**A Comprehensive Review of Polyethylene and Biodegradable Plastic Mulch Films: Impacts on Soil health and Plant Growth**

**ABSTRACT:**

Mulching is an agricultural and horticultural practice that involves covering the soil surface with a protective layer of material to improve soil health, conserve moisture, regulate temperature, and suppress weeds. Mulches can be organic or inorganic, each offering distinct benefits. Polyethylene (PE) and biodegradable plastic mulch (BDM) films are widely used in agriculture to enhance plant growth, conserve soil moisture, and suppress weeds. PE films, known for their durability and effectiveness, improve crop yields but pose environmental concerns due to their non-biodegradability, leading to soil microplastic accumulation, reduced aeration, and potential chemical contamination. In contrast, BDM films decompose naturally through microbial activity, improving soil health by enhancing microbial diversity, reducing plastic pollution, and maintaining soil structure. Both mulch types contribute to better plant growth, but BDM films offer a sustainable alternative with minimal environmental impact. However, BDM faces challenges such as variable degradation rates and higher initial costs. A shift toward biodegradable alternatives can promote sustainable agriculture by mitigating soil degradation and plastic pollution while ensuring productive crop yields. Future research should focus on improving BDM formulations, assessing long-term impacts on soil health, and making these materials more cost-effective for widespread use.

**Keywords:** Mulching, Polyethylene, Biodegradable plastic mulch, soil health, plant health.

1. **INTRODUCTION:**

The Germanic word "mulch," derived from "molsh," means soft, though not all mulches are necessarily soft (Reichard 2011). It refers to the spongy layer commonly found in forest ecosystems (Prem *et al*, 2020). Mulch is generally defined as any material applied to or growing on the soil surface, playing a crucial role in preventing drought stress, protecting against freezing, improving soil’s chemical, physical, and biological properties, controlling diseases, and enhancing crop productivity (Demo *et al*, 2024, Saputra *et al*, 2025). Various types of mulch are used in farming systems, each with distinct characteristics (Chopra and Koul 2020). Common mulches include gravel, pebbles, polyethylene film, and organic materials such as straw, hyacinth, wood, bark, and leaves, which can be used individually or in mixtures (Amare and Desta 2021). Additionally, living mulches such as turfgrass, rye, and clover are also widely utilized. The development of polyethylene (PE) as a plastic film in 1938, followed by its introduction as a plastic mulch for vegetable crop production in the 1950s, significantly boosted commercial crop production (Kumar and Singh 2022). In 2018, global plastic production reached 360 million tonnes, with its distribution as follows: Asia 51%, Europe 17%, NAFTA (North American Free Trade Agreement) 18%, Africa 7%, CIS (Commonwealth of Independent States) 3%, and Latin America 4% (Chen *et al*, 2021, Getachew and Bizuayehu 2021). Polyethylene mulch is a synthetic plastic film commonly used in agricultural practices to cover soil surfaces (Somanathan *et al*, 2022). It is widely employed in horticulture, vegetable farming, and row cropping to improve soil conditions, regulate temperature, suppress weeds, and enhance crop yields (El-Beltagi *et al*, 2022). Polyethylene mulch comes in different colours, including black, white, transparent, and reflective (silver or red), each serving different purposes (Getachew and Bizuayehu 2021). However, its long-term effects on soil health have been a subject of study and debate. The benefits of mulching on the growth and yield of both annual and perennial crops have long been recognized by researchers (Dzvene *et al*, 2023). Mulching, whether using organic or inorganic materials, serves to cover the soil, creating a physical barrier that limits soil water evaporation, controls weed, maintains soil structure, and protects crops from contamination (Prem *et al*, 2020). Natural mulches, derived from animal and plant materials, offer many of the same benefits as other types of mulches when properly utilized. They contribute to maintaining soil organic matter and structure (Stratton and Rechcigl 2020). while also providing food and shelter for beneficial soil organisms such as earthworms. However, natural mulches have certain limitations, including inconsistent quality, limited availability, and the need for significant labour to apply them. They do not always effectively control weeds, as they may contain weed seeds, and they can slow soil warming in the spring, which may delay crop growth and ripening, particularly in warm-season vegetables. Straw mulches can introduce weed seeds into the soil and deplete nitrogen in the seedbed due to their high carbon-to-nitrogen (C/N) ratio (Chaudhary 2022). Organic materials with a high C/N ratio, such as grain straw, can temporarily immobilize soil nitrogen during decomposition (Yansheng et al, 2020). Additionally, natural mulches can harbour pests like termites, slugs, snails, and earwigs. While they have been reported to reduce soil temperature and evaporation, they do not always result in higher crop yields, making them less efficient for use in all seasons. To address these challenges, paper and plastic mulches have been developed as alternatives for agricultural use.

Paper mulches gained attention in the early 1920s but were not widely adopted for commercial vegetable production due to their short lifespan and the high cost of both materials and labour, which was not mechanized at the time (Conrad 2024). Over time, the focus shifted toward synthetic mulches, including paper formulations combined with polyethylene, foils, and waxes. Petroleum and resin-based mulches were also developed for arid climates (Bates 2019). Synthetic mulches, such as plastic and petroleum-based materials, offer greater benefits than natural mulches, with polyethylene-based mulches becoming the most widely used in modern agriculture. The use of plastic film as mulch has revolutionized traditional mulching practices (Mansoor *et al*, 2022).

Plastic mulch was first recognized for its ability to increase soil temperature in the 1950s (Mansoor et al, 2022). It alters the crop microclimate by modifying the soil’s energy balance, which in turn affects soil temperature, plant growth, and yield (Demo *et al*, 2024). The heating properties of plastic—such as reflectivity, absorptivity, and transmittance—interact with solar radiation to directly influence soil temperature (Jones *et al*, 2021). The use of clear plastic mulch in colder regions or seasons can significantly increase soil temperature, promoting germination and crop emergence (Tang *et al*, 2020). The optical properties of different plastic mulch colours affect the amount of light radiation reaching the soil, leading to variations in soil temperature (Xu *et al*, 2023). Among the various colours, black and clear plastic mulches have shown the highest soil warming potential (Amare and Desta 2021). Since plant growth relies on radiation for photosynthesis, the ability of plastic mulch to increase soil temperature enhances nutrient availability, root nutrient uptake, microbial activity, and overall plant development (Zhao *et al*, 2023). Studies have shown that plastic mulch environments receive higher net radiation compared to non-mulched conditions, affecting the surrounding microclimate (Jones 2019). Plastic mulch has also been found to increase air temperatures, with reports indicating that mulch-treated areas can reach temperatures up to 20°F (11°C) higher than bare soil (Naik *et al*, 2022). By stabilizing soil temperature fluctuations within the top 20–30 cm, plastic mulch promotes root growth and accelerates crop development, leading to earlier harvests (El-Beltagi *et al*, 2022). This is particularly beneficial for warm-season vegetable crops grown in regions with short and cool growing seasons. However, while increased root-zone temperature is generally an advantage, excessive soil heating caused by plastic mulches may have adverse effects on plant growth and yield, depending on the crop species, geographical region, or time of year (Zhao *et al*, 2023).

Beyond temperature regulation, plastic mulches influence the microclimate around plants by altering the radiation balance and reducing soil water loss (Lin *et al*, 2024). The plastic film acts as a barrier that prevents soil water evaporation and channels excess rainfall away from the root zone, maintaining a more stable moisture level (Abdelhak 2024). This reduces irrigation demands and helps prevent physiological disorders such as blossom end rot, which can result from water or nutrient imbalances. The extent of evaporation reduction depends on the type of mulch used (Ramos *et al*, 2024). By conserving soil moisture, plastic mulching enhances water-use efficiency, ensuring that water reserves remain available for plant uptake while also promoting a more consistent nutrient supply (Demo *et al*, 2024, Saputra *et al*, 2025)). Additionally, plastic mulching supports early yields and reduces nitrogen leaching, further enhancing crop productivity (Gao *et al*, 2019). It also serves as a protective barrier against environmental stressors, preventing soil erosion caused by wind and water, as well as damage from hailstorms (Debangshi *et al*, 2021). One of the most significant advantages of polyethylene mulch is its ability to retain nutrients within the root zone, allowing for more efficient nutrient absorption by crops (Iqbal *et al*, 2020). The combination of stable moisture levels, increased temperatures, and improved aeration creates favourable conditions for soil microbial activity, leading to higher microbial biomass and enhanced nitrification processes (Zhang *et al*, 2024). However, plastic mulching has also been reported to alter microbial community composition and influence microbial biomass carbon levels, which may vary depending on the crop and environmental conditions (Munoz *et al*, 2022).

The benefits of plastic mulch in crop production are well documented and include increased root growth, improved nutrient uptake, earlier ripening, and higher fruit yields (El-Beltagi *et al*, 2022). It has also been associated with improved fruit quality and a lower incidence of viral diseases compared to crops grown without mulch (Ngosong *et al*, 2019). Some researchers have debated whether the reflective properties of certain plastic mulches contribute to improved plant development, yields, and fruit ripening (Singh *et al*, 2020). Changes in light availability and spectral distribution can activate photosynthetic and photo morphogenetic mechanisms, potentially improving marketable fruit quality and overall yields (Kharshiing *et al*, 2022). While the advantages of plastic mulching are widely acknowledged, its effectiveness depends on factors such as crop type, climate, and soil conditions, requiring careful selection of mulch type and application strategies for optimal agricultural benefits (Jabran *et al*, 2019).

1. **EFFECT OF POLYETHYLENE MULCHES ON SOIL HEALTH AND PLANT HEALTH:**

Any treatment or technological application aimed at enhancing plant growth and development has a significant impact on the soil (Aparicio *et al*, 2022). These technological inputs influence the physical, chemical, and biological properties of the soil, which in turn affect crop production. One of the most critical soil properties is temperature, as it plays a key role in various soil processes (Certini and Scalenghe 2023). According to different studies, soil temperature directly affects nutrient uptake, water absorption, root growth, and the survival of soil microorganisms (Zhang *et al*, 2023). These factors are essential for maintaining soil health and ensuring optimal plant growth. Studies on polyethylene mulching indicate that black plastic mulch records higher soil temperatures compared to olive, silver, white, and blue mulches (Kirigiah *et al*, 2022). However, brown and blue plastic mulches have been found to generate even higher soil temperatures than black mulch in some cases (Jabran and Jabran 2019). This variation is attributed to differences in soil type and climatic conditions. Research confirms that black plastic mulch is particularly effective in increasing minimum, maximum, and mean soil temperatures compared to white/black and aluminium /black plastic mulching systems (Amare and Desta 2021, Kirigiah et al, 2022). Covering the land with black and white plastic mulch during crop production can significantly raise soil temperatures, sometimes reaching up to 60°C due to the trapping of solar radiation (El-Beltagi et al, 2022). This increase in temperature is particularly beneficial for weed suppression in weed-infested areas (Mondal *et* *al*, 2020). Other studies have also reported that black and brown plastic mulches generate higher temperatures than white mulch (Rao *et al*, 2023). However, when tested for their role in overwintering, black and white plastic mulches were found to be less effective in protecting shrubs from cold temperatures and, in fact, reduced their overwintering capacity (Shivran *et al*, 2023). Additionally, black and brown plastic mulches have been found effective in increasing root zone temperature (RZT), which is particularly beneficial in cold climates but unnecessary in warmer regions (Kirigiah 2023). It has also been observed that as plants develop a full canopy, the temperature in the root zone decreases. This phenomenon, recorded in tomato and radish plants, occurs because increased canopy cover shades the plastic mulch, limiting direct solar radiation and reducing heat transfer from the surrounding air and soil (Khan *et al*, 2020). Overall, the use of coloured plastic mulches has been shown to enhance soil temperature more effectively than bare land (Kader *et al*, 2020). Growers seeking to increase soil temperature can utilize coloured plastic mulches, but the choice of colour should depend on factors such as climate, soil type, crop type, and the intended purpose of mulching.

1. **POLYETHYLENE MULCH ON SOIL**

The distribution of microplastics originating from polyethylene mulching materials is influenced by various factors, including soil biota, soil properties such as cracking and aggregation, soil macropores (pores larger than 75 mm), and agricultural practices like ploughing, harrowing, and harvesting (Zhou *et al*, 2020, Qiang *et al*, 2023). Additionally, plant processes such as root growth and uprooting, along with the activities of larvae, earthworms, and vertebrates, contribute to the movement of these microplastics within the soil (Zubair *et al*, 2024). The fragmentation of polyethylene mulching materials results in the accumulation of microplastics, which can loosely integrate into soil aggregates (Ju *et al*, 2023). While polyethylene and polyacrylic acid-containing microplastics do not improve the soil’s water-holding capacity, polyester fibres have been found to enhance it significantly (Fei *et al*, 2024). These fibres also reduce bulk density and promote the formation of water-stable soil aggregates (Liang *et al*, 2021). Furthermore, research indicates that microplastics from polyethylene mulches alter the soil’s water retention and permeability, ultimately affecting water evaporation (Jannesarahmadi *et al*, 2023). The addition of microplastics to clay soils has been shown to increase both water evaporation and desiccation cracking (Wan *et al*, 2019). As soil water dynamics change, several physiological indicators of photosynthetic efficiency may also be affected, potentially impacting overall plant performance (Coelho *et al*, 2022).

* 1. **Impacts of Plastic particles on biochemistry of soils:**

Enzymes present in the soil play a crucial role in regulating various biochemical processes, serving as indicators of soil fertility and influencing the cycles of essential nutrients such as carbon, nitrogen, and phosphorus (Neemisha and Sharma 2022). The presence of microplastics in soil affects the expressivity and functions of key enzymes, including fluorescein diacetate hydrolase, urease, catalase, and phenol oxidase, potentially leading to short-term changes in soil quality (Chang *et al*, 2024). The accumulation of microplastics also alters the organic carbon pool in the soil, which may impact carbon storage and disrupt soil bulk density, a vital factor for soil fertility (Wang et al, 2022). Furthermore, after 14–30 days, a higher concentration of microplastics [28% (w/w)] was found to increase the amount of dissolved organic matter, thereby releasing essential nutrients such as organic carbon, nitrogen, and phosphorus (Gao *et* *al*, 2025). Enzyme inhibition or enhancement: Microplastics have been found to alter the activity of soil enzymes such as fluorescein diacetate hydrolase, urease, catalase, and phenol oxidase (Fan *et al*, 2024). Microplastics introduce new surfaces for microbial colonization, leading to shifts in soil microbial communities (Liu *et al*, 2022). This change in microbial composition can influence various biochemical processes, including the production and functionality of soil enzymes. As different microbial species interact with microplastic particles, some may proliferate while others decline, disrupting the natural balance of microbial activity (Jain *et al*, 2023). These alterations can affect nutrient cycling, organic matter decomposition, and overall soil health, potentially leading to long-term consequences for soil fertility and ecosystem stability. Plastics often contain various chemical additives, including plasticizers, stabilizers, and flame retardants, which can leach into the soil over time (Andrady and Rajapakse 2019). These contaminants may interfere with biochemical processes by altering microbial activity, enzyme functions, and nutrient cycling. Additionally, the release of toxic compounds from plastics can have harmful effects on soil biota, potentially reducing microbial diversity and affecting the health of plants and other organisms that rely on the soil ecosystem (Zhou *et al*, 2021). The accumulation of these chemicals in the soil can lead to long-term environmental consequences, making plastic pollution a significant concern for soil health and sustainability (Allouzi *et al*, 2021). Microbial Diversity: The presence of microplastics can lead to shifts in microbial diversity by favouring plastic-degrading bacteria while reducing the abundance of other essential soil microbes (Maclean *et al*, 2021). Pathogenic Microorganisms: Some studies suggest that plastic particles may act as carriers for pathogenic microbes, increasing the risk of soil-borne diseases (Trojan *et al*, 2024).



**Figure 1: Indicting the impact of polyethylene mulch on soil health and plant growth.**

1. **IMPACTS OF POLYETHYLENE MULCH ON PLANT GROWTH:**

Polyethylene (PE) mulch is widely used in agriculture to improve crop yields, conserve soil moisture, and regulate soil temperature (El-Beltagi *et al*, 2022). However, while it offers several agronomic benefits, its long-term impact on plant growth and soil health can be both beneficial and detrimental. The breakdown of polyethylene mulch into microplastics and its effects on soil properties, nutrient availability, microbial communities, and environmental sustainability are critical concerns in modern agriculture (Khalid *et al*, 2023). The polyethylene mulch has both positive and negative impacts on plant growth.

* 1. **Positive impacts of Polyethylene mulch on plant growth:**

Improved Soil Moisture Retention: PE mulch reduces evaporation by forming a physical barrier over the soil surface, ensuring adequate water availability for plant uptake (Somanathan *et al*, 2022). This is particularly beneficial in arid and semi-arid regions were water scarcity limits plant growth (El-Beltagi *et al*, 2022). Temperature Regulation: Mulch modifies soil temperature by absorbing and transmitting heat (Luo *et al*, 2025). Black polyethylene mulch increases soil warmth, promoting seed germination and root development in cooler climates, while reflective or white mulch prevents excessive heat buildup in warmer regions (Prem *et al*, 2020). Weed Suppression: By blocking sunlight, PE mulch minimizes weed growth, reducing competition for nutrients, water, and space, leading to improved crop yields (Mechergui *et al*, 2021). Enhanced Soil Nutrient Availability: The reduction in water loss helps retain essential nutrients in the root zone, preventing leaching and ensuring better nutrient uptake by plants (Yadav *et al*, 2023). Disease and Pest Management: Mulching reduces direct soil contact with plant foliage, lowering the risk of soil-borne diseases (Panth *et al*, 2020). Additionally, certain mulch colours can repel specific insect pests, decreasing the need for chemical pesticides (Ngosong *et al*, 2019).

* 1. **Negative impacts of Polyethylene mulch on plant growth.**

Microplastic Pollution: Over time, PE mulch degrades into microplastic particles due to environmental factors such as UV radiation, mechanical disturbance, and microbial activity (Qiang *et al*, 2023). These microplastics accumulate in the soil, potentially disrupting root development, altering soil structure, and affecting water infiltration and retention (Wang *et al*, 2022). Altered Soil Microbial Communities: The presence of PE mulch affects soil microbial activity and diversity (Li *et al*, 2022). While some microorganisms may thrive on mulch surfaces, others may decline due to changes in aeration, moisture, and nutrient distribution, leading to imbalances in microbial-mediated soil functions (Zhai *et al*, 2024). Soil Compaction and Reduced Aeration: Long-term use of polyethylene mulch can contribute to soil compaction, limiting root penetration and reducing oxygen availability in the root zone, which can negatively impact plant growth and overall soil health (Xing *et al*, 2025). Chemical Contamination: Additives used in polyethylene production, such as stabilizers and plasticizers, can leach into the soil over time (Bridson *et al*, 2021). These chemicals may interfere with nutrient uptake, microbial processes, and plant metabolism, potentially reducing crop quality and yield (Dewi *et al*, 2024). Disposal and Environmental Concerns: Polyethylene mulch is non-biodegradable, and improper disposal leads to environmental pollution. Residual plastic fragments left in the soil can persist for years, affecting subsequent plant growth and contributing to long-term soil degradation (Salama and Geyer 2023).

1. **Biodegradable plastic mulch:**

Biodegradable plastic mulch is an eco-friendly alternative to traditional polyethylene mulch, designed to break down naturally in the soil through microbial activity (Hayes *et al*, 2019). Made from renewable sources such as starch, polylactic acid (PLA), and polyhydroxyalkanoates (PHA), these mulches offer similar benefits to conventional plastic mulch, including moisture conservation, temperature regulation, and weed suppression (Rajgadia and Debnath 2023). Unlike polyethylene, biodegradable mulch decomposes over time, reducing plastic waste accumulation and minimizing soil pollution (Somanathan *et al*, 2022). However, its degradation rate depends on environmental conditions, soil microbial composition, and mulch material properties (Serrano-Ruiz *et al*, 2021). While biodegradable mulch can enhance soil health by reducing microplastic contamination, its impact on nutrient availability and microbial communities varies (Sintim *et al*, 2019). Some formulations may temporarily alter microbial activity or carbon-nitrogen balance during decomposition. Despite these challenges, biodegradable mulch films are a promising solution for sustainable agriculture, providing the benefits of plastic mulching while reducing long-term environmental harm (Serrano-Ruiz *et al*, 2021). A variety of biodegradable plastic mulches, composed of different polymers and additives, are now available in the market, with several demonstrating yield improvements comparable to low-density polyethylene (LDPE) mulches for various crops (Serrano-Ruiz *et al*, 2021). In Europe and the United States, biodegradable plastic mulch (BDM) is also being considered for reducing agrochemical use in organic farming (Shcherbatyuk *et al*, 2024). However, a significant challenge in the U.S. is the requirement for these mulches to be 100% biobased, a criterion that no commercial plastic film currently meets, thereby hindering their adoption in organic farming (Mansoor *et al*, 2022). Additionally, the higher cost of biodegradable mulches compared to LDPE further limits their widespread use (de Sadeleer and Woodhouse 2024). While the substitution of LDPE with biodegradable alternatives has been encouraged, concerns are emerging regarding their long-term environmental impact (Bandyopadhyay *et al*, 2023). Like LDPE, biodegradable mulches undergo fragmentation, and the accumulation of these fragments in the soil may produce physical effects comparable to those of conventional plastic residues (Serrano-Ruiz *et al*, 2021). Research on the impact of biodegradable microplastics and nano plastics on terrestrial environments remains limited, with insufficient attention given to the surface functionalities of in-soil biodegradable microplastics (Zhou *et al*, 2025). Furthermore, additives incorporated into these mulches, along with monomers and intermediates from their degradation, can leach into the soil (Huang *et al*, 2023). Over time, repeated use of biodegradable mulches introduces a diverse array of chemical compounds into the soil, with potentially unknown consequences for soil health and living organisms (Zhou *et al*, 2023).

* 1. **Biodegradable plastic mulch impact on soil health:**

Biodegradable plastic mulch (BDM) is an eco-friendly alternative to conventional plastic mulch used in agriculture (Soylu *et al*, 2024). Unlike traditional polyethylene (PE) mulch, BDM decomposes over time into natural components like water, carbon dioxide, and biomass, reducing plastic waste accumulation in the soil (Xiong *et al*, 2024). The impact of biodegradable plastic mulch on soil health is multifaceted, influencing physical, chemical, and biological soil properties (Serrano-Ruiz *et al*, 2021).

* + 1. **Physical impact of Biodegradable plastic mulch on soil health:**

Soil Moisture Retention: BDM reduces water evaporation, maintaining soil moisture levels. It improves water use efficiency, reducing irrigation requirements (Ravichandran *et al*, 2022). Soil Temperature Regulation: Like conventional mulch, BDM moderates soil temperature, promoting optimal root growth (Hayes *et al*, 2019). Depending on the colour and material composition, it can warm or cool the soil, impacting microbial activity and nutrient cycling (Amare *et al*, 2021). Soil Structure: BDM degradation over time contributes organic matter, potentially enhancing soil aggregation and aeration (Huang *et al*, 2023). It reduces soil compaction compared to traditional plastic films, which require manual removal (Dewi *et al*, 2024).

* + 1. **Chemical impact of Biodegradable mulch on soil health:**

Nutrient Availability: The breakdown of BDM can release carbon and other nutrients, potentially improving soil fertility (Iamsaard *et al*, 2024). Some BDMs contain additives that may influence soil pH and nutrient balance (Huang *et al*, 2023). Microplastic and Residue Accumulation: Unlike conventional plastic, BDM decomposes into non-toxic components, reducing microplastic contamination (Dada *et al*, 2025). However, incomplete degradation of biodegradable plastic mulch under suboptimal conditions may leave residues, affecting long-term soil quality (Imasaard *et al*, 2024). Pesticide and Agrochemical Interaction: BDM can alter pesticide retention and degradation in soil, influencing crop protection strategies. Some biodegradable films may interact with agrochemicals, modifying their effectiveness (Lewicka *et al*, 2024).

* + 1. **Biological impact of Biodegradable mulch on soil health:**

Microbial Activity and Diversity: BDM promotes microbial proliferation by providing a carbon source, supporting soil biodiversity (Liu *et al*, 2025). Certain microbes specialize in degrading BDM components, enriching microbial communities (Liu *et al*, 2022). Soil enzyme activity: The breakdown of BDM enhances enzymatic processes related to organic matter decomposition (Huang *et al*, 2021). Increased enzymatic activity can accelerate nutrient cycling and organic matter turnover. Plant microbe interactions: BDM indirectly influences beneficial rhizosphere microbes, improving plant growth. Biodegradable plastic mulch may support mycorrhizal fungi, enhancing plant nutrient uptake and stress resistance (Bandyopadhyay *et al*, 2023).



**Figure 2: Indicating the impacts of biodegradable plastic mulch on soil and Plant health.**

* 1. **Environmental Considerations and Challenges of Biodegradable plastic mulch:**

Decomposition Rate and Environmental Factors: The degradation rate of BDM depends on temperature, soil moisture, microbial composition, and material properties (Zhang *et al*, 2023). In colder climates or low-microbial-activity soils, decomposition may be slower, leading to potential residue accumulation (Su *et al*, 2024). Impact of BDM on soil fauna: Earthworms and other soil organisms may benefit from BDM decomposition as an organic matter source (Astner *et al*, 2023). However, synthetic additives in some BDMs could affect soil fauna if not fully biodegradable. Long-Term Soil Sustainability: Continuous use of high-quality BDM can enhance soil health by minimizing synthetic plastic pollution (Liu *et al*, 2022).

Biodegradable plastic mulch offers significant benefits for soil health, including improved moisture retention, nutrient availability, and microbial diversity (Sintim *et al*, 2021). However, its effectiveness depends on material composition, environmental conditions, and degradation rates. Proper selection and application of BDM can contribute to sustainable agriculture while mitigating the environmental risks associated with conventional plastic mulch (Xiong *et al*, 2024).

* 1. **Biodegradable plastic mulch impact on plant health:**

Biodegradable plastic mulch (BDM) is an alternative to conventional polyethylene (PE) mulch, designed to decompose naturally in the soil over time (Yu *et al*, 2023). It plays a crucial role in agricultural production by influencing plant growth, development, and overall health (Serrano-Ruiz *et al*, 2021). The impact of BDM on plant health can be categorized into several key aspects, including plant growth conditions, stress resistance, disease management, and crop yield quality (Somanathan *et al*, 2022).

* + 1. **Influence of biodegradable plastic mulch on Plant Growth and Development**

Soil Moisture Retention and Water Use Efficiency: BDM helps maintain soil moisture by reducing evaporation, ensuring plants have consistent access to water (Riseh 2024). Improved water retention reduces plant drought stress and enhances root water absorption. Soil Temperature Regulation: By moderating soil temperature, BDM creates favourable conditions for seed germination and root development (Shcherbatyuk *et al*, 2024). Warmer soil temperatures in cooler climates promote early crop growth, while lighter-coloured BDM can prevent overheating in warm climates. Root Development and Aeration: BDM prevents soil compaction, facilitating better root penetration and expansion. The gradual degradation of BDM can enhance soil aeration, promoting root oxygen exchange (Shah *et al*, 2023).

* + 1. **Influence of biodegradable plastic mulch on Nutrient availability and Plant nutrition:**

Enhanced Nutrient Uptake: As BDM decomposes, it can release carbon and other organic compounds, indirectly supporting nutrient cycling. By reducing nutrient leaching, it ensures plants have prolonged access to essential nutrients (Riseh *et al*, 2024). Interaction with Fertilizers and Soil Amendments: Some BDM materials alter the rate at which fertilizers are absorbed, potentially affecting plant nutrient balance (Kulhanek *et al*, 2023). The presence of biodegradable mulch can enhance microbial activity, indirectly aiding nutrient mineralization for plant uptake (Sander 2019).

1. **Effect of Biodegradable plastic mulch on Plant stress tolerance:**

Drought and Water Stress Resistance: By conserving soil moisture, BDM reduces plant water stress, enhancing resilience in dry conditions (Giband and Kranthi 2023). Less frequent irrigation needs contribute to better root system establishment. Temperature Stress Mitigation: BDM protects plants from extreme temperature fluctuations, reducing stress-related growth suppression. In colder climates, it can promote early-season crop growth by warming the soil (Khan *et al*, 2022). Weed Suppression: BDM effectively suppresses weeds by blocking sunlight, reducing competition for nutrients and water. Decreased weed pressure minimizes the need for herbicides, leading to healthier plant growth (Hayes *et al*, 2019).

1. **Effect of Biodegradable plastic mulch impact on disease and pest management:**

Reduction in Soil-Borne Diseases: BDM creates a physical barrier that prevents soil-borne pathogens from splashing onto plant leaves. By improving soil aeration, it reduces excessive soil moisture, minimizing fungal disease risks (Moya *et al*, 2024). Influence on Pest Populations: BDM alters pest behaviour by disrupting insect movement and reproduction cycles. Some biodegradable films are embedded with pest-repelling compounds, offering additional protection. Impact on Beneficial Microorganism: BDM enhances microbial activity in the soil, promoting beneficial microbes that aid in plant disease resistance (Somanathan *et al*, 2022). Certain formulations may support mycorrhizal fungi, improving plant nutrient uptake and stress resilience.

1. **Effect of Biodegradable plastic mulch effect on crop yield and quality:**

Yield Improvement: By optimizing growth conditions, BDM leads to higher yields in many crops, especially vegetables and fruits (Morra *et al*, 2021). Reduced weed competition and improved moisture retention contribute to increased productivity. Influence on Fruit and Vegetable Quality:BDM can enhance fruit size, colour, and texture by ensuring optimal growth conditions. By minimizing soil contact, it reduces the risk of fruit rot and contamination (Somanathan *et al*, 2022). Shelf Life and Post Harvest Benefits: Healthier plants grown under BDM may produce crops with extended shelf life due to reduced stress-related degradation (Khan *et al*, 2022). Lower pesticide use under BDM cultivation may result in cleaner, more marketable produce (Serrano-Ruiz *et al*, 2021). Impact on Crop-Specific Growth Requirements: Not all crops respond equally to BDM; some may require different mulch properties to optimize their growth. Understanding crop-specific interactions with BDM is essential for maximizing benefits (Mousumi *et al*, 2023). Biodegradable plastic mulch has a significant positive impact on plant health by improving moisture retention, nutrient availability, stress tolerance, and disease resistance (Gao *et al*, 2021).

**Table 1: Indicating the differences between Polyethylene mulch and Biodegradable plastic mulch.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **S. No** | **Parameter** | **Polyethylene mulch** | **Biodegradable mulch** | **Reference** |
| 1 | Durability | High in durability. | Moderate durability and durability decrease over time. | Tan *et al*, 2023. |
| 2 | Weed control | Good in control weeds. | Good in control weeds. | Zhang *et al*, 2019. |
| 3 | Soil health | Potential microplastic pollution, reduced aeration. | Improves microbial activity, no plastic residue. | Huang *et al*, 2023. |
| 4 | Impact on environment | High environmental due to waste accumulation. | Low impact on environment to biodegradable in nature. | Somanathan *et al*, 2022. |
| 5 | Plant growth | Improved moisture retention, early yield. | Similar or better growth due to microbial benefits. | El-Beltagi *et al*, 2022. |
| 6 | Cost | Lower initial costs, but higher disposable costs. | Initial cost is higher, but no disposal needed. | Tan *et al*, 2023. |
| 7 | Degradation | None, needs manual removal. | Decomposes in soil (varies by material & conditions). | Divya et al, 2019. |

1. **Conclusion:**

Polyethylene (PE) and biodegradable plastic mulch films play a significant role in modern agriculture, influencing both soil health and plant growth. While PE mulch enhances crop productivity by conserving soil moisture, regulating temperature, and suppressing weeds, its long-term use raises environmental concerns, particularly due to microplastic accumulation, soil degradation, and chemical contamination. These negative effects can disrupt soil microbial communities, alter nutrient cycling, and reduce overall soil fertility. In contrast, biodegradable mulch films offer a more sustainable alternative, as they decompose naturally, reducing plastic waste accumulation and minimizing soil pollution. However, their degradation rate and impact on soil properties depend on factors such as environmental conditions, microbial activity, and material composition. Some biodegradable mulches may temporarily affect microbial balance and nutrient availability, requiring careful selection and management. To achieve sustainable agricultural practices, it is crucial to balance the benefits of mulch films with their potential risks. Adopting biodegradable alternatives, improving waste management strategies, and incorporating organic amendments can help mitigate negative impacts while maintaining soil health and supporting long-term plant growth. Continued research and innovation in biodegradable materials will further enhance their effectiveness, ensuring environmentally friendly solutions for future agricultural production.

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**1.**

**2.**

**3.**

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