__Review Article__

Mulching: An efficient technology for sustainable agriculture production

Abstract

The application of mulching practices reduces soil evaporation, conserves soil moisture, suppresses weed growth, controls soil structure and temperature, influences soil micro-organisms, and is aesthetically pleasing. This study has reviewed, and described the effects of various mulching materials and methods on soil and environment that influence crop productivity. This paper describes the extent of the influence of different mulching materials and methods on the hydrothermal environment of soils. It is imperative to know the processes that control soil environments under various mulching conditions and the effects of mulching materials on crop yield, productivity and water use efficiency. Plastic mulching materials also have a greater importance to control soil environment and increase crop yield. Organic mulching materials are inexpensive and environmentally friendly. The selection of an appropriate mulching material is, however, guided by crop type, crop management practices and climatic conditions. Future research is needed on the effects of low-cost biodegradable mulching materials on microclimate modifications, soil biota, soil fertility, crop growth and crop yields.

Keywords: mulching, sustainable agriculture, crop production, straw mulching

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Introduction

In the present scenario, the most common goal of all agricultural researchers is to sustain production without exhaustive use of natural resources and conserve them for future generations to satisfy the present needs of human resources. "To mitigate the exhaustive use of natural resources in agriculture, mulching has a crucial role as a sustain crop production by soil moisture conservation, reducing the impact of weeds, changing the microclimate of crops, and altering the physical, chemical and biological properties of soil in rainfed and drought areas. On the other hand, global warming, high and low temperature, irregular rainfall patterns, and lower soil moisture availability are responsible for the shortage of water resources which limit agricultural production" (Li *et al.*, 2017). "The goal of all the conservation measures is to maximize yield by minimizing resource use" (Kader *et al.*, 2019). The efficient use of resources is a crucial factor during crop growing season which can greatly improve yield. Therefore, the conservation of soil resources by using mulching may be an efficient option for raising production in a sustainable manner.

The English word 'mulch' is derived from the German word "molsch", which means soft or beginning to decay (Jacks *et al.*, 1955). "Mulches are defined as materials that are applied to the soil surface, as opposed to materials that are incorporated into the soil profile" (Chalker-Scott, 2007). "Mulch is a layer of material(s) that covers the soil surface, and Mulching is the technique of covering the soil surface around the plants with an organic or synthetic mulch to create favourable conditions for plant growth and proficient crop production" (Kader *et al.*, 2017). "It increases water infiltration into the soil, retards soil erosion and reduces surface runoff" (Adekalu *et al.*, 2007). "Mulching is an effective method of manipulating the crop-growing environment to increase crop yield and improve product quality by controlling soil temperature, retaining soil moisture reducing soil evaporation and insulating soil to protect organisms and plant roots from different meteorological conditions". (Chakraborty et al., 2008) "Mulch creates congenial conditions for growth and ameliorates various environmental stresses" (Macilwain, 2004). "It exerts decisive effects on earliness, yield and quality of the crop. Straw mulching has a major effect on soil water and thermal regimes". (Macilwain, 2004).

"Mulching is a common practice recommended for tropical small farming holders, due to its ability to conserve soil and moisture and also suppress weeds" (Shah, 2015). "The

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yield and water productivity gains were due to greater root proliferation which was the result of moderation of soil temperature and water conservation with straw mulching" (Arora *et al.*, 2011).

"However, the ability to sustain, let alone increase, the productivity of these systems to meet the needs of the growing population is threatened by depletion and/or degradation of natural resources (water, air, soil, biodiversity), increasing farm labour scarcity, and high production costs" (Erenstein *et al*., 2007; Ladha *et al*., 2003, 2009; Rijsberman, 2006). Current practice involves intensive tillage for both crops and the removal of all crop residues.

Mulching materials and methods

"The mulching materials are mainly classified into three main groups; A) organic materials (e.g., plant products, animal wastes), B) inorganic materials (synthetic materials) and C) special materials (Table 1). The organic mulching materials are derived from organic substances such as agricultural wastes (straw, stalks), wood industrial wastes (sawdust), processing residues (rice husks) and animal wastes (manure). The inorganic mulching materials include polyethene plastic films, which are petroleum-based products (Gill, 2014), and synthetic polymers" (Kyrikou and Briassoulis, 2007). "Several new types of biodegradable and photodegradable plastic films as ecological materials, and proposed sprayable and biodegradable polymer films for easy application and versatility" are described by Adhikari *et al*. (2016) and Yang *et al.* (2015). "Some special materials, such as sand and concrete are easily available and have also been used for mulching, each type of mulching material has a particular set of characteristics. The choice of selection of an appropriate mulching material depends on local climate, cost-effectiveness and feasibility for the crop". (Wang et al., 2015)

Table 1; Different classes of mulching materials

Organic materials	Inorganic materials	Special type materials
Straw (rice, wheat, maize) Dry clips (grass, weeds, wood, bark) Chopped leaves, Cassava bagasse Geo-textile materials Husks (rice, coconut, maize stalk) Small branches of the tree Paper (newspaper, kraft paper) Animal wastes (cow dung, manure) Cover crops (weed, fodder)	Biennial colour plastic film Black plastic film Silver plastic film Transparent plastic film with holes Biodegradable and photo-degradable plastic film Spray able polymer film	Gravel (sand–grave) Concrete Tephra mulch

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"Several mulching materials are imposed in crop fields by different approaches. Flat mulching is a conventional method of mulch application in which the soil surface is enclosed by organic, inorganic or mixed mulching" (Ghosh *et al.,* 2006; Sun *et al.,* 2012). "In flat mulching organic mulching materials can maintain various thicknesses according to the intended purpose while in plastic mulching with holes it only partially covers the soil surface. This mulching increases soil aeration and rainfall infiltration compared to traditional flat mulching" (Kader, 2016). "In ridge shape mulching, the ridge is covered by plastic film and furrows are commonly used for harvesting rainwater to minimise surface runoff" (Tian *et al*., 2003; Gan *et al*., 2013), consequently increasing water use efficiency. either on the ridge or in the furrow or on both (Yin *et al*., 2016) and it has been found more effective in harvesting rainwater and reducing soil surface evaporation compared to conventional flat mulching (Gan *et al*., 2013).

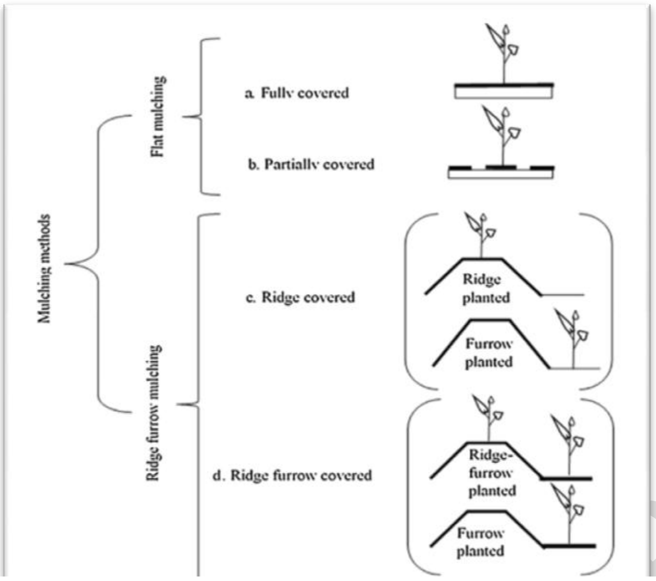

Fig. 1. Different mulching method of application

Effect on soil moisture conservation

Evaporation is the major process of loss the water from open or baren soil. To check the evaporation and minimize water losses by the mulching application because mulching blocks water vapor exchange between soil and open air and reduces soil evaporation. Straw mulch has a great role in soil moisture conservation through the alteration of microclimatic soil conditions. It supports preventing weed growth, decreasing evaporation, and rising the infiltration of rainwater during the growing season (Yang *et al.,* 2003) and modifying the retention capacity of the soil (Lal, 1974). "The soil -moisture is not the same under different mulching materials. This mainly depends on the types and how much quantity of mulching materials used and also differs in different soil types and climatic". (Chakraborty et al., 2008).

"The soil moisture changes in the upper surface layer (0– 10 cm) of soil is highly dynamic due to water vapour fluxes across the soil-atmospheric interface but, after mulching application, these fluctuations of soil moisture reduce and supply a constantly stored soil moisture thought out the growing period of the crop" (Kader, 2016). Teame *et al.* (2017) found that "organic mulching had a significant effect on soil moisture content at 0-20 cm, 20-40 cm, and 40-60 cm in every two-week interval after sowing to the harvesting stage of sesame crop and sesame straw mulch conserved highest soil moisture content as compared with respective other mulching materials". Tetarwal and Rana (2006) observed that "the application of organic manure like FYM with soil mulch and straw mulch significantly affected the soil moisture content and increased N and P uptake by the crop and water use efficiency". "In organic mulching, soilmoisture storage depends on the type of mulching materials and thickness of mulching., Plastic mulch conserves soil moisture is greater than organic mulches. Plastic mulch treatment stored the highest amount of soil moisture compared to the organic mulch treatments, which stored greater moisture than the bare soil" (Ogundare *et al.,* 2015). In the experiments of Ashrafuzzaman *et al.* (2011), "transparent plastic mulch provided the highest soil moisture (21.1%), followed by black plastic mulch (20.4%) and blue plastic mulch (19.2%), and the control (bare soil) (14.6%) provided the lowest soil moisture at 0–10 cm soil profile at 90 days after sowing" and Thakur *et al.* (2011**)** also reported significantly higher soil moisture content at 70 days after sowing in *Glyricidia* leaves mulch treatment and it was statistically at par with the green weed biomass mulching compared to no mulch treatment. In an experiment, Godawatte and Silva (2014) reported that ambient and stress-full temperatures (34 ^{0}C) did not affect the soil moisture content but this temperature with mulching treatments significantly affected the soil moisture content. In ambient temperature the highest moisture percentage was observed from saw dust mulched treatments while coir dust was highest and followed by sawdust mulch in stressful temperatures (34°C) so in higher temperature conditions mulch helps to increase the soil moisture content.

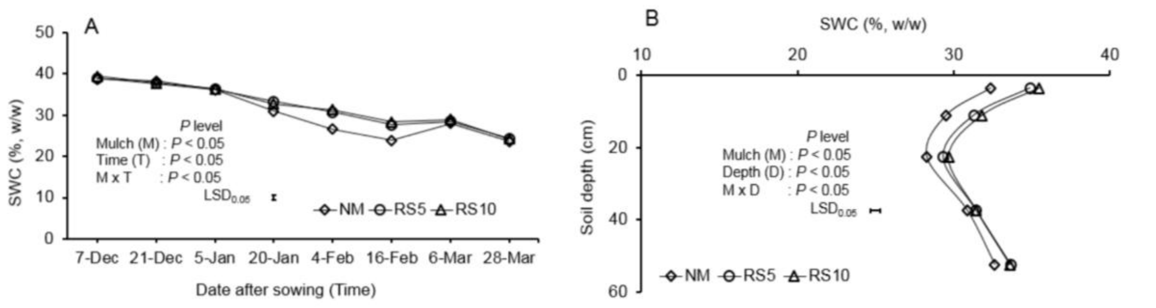

Figure 2. A) Effect of mulch and interaction between mulch and time on soil water content and B) interaction between mulch and soil depth.
NM = no-mulch, RS5 = Rice straw at ~5 t ha^{-1}, RS10 = Rice straw at ~10 t ha^{-1}
(Paul *et al.*, 2021)

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Kanwar *et al*. (2014) observed that 25 µ plastic mulch recorded higher water use efficiency, and grain and stover yields in pearl millet crop. Awal *et al.* (2016) showed increased soil water content and reduced weed dry matter due to black polythene mulch treatment. Plastic mulching under the ridge and furrow system stores higher content of water up to cm of soil depth (Liu *et al.*, 2018). Paul *et al.* (2021) reported soil water content is affected by the time of mulch application and mulching materials.

Effect on soil temperature:

"Mulching involves putting a barrier between the soil and atmosphere that decreases heat exchange between soil and environment and leads to steadily increasing soil temperatures. In general, the temperature regime of soil varies depending on mulching materials to reflect and transmit solar energy. Mulches raise soil temperature in winter and reduce it in summer. Mulches alter soil temperature, which affects the thermal regime of a soil" (Arora *et al*., 2011; Pramanik *et al.,* 2015). Plastic mulches increase topsoil temperature up to 3-6 ^{o}C in the top layer and some heat is transferred into deeper layers. This enlarged temperature increases the spring and autumn growing season by 10-20 days. It is reported that crop yields of maize with white, blue and black plastic film mulch, and rice straw had 149%, 109%, 78% and 25% grain yield increase in 2016, and 173%, 117%, 99% and 47% in 2017 over control, respectively (Haque *et al.,* 2018) in the same time plastic mulch treatments, soil covered with white plastic film mulch (semi-transparent) had the highest temperature, blue plastic mulch had the second, while soil covered with black plastic film mulch had the lowest temperature while, Gheshm and brown (2020) reported higher mean soil temperature (18.9 ^{o}C) under black polyethene than the mulched with white-on-black polyethene (17.7 ^{o}C) and bare ground plots (17.1 ^{o}C) and also found increased daily low temperature 1.4 ^{o}C under black polyethene than bare soil. A strong correlation was reported by Haque *et al*., 2018 between soil temperature and 1000-grain weight, the significant r value being 0.962 in 2016 and 0.923 in 2017 which otherwise indicates larger grain size in high-temperature producing treatments. In an experiment, Ramkrishna *et al.* (2006) observed that black plastic mulch treatment gave significantly higher soil temperatures in both Autumn and spring seasons in groundnut crops and also, and Deshmukh *et al.* (2013) reported higher soil temperatures under black plastic mulch than the straw mulch and without mulch treatment. Transparent plastic mulch increases the soil temperature and it preferred for soil solarization

In Organic mulching practices, soil temperature is reduced due to less heat conduction by retaining incoming solar radiation (Komariah *et al*., 2008). These mulches raise the minimum temperature but decrease the maximum temperature. In an experiment,

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Zhang *et al.* (2009) observed "a 4 ^{0}C reduction in soil temperature in the warmer period and a 2 ^{0}C increase in soil temperature in the colder period at 10 cm soil depth also, the timing of soil temperature measurements and mulching thickness cause variation in soil temperature".

Table 2: Effect of different mulches on soil temperature

Treatments	**Soil temperature (^{o}C)**	
	2016	2017
No mulch	32.0 b	31.0 bc
Rice straw mulch	30.0 c	29.5 c
Blue plastic mulch	33.7 ab	33.0 a
Black plastic mulch	32.2 ab	32.0 ab
White plastic mulch	34.0 a	33.0 a
CV (%)	3.24	3.23
Significance level (5%)	*	*
SE (±)	0.856	0.836

***** Significant at a 5% level of probability. (Haque *et al.*, 2018)

Effect on weeds

"Chemical control is one of the most widely used weed management methods in field crops and horticultural crop fields. Weeds, when not controlled in crop fields, could cause yield losses of up to 90.0 %" (Yadav *et al.*, 2018). However, long-term use of chemicals causes unsustainability in the control of weeds due to the induction of resistance and also causes environmental pollution (Chauhan *et al.*, 2014). They further emphasize the need to develop sustainable strategies in different crop cultivation systems. Mulching application with other agronomic practices of crop production like manipulation in spacing, spatial arrangement, land configuration, tillage, irrigation management and crop density, can be used for sustainable strategies for crop production (Ahmed *et al.*, 2014; Ranaivoson *et al.*, 2018). The application of mulching in field crops may also effective way for the manage weeds by inhibiting the light penetration to the soil surface and the possible chemical effects of the released substances (Abouziena & Haggag, 2016). In an experiment, Ghosh *et al.* (2006) observed that the lowest weed population of grassy weeds/m^2, broad leaves weeds/m^2 and weed dry matter/m^2 with the wheat straw mulch and polyethylene mulch than the chemical control in groundnut crop and Rajeshkarappa *et al.* (2013) revealed that In-situ green manuring with sun hemp increases the weed control efficiency and grain yield of *kharif* maize. Whereas, mulch application as brown manuring also decreased the weed density as

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compared to no mulch reported by Yadav *et al.* (2018). Verma *et al.* (2017) showed that the lower weed density and dry weight were under dust mulch treatment (Ram *et al.*, 2013). Whereas, plastic mulch treatment also increases the weed control efficiency and weed index (Patel *et al.*, 2021).

Effect on soil physical, chemical and biological properties

Soil physical property, soil aeration, soil structure, organic matter content, soil moisture- -temperature and soil microbiology characteristics are altered by the soil mulching practices. Soil-water environments are directly related to soil moisture and temperature and have significant impacts on soil physics and soil microbiology. Mulching changes the soil environment like soil moisture (Lal, 1974), soil temperature (Ramakrishna *et al.*, 2006), water use efficiency (Wang *et al.*, 2015), infiltration rate (Bakr *et al.* 2015), runoff control (Atreya *et al.*, 2008), and soil microbiology properties like soil microbial activity (Huang *et al.*, 2008), soil enzyme (Zhang *et al.*, 2015), earthworm population (Tian *et al.*, 1997), N mineralization (Cabrera *et al.*, 2005), soil biodiversity (Lin *et al.*, 2008), soil solarization (Komariah *et al.*, 2011) and soil properties like soil quality and productivity (Mulumba and Lal 2008), soil aggregates and density (Tindall *et al.*, 1991), soil erosion (Smets *et al.*, 2008), electrical conductivity, pH (Kitou and Yoshida, 1994), soil organic carbon (Luo *et al.*, 2015), soil texture (Arora *et al.*, 2011). A different experiment of mulching on soil property reported that mulch reduces the deterioration of soil quality by acting as a barrier against erosion and runoff losses that saves the soil properties also, a higher rate of mulch application improves aggregate stability, increases soil porosity, reduces soil bulk density and enhances organic matter content. In a research Sutaria *et al.* (2010) recorded the lowest bulk density and soil cracking under groundnut shell @5 t/ha and higher organic carbon, N and K availability in farm waste @ 5 t/ha whereas, P availability was higher under wheat straw @ 5t/ha. Sharma *et al.* (2010) observed that Sunnhemp+*Leucaena* leaves @10 t/ha recorded higher yield, N, OC and infiltration rate of soil. Similarly, FYM used as a mulch practice at the rate of 30 t ha^{-1} increases the organic carbon content and N, P and K availability compared to no mulch practice (Singh *et al.* 2011) and increases porosity, infiltration rate, soil water content and reduce the bulk density by the mulching practices reported by Abrol *et al.* (2015). Mathukiya *et al.* (2015) also reported lower bulk density due to wheat straw and groundnut shell mulching. Plastic mulch, on the other hand, under ridge-furrow systems, improves soil fertility by reducing the exhaustion risk of organic carbon and nitrogen in the soil (Liu et al., 2015). Zhao *et al.* (2009) showed that ridge-furrow planting under straw or plastic mulching

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increased soil-water infiltration, and prevented surface runoff and loss of topsoil from farmland.

Muhammed *et al.* (2015) recorded that higher bacterial count under paddy straw mulching @ 5 tha and Fungi population was higher in unweeded plots but it was at par with paper mulching and fresh weed mulching, whereas actinomycetes count was significantly higher in hand weeding treatment which was at par with coconut leaves and paper mulching treatment.

Effect on yield of different crops

This conserved moisture was essential for nutrient transporting, translocation of assimilate, cell division, and cell differentiation. So, plants that grow on mulch treatment had enough soil moisture to support the plant growth while plants that grow under no mulch suffered from moisture stress and became shorter and less yielder. Ghosh *et al.* (2006) showed that N application with wheat straw mulching treatment had a significant effect on pod yield of groundnut crop than the polyethene mulch and no mulch treatment. Under rainfed conditions, the ridge and furrow land configuration with crop residue mulching noted significantly higher total biomass, grain yield and total factor productivity in rainfed cowpeas (Ramesh and Devasenatathy, 2007). In the pigeonpea + mungbean intercropping system, the application of anti-transparent with soil mulch and FYM combination recorded higher plant height, dry matter accumulation, No. of pods/plant, No. of grains/pod, grain yield, stalk yield and PEY reported by Kumar and Rana (2007). Mahitha *et al*. (2014) reported mulching made from gunny bags and paddy straw mulch increased rainfall use efficiency and grain yield of maize. Application of wheat straw mulch noted significantly higher branches/plant, pods/plant, grains/pod, grain weight/plant, test weight and grain and stalk yields of pigeon pea (Mathukia *et al*., 2015). Mulching application with a higher and recommended dose of fertilizer showed increased growth and yield of crops than the higher dose of fertilizer without mulching (Pal *et al.*, 2015). Mulching acts as conservation technology particularly in dry and rainfed areas. It enhances rainfall use efficiency and yield of crops with the use of anti-transparent (Sanbagavalli *et al.*, 2017). The application of mulch affects the absorption of solar radiation and decreases the thermal admittance of the surface relative to that of bare soil. Its levels consistently increase significantly grain yield, straw yield and harvest index of summer moth-bean (Singh *et al.*, 2019).

In plastic mulching 25 μ plastic mulch recorded higher plant height, ear head length and diameter, No. of tillers/plant, grain and stover yields in pearl millet noted by Kanwar *et al*. (2014). Dey *et al.* (2020) observed that the highest seed yield was recorded from In-situ

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maize stalk mulch + Paddy straw in chickpea, lentil and lathyrus. Singh *et al.* (2021) showed mulching not only conserves the soil by preventing evaporation but also control weed, moderates soil temperature, reduce runoff and increase infiltration in a barley crop.

Conclusion

It is summarized that different organic mulch like rice & wheat straw, castor & groundnut shell, leaf (fresh/dry) and inorganic mulch like plastic sheet increases soil moisture, and soil temperature, improve soil physical, chemical and biological property and reduce weeds, so proper growth of crops improve the yields and it is very effective for sustainable agriculture production.

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