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CONTENTS

Effect of organic and inorganic mulches on soil properties and productivity of chilli (*Capsicum annuum l.*) crop grown on alfisols

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ABSTRACT: Soil mulching has been used globally as an efficient strategy for improving soil properties and enhancing crop growth and productivity. Since most plastic mulches used in agriculture are made of polyethylene, microplastic residues are non-biodegradable and generally difficultly recovered from soils, leading to a potential environmental risk after long-term application. Present study investigated the effects of organic and inorganic mulches on soil properties and productivity of chilli (*Capsicum annuum* L.) crop by conducting an experiment with treatments including no-mulch, maize straw (6 t ha^{-1}), groundnut shells (6 t ha^{-1}), saw dust (6 t ha^{-1}), transparent polythene (25 μ thickness), black polythene (25 μ thickness) and soil dust (1-2 cm soil depth). Results indicated that transparent polythene raised soil temperature by 8% and moisture content by 20% compared to no-mulch, but was similar to organic mulches. Chilli pod yield with transparent polythene mulch (3155 kg ha^{-1}) was statistically on par with groundnut shells (2842 kg ha^{-1}) and also had lower weed dry mater (94, 60 and 59 % at 20, 40 and 60 days after transplanting (DAT), respectively) over control, but was statistically similar with organic mulches. All organic mulches improved soil physical properties like bulk density (BD), porosity and infiltration rate by 6.47, 10 and 4.09 %, respectively over polythene-mulch.

Key words: Chilli, organic mulches, productivity, soil physical properties

In agriculture, irrigation water is one of the important factors of production. Research studies explained that only about 1% of the applied water is being used for plant metabolic activities and the rest is lost through transpiration and evaporation processes. The evaporation losses from soil can be reduced by covering the soil with any material that act as a barrier, which is regarded as 'mulch'. Mulch is primarily used in crop production for water and soil conservations; and suppress weed growth (Bhardwaj *et al.,* 2011; Debarati *et al.*, 2017). Added to this, mulching material helps in moderating the extreme soil temperature that is influenced by atmospheric temperatures, which favours optimum plant nutrient availability and ultimately crop growth. Owing to many advantages of mulches, their usage by farmers has been increasing in recent years. At present, polythene mulches are widely used by vegetable growers. Besides many advantages of polythene mulches, disposal of the synthetic mulch after harvest of the crop, environmental pollution, no addition of nutrients to soil are the serious problems, which need to be addressed. Under these situations, use of mulching materials that are quickly degradable and improve soil nutrient status can be an alternative to existing synthetic plastic mulches. Numerous research studies (Prajapati *et al*., 2017; Milena, 2017; Pal *et al.,* 2014) confirmed that materials such as crop residues, grain straw, stover, tree leaves, hull portion of various crops (groundnut shells, wheat husk, rice husk, saw dust etc.) can be used for mulching (Yogita and Manisha, 2019). These organic mulches provide all the benefits of polythene mulch besides their bio degradable nature (Sivaramanan, 2014). Bio degradation of organic mulches enhance biological activity in soil; there by improve physical and chemical properties of the soil.

Chilli (*Capsicum annuum* L.) an important spice cum vegetable crop is cultivated extensively in India. Chilli pods are rich in proteins, carbohydrates, lipids, minerals such as (calcium, phosphorus, and iron) and vitamins (A, D and C, K, B2 and B12) (Ananthan *et al.,* 2014). Due to its remunerative price, many farmers show interest in growing chilli crop during rabi season under assured irrigation. Chilli crop is irrigated through drip irrigation for efficient utilization of irrigation water. The efficiency of applied water can further be increased by arresting evaporation losses through soil surface mulching. Mulching of soil surface also helps in minimizing weed growth, thereby reducing the depletion of available soil moisture and nutrients in soil. In addition, mulching material also helps in moderation of soil extreme temperatures (low temperature during initial stage of crop and high temperature towards maturing), which facilitates optimum root growth and ultimately increase crop dry matter production and resulting high yield (Abolfazl, 2016). Hence, there is a need to identify suitable mulching material to increase productivity of chilli crop grown on alfisols. With this background, the field experiment was carried out to study the influence of organic and inorganic mulches on soil temperature and soil moisture content and soil physical parameters and productivity of chilli crop.

MATERIALS AND METHODS

A field experiment was carried out during rabi (December-March) season (2016-17) in College farm at College of Agricultural Engineering, Madakasira, located at 13^0 56'58" N and 77^0 18'42" E with an elevation of 641.6 meters above mean sea level. The mean annual temperature and annual rainfall of the study area are 25.7^0 C and 532 mm, respectively. Most of the rainfall (~ 80%) is received during South-West monsoon. The meteorological data of the study area during 2016-2017 is shown in Fig. 1. The soil of the experimental site was alfisols with sandy clay loam in texture. The pH of soil was 8.35, EC of 0.37 mm hocm^{-1}, and was low in organic carbon (0.35%), available nitrogen (205 kg ha^{-1}), phosphorus (54 kg ha^{-1}) and potash (136 kg ha^{-1}).

The sources of organic material for mulching were maize straw, groundnut shells, sawdust and the inorganic mulching materials were polythene (black and transparent) mulches. The field experiment comprised of seven treatments namely T1 - control, where no mulching material was used; T_2- maize straw was covered over the soil surface up to a height of 15 cm (@ 6 t ha^{-1}); T_3- groundnut shells were spread over the soil surface upto a height of 15 cm (@ 6 t ha^{-1}); T_4- sawdust was laid over the soil surface upto a height of 15cm (@ 6 t ha^{-1}); T_5- the soil surface was covered with transparent polythene (25 μ thickness); T_6- the soil surface was covered with black polythene (25 μ thickness); and T_7-the top soil surface (1-2 cm) depth was repeatedly harrowed so that a layer of soil dust is maintained.

All the seven treatments were laid out in a completely randomized block design and replicated thrice. The size of each plot was 4 m × 4 m. The chilli seedlings (30 days old) of variety 'Demon' transplanted on 17th January 2017. The recommended dose of fertilizer to chilli crop is 138 kg N, 40 kg P and 87 kg K ha^{-1}. The entire dose of phosphorus and potash along with half dose of N were applied as basal at the time of transplanting. The remaining half dose of N was applied in two splits at 30 and 60 days after transplanting (DAT). The sources of nitrogen, phosphorus and potash were urea, single super phosphate and muriate of potash, respectively. The chilli crop was irrigated through drip irrigation system with a lateral spacing of 70 cm and emitter spacing of 40 cm. The irrigation was scheduled once in every 2 days during the entire crop growth period. Hand weeding was done at 20, 40 and 60 DAT and the plots were kept weed free during the crop growing period. In soil dust mulch plot, in order to maintain soil dust layer, harrowing was done at weekly intervals. During initial stage of crop growth, infestation of sucking pests like thrips and mites were noticed. The thrips and mites were controlled by spraying phosolone @ 5 ml litre^{-1} and wettable sulphur @ 3g litre^{-1} of water, respectively. In the later stages of crop growth, lepidopteran pests' *viz*., pod borer (*Heliothis* sp.) infested the crop and the pest was controlled by spraying monocrotophos @ 1.6 ml litre^{-1} and neem oil @ 5 ml litre^{-1} of water. Chilli pods were harvested at their maturity stage. Harvesting of pods was done manually at 90,105 and 120 DAT.

The bulk density (BD) of soil was determined using soil samples collected before start of the experiment and after crop harvest at 0-15 cm soil depth by using core sampler (Choi and Chung, 1997). The infiltration rate of the soil before start of the experiment and after crop harvest was determined by double ring in filtrometer. The soil infiltration rate is expressed in cm hr^{-1}. Soil temperature at 0, 5 and 10 cm soil depth were recorded daily at 7 A.M and 5 P.M by using infrared thermometer for surface (0 cm) and soil thermometers for (5 and 10 cm) soil depth during the crop growth period. The soil temperature is expressed in ^{0}C. For estimation of moisture content, the soil samples were collected from each plot at 15 cm soil depth by using soil auger. Soil sampling was done every time before giving irrigation to the crop during the crop growth period. The soil samples collected in aluminum boxes were kept in hot air oven at a temperature of 110^{0}C for 24 hours. The soil moisture content was estimated on dry weight basis and expressed in percentage.

Plant sampling was done at 20, 40 and 60 DAT, which correspond to vegetative, flowering and maturity stages, respectively. Two representative plants from each plot were selected and washed with water to remove surface contamination and were separated into stem, leaves and roots. These were placed in paper packets and kept in hot air oven at a temperature of 70^{0}C for 48 hours. The dry weight of stem, leaves and roots were recorded and expressed in g plant^{-1}. The sum of dry weight of stem and leaves were expressed as above ground biomass. At harvesting stage, five representative plants in each plot were selected and all the pods were separated, counted and weighed. From the sample plants, average pod number and pod weight per plant was calculated and per plant pod yield was extrapolated to per hectare basis and expressed in kg ha^{-1}.

Water use efficiency (WUE) is the ratio of total yield obtained to the total amount of water applied to crop. For calculating the WUE, the yield obtained from each experimental plot and the amount of water used for each plot was recorded and was expressed in kg ha^{-1}mm^{-1}

$$\text{WUE} = \frac{\text{Yield (kg ha}^{-1}\text{)}}{\text{Amount of water applied (mm)}}$$

Weed dry matter

The total number of weeds present in 0.5 m^2 area of each plot was recorded at 20, 40 and 60 DAT by using 0.5 m^2 quadrat. The weeds were uprooted, washed and then placed in paper packets which were dried in hot air oven at a temperature of 70^{0}C for 48 hours and the dry weight of weeds was expressed in g m^{-2}.

Weed control efficiency (%)

Weed control efficiency (WCE) indicates the magnitude of reduction in weed dry matter of weed control plot as compared to unweeded plot. The WUE was estimated by using the following formula (Mani *et al.,* 1973) and expressed in percentage.

$$WCE = \frac{(DWC - DWT)}{DWC} \subset 100$$

Where,

DWC= Dry weight of weeds from control plot and

DWT= Dry weight of weeds from treated plot.

Weed index (%)

Weed index (WI) indicates the competition offered by weeds measured by percent reduction in yield owing to their presence in the field (Gill and Vijaya, 1969). The WI was calculated by using following formula.

$$WI = \frac{\text{Yield in maximun weed free plot (kg ha}^{-1}\text{) - Yield in the plot under treatment (kg ha}^{-1}\text{)}}{\text{Yield in maximun weed free plot (kg ha}^{-1}\text{)}}$$

Statistical analysis

The data pertaining to various parameters *viz.,* soil physical properties, growth and yield of chilli crop and dry matter production of weeds were subjected to analysis of variance (ANOVA) for randomized complete block design and when ANOVA indicated significant values, and then the treatment means were compared by least significance difference at 5% level of confidence (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Effect of organic and inorganic mulches on soil temperature and soil moisture content

Soil temperature plays a vital role in growth and development of crop plants by influencing the availability of essential plant nutrients and soil moisture. The soil temperatures vary with atmospheric temperature, are generally higher during summer and lower during winter season. These extremes in soil temperature adversely affect plant root growth directly and shoot growth indirectly. Our results indicated that soil temperature recorded at 7 AM and 5 PM at different soil depths was influenced by organic and inorganic mulches. In general, soil temperature at 0, 5 and 10 cm soil layers were lower at 7 AM as compared to soil temperature at 5 PM at their respective depths. Among different mulches, both at 7 AM and 5 PM, the soil temperatures with transparent mulch were relative higher (23.7%) as compared to control, but were similar to the organic mulches viz., saw dust (23.3%), groundnut shells (23.1%) and maize straw (22.8%). The relatively higher soil temperature noted with transparent polythene mulch was attributed to more transmittance of solar energy (short wavelength) through transparent polythene sheet and emitted long wave radiation back to atmosphere that causes heating effect (Schales and Sheldrake, 1963). Many research findings revealed that organic mulches moderated the temperature fluctuations. Thus, the existing lower soil temperatures were relatively increased with organic mulches as evidenced from our investigation and these observations are in line with earlier research (Hu *et al.*, 1995). The chilli crop transplanted during January was subjected to lower soil temperature (about 10-12^{o}C), which severely affects the root growth and their establishment percentage. Hence, the adverse effect of lower soil temperature during initial crop growth stages can be mitigated by using either organic mulches or transparent polythene mulch.

For efficient utilization of irrigation water, evaporation losses need to be reduced as 25-50% of the applied water is lost through evaporation (Hemphill and Crabtree, 1988). The evaporation losses from soil surface can be reduced by covering the soil surface with mulching material. In our study, organic and inorganic mulches influenced the soil moisture content at 0-15 cm soil depth. Our results showed that covering the soil surface with either organic or inorganic mulches resulted higher soil moisture content as compared to control at different stages of crop growth. Among different mulches, transparent polythene mulch resulted relatively higher (20%) average soil moisture content at all stages of the crop growth as compared to control. Among organic mulches, groundnut shells registered relatively higher soil moisture content as compared to saw dust and maize straw (Table 1). Hence, evaporation losses from soil surface can be reduced by covering the soil surface with transparent polythene/

Table 1: Effect of organic and inorganic mulches on soil moisture content (0-15 cm soil depth) at different days after transplanting during rabi season of 2016-17

Treatments	Soil moisture content (%) at different DAT									
	20	22	24	26	28	30	32	34	36	38
T_1- Control	10.7	11.2	14.0	14.8	12.3	13.4	12.7	12.5	14.0	14.5
T_2- Maize straw	11.89	13.1	14.5	15.01	14.67	14.1	14.01	13.9	15.4	14.9
T_3- Groundnut shells	12.4	14.1	15.0	16.12	16.56	14.9	15.8	14.4	16.2	15.5
T_4- Sawdust	12.3	13.4	14.8	15.4	15.12	14.6	15.4	13.9	15.5	15.3
T_5- Transparent polythene	14.6	15.9	15.7	16.8	17.0	15.9	17.3	15.9	18.0	18.5
T_6- Black polythene	13.1	14.4	15.5	16.4	16.9	15.3	15.9	15.1	16.6	15.5
T_7- Soil dust	11.4	12.9	14.1	15.0	13.9	13.5	13.7	13.5	15.3	14.8

groundnut shells mulch, which result in higher soil moisture content, increase the availability of plant nutrients there by higher dry matter production.

Effect of organic and inorganic mulches on productivity and WUE of chilli crop

The above ground biomass of chilli crop varied with the type of mulching material used. At 20 DAT, the above-ground biomass recorded with transparent polythene mulch was significantly higher than all other treatments, except black polythene mulch. Among organic mulches, groundnut shells registered significantly higher above-ground biomass as compared to that of saw dust and maize straw. At 40 DAT, the above-ground biomass noted with transparent polythene was significantly higher than black polythene mulch, which in turn was significantly higher than rest treatments, except groundnut shells (Table 2). A similar increase in plant growth rate due to increasing soil temperature with polythene mulch has been reported by earlier researchers (Soltani *et al*., 1995; Zimdahl, 2013). Transparent polythene mulch registered significantly higher pods per plant as compared to rest treatments. Among organic mulches, groundnut shells registered significantly higher number of pods per plant as compared to maize straw, but were statistically on par with saw dust. In control where there was no mulching, significantly lower number of pods was recorded. The pod yield varied significantly with organic and inorganic mulches. Significantly higher pod yield was realized with transparent polythene as compared to all other treatments. The increased pod yield with transparent mulch was attributed to registering significantly higher pod numbers per plant. The next higher pod yield was noted with black polythene mulch which was significantly higher than rest treatments. Among organic mulches, groundnut shells registered higher pod yield as compared to saw dust, which in turn was significantly higher than that of maize straw. Among all mulches, significantly lower pod yield was noticed with soil dust, but was significantly higher than control.

Among all the treatments evaluated, the highest WUE was obtained with transparent polythene (5.89%) followed by black polythene (5.65%), groundnut shells (5.30%), saw dust (4.48%), maize straw (3.87%) and soil dust (3.36%). The least WUE was noted with control (2.59%). The significantly higher WUE with transparent polythene mulch was attributed to its higher pod yield. Hence, WUE can be increased by using mulches and among different mulches, transparent polythene mulch could increase WUE of chilli crop grown on alfisols. Further, it was noted that among organic mulches, groundnut shells as mulch registered a WUE of 5.30 kg ha^{-1} mm^{-1}, which is next to transparent and black polythene mulches (Table 2).

Table 2: Effect of organic and inorganic mulches on above ground biomass at different days after transplanting, pods plant^{-1}, pod yield and water use efficiency of chilli crop during *rabi* season of 2016-17.

Treatments	Above ground biomass (g plant^{-1}) at different days after transplanting			Pods plant^{-1} (Nos.)	Pod yield (kgha^{-1})	WUE (kgha^{-1}mm^{-1})
	20	40	60			
T_1- Control	0.27	2.59	9.41	44	1391	2.59
T_2- Maize straw	0.40	2.93	12.32	58	2072	3.87
T_3- Groundnut shells	0.81	3.35	14.75	94	2842	5.30
T_4- Sawdust	0.50	3.01	12.99	91	2398	4.48
T_5- Transparent polythene	0.90	3.59	25.85	108	3155	5.89
T_6- Black polythene	0.83	3.52	15.25	98	3030	5.65
T_7- Soil dust	0.34	2.68	11.18	56	1802	.3.36
SEm (±)	0.05	0.23	1.11	6.5	99.8	
CD (p=0.05)	0.14	0.71	3.45	20.3	311	

Table 3: Effect of organic and inorganic mulches on weed dry matter, weed control efficiency at different days after transplanting and weed index of chilli crop during *rabi* season of 2016-17.

Treatments	Weed dry matter (g m^{-2}) at different days after transplanting			Weed control efficiency (%) at different days after transplanting			Weed index (%)
	20	40	60	20	40	60	
T_1- Control	6.77	59.81	60.89	-	-	-	59.9
T_2- Maize straw	0.79	33.49	33.59	81.7	54.8	44.1	31.6
T_3- Groundnut shells	0.56	26.54	27.21	86.7	61.6	53.5	9.9
T_4- Sawdust	0.82	28.85	30.63	85.8	56.4	46.1	31.6
T_5- Transparent polythene	0.55	24.22	24.94	87.1	65.2	56.5	-
T_6- Black polythene	0.53	19.74	21.87	89.8	69.1	66.5	4.0
T_7- Soil dust	0.50	16.90	16.92	91.1	73.5	69.2	42.9
SEm (±)	0.14	2.23	2.53	0.1	2.2	2.5	
CD (p=0.05)	0.45	6.94	7.90	0.5	6.9	7.9	

Effect of organic and inorganic mulches on weed growth

In general, soil surface mulching results in lower weed growth as compared to without mulching. Our experiment results revealed that at 20, 40 and 60 DAT, significantly higher weed dry matter was noted with control as compared to all other treatments. At all stages of crop growth, soil dust mulch treatment registered significantly higher weed dry matter m^{-2}, and remained on par with transparent mulch. Among organic mulches, saw dust registered lower weed dry matter as compared to maize straw, but remained on par with groundnut shells (Table 3). The lowest weed dry matter with soil dust was due to continuous removal of weeds in the course of maintaining soil dust in surface layer. The reduced growth of weeds in transparent/black polythene mulch might be due to reduced availability of sun light (Mathieu and Jeremy, 2004).

The WCE estimated with different types of mulches varied significantly. The soil dust mulch registered significantly higher WCE followed by black polythene, transparent polythene, groundnut shells, saw dust and maize straw. The control registered significantly lower WCE as compared to rest of the treatments. The higher WCE with soil dust and other mulching materials was due to efficient reduction of weed dry matter (Table 3). Among all other treatments with respect to transparent mulch, the weed index was lower with black polythene mulch followed by groundnut shells, saw dust, maize straw and soil dust. The least weed index was noted with control (Table 3).

Table 4: Effect of organic and inorganic mulches on soil bulk density at initial and after harvest of chilli crop during *rabi* season 2016-17

Treatments	Average Bulk density ($g\ cm^{-3}$) At initial stage	Average Bulk density ($g\ cm^{-3}$) At harvest stage	Porosity (%)
T_1- Control	1.99	1.76	37.4
T_2- Maize straw	1.99	1.74	38.1
T_3- Groundnut shells	1.99	1.69	40.0
T_4- Sawdust	1.99	1.67	40.8
T_5- Transparent polythene	1.99	1.80	35.8
T_6- Black polythene	1.99	1.84	34.3
T_7- Soil dust	1.99	1.70	39.6
SEm (±)	-	0.03	
CD (p=0.05)	-	0.10	

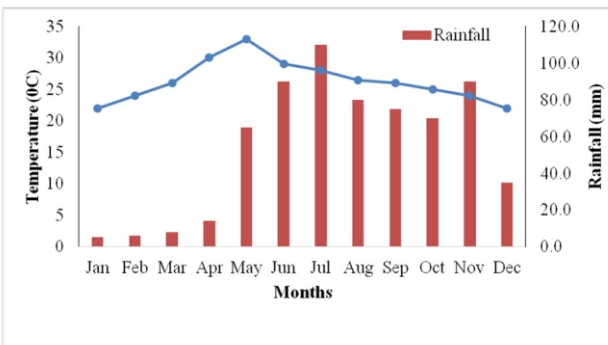

Figure 1: The mean monthly average temperature and rainfall during 2016-17 at Madakasira

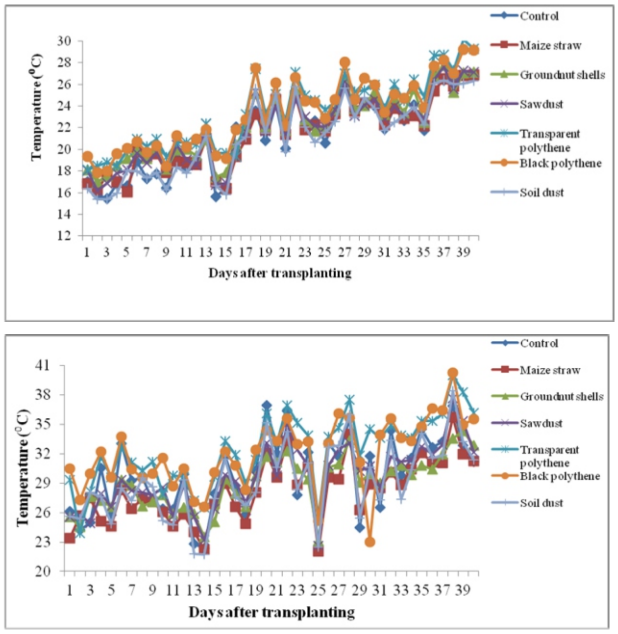

Figure 2: Soil temperature at 7 AM (a) and 5 PM (b) in 0 cm depth layer at different days after transplanting as influenced by organic and inorganic mulches during rabi season 2016-17.

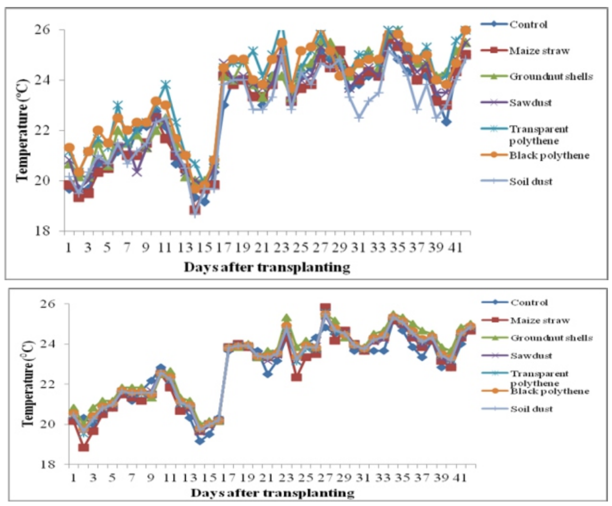

Figure 3: Soil temperature at 7 AM (a)and 5 PM (b) in 0-5 cm depth layer at different days after transplanting as influenced by organic and inorganic mulches during rabi season 2016-17.

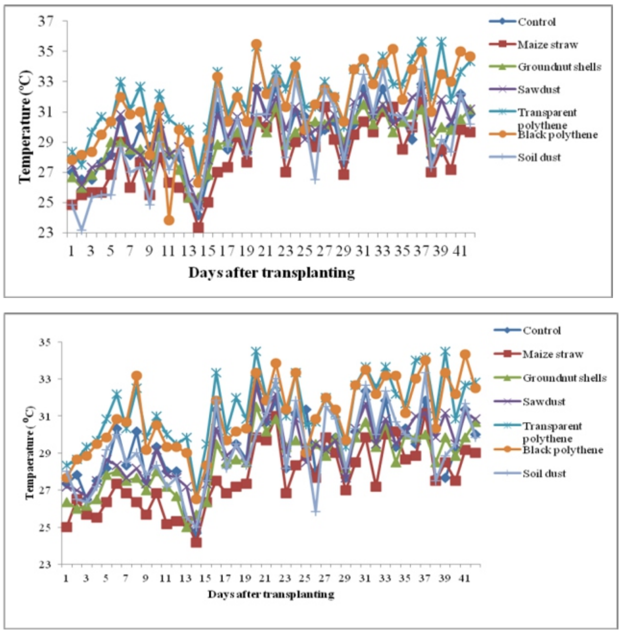

Figure 4: Soil temperature at 7 AM (a) and 5 PM (b) in 5-10 cm depth layer at different days after transplanting as influenced by organic and inorganic mulches during rabi season 2016-17.

Effect of organic and inorganic mulches on changes in soil physical properties

In general, external addition of any organic material to soil improves the physical properties of soil. In our experiment, soil physical properties like BD, porosity and infiltration rate were influenced due to addition of organic and inorganic mulches. Our results showed that the BD of soil at harvest stages was less than that of initial stages with respect to all treatments. The external addition of either saw dust or groundnut shells to soil resulted in significantly lower soil BD as compared to transparent/black mulch, but were statistically on par with rest treatments (Table 4). The significant lower soil BD with respect to saw dust/groundnut shells mulch might be due to addition of organic material to soil resulted in increased porosity, which was evidenced in our experimental results. The saw dust/groundnut shells registered maximum porosity (40.8 and 40.0%, respectively) in soil and the least porosity was noticed in black/transparent mulch (34.3 and 35.8%, respectively) (Table 4).

In our experiment, the infiltration rate of soil varied with different types of mulches. In general, all the organic mulches increased the infiltration rate of soil as compared to inorganic mulches. Further, maximum increase in infiltration rate over the initial value (Table 5) was noted with saw dust followed by groundnut shells, maize straw, soil dust, control, transparent polythene and black polythene. Hence, addition of organic material to soil as mulches improved the soil physical properties of alfisols.

CONCLUSION

Our research findings clearly indicated that transparent polythene mulch increased the soil temperature to an extent of 5-10% and soil moisture content by 26-30% as compared to that of control. Further, transparent polythene mulch resulted in the highest chilli pod yield (3155 kg ha^{-1}), but remained on par with groundnut shells mulching (2842 kg ha^{-1}). Moreover, transparent polythene mulch efficiently controlled weed growth in terms of weed dry mater (94, 60 and 59% at 20, 40 and 60 DAT, respectively) as compared to control. Organic mulches like groundnut shells, sawdust and maize straw improve the soil physical properties like BD, porosity and infiltration rate by 6.47, 10 and 4.09%, respectively as compared to polythene mulch.

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Table 5: Effect of organic and inorganic mulches on infiltration rate (cm hr^{-1}) days after transplanting of chilli crop during *rabi* season of 2016-17.

Time (min)	Before	Infiltration rate (cm hr^{-1}) at harvest						
		Control	Maize straw	Groundnut shells	Saw dust	Transparent polythene	Black polythene	Soil dust
0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
1	14.0	14.4	14.3	14.4	14.5	14.3	14.4	14.5
2	13.9	14.2	14.1	13.9	13.8	14.1	13.9	14.0
3	13.6	13.9	13.8	13.7	13.6	13.9	13.5	13.5
4	13.5	13.5	13.5	13.4	13.3	13.5	13.2	13.2
5	13.4	13.2	13.1	13.1	13.1	13.2	12.9	12.9
10	13.2	12.9	12.8	12.9	12.8	12.8	12.6	12.7
15	12.8	12.4	12.6	12.5	12.6	12.4	12.4	12.4
20	12.4	12.1	12.3	12.3	12.4	12.2	12.1	12.2
25	11.8	11.9	12.1	12.2	12.3	11.9	11.8	11.9
30	11.5	11.8	11.9	12.2	12.3	11.7	11.6	11.8
45	11.5	11.8	11.9	12.2	12.3	11.7	11.6	11.8
60	11.5	11.8	11.9	12.2	12.3	11.7	11.6	11.8

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