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Microclimate variations in relation to different types of polyethylene-film mulch on growth and yield of groundnut (*Arachis hypogaea*)

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ABSTRACT

A field investigation was conducted at Vridhachalam in Tamil Nadu during post- rainy seasons of 2001-02 and 2002-03 to study the microclimatic variation in relation to different types of polyethylene-film mulch and its effect on the growth and yield of groundnut (*Arachis hypogaea* L.). Results revealed that, irrespective of the colour, plastic-film mulch significantly increased the soil temperature (1.0-1.9°C) at different phenophases of crop growth from sowing to harvest. The soil temperature was higher under black-film mulch, followed by transparent - and white-polyethylene film mulches among the different mulches evaluated. The soil temperature under ridges-and-furrows land configuration was 0.3° C lesser than flat-bed and broad-bed furrow methods. Growing degree-days (GDD) and helio-thermal unit (HTU) did not show much variation between the different types of polyethylene films up to 80 days after sowing (DAS). However, heat unit efficiency (HUE) differed significantly among different types of plastic mulches but there was no such significant difference between the for soil temperature, GDD, HTU and HUE. The dry-matter production and yield attributes were significantly higher under black polyethylene-film mulch which gave the highest pod yield of 2.87 t/ha compared with 2.21 t/ha by the non-mulched control. Hence black polyethylene film mulch in groundnut with adoption of flat-bed system of land configuration could be an important agricultural practice to augment groundnut productivity besides improving microclimatic conditions.

Key words **:** Growing degree days, Groundnut, Heat-unit efficiency, Helio-thermal unit, Land configuration, Polyethylene mulch, Soil temperature

Groundnut (*Arachis hypogaea* L.) can be grown over a wide range of climatic conditions. The knowledge of the influence of weather parameters on crop growth and reproduction helps in reducing the yield losses by adopting suitable agronomic practices (Murthy and Rao, 2000). Weather influence on groundnut yield is much pronounced, but it is hard to investigate under field conditions. Pods and seeds develop below the soil surface. Therefore, soil temperature has a major influence on the reproduction and yield of groundnut. During floral development high air temperature is required as well as high soil temperature is needed during pod growth. In groundnut soil temperature can be varied by the usage of plastic mulches. The temperature in the top 5 cm soil layer under transparent polyethylene film was found to be 2.5 to 3.9°C higher than in the open field during the first growing stages of groundnut development and 0.6 to 1.1°C higher during the later stages. The accumulated soil temperature and reduced wind speed under transparent polyethylene film increased the photosynthetic efficiency of the crop (Hu *et al.*, 1995). Studies on the effect of air temperature on groundnut are mostly reported, but information about the effect of soil temperature is comparatively sparse. Although groundnut flowers above-ground, pod growth and development happen entirely underground. The podding depth in groundnut is usually 3-6 cm and the most extensive rooting occurs in the top 30 cm soil layer (Golombek *et al.*, 2001). Therefore, soil temperature especially at surface layer is important for the translocation of photo-assimilates to growing pods. It may be possible to alter the soil temperature to improve groundnut production. The present investigation was planned to study the performance of different types of polyethylene-film mulches and land configuration on the soil temperature as well as the growth and yield of groundnut.

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MATERIALS AND METHODS

A field experiment was conducted during post-rainy seasons, viz. 2001-2002 and 2002–2003 at Regional Research Station, Tamil Nadu Agricultural University, Vridhachalam. Randomized complete block design was followed with two factors, viz. polyethylene film mulches (black, transparent, white and non-mulched control) and land configurations (broad beds and furrows, ridges and furrows and flat bed). All the treatments were replicated thrice. The soil was red sandy loam, low in available N (160 kg/ha), moderate in available P (7.63 kg/ha) and available K (120.3 kg/ha) with pH 7.3. During the cropping season the maximum and minimum air temperatures ranged from 29.3-37.6°C and 19.7-24.4°C respectively. Relative humidity ranged from 81-90% and 67-82% in the morning and afternoon respectively. The plot size was 27 m^2 (4.5 x 6.0 m).

Polyethylene sheets of 7 μ (micron) thickness with holes at the required spacing of 20 x 20 cm were spread over the soil in the mulched plots, and seeds of groundnut variety ('VRI 2') were dibbled in the holes. A uniform fertilizer schedule of 17:35:45 kg NPK/ha was applied to groundnut. The entire quantity of fertilizers was applied to groundnut at the time of sowing. No after-cultivation was done in the mulched plots, whereas in the non-mulched plots one hand-weeding at 30 days after sowing (DAS) and one earthing-up at 45 days after sowing was carried out. To determine the effect of treatments on total flower production, flower were counted from the first day of flowering to cessation of flowering in each treatment. For this purpose five plants were peg-marked in each treatment and in each replication. From the total blooming (flowering) duration, the days required to achieve 50% of the total flower production in a single plant from date of sowing was taken as days to 50% flowering in a single plant. The pegging percentage and pod-setting ratio were computed by using the formula suggested by Chai and Chang (1997).

Soil temperature at 10, 20 and 30 cm depths was recorded at 0600, 0800, 1000, 1200 1400, 1600 and 1800 hr using IMD-approved soil thermometers fixed at 45^0 angles for the individual treatment and expressed as degree centigrade. This was attempted for only one replication. The mean soil temperature corresponding to different phenological phases of groundnut, viz. sowing to emergence (0-6 days), emergence to beginning of flowering (7-24 days), beginning of flowering to beginning of peg (25-31 days), beginning of peg to beginning of pod formation (32-38 days), beginning pod formation to full pod formation (39-44 days), full pod to formation beginning of seed development (45-50 days), beginning seed development to full seed development (51-60 days), full seed development to beginning of maturity (61-74 days) and beginning of maturity to harvest (75 days to harvest) was worked out. The factor growing degree days (GDD) was computed using the formula given by Iwata (1984); the factor heliothermal units (HTU) at different stages of crop growth was computed using the formula of Singh *et al.* (1990); and the heat unit efficiency (HUE) was computed using the given formula (Rajput, 1980). The yield parameters and pod yield were recorded and the economics were worked out.

RESULTS AND DISCUSSION

Mulch

Soil temperatures at 10, 20 and 30 cm depths during different phenophases of groundnut are presented in Tables 1 and 2. Irrespective of the treatment, the soil temperature increased with the advancement in each phenopahase of groundnut crop up to pod-beginning stage (32-38 days) and thereafter a gradual decrease in the soil temperature was observed up to beginning of full seed development (51 to 60 days). The temperature peak was observed at pod-beginning stage (39-44 days), though the highest soil temperature was observed during the beginning of maturity to harvest (75 days to harvest), which coincided with April (summer). Among the different polyethylene-film mulches evaluated, soil temperature was 0.1^0 C higher under black polyethylene than under transparent mulch. However, the soil temperature under black polyethylene film mulch was 1.9^0 C higher than under the non-mulched control. Ham *et al.* (1993) studied the optical properties of plastic mulch and reported that highest midday soil temperature beneath the mulches was due to high short-wave absorption (black) or high short-wave transmittance (transparent) along with long-wave transmittance. In general the soil temperature was highest during (1400 hr) in all the polyethylene film-mulch treatments compared with the non-mulched control. With increase in soil depth the soil temperature decreased under different polyethylene-film mulches. Lamont (1999) reported that soil temperatures under black plastic mulch during the day-time were generally 2.8°C more at 5 cm depth and 1.7°C at 10 cm depth compared with the bare soil.

Among the different colours of polyethylene film mulch used, much variation was not found in GDD as well as in HTU up to 80 DAS (Table 3). However, the variation in crop maturity led to differences in GDD and HTU values during 80 DAS to harvest. The total accumulated soil temperature under polyethylene-film mulched groundnut @ $1.4\text{-}2.7^0$ C per day higher than non-mulched control over the entire growing period was $195.3\text{-}370.8^0$ C. The increased accumulated soil temperature shortens the crop period (Hu *et al.*, 1995). The GDD and HTU were the lowest with black polyethylene-film mulches. The total GDD and HTU values were higher with non-mulched control. Nalawade and Patil (2000) also reported similar findings. There was no difference between land configurations in GDD and HTU, as there was no variation in crop maturity among these. The results indicate that all the colours of polyethylene-film mulch did increase the HUE during 20 to 80 DAS. At harvest black polyethylene-film

Table 1. Effect of polyethylene film mulches and land configurations on soil temperatures (⁰ C) during different phenophases of groundnut (pooled mean data of 2001-02 and 2002-03)

Growth stages	Polyethylene film				Land configuration		
	Black	Transparent	White	Control	Broad bed and furrows	Ridges and furrows	Flat bed
Sowing – emergence	28.0	27.8	27.0	26.0	27.2	27.0	27.2
Emergence – beginning flowering	28.0	27.8	27.9	26.3	27.4	27.4	27.6
Beginning bloom – beginning peg	28.8	28.7	28.2	26.8	28.0	28.0	28.0
Beginning peg – beginning pod	29.1	29.0	27.9	26.9	28.4	28.2	28.4
Beginning pod – full pod	28.0	28.2	26.9	26.0	27.7	26.6	27.7
Full pod – beginning seed	26.6	26.5	25.6	25.3	26.5	25.2	26.2
Beginning seed – full seed	27.7	27.7	26.4	25.8	27.0	26.8	27.0
Full seed – beginning maturity	28.0	27.9	26.9	26.2	27.4	27.2	27.4
Beginning maturity – harvest	29.3	29.2	28.4	27.6	28.8	28.3	28.8
Mean	28.2	28.1	27.3	26.3	27.6	27.2	27.6

Table 2. Effect of polyethylene film mulch and land configuration on mean soil temperatures (⁰C) of entire growth period at different times of observation and depths (pooled mean data of 2001-02 and 2002-03)

Soil temperature (⁰C)	Polyethylene-film					Land configuration			
	Black	Transparent	White	Control	Mean	Broad bed and furrows	Ridges and furrows	Flat bed	Mean
Time of observations									
006 hrs	26.0	25.9	24.9	24.7	25.4	25.6	25.0	25.6	25.4
1400 hrs	29.8	29.7	28.8	28.2	29.1	29.3	28.9	29.2	29.1
1800 hrs	28.7	28.6	28.2	26.0	27.9	28.0	27.8	28.0	27.9
Mean	28.2	28.1	27.3	26.3		27.6	27.2	27.6	
Depth									
10 cm	28.4	28.3	27.5	26.5	27.7	27.9	27.4	27.8	27.7
20 cm	28.1	28.1	27.3	26.3	27.5	27.6	27.2	27.6	27.5
30 cm	28.0	27.9	27.0	26.2	27.3	27.4	27.0	27.4	27.3
Mean	28.2	28.1	27.3	26.3		27.6	27.2	27.6	

Table 3. Effect of polyethylene film on growing degree days (GDD) and helio-thermal unit (HTU) (pooled mean data of 2001-02 and 2002-03)

Growth stage	GDD				HTU			
	Black	Transparent	White	Control	Black	Transparent	White	Control
0–20 DAS	115	115	115	115	699	699	699	699
20–30 DAS	153	153	153	153	829	829	829	829
30–40 DAS	157	157	157	157	1257	1257	1257	1257
40–50 DAS	168	168	168	168	1154	1154	1154	1154
50–60 DAS	172	172	172	172	1399	1399	1399	1399
60–70 DAS	183	183	183	183	1474	1474	1474	1474
70–80 DAS	207	207	207	207	1369	1369	1369	1369
80–Harvest	163	264	204	264	499	956	499	956
Total	1321	1423	1362	1423	8684	9141	8684	9141

mulch increased the HUE compared with white and transparent film mulches and the control.

The groundnut crop matured 5 days earlier when raised under black film mulch compared with that in control. Kathmale *et al.* (2000) reported that under polyethylene film mulch the groundnut crop matured by 8 days earlier than non-mulched groundnut. In general, the dry-matter accumulation between polyethylene film mulches and non-mulched control differed markedly at all the stages (data not reported). Black-polyethylene-film mulch had higher DMP at harvest, which was comparable with white polyethylene-film mulch. It showed 28.8% increase over non-mulched control. Significant increase in plant height and dry matter production by 9% over control was also noted under polyethylene-film mulched groundnut (Nalawade and Patil, 2000). Similarly, Hu *et al.* (1995) reported that the total biomass under plastic-mulched groundnut was 351 kg/ha/day during the peak growing stage (21% higher than the control), 270 kg/ha/day during vegetative stage (22% higher than the control) and 81 kg/ha/day during reproductive stage (31% higher than the control). The different polyethylene-film mulches behaved differently for days to 50% flowering. Transparent polyethylene-film mulch came earlier for days to 50% flowering in a single plant, whereas black polyethylene film mulch had the highest number of flowers and pegs/plant. However, the pegging percentage and pod-setting ratio were highest under white polyethylene-film mulch. Black polyethylene-film mulch had significantly more number of matured pods/plant compared with non-mulched control (Table 4). The appearance of each phenological event occurs with the attainment of a certain cumulative heat sum (temperature). Groundnut crop with a higher root temperature accumulated thermal time sooner than plants with a lower root temperature. The resultant faster flowering, podding and maturity observed by us are in consonance with the results of Awal and Ikeda (2002). Among the different colours of polyethylene film mulches, the black polyethylene-film mulch registered significant higher pod yield (2.87 t/ha) than non-mulched control (2.21 t/ha). Higher root temperature would have improved the root functions that supply soil water and nutrients to shoots, favouring the partitioning of biomass to shoots. Ramakrishna *et al.* (2002) reported that increase in soil temperature helped early (2-3 days) and better germination with good seedling vigour, good pod development and early maturity of groundnut besides double yield (1.5 t/ha) compared with the control (0.7 t/ha).

Land configuration

In respect of soil temperature, much difference was not observed among the three configurations. However, ridges

Table 4. Effect of polyethylene film mulch and land configuration on growth and yield attributes and pod yield of roundnut (Pooled mean data of 2001-02 and 2002-03)

Treatment	Days to 50% flowering in single plant	Total no. of flowers/ plant (A)	Total pegs/ plant (B)	Pegging (%) (B/A)	No. of matured pods/ plant (C)	Pod-setting ratio (C/A)	100-seed weight (g)	Shelling (%)	Pod yield (t/ha)
Mulch									
Black	33.1	81.6	30.1	36.9	22.2	27.2	44.8	72.9	2.87
Transparent	32.0	77.3	26.5	34.2	17.7	22.9	43.0	73.	2.53
White	32.9	69.9	28.9	41.3	21.5	30.8	44.2	73.7	2.72
Control	34.6	73.5	25.4	34.6	14.6	19.9	41.4	71.3	2.21
SEm±	0.3	3.1	0.7	2.1	0.7	2.3	0.5	0.4	0.03
CD (P=0.05)	0.8	NS	2.2	NS	2.1	4.8	1.5	1.2	0.10
Land configuration									
Broad bed and furrows	33.5	79.6	26.9	33.8	19.0	23.1	43.4	73.3	2.53
Ridges and furrows	33.0	73.0	29.5	40.4	17.8	26.8	42.0	72.5	2.51
Flat bed	33.0	74.1	26.7	36.0	20.3	24.0	44.5	72.9	2.70
SEm±	0.2	2.7	0.6	1.8	0.6	2.0	0.4	0.3	0.03
CD (P=0.05)	NS	NS	NS	NS	NS	NS	1.3	0.5	0.08

Table 5. Economics of groundnut as influenced by polyethylene film mulches and land configurations (pooled mean data of 2001-02 and 2002-03)

Treatment	Total variable cost (x10^3 Rs/ha)	Gross returns (x10^3 Rs/ha)	Returns above variable cost (x10^3 Rs/ha)	Benefit : cost ratio (Rs/ha)
Mulch				
Black	20.74	56.52	36.78	2.78
Transparent	20.74	50.62	29.88	2.44
White	20.74	54.46	33.72	2.63
Control	18.62	44.27	25.65	2.38
Land configuration				
Broad bed and furrows	20.39	49.69	29.29	2.43
Ridges and furrows	20.39	50.87	30.48	2.48
Flat bed	19.85	54.61	34.75	2.74

and furrows configuration recorded 0.4° C lesser soil temperature than flat-bed and broad-bed furrows. Irrespective of the time of observation and depth of the soil, unlike polyethylene films, no great variation in soil temperature was observed among land configurations. However, both flat-bed and broad-beds and furrows were superior to ridges and furrows.

The effect of land configuration on crop DMP was non-significant. Similarly land configurations did not have any profound influence on flower production, days to 50% flowering, total pegs/plant, no. of matured pods/plant, pegging percentage and pod-setting ratio. However, 100-kernel weight increased significantly by flat bed method of land configuration leading to significantly higher pod yield. Though ridges and furrows configuration appears satisfactory under high radiation, this technology did not work very well under irrigated condition. This might be due to the nature of soil type where this land configuration was practised. The present experiment field had a sandy loam soil, which showed lower yield. Kumar and Shivani (2001) reported that only 433 kg/ha pod yield was obtained under ridges and furrows compared with broad beds and furrows (875 kg/ha) and flat bed (1063 kg/ha) in a clayey loam soil under irrigated condition.

Economics

Black polyethylene film mulch gave higher gross returns (Rs 57,533/ha), returns above variable cost (Rs 36,787/ha) and benefit : cost ratio (2.78) (Table 5). The higher values obtained under these economic parameters must be due to higher pod yield obtained under these treatments, though the cost of cultivation remained the same for different polyethylene film mulches tried. Similarly owing to higher yield obtained in flat bed system, gross returns, returns above variable cost and B : C ratio were higher for flat bed system. Though interactions for pod yield were non-significant, result on economic analysis indicated that the technology of black polyethylene film mulch + flat bed system was economically viable.

It was concluded that black polyethylene film mulch in groundnut with adoption of flat bed system of land configuration could be an important agricultural practice to augment groundnut productivity besides improving microclimatic conditions.

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