

Potential Organic Mulches For Sustainable Agricultural Production And Improving Soil Environment

Md. Abul Khaiyer Mollah^{1,2}, Md. Kamal Uddin^{2*}, Susilawati Kasim², Syaharudin Zaibon², Md. Mostafizur Rahman³, M. A. S Jiku⁴, Md. Jahangir Alam⁵ and Md. Ariful Islam Khalid⁶

¹Training Department, Bangladesh Jute Research Institute, Dhaka-1207, Bangladesh.

e-mail: gs70892@student.upm.edu.my

²Department of Land Management, Faculty of Agriculture, Universiti Putra Malaysia, Selangor, Serdang-43400, Malaysia. e-mail: mkuddin@upm.edu.my

²Department of Land Management, Faculty of Agriculture, Universiti Putra Malaysia, Selangor, Serdang-43400, Malaysia. e-mail: susilawati@upm.edu.my

²Department of Land Management, Faculty of Agriculture, Universiti Putra Malaysia, Selangor, Serdang-43400, Malaysia. e-mail: syaharudin@upm.edu.my

³ Pulp and Paper Research Division, Bangladesh Council of Scientific and Industrial Research, Dhaka-1205, Bangladesh. e-mail: mmrbcsir@yahoo.com

⁴ Agronomy Division, Bangladesh Jute Research Institute, Dhaka-1207, jiculy@gmail.com

⁵ Soil Science Department, Bangladesh Agricultural Res. Inst. jahangirssd2013@gmail.com

⁶ Agronomy Division, Bangladesh Rice Research Institute, Gazipur-1701.

email: khalidbau95@gmail.com

*Corresponding Author: Md. Kamal Uddin, e-mail: mkuddin@upm.edu.my

Abstract

Climate change has led to a gradual increase in global temperatures over time. As a result, it has disrupted the global equilibrium of agro-environmental systems, impacting agricultural productivity. Thus, new eco-friendly farming methods are required to produce sustainably. This study summarizes research papers on the effects of various mulching materials and techniques on soil and environmental factors that affect crop production. Organic mulching techniques could decrease weed growth, reduce soil evaporation, maintain temperature, boost soil microorganisms, and increase water-holding capacity. Mulches also benefit agriculture and landscaping in terms of cost, appearance, and environmental impact, as well as improve soil aesthetics through crop production. This study reviewed the effects of different mulching materials and techniques on soil and environmental issues, with a particular focus on suppressed weed control, increased water-holding capacity, and controlled soil temperature, which affect crop production. Mulches improve soil moisture, nutrients, reduce soil erosion in crops, and mitigate the lingering influence of heavy metals, fertilizers, and pesticides. In agriculture, excessive plastic film residues in soil lead to contamination and vegetation destruction. An environmentally friendly organic mulch provides by substitute for traditional polyethylene mulch. However, the choice of potential mulching materials is influenced by crop management, techniques, and climatic conditions. The effect of inexpensive, environmentally friendly, mulching materials on crop productivity, soil fertility, soil microbes, and microclimate alteration requires further study.

Keywords: organic mulch, soil micro-organisms, soil evaporation, soil temperature, water holding capacity, weed suppression.

1. INTRODUCTION

Mulching involves applying a layer of material on top of the soil surface, making it a crucial soil management technique (Prosdocimi et al., 2016; Blanco et al., 2024). Mulches have been applied for commercial vegetable production for thousands of years. It improves soil moisture retention, efficiently suppresses weeds, and regulates soil temperature (Bodner et al., 2015). Mulches have been applied for commercial vegetable production for thousands of years. Eco-friendly environment and with increased agricultural productivity, mulching often entails applying a layer of material (plastics, organic, and inorganic materials) to the soil surface surrounding the intended crop. By limiting light or establishing environmental circumstances that can either prevent germination or decrease weed growth soon after germination, mulching serves the primary objective of suppressing weeds in crop fields (Kundu et al., 2018). However, mulching also has other advantages, such as reducing nutrient leaching, regulating temperature at the root zone and aboveground growing environment, reducing soil compaction, improving soil organic matter or nutrient content, and reducing insect and disease pressures (Coolong, 2012). By inhibiting weed growth, regulating soil

temperature, increasing soil porosity, preserving soil moisture, decreasing soil erosion, enhancing soil structure, and boosting the soil's organic matter content, mulching is a useful technique for enhancing crop growing conditions and yield (Sarkar and Singh, 2007; Glab and Kuling, 2008). Inorganic mulches include things like plastic or polyethene film, sand, gravel, pebbles, etc., while organic mulches are typically made of materials like wheat straw, rice straw or husk, grass, weeds, leaves, leaf mould, animal manures, compost, sawdust, and wood chips (Khurshid et al., 2006; Quilty and Cattle, 2011). The best methods for altering the soil environment, controlling weeds, and boosting crop output are jute geotextiles or agro-textile mulches (Manna et al., 2018). Agriculture is a profession that relies on natural resources to advance, and among these resources, water is one of the key limiting variables that significantly affects agricultural productivity. To address the issue of water use in crop production, farmers have implemented some strategies in recent years. One such method is mulching, which is used to enhance the physical properties of the soil, promote plant growth, boost productivity, and conserve water (Nithisha et al., 2022). Mulching is a water-saving practice that enhances water penetration into the soil, delays soil erosion, and decreases surface runoff. Mulch is a layer of material or materials that covers the soil surface (Islam et al., 2024). Mulch also modifies the soil microclimate, encourages the emergence of seedlings and the growth of roots, and inhibits the growth of weeds without the use of herbicides (Asif et al., 2020).

Organic mulches, as opposed to synthetic ones, increase soil organic matter, boost microbial activity, control soil temperature, inhibit weed growth, and hold onto soil moisture. Additionally, by recycling agricultural waste, they support a circular economy. This study summarized the possibility of organic mulching as a means of attaining environmental advantages like soil erosion prevention, water conservation, and a decreased dependency on agrochemicals, in addition to its potential as a tool for increasing sustainable agricultural output. Future research should explore innovative mulching strategies in combination with diverse crop management practices across different soil types and climatic conditions.

2. Geographic Distribution of Global Mulch

With an emphasis on the top ten contributing nations, the heatmap shown in Figure 1.0 illustrates the geographic distribution of the top 15 terms found in the examined research literature. The intensity of blue shading in each cell indicates the frequency with which a specific keyword appears in publications from a particular nation (Kamboj et al., 2024). Notably, India has the highest frequency of keywords such as mulching, soil temperature, and yield (Ravichandran et al., 2022; Manna et al., 2017). Research activity across several keywords, especially "mulching," "growth," and "yield," indicates that their bioremediation research places a high priority on these elements.

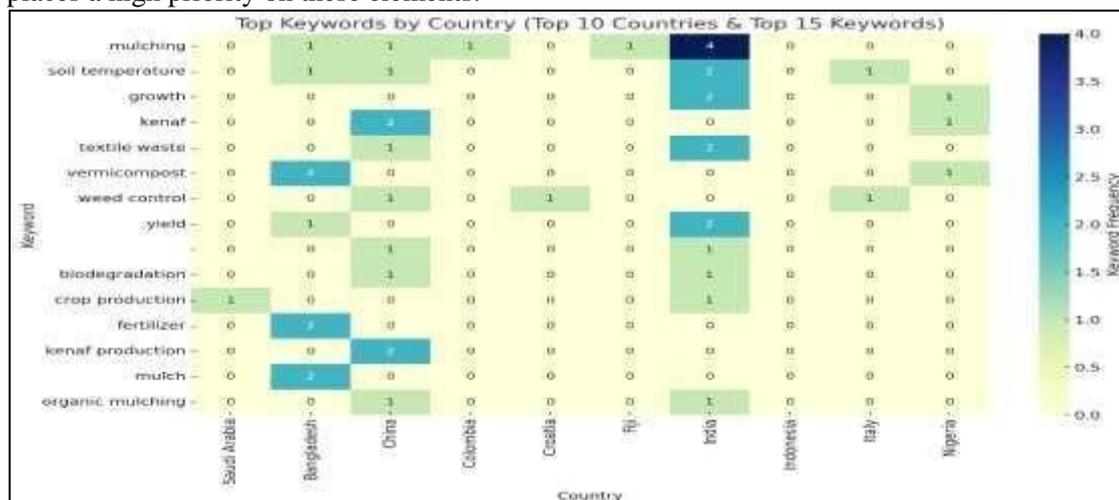


Figure 1.

China and Bangladesh have different priorities regarding vermicompost, kenaf, and fertilizer (Cao et al., 2024; Al-Amin, 2017). "Vermicompost" and "fertilizer," in particular, are heavily emphasized in Bangladesh, suggesting a regional interest in these particular bioremediation techniques (Al-Amin et al., 2017). The study environment in China seems to be varied, with prominent instances of "textile waste," "kenaf," and "kenaf production." This geographic grouping of keywords highlights potential geographical specializations and

research priorities in bioremediation. A global perspective on the area requires an understanding of these trends, which enables focused knowledge exchange and the identification of potential partnerships to address specific environmental issues in diverse geographical contexts. Although they occur less frequently, organic mulching, biodegradation, and weed control are seen in a variety of locations (El-Beltagi et al., 2022). The different keyword distributions within nations might reflect variations in industrial operations, agricultural methods, and locally significant pollution sources, all of which have an impact on the course of bioremediation research.

3. MATERIALS AND METHODS FOR MULCHING

Mulching materials can be divided into three primary categories: inorganic (polyethylene), organic (animal and agricultural waste), and special (Table 1) (Kader et al., 2017). Biodegradable materials, such as agricultural residues (straw, stalks), jute and related fibers, textile residues, wood industry residues (sawdust), processing residues (rice husks), and animal waste (manure), are sources of organic mulching ingredients.

Table 1: Various Types of Mulching Materials

Organic materials	Inorganic materials	Special type of materials
Legume mulch (sunhemp, leucaena twig, gliricidia, acacia) Straw (barja, rice, wheat, maize) Dry clips (grass, weeds, wood, bark), chopped leaves, cassava Husks (rice, coconut, maize, stalk) Tree leaves (akashmoni, minjiri, eucalyptus, sada koroi) Paper (newspaper, kraft paper) Agriculture/ animal wastes (cow dung, manure, jute, kenaf) Cover crops (weed, fodder)	Bio-colored silver Polythene (blue, black, white) Biennial color plastic film Weed mat mulch Silver plastic film Transparent plastic film Plastic film with holes Biodegradable and photodegradable plastic mulch Sprayable polymer film	Stone gravels Gravel (sand-grave) Concrete Tephra mulch

Other kinds of organic and inorganic mulching materials are also available. Adhikari et al. (2016) identified several novel biodegradable and photodegradable plastic film types as environmentally friendly materials and suggested sprayable and biodegradable polymer films for convenience and adaptability. Certain readily available special materials, like sand and concrete, have also been used for mulching, but very infrequently because of their inherent drawbacks. For instance, sand mulching depletes soil nutrients (Gan et al., 2008), and concrete mulching is highly costly to build. In agricultural fields, different mulching materials are applied using various techniques (Figure 2).

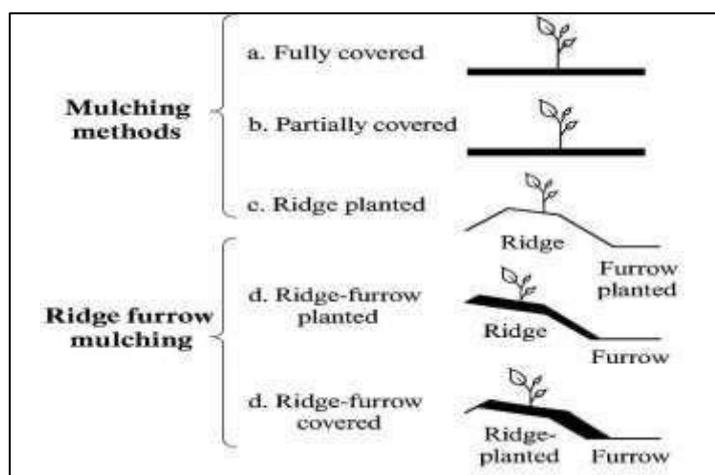


Figure 2. Various mulching techniques are shown schematically (the line denotes cover by mulch materials) (Kumar and Usadadiya, 2023; Kader et al., 2017).

In agricultural fields, different mulching materials are applied using various techniques (Figure 2). A classic technique for applying mulch is "flat mulching," which involves covering the soil's surface with organic, inorganic, or mixed mulching materials (Figure 2a & b) (Ghosh et al., 2006; Sun et al., 2012). Depending on its intended use, flat mulching can maintain different thicknesses for organic mulching materials. A modified flat mulching technique known as "PE mulching with holes" (Figure 2b) only partially covers the soil surface. Compared to conventional flat mulching, these mulches improve soil aeration and rainwater infiltration (Kader, 2016). In China's Loess Plateau, "edge shape mulching" has been widely employed to collect rainfall (Kader et al., 2017).

By covering the ridge with plastic film, this kind of mulching reduces surface runoff and directs rainfall into furrows, which in turn improves water use efficiency (Gan et al., 2013). Although crops like maize are typically grown on the ridge portion that is covered with mulching materials, crops are occasionally also planted in the furrow portion, either with or without mulching (Figure 2d&c). In "ridge-furrow mulching," crops are planted on the ridge, in the furrow, or on both (Figure 2d) (Zhao et al., 2014). This is accomplished by completely covering both ridges and furrows with plastic film or by combining organic mulches with plastic layers (Yin et al., 2016). The semi-arid ridge-furrow mulching system was briefly described by Gan et al. (2013) as a way to improve soil productivity, increase crop water availability, and provide environmental advantages. To intercrop wheat and maize production in northwest China, Yin et al. (2016) described a double mulching system made of plastic film and straw mulch (Figure 2d). Recently, several researchers have documented the impact of different mulching patterns on water conservation through rainwater gathering for corn, wheat, and mixed agricultural practices (Ren et al., 2016).

3.1. Mulching Materials Applied to Different Crops

Mulching techniques in agriculture offer many benefits. By preserving water, they lessen the need for irrigation while shielding the soil from deterioration caused by physical, chemical, and biological factors. The use of mulching materials on different target crops was investigated by numerous researchers (Table 2). To improve soil microbial activity and crop productivity, the widely used organic mulching materials were applied as flat-type mulching (Figure 2a) (Kasirajan and Ngouajio, 2012). This increased soil moisture availability by lowering soil evaporation and preserving soil temperature. For its many advantages, including raising soil temperature, several inorganic mulching materials (Table 2) were applied using diverse techniques, such as a flat, ridge, or ridge furrow (Fig.2). They experimented with varied plastic colors and thicknesses. Plastic mulches were reported to improve soil moisture retention (Ghosh et al., 2006) and speed crop growth with higher yields (Kader et al., 2017) in several experiments (Table 2). Under diverse crop circumstances and climatic zones, combined applications of organic and inorganic materials as mulching treatments were also used (Table 2). Mulches thereby enhanced the soil conditions for the best crop development and yield. According to Kader et al. (2017), future research must thus investigate novel mulching applications in diverse soil and climate situations under a range of crop management techniques

Table 2: Studies on varied mulching elements conducted under different crops.

Mulching			Crop	Reference
Types	Materials	Position ^a		
Inorganic	Black polythene, weed mat Plastic film	1,3, 1	Yam, maize, lettuce	Kumar et al. (2024), Xiukang et al. (2015), Almeida et al. (2015) Kopitar et al. (2024)
	Biodegradable nonwoven mulch	1	Open field	
	Polythene mulch, Plastic film	4	Corn, vegetables cauli flower	Ren et al. (2016), Filifovic et al. (2016), Bhoutekar et al. (2017)
	Plastic film	4	Potato, cotton	Zhao et al. (2014), Dong et al. (2009)
	Black, silver, clear plastic	1	peanut	Sun et al. (2015)
	Narrow and wide plastic	1	Broccoli, wheat	Zhang et al. (2015)
	Plastic and biodegradable	1	Tomato, cabbage	Moreno and Moreno (2008)

Continuing table 2: Studies on varied mulching elements conducted under different crops.

Mulching			Crop	Reference
Types	Materials	Position ^a		
organic	Bajra straw, maize straw, grasses, straw and legume mulch	1,2	Lemon, Tomato	Kumar et al. (2015), Aruna Olasekan, A.(2018)
	Juncao grass, cowpea live, sawdust	1	Yam	Kumar et al. (2024)
	Straw (sugarcane, paddy), leaf	1	Carrot	Jaysawal et al. (2018)
	Straw, maize, straw burned	1,1	Maize, sugarcane	Cai et al. (2015), Hoshino et al. (2017)
	Straw, straw (paddy, wheat), sawdust, cut grass	1,1	Soybean, strawberry	Siczek et al. (2015), Bakshi et al. (2014)
	Straw mulch	2	Maize, wheat	Qin et al. (2015)
	Rice straw, compost	1	Wheat	Balwinder-Sing et al (2011), Agassi et al. (2004)
	Trash grass, sawdust	1	onion	Mutetwa and Mtaita (2014)
	Straw (soybean, wheat), straw	1,1	Maize, wheat	Cook et al. (2006), Ahmad et al. (2015)
	Paper	1	Squash	Coolong (2012)
	Rice straw, water hyacinth, straw	1,1	Onion, potato	Larentzaki et al. (2008), Doring et al. (2005)
	Jute agrotextile	1	broccoli	Manna et al. (2018)
	Textile waste, agricultural waste	1,1	Chilli, horticulture	Kamboj et al. (2022), Yang et al. (2020)
	Cotton waste	1	-	Cao et al. (2024)
Special	Stone gravel	2	-	Iqbal et al. (2020)
	Tephra	1		Diaz et al. (2005)
	concrete	1	jujube	Lei et al. (2004)
Mixed	Plastic, straw, concrete	1	jujube	Sun et al. (2012)
	Plastic, straw, grass	1	peace	Wang et al. (2015)
	Plastic, straw, gravel	4	maize	Liu et al. (2015)
	Straw, black plastic	1	groundnut	Ghose et al. (2006)
	Rice straw, clear plastic	1	groundnut	Ramakrishna et al. (2006)
	Straw, plastic,geo-textile	1	Chilli	Ashrafuzzaman et al. (2011), Zribi et al. (2015)

^a 1: Flat mulch, 2: Flat mulch with hole, 3: Ridge pattern, 4: Ridge–furrow pattern

Organic Mulch

Natural materials that can break down naturally are known as organic mulches. Examples of these materials include agricultural wastes used as mulch, such as rice hulls, paper waste, sawdust, jute and related fibers, bark chips, grass clippings, plant leaves, sugarcane bagasse, rice, wheat or paddy straw, and textile waste. It increases the soil's ability to store water as it decomposes over time (Ranjan et al., 2017). Additionally, when it decomposes, it releases nutrients into the soil, and it indirectly increases water use efficiency. Below is a description of some of the most popular organic mulching materials:

3.2. Straw Mulch

Straw is perfect for mulching since it is simple to apply in the field, remains in place, and reflects sunlight, which helps some vegetables produce fruit. It is applied as a summer mulch in vegetable fields and as winter protection. These mulches offer excellent weed control, water penetration, and insulation (Schonbeck, M.,

2015). The primary positive attribute is that it is free of weed seeds. Straw mulches are not recommended for use in high-traffic areas due to their high flammability. About 6 to 8 inches of straw mulch is present.



Figure 2. Straw mulch (Schonbeck, M., 2015).

3.3. Jute Geotextiles or Agrotexiles Mulch

Mulch mats are thin sheets that are laid on the ground as protective coverings to suppress weed development and water evaporation, control soil temperature, increase crop growth, and stop soil erosion. Additionally, it facilitates the water's downward travel. Temperature variations in the root zone have an impact on the uptake and transfer of vital nutrients, which in turn affect the growth of the roots and shoots (Kamboj et al., 2022). Jute agro-textile is a type of natural technical textile that is manufactured from 100% natural, environmentally friendly jute and related fibers. It can be woven or left unwoven and is applied to soil to increase agricultural productivity by enhancing the agronomic qualities of the soil and inhibiting the growth of undesired vegetation.



Figure 3. Open weave and non-woven jute agro-textile mulch (Kamboj et al., 2022)

3.4. Dry Leaves Mulch

Dry leaves are readily available, and when composted, they produce a superior mulch. When utilized as mulch, leaves help the soil by adding nutrients. In places with lots of trees and natural forests, it is commonly used. Dry leaves are useful as mulch over the winter, but they are not readily accessible in the spring. Small branches and wood barks are placed on top of the dry leaf mulch to prevent the dry leaves from blowing away (Gary et al., 2016). The dry leaf mulching is roughly three to four inches thick.



Figure 4. Dry leaves mulch (Gary et al., 2016).

3.5. Grass Clipping Mulch

In Indian agriculture, grass clipping is one of the most readily available and plentiful mulching materials. The soil's nitrogen percentage is raised when fresh grass clippings are utilized in the field because they break down quickly. Green, fresh, and dried grass clippings are among the many varieties that are widely accessible. Green grass clippings are typically not used during the rainy season because they could potentially form root systems and hinder crop growth (Ranjan et al., 2017; Gary et al., 2016)



Figure 5. Grass clipping mulch (Ranjan et al., 2017; Gary et al., 2016).

3.6. Sawdust mulch

A popular kind of mulch in places where it is readily available is sawdust. The nutrient content of this material, which is found during wood finishing procedures, is half that of straw. The high C: N ratio causes the breakdown to occur relatively late. Its decomposition will result in a nitrogen shortage in the soil, necessitating frequent fertilizer applications. It should not be used in acidic soils due to its acidic nature. It does, however, hold moisture for extended periods (Ellen, B. 2011).



Figure 6. Sawdust mulch (Ellen, B., 2011).

3.7. Compost Mulch

Compost is an excellent mulch and soil conditioner that enhances soil health and is simple to make at home by composting various municipal solid waste products, such as leaves, straw, grass, and plant residues. Practice in Indian agriculture involves the availability and use of compost. It improves the physico-chemical and biological qualities of the soil, as its carbon content increases the soil's ability to retain water. Due to their high nitrogen content and potential for weed seed contamination, they should not be used in vegetable fields (Ranjan et al., 2017).



Figure 7. Compost mulch (Ranjan et al., 2017).

3.8. Paper Mulch:

Newspaper mulching is easily accessible and aids with weed control. In a short period, the newspaper layer

biodegrades into the soil. Since the newspaper will eventually break down, it is preferable to use plastic. In fields where weeds have already grown and dropped seeds will sprout the following season, newspaper mulch can save a significant amount of time and labor (Ranjon et al., 2017; Cordell, 2011).



Figure 8. Paper mulch (Ranjon et al., 2017; Cordell,

4. Frequent Use of Mulching Across the World

The frequency of the top 30 most stated keywords in a collection of scientific papers or articles. The frequency of each keyword is indicative of its significance in the literature or research in the relevant topic. Here's a more detailed explanation of the chart, specifically focusing on the phrase "mulching":

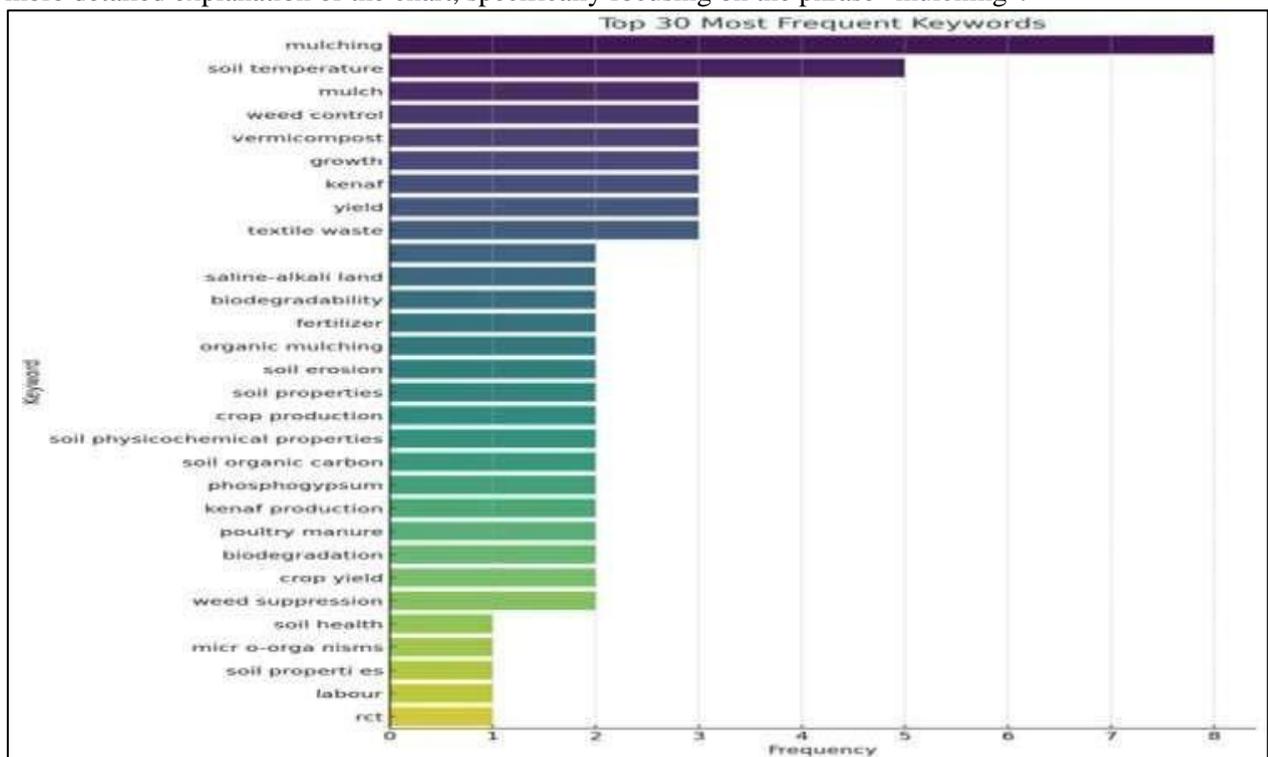


Figure 9. Frequently uses mulching

The Bar chart data demonstrates that "mulching" is the most frequent keyword, making it the most actively discussed topic in the reviewed papers. This shows that mulching is a key subject of focus in the literature. It presumably represents studies focusing on its multiple benefits, such as boosting soil moisture retention, regulating soil temperature, reducing soil evaporation, suppressing weeds, and enhancing soil fertility (Demo and Asefa Bogale, 2024; Ravichandran et al., 2022). The substantial attention on mulching may reflect its importance in sustainable agricultural methods, particularly in locations that have challenges with soil erosion, water retention, and crop productivity. Since mulching is known to affect soil temperature, the terms "soil temperature" and "mulching" are closely related (Yordanova, M., & Gerasimova, 2025). Some other keywords, like weed control or according to weed management, mulching is frequently brought up concerning weed management. One advantage of mulching is that it inhibits the growth of weeds by obstructing sunlight and stopping the germination of weed seeds (Alptekin and Gürbüz, R. 2022). Vermicompost demonstrates how organic farming methods, which use vermicompost as a soil amendment or as a component of mulching material, are frequently linked to mulching studies. The keywords "growth,"

"yield," and "fertilizer" show that mulching research is directly related to the effects on crop output and plant growth. Mulching is frequently studied as a way to increase soil fertility and promote plant growth. The results of the chart indicate that mulching is an important component of larger research on soil health, agricultural productivity, and sustainability, in addition to being a method for enhancing soil conditions.

5. Influence of Organic Mulching on Soil Physico-Chemical Characteristics

5.1. Water Holding Capacity

Mulching is a water-saving method for controlling temperature, preserving soil moisture, and lowering soil evaporation in arid regions (Yang et al., 2015; Kader et al., 2017a). Rain-fed farming systems frequently use surface mulching as a water-saving strategy (Zribi et al., 2015). According to Qin et al. (2018), 70% of the world's water use is attributed to agriculture. These include rain-fed crops, which comprise 80% of the world's agriculture and provide 60–70% of its food (Chen et al. 2018). According to Li et al. (2018) and Kader et al. (2019), the soil water and heat transfer mechanism beneath the mulching is crucial for increasing the system's availability for effective mulching use. Because of the interplay between the soil environment, microclimate, and plant growth, it is currently unclear how much water mulching saves (Steinmetz et al., 2016).

5.2. Soil Temperature

By creating a barrier between the soil and the atmosphere, mulching reduces heat transfer between the soil and the environment and raises soil temperatures gradually. In general, mulching materials' ability to reflect and transmit solar radiation causes variations in the soil's temperature regime. In the winter, mulches increase the temperature of the soil; in the summer, they lower it. According to Pramanik et al. (2015), mulches change the temperature of the soil, which impacts the soil's thermal regime. Rice straw and white, blue, and black plastic film mulch have been shown to improve grain yields in maize by 149%, 109%, 78%, and 25% in 2016, and by 173%, 117%, 99%, and 47% in 2017 compared to the control (Haque et al., 2018; Kumar & Usadadiya, 2023). The significant R-squared values of 0.962 in 2016 and 0.923 in 2017 reveal a strong link between soil temperature and 1000-grain weight, as reported by Haque et al. (2018). This suggests that higher temperatures produce larger grain sizes.

5.3. Weeds Suppression

In horticultural and field crops, chemical control is one of the most used weed management techniques. If left unchecked, weeds in agricultural fields can reduce yields by as much as 90.0% (Yadav et al., 2018).³⁾ However, because pesticides induce resistance, long-term use of weed control is unsustainable and pollutes the environment. Manna et al. (2018) emphasized that in comparison to other mulches for broccoli, nonwoven jute agro textile mulches decreased the weed population in dry lateritic soil. By preventing light from penetrating the soil surface and the potential chemical impacts of the released compounds, mulching field crops may also be an efficient method of managing weeds (Abouziena and Haggag, 2016). In contrast, Yadav et al. (2018) found that applying mulch in the form of brown manuring reduced the density of weeds when compared to none at all.



Figure 10. Weed growth application of different mulch

5.4. Soil Erosion checked by using Mulching

The primary cause of soil loss is soil erosion brought on by heavy rainfall, deforestation, unstable soil geomorphology, undulating topography, and poor land use practices. To ensure sustainable soil productivity, soil loss should be prevented or halted by employing environmentally friendly products (Kundu et al., 2018). When Datta et al. (2005) investigated the effectiveness of 300 gsm jute agrotextile in reducing soil loss on groundnut in the hilly region of Tripura, they discovered that soil loss in sloppy land (10–15%) varied between 29.9 t. ha⁻¹ (control) and 34.2 t. ha⁻¹ (300 gsm agrotextile). This suggests using woven

300 gsm jute agro textiles reduces soil loss by 12.5%.

5.5. Soil Microorganisms Through Mulching

The diversity of soil microbes in an agroecosystem is crucial for the cycling of nutrients and for providing structural stability to the soil (Bach et al., 2018). The physico-chemical characteristics of soil are significantly impacted by mulching, especially when using organic mulching techniques. Soil microbial populations often dictate how sustainable soil ecosystems are (Manna et al., 2017). Rich in carbon, organic mulches meet the dietary needs of microorganisms and promote their growth, which leads to the quick growth and decomposition of organic matter. This release vital plant nutrients in forms that are accessible through mineralization, improving the quality of the soil. However, the combined effects of mulching's thermoregulating properties and moisture conservation also contribute to creating a favorable environment for microbial growth in the soil (Song et al., 2018).

5.6. Impact of Organic Mulches on Greenhouse Gas Emissions

The practicality of using organic mulching to reduce greenhouse gas (GHG) emissions in agricultural systems is becoming more widely acknowledged. Organic mulches can inhibit microbial activity that produces carbon dioxide (CO₂) and nitrous oxide (N₂O) emissions. Additionally, they lessen fertilizer volatilization and soil disturbance, two major causes of greenhouse gas emissions. Additionally, as a carbon sink, the slow breakdown of organic mulches improves the soil's organic carbon storage. Straw mulching has been shown to improve soil carbon storage and dramatically reduce N₂O emissions, providing a twofold benefit for climate-smart agriculture, according to recent research by Akhtar et al. (2020). This data backs up the use of organic mulches as an inexpensive, environmentally friendly way to lessen the agriculture sector's impact on climate change.

5.7. Effect of Mulching on the Soil Environment

Farmland production is impacted by soil quality, which also controls the biological balance of agroecosystems (Kumar et al., 2024; Hartmann et al., 2023). Numerous indicators, such as physical characteristics (bulk density, texture, and water-holding capacity), chemical characteristics (pH, SOC, accessible N, P, and K), and biological factors (enzymatic activities, microbiological activity, and microbial biomass), can be used to evaluate the quality of soil. Applying various mulch materials has a big impact on soil attributes, which are important for improving the quality of the soil (Kumar et al., 2024; Lasmini et al., 2022). Given that nitrogen is one of the macro elements that plants require as the primary building block for protein for growth, it causes a rise in plant height, leaf count, and tiller count (Leghari et al., 2016). The element phosphorus helps maintain equilibrium in the accumulation of dry matter. Numerous vital enzymes, including those involved in protein synthesis, N and C metabolism, and photosynthesis, are activated by the nutrient potassium. Potassium is crucial for cell growth, which is a crucial process for plant function and development (Xu et al., 2020). It also plays a significant role in yield formation and quality enhancement. According to Yang, y. (2020), straw mulching greatly enhanced the number of soil enzymes and improved soil fertility.

6. Impact of Organic Mulching on the Crop Growth of Vegetation

Organic mulching improves crop growth, including early blooming, fruit set, and harvesting time. It also enhances the number of flowers and fruits in tomato crops compared to the control (Ranjon et al., 2017). A maximum quantity of fruits per plant is noted when using grass for mulching. Growth of plant, yield was higher in drip-irrigated crops with mulching than in non-mulched irrigation alone. According to Ranjon et al. (2017), the crop that was drip-irrigated and had straw mulch applied had the greatest plant height increase throughout every year. Sawdust, garbage, and no mulch treatment resulted in 43, 36, and 27 leaves per okra plant, respectively. The highest girdle diameter under sawdust and trash treatment was 37 mm, whereas it only reached 26 mm in the control plot. Fruit yields were nearly equal in the two mulched treatments (7.5 tons/ha for garbage mulch and 7.6 tons/ha for sawdust mulch), compared to 5.2 tons/ha in the control plot. According to Changli et al. (2024), the hemp mulch had the greatest kenaf plant height in the middle stage, while the rice straw mulch had the highest in the early stages. Rice straw produced the tallest plants in the early stages, whereas hemp mulch produced the tallest plants in the middle stages. That is the substantial effect of different mulches on yam development and yield indices, according to Kumar et al. (2024). The weed mat mulch treatment had the longest vine length per plant (m), which was noticeably longer than the vine length for the black polythene mulch treatment. In comparison to the black polythene treatment, the

organic compost mulch treatment showed the largest stem diameter (mm), which was noticeably larger.

7. Beneficial Effects of Organic Mulch

The properties of the soil are enhanced by organic mulches. It enhances the physical, chemical, and biological characteristics of the soil. These mulches help to maintain the soil's flexibility by increasing the amount of organic matter in the soil and decomposing gradually. The soil's organic carbon is additionally enhanced by the organic mulches. The more organic carbon in the soil, the more delicate it is. Better root development, penetration, and nutrient extraction from a deeper soil layer are all made possible by it. It increases the soil's ability to retain water, improves crop root growth, and increases water infiltration (Ranjan et al., 2017). The majority of the soil-beneficial microflora are drawn to organic mulches, which then act on the biodegradable wastes and facilitate the release of plant nutrients. Zribi et al. (2015) compared the efficacy of inorganic and organic mulching elements in maintaining soil evaporation and found that decreased evaporation caused by plastic mulching boosted water use efficiency by 20–60%.

7.1. Advantages of Agricultural Fields Using Mulch

Therefore, mulches offer several advantages when used in the agricultural sector, as:

(i) Decreased soil moisture loss, compaction, erosion, water droplets striking the soil surface, weed growth, and competition for nutrients and water from nearby fields. (ii) Earthworms are encouraged to enhance soil structure and nutrient cycling. (iii) Preventing root damage by keeping the underlying root zone colder in the summer and warmer in the winter. (iv) Preventing lawnmowers and weed whips from damaging trees. Lowering the pH of the soil improves crop roots' capacity to absorb nutrients. (v) Promoting plant growth and root development. (vi) Making recently planted trees look better. (viii) Improving soil nutrient availability over the long run. (ix) Because mulches are impervious to water, they assist in retaining moisture content over extended periods (Chopra and Koul, 2020).

8. Conclusion and opportunities for the future:

An essential component of good farming operations is organic mulch. Mulches have a minor impact on the pH of the soil, but they also assist in retaining water and moisture content, regulate weed growth, regulate soil temperature, and boost crop output. As a result, the farmer's choice of mulch has a significant impact on crop productivity; therefore, the kind of soil, local climate, and crop to be grown must all be considered. The application of organo-mineral mulch in soil management has a lot of potential. Because mulching enhances soil nutrient availability, raises pH levels, and promotes overall soil health, it can be a very effective way to reduce soil acidity. It is crucial to thoroughly evaluate the kind and characteristics of the organo-mineral mulches, select the appropriate feedstock, and employ the proper application rates and integration strategies to get the best results. The unique characteristics of the soil, such as its moisture content, mineralogy, and organic matter content, should also be considered while applying mulch. Overall, this analysis suggests that among other techniques, organo-mineral mulching may be a helpful strategy for managing soil acidity. It offers a sustainable approach that supports environmental sustainability and improves soil quality. Despite this, mulching is useful for enhancing the qualities of the soil, particularly for controlling temperature, water retention, weed development, and soil fertility. To further enhance the usefulness and effectiveness of mulching for various soil types, more research is necessary.

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