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Research article

DO ORGANIC AND INORGANIC MULCHES AFFECTS SOIL MOISTURE CONSERVATION AND CROP YIELD?

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HIGHLIGHTS

- Mulching either organic or inorganic are found to be an important tool to conserve soil moisture.
- Mulching shows positive effect on soil moisture conservation as well as plant growth and yield.

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Key words: Moisture retention, Organic mulches, Inorganic mulches, Chilies

ABSTRACT

Soil moisture conservation is an important issue of rainfed area. Mulching as a soil cover is of great importance for conserving soil moisture and consequently crop yield. A field experiment was executed at Soil and Water Conservation Research Institute, Chakwal during the years 2015 to 2017. The objective of the study was to elucidate the effect of organic and inorganic mulches on growth and yield of chili crop. The experiment was carried out in Randomized Complete Block Design (RCBD) with four treatments replicated thrice. The mulching material includes organic (wheat straw) and inorganic (black plastic sheet and transparent plastic sheet) with a control treatment of un-mulched/ uncovered plot. The results revealed that the highest average soil moisture content (17.4%) was observed in black plastic mulch followed by (16.8%) in the treatment with transparent plastic mulch as compared to un-mulched (11.3%) treatment. The maximum plant height (44.7cm) and fruit yield (293g/ plant) was observed in transparent plastic mulch treatment. Wheat straw improved the fruit yield (228g/plant) as compared to un-mulched (172g/plant). Capsaicin content (0.188 %) in chili fruit was recorded in control as compared to all mulched treatments. Therefore, mulching either organic or inorganic are found to be an important tool to conserve soil moisture and shown positive effect on soil moisture conservation as well as plant growth and yield.

1. Introduction

Green Chili (*Capsicum annuum L.*) is most famous and widely used universal spice in the world, known as wonder spice. It belongs to the family "Solanaceae". It is mostly cultivated as a cash crop, green vegetable and condiment in the tropical and sub-tropical part of the world. It has high nutritional

value and is rich in Vitamins especially Vitamin A, C and E and ascorbic acid (Narayan *et al*., 2017).It has high content of vitamin C than any other vegetable crops and contain pro vitamin A, E, P, B1 (thiamine), B2 (riboflavin) and B3(niacin/niacinamide) (Poulos, 1993). Chilies has significant role in the human diet and consumed both as fresh or dried forms.

Different varieties of green chiliesare cultivated for different purposes such as vegetable, pickles, spices and condiments. It is the integral part of daily life food. It adds pungency, taste and flavor and color to the dishes. The pungency in green chili is due to the presence of an alkaloid capsaicin that has high medicinal value especially anti – cancerous and instant pain relief. At present, it is the most recommended topical medication for arthritis (Bosland and Votava, 2000).

Major chilies growing countries with their export share are India (25%), China (24%), Spain (17%), Mexico (8%), Pakistan(7.2%), Morocco (7%) and Turkey (5%). India, China and Pakistan are major exporter and consumer of chilies (Kumar *et al*., 2016)

Water deficiency limits the crop growth and development. Green chilies are sensitive to water stress especially at the time of floral initiation, during flowering, and to a lesser extent, during fruit development (Hegde, 1989). To improve the productivity of crops where either water deficiency or excess frequently occurs, proper water management is necessary (Hale and Orcutt, 1987).

The soil water loss is a big issue due to evaporation, transpiration and percolation. The percolation losses can be avoided by applying water to the root zone of plants through drip irrigation system. The evaporation losses can be minimized by the use of mulches such as crop wastes and polyethylene plastics (Pandian *et al*., 2017).

Mulching is a one of the efficient soil and water practice in which the soil cover provide suitable environment for development. Mulching material includes plastic sheets, films, sawdust, sugarcane waste, leaves, farm yard manure, compost, wheat straw, rice straw, plant residues and poultry litter etc. The organic material such as straw, dry leaves and grasses have been practiced by farmers for centuries to boost up vegetable yield and also add organic matter into the soil which further improves soil structure. The plants grown on mulch material are more productive because organic mulch increases vegetative growth, blooming and number of fruit per plant which leads to early maturity (Gomez *et al*., 1997).

Furthermore, mulches can offer a barrier against weeds, moisture loss, nutrient loss, soil erosion, insect and disease injury while encouraging plant establishment and a crop of potentially higher quality. It is also reported that artificial or plastic mulches are completely resistant to water hazards (drought and flood) and reduces soil and water losses through runoff. Organic mulches decrease the cost of production, improve soil structure and prevent insect pest attack (Mugalla *et al*., 1996).

Now-a-days, Black plastic is the predominate mulch utilized for vegetable production. It requires higher cost per acre compared to other mulches. However, black plastic mulch also effectively warms the soil, improves early crop production and eliminates most in-row weed growth. The use of black plastic mulches typically results in higher yields and quality in vegetable crops enhancing profitability for the grower (Helaly *et al*., 2017).

Tan *et al*. (2009) observed higher number of primary branches under straw mulch relative to the bare plot on bottle gourd. Aiyelaagbe and Fawusi (1986) showed that mulching increase the pepper plant height, canopy diameter, leaf area per plant, number of fruits per plant and total fruit dry weight under organic mulches with saw dust, dry grass and maize crop.

There is significant effect of mulching on leaf number per plant in onions and higher numbers of leaves on mulched plot over the bare plot in onion were noticed.(Umar *et al*., 2000).

In plants chlorophyll is an important catalyst for photosynthesis process. It is found in thylakoid membranes as a green pigment in photosynthetic tissues. Taller plants like chilies have two types ofchlorophyll that are chlorophyll a and chlorophyll b. The structure of chlorophyll-b is different from chlorophyll-a because chlorophyll-a has a methyl catalyst, while chlorophyll-b has an aldehyde group which is attached on the right top of the pyrrole ring (Harborne, 1987).

The objective of this research study was to investigate the effect of inorganic and organic mulches on the yield components of chili and to compare efficiency of inorganic and organic mulches for soil moisture conservation.

2. Materials and method

The experiment was conducted during three consecutive Kharif seasons of 2015 to 2017 at the farm of Soil and Water Conservation Research Institute, Chakwalat 32.93° N latitude and 72.72 ° E longitude above sea level of 498 m. The experimental soil was well drained and loamy in texture, having pH of 7.69, with no salinity problem (EC 0.36 dS/m), low in O.M. (0.45 %) and Phosphorous (5.5 ppm) and medium in Extractable K (113 ppm). The experiment was laid out in a Randomized Complete Block Design (RCBD) with four treatments and three replications. The test crop was chili (*Capsicum annuum* L.).

The following treatments were tested:

a) T1: Control (no mulch)

b) T2: Wheat straw

c) T3: Transparent plastic mulch

d) T4: Black plastic mulch

The experimental field was ploughed and well decomposed farm yard manure (10 tons/acre) and recommended dose of fertilizers were incorporated uniformly.The raised beds were formed with plot width of 1.20 m and length of 3 m. The lateral drip lines were spread over the beds for irrigation for T1 without any mulch.

The raised beds assigned for treatments T2 were covered with required quantity of chopped wheat straw. Similarly, mulch sheets were spread over the beds for the treatments T3 and T4.

All required cultural practices such as weeding and fertilizers were carried out uniformly to all experimental plots. Data regarding number of leaves per plant, plant height (cm), fruit length (cm), fruit circumference (cm), fresh fruit weight (g) and fruit yield per plant were recorded.

Plant height was measured from ground level to top of chili plants by using measuring tape. Fresh fruit weight was measured by using electrical balance and was expressed in gram. Fruit length and circumference was measured by using measuring tape. Pre sowing composite soil samples were collected, analyzed for soil fertility status (EC, pH, texture, N, P, K, Organic matter (Table 1).Soil moisture content was determined gravimetrically. Electrical conductivity was measured by using EC meter (JENWAY Conductivity meter Model 4510). Soil pH was measured by using pH meter (HANNA pH Model 211). Soil Texture was measured by hydrometer method. Nitrate nitrogen was measured by Spectrophotometer. Available Phosphorous was by using Spectrophotometer (Olsen and Sommers, 1982). Extractable Potassium was measured by Flame Photometer model JENWAY PFP7 (Helmke and Sparks, 1996).

For the nutritional analysis fresh fruit was used. The sample was washed with distilled water before performing the analyses. Moisture content was determined immediately. The samples were stored in -20 °C for further analysis. Moisture was determined by drying 2 g sample in an oven. Capsaicin content was estimated as per the procedure developed by Quagliotti and Ottoviano (1971). Vitamin C content was estimated by 2, 4-dinitrophenyl hydrazine method (ISI, 1971).Plant

chlorophyllcontent was measured with a spectrophotometer (Harborne, 1987).

Data were subjected to statistical analysis by analysis of variance method (Panse and Sukhatme, 1985). The critical difference was worked out for 5 per cent probability. The results of the experiment were tabulated and presented below:

Table 1: pH values for fresh material digester (FMD)

Sr.#	Parameter	Unit
1	pH	7.69
2	ECe	0.36 dS/m
3	Organic Matter	0.45 %
4	Texture	Loam
5	NO_3-N	1.03 mg/kg
6	Available Phosphorous	5.5 mg/kg
7	Extractable K	113mg/kg

3. Results and discussion

The mulching involves placing of a layer of material on the soil around the crop of interest to modify the micro environment to improve crop productivity. Mulches typically function by blocking light or creating environmental conditions, which can prevent germination or suppress weed growth shortly after germination. However, other benefits including earliness, moisture conservation, temperature regulation, reduce nutrient leaching, affect insect and disease pressures and some instances reduce soil compaction, improved soil organic matter. The use of mulches typically, results in higher yield and quality in vegetable crop enhancing profitability for the growers.

The meteorological data was recorded at weather station Soil and Water Conservation Research Institute, Chakwal (Table 2). The Minimumand Maximum and temperature were recorded during the crop growth season from April to August. Mean Evaporation (mm/day) was also recoded to measure the evaporation losses during the growth period of the crop.The mean minimum temperature of 14.90^{o}C, 13.72^{o}C and 15.39 ^{o}C was recorded in the month of April during the year 2015, 2016 and 2017 respectively. The mean maximum temperature of 36.50^{o}C, 38.84^{o}C and 37.26^{o}C was recorded during the year 2015, 2016 and 2017, respectively.The mean maximum evaporation of 6.70mm/day, 9.43mm/day and 6.22 mm/day was recorded during the year 2015, 2016 and 2017, respectively in the month of May, June and May respectively.

The rainfall (mm) was recorded during the growth period of crop by the digital rain gauge installed at Soil and Water Conservation Research Institute Chakwal. The highest rainfall was recorded in the month of July during all the three studied years. During these three consecutive years the lowest rainfall was recorded in the month of May (Figure1).

3.1 Soil Moisture Content: Comparatively higher average moisture content was recorded in mulched soil as compared to control in three studied years. The black plastic mulch showed the highest soil moisture content (17.4%) followed by transparent plastic mulch (16.8 %). The lowest soil moisture content was noticed in control (11.3 %)(Figure2). In plastic mulching, higher moisture content was observed due to less moisture evaporation losses from the soil. The evaporated water content from the soil was again trapped under the mulches, resulting in vapors which again dropped into upper soil layer. The results are similar to the findings of Wang *et al.* (1998) who reported that all types of polythene mulch increased the soil moisture content in chili field compared to control that consequently influenced the crop productivity.

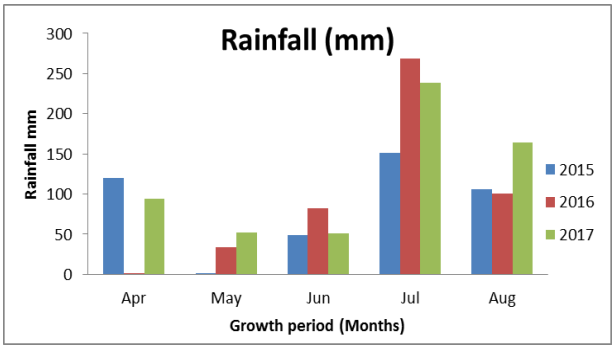

Figure 1: Rainfall (mm) during the growth season of crop: Source: SAWCRI Chakwal

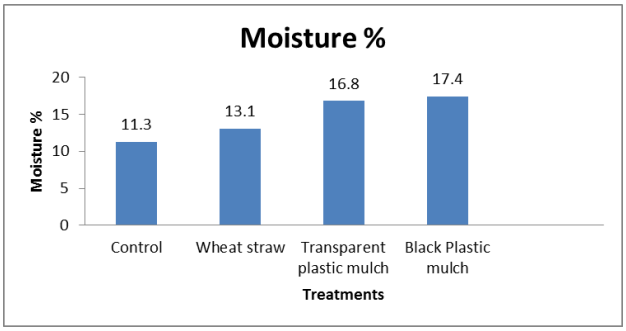

Figure 2: Soil Moisture Percentage in treatments during the growth period

3.2 Number of leaves per plant: Significant differences were observed between the inorganic and organic mulches for number of leaves per plant. The data revealed that the maximum numbers of leaves per plant (66.6) were observed in black plastic mulch followed by transparent plastic mulch (65.4). The lowest numbers of leaves per plant (49.6) were recorded in control (Table 3).Hallidri (2001) reported that number of leaveswere higher in black and transparent plastic mulch as compared to control (without mulch). Theseresults were similar to the findings of Wien *et al*., (1993) whonoticed an increase in tomato growth and yield bypolyethylene mulching; it might be due to enhanced root growth and nutrient uptake early in the season.

3.3 Plant height (cm): There was significantdifference was observed in plant height (cm) between unmulched and mulched treatments (organic and inorganic). Maximum plant height was observed in transparent plastic mulch (44.7 cm) followed by black plastic mulch (43.3 cm). The plant height (38.4cm) was recorded in wheat straw treated plants. The minimum plant height (33.9 cm) was observed in plant having no mulch (control). Plastic mulches showed superior performance in plant height as compared to control, indicating that mulches had positive effect on the growth and development of chili plant (Table 3). The increased plant height in mulched plant was possibly due to better availability of soil moisture and optimum soil temperature provided by the mulches. These findings were confirmed by the results of Olabode *et al*.(2007) that use of polyethylene mulch increased the plant height in okra.

3.4 Fruit length (cm): The data revealed that significant difference exist in all treatment (Table 3).The result indicated that there is significant variation in fruit length of organic and inorganic mulches. The maximum fruit length was recorded in transparent plastic mulch (5.1 cm) that was statistically different than black plastic mulch (4.8 cm) followed by wheat straw (4.2 cm). The minimum fruit length (3.5 cm) was recorded where no mulch was used. These results are similar to those results reported by Farios-Larios and Orozco-Santos (1997). They showed that fruit length of watermelon was higherwith polyethylene mulches because the mulchesconserved the soil moisture and enhanced soiltemperature which increased the fruit length.Nagalakshmi *et al.* (2002) showed that in chili plant the maximum number of fruits per plant (97.67), length of fresh fruit (6.93 cm) and circumference of fruit (3.57 cm) was recorded with the use of black plastic mulch compared to organic and no mulch (control).

3.5 Fruit Circumference (cm): All the tested treatments were found significantly different from each other (Table 3). The maximum fruit circumference was observed in transparent plastic mulch (2.90 cm) that was statistically significant than black plastic (2.23 cm) mulch followed by (1.67cm) in

wheat straw. Minimum fruit circumference was produced in control with no mulch (1.13 cm). Mulches mostly influence the field microclimate by modifying the radiation budget of the surface and decreasing soil water losses. These microclimate factors strongly affect the soil temperature and moisture in the root area, which in response may increase plant growth and yield (Aguyoh et al., 1999).

3.6 Fruit weight (g): Significant differences were observed in different treatments tested (Table 3) each other. The average maximum single fruit weight was observed in black plastic mulch (6.27 g) followed by transparent plastic sheet (6.03 g). The minimum fruit weight was recorded in control (3.40 g) with no mulch. Farias-Larios and Orzoc-Santos(1997) observed increased fruit weight in watermelon by the application of clear polyethylene mulch as compared to un-mulched soil as early and highervegetative growth support better fruit weight gain.Fruit yield increased in mulched plot because of increased number of fruit/plant and fruit weight which may be attributed to the better utilization of inputs due to lowest weed competition and better soil moisture. The results are in accordance with Ashraf uz Zaman *et al*. (2011) who reported maximum fruit yield in case of black plastic mulch in chili.

3.7 Fruit Yield per plant (g): All the tested treatments were found statistically different from each other. The fruit yield per plant was increased significantly by the use of plastic mulch. The maximum fruit yield per plant was observed in transparent plastic mulch (293g) followed by black plastic mulch (281g). Minimum fruit yield per plant (172g) wasrecorded in control (Table 3). Taber and Lawson (1997) reported that totaland early yields increased with polyethylene mulches.Similar results with other vegetables were obtained byPakyurek and Kaşka (1992) in watermelon, Tuzel andBoztok (1990) in tomato, Çevik *et al*., (1992) incucumber. Inorganic mulches, predominantlypolyethylene mulch, produced the higher yields ascompared to the non-mulch materials.The results are in accordance with the earlier reports of Ravinder *et al*. (1997) and Ashrafuz Zaman *et al*. (2011) who reported that mulching significantly improved the number of fruits per plant and reduced the percentage fruit abortion compared to unmulching control. The increase in the number of fruits per plant associated with plastic mulching can probably be attributed to conservation of moisture, improved microclimate and less competition from weed growth. The suitable conditions enhanced the plant growthand development and produced increased fruit bearing nodes compared to the control (Ashrafuz Zaman *et al*., 2011)

3.8 Weed density: The highest numbers of weeds per m^2 were observed in transparent plastic mulch (118.3) and lowest number of weeds was observed in black plastic mulch (23.3) (Table 4). The black plastic mulch was very much effective in decreasing the weed density as compared to the organic and transparent plastic mulches. Black plastic mulching blocked the weeds which might be due to the lack of percentage of light through them(Schonbeck, 1998). Zhang *et al*., 1992 reported that black plastic mulch resulted in 100% control of all the weeds in maize that supported the present experimental result.Transparent plastic mulch produced maximum weed population due to direct entrance of solar radiation through them and due to high soil temperature and soil moisture especially at upper layer of soil.

3.9 Chlorophyll content: The effect of organic and inorganic mulches on Chlorophyll-a, Chlorophyll-b and total Chlorophyll are presented in Table 5. The data revealed that highest Chlorophyll- a, Chlorophyll- b, total Chlorophyll content were found in black plastic mulch (0.48 mg/g, 3.52 mg/gand 2.09mg/g), respectively. In comparison to that the lowest Chlorophyll- a, Chlorophyll- b, Total Chlorophyll content were found in control (0.41 mg/g, 3.07 mg/gand 1.63mg/g),respectively. Similar results were reported by Panchal *et al*. (2001) who observed a significant difference of mulches on total

Table 2: Meteorological data of Chakwal during crop growth period

	Mean Min. Temp. (^{OC})			Mean Max. Temp. (^{o}C)			Mean Evaporation (mm/day)		
Months	2015	2016	2017	2015	2016	2017	2015	2016	2017
Apr	14.90	13.72	15.39	29.20	32.25	31.45	3.70	5.56	3.32
May	18.80	20.53	21.34	35.80	38.84	37.26	6.70	8.53	6.22
Jun	21.90	23.87	23.20	36.50	38.82	35.95	6.50	9.43	5.89
Jul	23.20	23.58	24.03	33.70	35.34	34.03	3.80	6.95	4.97
Aug	22.80	22.47	23.97	32.20	34.37	34.40	3.70	7.74	4.10

(Source: SAWCRI Chakwal)

Table 3: Effect of Organic and Inorganic mulches on the vegetative components of Chili

Treatments	**No. of leaves/ plant**	**Plant height (cm)**	**Fruit length (cm)**	**Fruit circumference (cm)**	**Fruit weight (g)**	**Yield per plant (g)**
Control	49.6 d	33.9 c	3.5 d	1.13 d	3.40 d	172 d
Wheat straw	52.7 c	38.4 b	4.2 c	1.67 c	3.97c	228 c
Black Plastic sheet	66.6 a	43.3 a	4.8 b	2.23 b	6.27 a	281 b
Transparent Plastic Sheet	65.4 b	44.7 a	5.1 a	2.90 a	6.03 b	293 a
LSD$_{(0.05)}$	**0.593**	**0.651**	**0.099**	**0.065**	**0.061**	**2.85**

Table 4: Effect of organic and inorganic mulches on weed infestation

Treatments	**Number of weeds per m^2**	**Fresh weight (g/m^2)**	**Dry weight (g/m^2)**
Control	73.7b	83.8c	22.9b
Wheat straw	66.7b	90.2b	25.2b
Black Plastic sheet	23.3*	17.5*	5.4c
Transparent Plastic Sheet	118.3a	213.1a	71.1a
LSD$_{(0.05)}$	4.10	1.87	2.16

Table 5: Effect of different organic and inorganic mulches on Chlorophyll and Vitamin- C content in green chili.

Treatments	Chl-a	Chl-b	Total chl.	Vitamin -C	Capsaicin
	mg/g fresh weight			mg/g	(%)
Control	0.41b	3.07b	1.63c	110.8c	0.188 a
Wheat straw	0.42b	3.13ab	1.74b	114.47b	0.170ab
Black Plastic sheet	0.48a	3.52a	2.09a	121.94a	0.166b
Transparent Plastic Sheet	0.44ab	3.42ab	2.05a	121.6a	0.165b
$LSD_{(0.05)}$	0.023	0.164	0.042	1.363	0.019

chlorophyll contents in the chili fruit and the highest total chlorophyll content was found in black mulches as compared to other mulches.

3.10 Vitamin –C content in fruit: The effect of organic and inorganic mulches on Vitamin –C content in chili fruit is presented in Table 5. On overall basis,Vitamin –C was higher in mulched treated fruit as compared to control. Among the all mulched treatments the highest Vitamin –C content was found in black plastic mulch (121.9mg/g). The lowest Vitamin –C content was found in control/ no mulched treatment (110.8mg/g). Similar results were found by Panchal *et al*. (2001) that higher content of Vitamin – C was found in fruits from black plastic mulches as compared to other mulches.

3.11 Capsaicin in fruit: The effect of organic and inorganic mulches on Capsaicin content in chili fruit is presented in Table 5. The data exhibited that the highest Capsaicincontent (0.188 %)in chili fruit was recorded in control as compared to the mulched treated plants. The pungency of chili peppers is conferred by compounds called capsaicinoidsthat are produced only in the fruits of the Capsicum genus. Accumulation of capsaicinoidsin these fruits may be affected by environmental conditions such as water and nutrient stresses.Estrada *et al*. (1997) reported that theamount of capsaicinin pepper (C.annuum L.) fruits from water-stressed plantswas higher than in control (mulched) plants.According to the research study the capsaicin content of different chili varieties are found in the range of 0.08 to 0.37% (Chattopadhyay *et al*., 2011).

4. Conclusion

From the research study it was observed that inorganic plastic mulch (black and transparent) are beneficial for the growth and development of chili plant.They have a positive impact on the fruit yield due to increase in soil temperature. They also conserve the soil moisture for longer time due to less evaporation losses. But on the contrary they are cost bearing and are difficult to remove from the field because they don't decay in the soil. While organic mulch like wheat straw can also be used as mulch for moisture conservation and it can be dumped in the soil after harvesting of crop. The incorporation of wheat straw or other organic mulch can also improve the structure and fertility of soil.

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