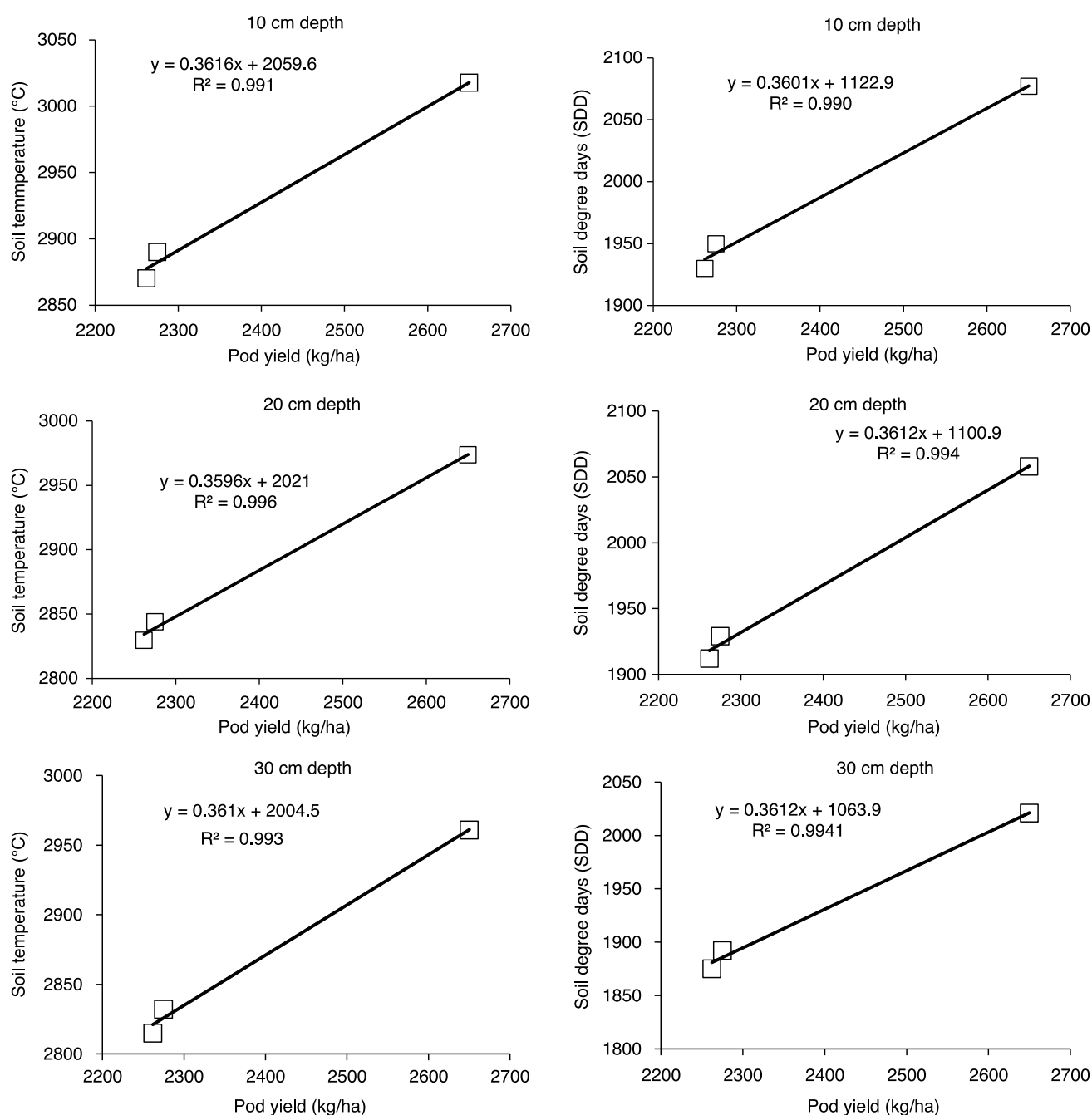


Fig. 1 Soil degree days (SDD) at 10, 20 and 30 cm depth as influenced by mulch and land configurations.

better soil hydrothermal conditions than the flatbed method of land configuration as earlier reported by Li *et al.* (2021).

The results further revealed that the soil degree days increased with the advancement in phenophase of groundnut up to the beginning pod and thereafter, a decrease in the soil degree days was noticed up to full pod formation stages at all the depths. An increase in the leaf area would have decreased the soil temperature due to the shading of the soil surface by the growing crop canopy. The temperature peak was observed during the phenophase of the beginning of maturity to harvest at all the depths.

Relationship between soil temperature, SDD and pod yield: The correlation between soil temperature, soil degree days and pod yield of groundnut exhibited a strong relationship (Fig. 1). The correlation between soil temperature, SDD and pod yield was stronger at all the depths. The coefficient of determination (R^2) at three depths ranged from a value of 0.991–0.996 for pod yield and soil temperature, which indicated a strong correlation. Similarly, the R^2 between the soil degree days (SDD) and pod yield was also in the range of 0.990–0.994 at all the layers of the soil (10, 20 and 30 cm). Irrespective of the soil thermal indices, the correlation with pod yield did not decrease as the soil layer depth increased. Normally, the surface soil gets heated rapidly and the soil temperature increases at the surface (0–10 cm) and the soil temperature below the layer of 10 cm did not increase similar to the surface layer due to the slow transfer of heat to deeper layer through conduction and convection (Tang *et al.* 2022). However, in the present study, the use of transparent plastic mulch would have improved the hydrothermal condition by reducing soil evaporation, heat loss and latent heat flux and thereby increasing the soil temperature in all the layers. Similar observation was also made by Zhang *et al.* (2022). Though normally podding depth in groundnut is limited to 15 cm, the root activities might have been triggered through the higher transmissivity of solar radiation and increase in soil temperature in the deeper layers, which eventually resulted in higher pod yield though nutrient mobility and moisture recycling. The above facts would be the reasons for the strong correlation between pod yield and soil thermal indices.

Growth parameters and pod yield: The dry matter production (DMP) (Table 3) was significantly higher with transparent plastic mulch which was 15.2 and 18.7% higher than organic and no mulch, respectively. Significant variation in crop DMP due to land configurations was also observed. Gan *et al.* (2013) also noted that soil temperature was more vital in crop growth enhancement than aerial temperature with respect to crop growth. A reduction of 13.71% DMP was observed with the flatbed method of land configuration as compared to the raised bed method of groundnut cultivation. The data on number of matured pods/plant, and 100-kernel weight indicated significant influence of transparent plastic mulch on groundnut. As a result of increased growth and yield parameters, pod yield was also highest with transparent plastic mulch as compared to organic mulch and non-mulched control. However, the

Table 3 Growth and yield parameters and pod yield of groundnut as influenced by different treatments (Pooled mean of 4 seasons)

Mulch (M)/Land (L) configurations	DMP at harvest (g/plant)				No. of matured pods/plant				100-kernel weight (g)				Days to maturity				Pod yield (kg/ha)			
	NM	OM	PMG	Mean	NM	OM	PMG	Mean	NM	OM	PMG	Mean	NM	OM	PMG	Mean	NM	OM	PMG	Mean
Flatbed	30.9	31.6	35.8	32.8	10.6	11.6	14.0	12.1	46.3	45.9	47.3	46.5	99	100	93	97	2278	2205	2744	2409
BBF	33.1	36.0	41.7	36.9	11.2	15.6	18.4	15.1	46.7	46.6	47.5	46.9	99	100	93	97	2188	2135	2304	2209
R and F	35.0	35.7	41.6	37.4	15.6	16.4	18.8	16.9	46.2	46.8	47.8	46.9	99	100	93	97	2307	2345	2742	2465
RB	35.8	35.3	40.8	37.3	17.0	16.4	22.4	18.6	47.0	47.3	48.1	47.5	99	100	93	97	2326	2363	2811	2500
Mean	33.7	34.7	40.0		13.6	15.0	18.4		46.6	46.7	47.7		99	100	93		2275	2262	2650	
CD ($p=0.05$)																				
M		2.6					1.0			0.6					2				42	
L		3.3					1.2			0.9					NS				63	
M at L		NS					NS			NS					NS				112	
L at M		NS					NS			NS					NS				126	

DMP, Dry matter production; NM, No mulch; OM, Organic mulch; PMG, Plastic mulched groundnut; BBF, Broad bed furrow; RB, Raised bed; R and F, Ridges and furrow.

yield obtained under organic mulch was 0.57% lower than control. The yield increase under transparent plastic mulch was 16.48% higher than non-mulched control. Soil heat storage, soil heat flux, soil water flux, seed emergence, nutrient transformation, transport and uptake and crop growth were significantly influenced by soil temperature and as a result, the increase in soil temperature eventually increased the yield (Onwuka and Mang 2018). The increased accumulated soil temperature shortens the crop period of groundnut by 6 days. Similarly, Zhou *et al.* (2012) also reported that crop growth was advanced due to enhancement in soil temperature and as a result the biomass under the soil was also increased substantially. The raised bed and furrows method of land configuration resulted in a higher pod yield of 2500 kg/ha as compared to the ridges and furrows (2465 kg/ha), flat bed (2409 kg/ha) and broad bed and furrow (2209 kg/ha). Though all the land configurations were efficient in soil warming compared to flat bed, the yield reduction in broad bed and furrows was due to poor establishment of crops in the center row of the bed.

The results indicated that the soil temperature and soil degree days were significantly higher with transparent polyethylene film at all the phenophases of the crop and depths as well. The increase in the accumulated soil degree days shortens the crop period and as a result, the crop under polyethylene film mulch attained maturity one week earlier to organic and no mulch as well. The reduction of soil temperature in organic mulch did not favour crop growth which emphasized the need for increasing the soil temperature even during the south-west monsoon period through plastic mulch. The enhanced soil temperature in the podding zone improved the growth and yield parameters and eventually the pod yield. The higher coefficient of determination between soil degree days and pod yield also confirmed the above findings. The results further confirmed that all the methods of elevated land configurations were efficient in soil warming as compared to the flatbed method at all the soil depths. Though the broad bed and furrow method of land configuration had elevated soil temperature, the yield reduction was mainly due to poor establishment of crop in the middle row of the bed. Hence, transparent polyethylene film mulch and raised bed and furrow method of land configuration may be recommended in the study area during the south-west monsoon season.

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