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Review

Mulching as a Sustainable Water and Soil Saving Practice in Agriculture: A Review

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Abstract: This research was carried out in order to demonstrate that mulching the ground helps to conserve water, because agricultural sustainability in dryland contexts is threatened by drought, heat stress, and the injudicious use of scarce water during the cropping season by minimizing surface evaporation. Improving soil moisture conservation is an ongoing priority in crop outputs where water resources are restricted and controlled. One of the reasons for the desire to use less water in agriculture is the rising demand brought on by the world's growing population. In this study, the use of organic or biodegradable mulches was dominated by organic materials, while inorganic mulches are mostly comprised of plastic-based components. Plastic film, crop straw, gravel, volcanic ash, rock pieces, sand, concrete, paper pellets, and livestock manures are among the materials put on the soil surface. Mulching has several essential applications, including reducing soil water loss and soil erosion, enriching soil fauna, and improving soil properties and nutrient cycling in the soil. It also reduces the pH of the soil, which improves nutrient availability. Mulching reduces soil deterioration by limiting runoff and soil loss, and it increases soil water availability by reducing evaporation, managing soil temperature, or reducing crop irrigation requirements. This review paper extensively discusses the benefits of organic or synthetic mulches for crop production, as well as the uses of mulching in soil and water conservation. As a result, it is very important for farmers to choose mulching rather than synthetic applications.

Keywords: biodegradable mulches; crop production; nutrient availability; organic; soil properties

1. Introduction

Agriculture is the world's largest water user, accounting for 70% of total consumption. According to Chen et al. [1], rainfed agriculture accounts for 80% of global cultivated land and provides 60–70% of the globe's food. Rainfed agriculture is becoming more popular in the world for helping in food production as a consequence of increasing drought conditions. Water scarcity is caused by climate change or changing rainfall patterns that reduce agricultural production in arid or semi-arid regions [2]. As a result, water management and conservation in the agriculture sector are now a challenge. In addition, rainfed agriculture in dry land farming is under strain, necessitating more efficient use of water-saving devices [3]. The main factors limiting agricultural output in dry and semi-arid areas are restricted water accessibility, availability, and limited precipitation [4,5]. This issue is becoming more serious as global climate change has a significant impact on agricultural systems [6]. In dryland regions, inefficient use of precious water, along with drought or heat stress throughout cropping seasons, poses a danger to agricultural sustainability [7]. Climate change causes severe soil drought and the water in the soil becomes insufficient for crop growth [8–11]. Figure 1 depicts a schematic representation of how conservation agriculture interferes with climatic changes and crops.

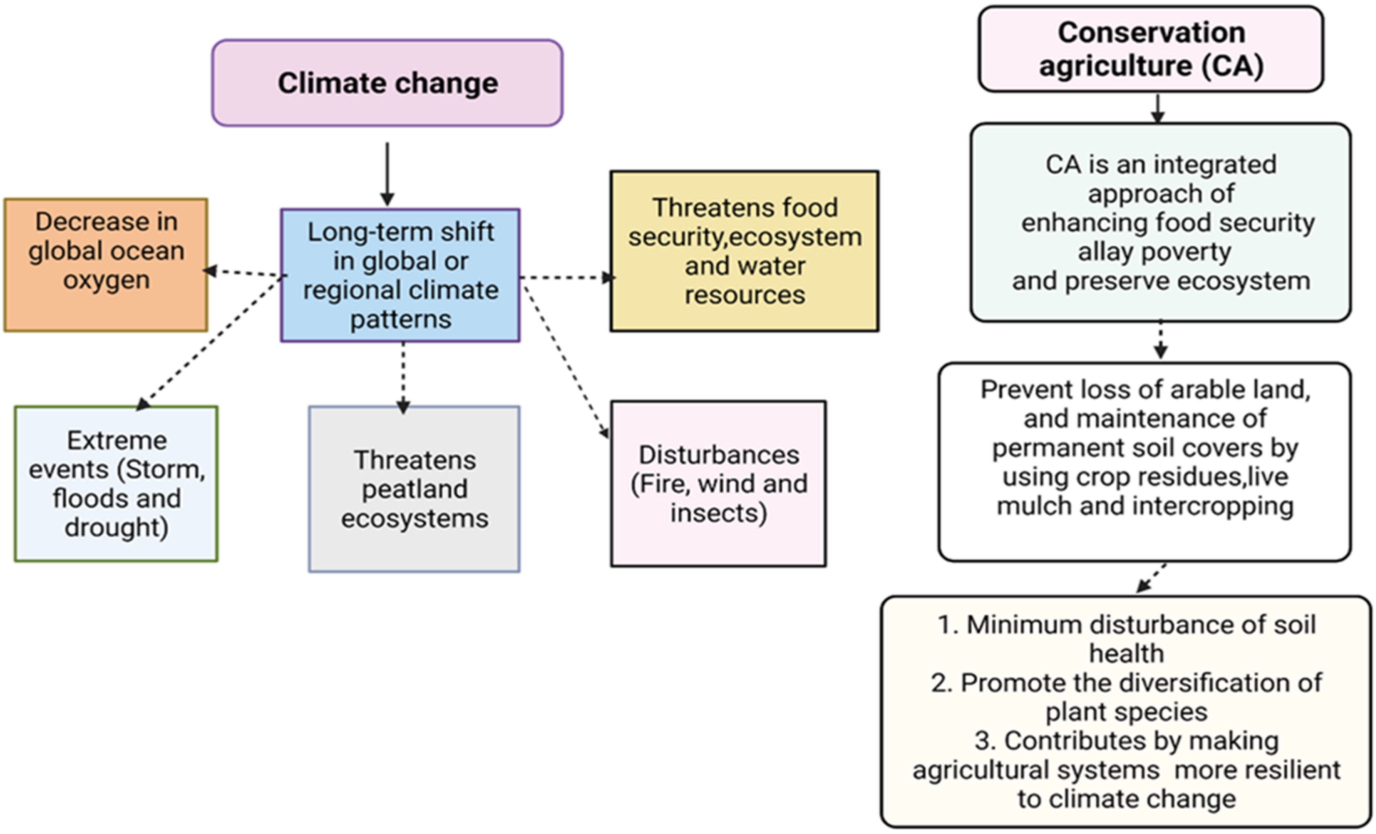

Figure 1. Schematic representation of how conservation agriculture interferes with climatic changes and crops.

Drought is a serious problem that is limiting crop production and decreasing agricultural development around the world for a variety of reasons, including rare annual precipitation and uneven temporal distribution, high evaporation, and water scarcity [12]; these issues are becoming more serious as a result of the significant impacts of global climate change [13–15] as shown in Figure 2. The main reason for using less water in agriculture is the rising demand caused by the world's growing population. Water availability for agricultural producers is steadily declining because urban populations' water needs are essentially increasing. Farmers are looking for novel approaches to enhance soil moisture to resolve both of these problems [16–18]. Mulching is one traditional practice that can aid in the solution to this issue.

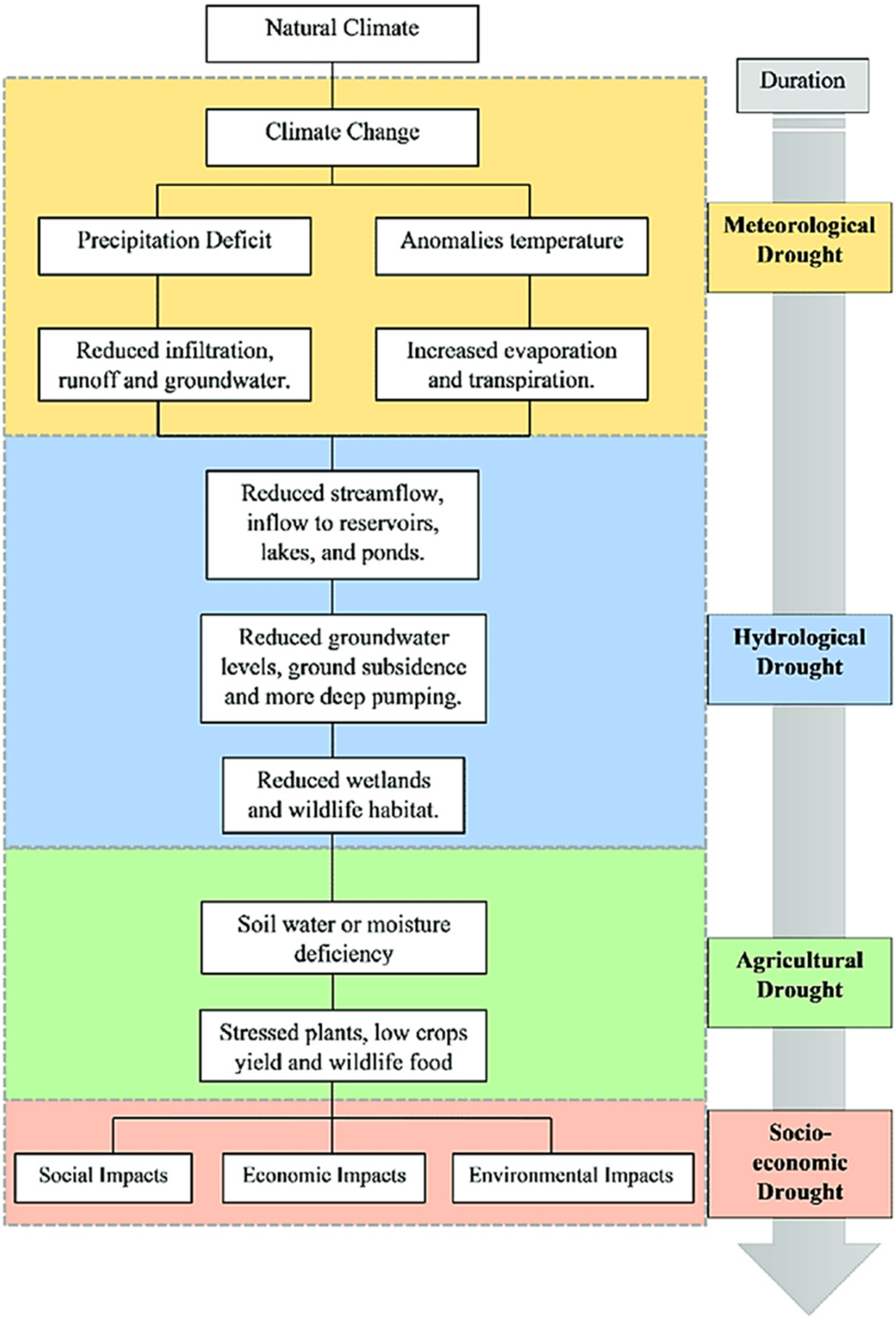

Figure 2. General diagram of different types of drought.

Mulching is a common practice that involves applying materials to the field before, during, or soon after sowing in order to support and spread over the soil surface, such as plastic material, crop residues, livestock manure, sands, rocks, and cement [19]. The main goals of mulching are to limit evaporation or water erosion [20], boost soil temperature, improve the soil water supply capacity [21,22], and suppress weeds [23]. Mulching causes improvement in crop production, fosters plant growth, and reduces water usage [24,25] as shown in Figure 3.

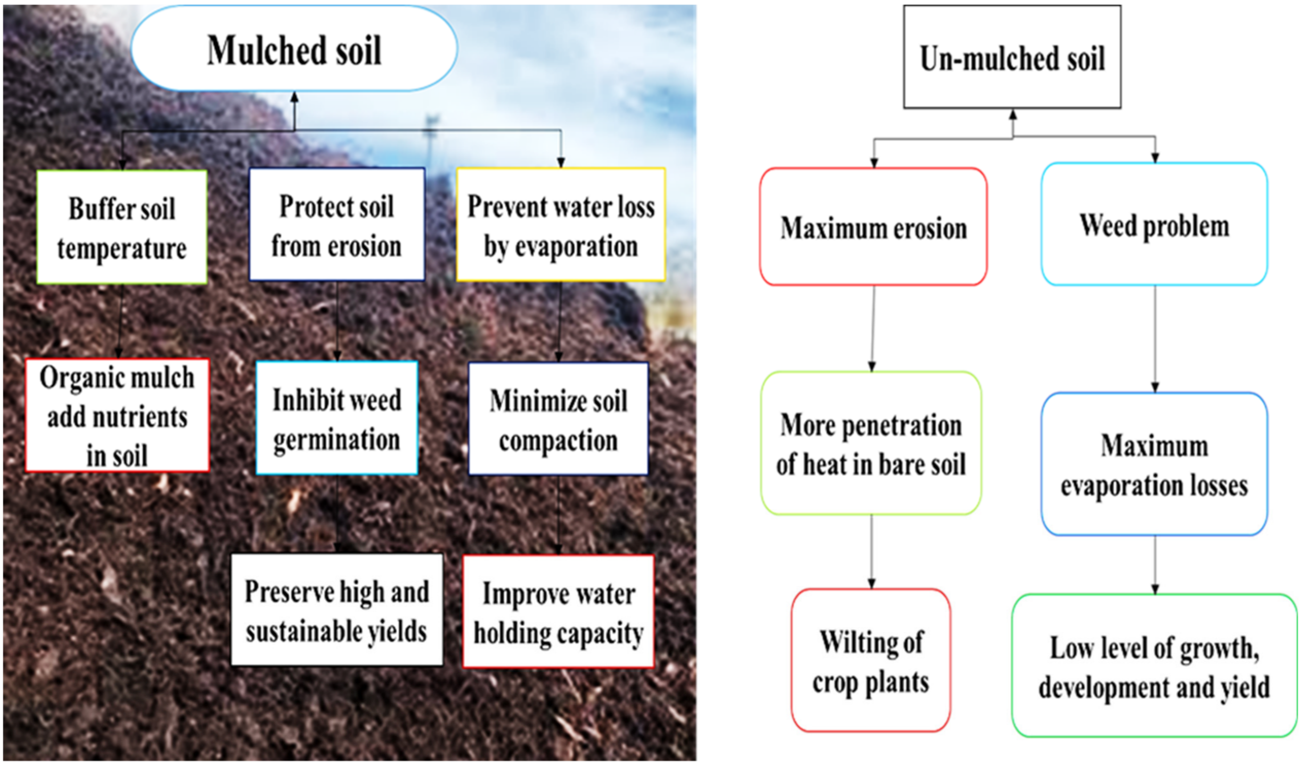

Figure 3. Comparative approach to the mulched and un-mulched soil/crops.

This review compiled information about mulching, different types of mulching materials, water conservation through mulching, and the effects of diverse mulching soil environments on crop growth and development.

2. Types of Mulching Materials

Organic, inorganic, and special materials are the three types of mulching materials. Agricultural wastes, wood industrial wastes, processed leftovers, and animal manures are used to make organic mulching materials (Figure 4). Polyethylene plastic films and synthetic polymers are examples of inorganic mulching materials [26]. Several innovative biodegradable and photodegradable plastic films, as well as surface coating and biodegradable polymer films for ease of implementation and flexibility, were also introduced as ecologically friendly materials [27].

2.1. Organic Mulches

Organic mulches are made from plant or animal matter. To get the most out of organic mulch, it is best used as soon as the crop germinates or when the vegetable seedlings are transplanted at 5 t ha^{-1}. Organic mulches are effective at minimizing nitrate leaching, boosting soil physical qualities, enhancing biological activity, balancing the nitrogen cycle, providing organic matter, controlling temperature and water retention, and reducing erosion. Natural ingredients are difficult to apply to growing crops and necessitate a lot of human effort. Organic mulch's application in horticultural crop production has been limited due to cost and logistical issues, with only a small amount of large-scale commercial utilization [28].

2.1.1. Straw

After harvesting, straw or crop remains are readily available. Straw mulch is a lightweight material that is simple to apply and use. Paddy straw is now commonly utilized as field mulch, as it improves crop cultivation conditions. When straw is utilized as mulch, it might cause several issues. Straw mulches need to be replaced every year because they are extremely flammable and include grain seeds that could germinate and deplete soil nitrogen levels as they decompose [29].

Figure 4. Different types of mulching techniques.

2.1.2. Bark Mulches

These are effective mulches as they hold more moisture for an extended time and prolong the availability of water to the crop. It is often used for landscaping and vegetation. However, because it is acidic, it should not be used in vegetable fields. On the other hand, this mulch is ideal for covering the walkways between the beds [30].

2.1.3. Wood Chips

Reprocessed wood and a variety of tree species are used to make wood chips. Because wood chip mulches have a high C:N ratio, they may restrict the availability of soil nitrogen available for plant absorption while they decompose [31].

2.1.4. Sawdust

Sawdust is a popular mulch in locations where it is readily available. It is found during wood finishing procedures. It is lower in nutritional value than straw, with only half the nutrients. The breakdown is very slow due to the high C:N ratio. Its decomposition will result in N_2 deficiency in the soil, necessitating the use of fertilizer regularly. Because of its acidic nature, it should not be utilized in low pH soil. It does, however, retain moisture for an extended period of time [32].

2.1.5. Compost

Compost is an excellent mulch and soil conditioner that may be easily made at home using a variety of waste items such as leaves, straw, grass, and plant wastes, among others. Compost availability and utilization in agriculture is a long-standing tradition. It boosts the properties of the soil, as well as the carbon content, which improves the soil's capacity to retain water and improves soil health. Due to its higher N content, compost is not recommended for use in vegetable fields because of the greater chances of weed growth [33].

2.1.6. Newspaper

Newspaper mulching is a cost-effective way to reduce weeds by reducing the chances of germination of weed seeds fallen from the previous season. The newspaper layers biodegrade quickly into the soil. Newspaper is preferable to plastic since it decomposes over time. It is less expensive and less time consuming [34].

2.2. Inorganic Mulches

Plastic mulch is an example of inorganic mulch; it comprises the majority of mulch used in commercial crop cultivation. Polyvinyl chloride or polyethylene films are the plastic materials used as mulch. It may raise the temperature around the plants at night in winter due to its higher permeability to long-wave radiation. As a result, polyethylene film mulch is recommended as a mulching material for horticultural crop cultivation [35]. Throughout the 1960s, a variety of plastic films based on various types of polymers were examined for mulching purposes. The technical distinctions between flexible polyvinyl chloride (PVC), high-density polyethylene (HDPE), and low-density polyethylene (LDPE) were minimal [36]. Because it is more cost effective to use, LLDPE makes up the overwhelming majority of plastic mulch today. Black plastic mulch film application is growing in popularity and it has produced excellent results, especially in arid and semi-arid regions. Black polyethylene mulch achieved a greater crop yield and quality which increased the economic value for farmers. It also decreased soil evaporation, modified the microbial community, and increased soil moisture levels [37].

Fresh vegetables are progressively being produced through a practice known as "plastic culture", which involves using plastic as mulch in farming [38]. Over one million tons of plastic film mulch is used each year in all parts of the world [25]. For instance, plastic film mulching was used in more than 60,000 ha of greenhouses in Spain in 2012, an increase of 5.7% (Transparency Market Research, 2016). According to estimates, China uses 0.7 million tons of plastic mulch annually, or 40% of the global total [39]. China, Japan, and South Korea are currently the three countries that use plastic film mulch the most globally (80%) [40]. Plastic mulching has increased the production of wheat by about 33.2% and maize by about 33.7% in China [41].

2.3. Photodegradable or Biodegradable Mulches

A kind of mulch that is simple to use and versatile is photodegradable and biodegradable [42]. Sand, gravel, and concrete are specific sorts of mulch that are rarely utilized, leading to the absence of nutrients and being very expensive to integrate. Biodegradable plastic mulch is a more environmentally friendly alternative to polythene mulch. It was created to prevent the accumulation of LDPE and the pollution caused by plastic waste in the environment [43]. Biodegradable plastic mulches are now composed of a variety of polymers or additives that are readily available in the global markets or are similar to LDPE mulches in terms of crop yield productivity [44]. In organic farming, this form of mulch also minimizes the need for agrochemicals [45]. According to Wang et al. [46], every kind of mulch has unique qualities. However, the potency and cost, the local climate, and the feasibility of planting the crop all play a role in the selection of mulch material that is incorporated into the soil. Regular application of mulch may have negative effects on soil efficiency, crop productivity, contamination, and ecosystem services such as food and water processing, disease control, N_2 cycling, and O_2 formation, as well as cultural and aesthetic values [47]. Complete and incomplete degradation are two different levels of degradation; photodegradation, water degradation, thermal oxidative degradation, and biological degradation are four different types of degradation mechanisms [48].

Starch, cellulose, polyhydroxyalkanoates (PHA), and polylactic acid (PLA) are typical biobased polymers used in BDMs. Poly (butylene succinate) (PBS), poly (butylene succinate-co-adipate) (PBSA), and poly (butylene-adipate-co-terephthalate) (PBAT) are examples of polyesters derived from fossil sources and used in BDMs [49]. Ester bonds or polysaccharides, which are amenable to microbial hydrolysis, are found in the polymers used in BDMs [50]. Theoretically, soil microorganisms should completely catabolize BDMs, converting them to microbial biomass, CO_2, and water [51]. In addition to the primary polymers, plastic mulches also contain trace amounts of organic (additives, plasticizers, etc.) and inorganic (Cu, Ni, etc.) elements, the effects of which are largely unknown. Traditional plant toxicity tests have not been modified to detect the effects of substances released by BDMs. First, as compounds degrade, they release various compounds at various times. Second, by concentrating only on germination, commonly used tests miss out on accounting for the shifting needs and responses throughout plant development [51].

Previous research has shown that biodegradable film mulch has similar moisture and heat preservation properties to regular polyethylene mulch and can also improve the water and temperature conditions of the soil's plough horizon on farmland. For the cultivation of potatoes, cotton, peanuts, and beets, biodegradable mulches can take the place of common polyethylene mulches [52–56]. The soil's total nitrogen, available phosphorus, and available potassium contents all increased under the biodegradable film mulch treatment. Plastic films are commonly used to control soil temperature and preserve soil moisture [39,40]. Mulching has an impact on soil nutrients as well, because raising soil temperature or moisture levels can improve soil nutrient mineralization [41]. According to studies [28], biodegradable mulches are abundant in organic carbon. They can increase the amount of organic carbon in the soil and have a positive impact on how well the soil stores carbon once they are introduced [42]. According to Zumstein et al. [43], soil microorganisms use the PBAT's carbon to produce energy and increase the soil's carbon stock.

The effects of soil mulching treatments on soil microorganisms and enzymatic activity were also observed. According to a few studies, biodegradable mulches do have an effect on microbial activity and the enzymatic activity of the soil; they increase microbial abundance, respiration, and activity [37,51–54] when compared with using polyethylene film mulch as a mulch. Exogenous organic materials in agricultural soil have been shown to have an impact on the microbial networks' metabolic processes and complexity [55]. For the biodegradable plastic film, microorganisms are supposed to use the released monomers during degradation to grow, thereby increasing microbial biomass [38]. The microclimate of the soil can also be enhanced by biodegradable film mulch. Favorable water and temperature conditions under the mulch have an impact on the root system of the plant, generally promoting root development and increasing root secretion [55]; these modifications all control microbial and enzymatic activity.

3. Advantages of Mulching

Mulching improves soil properties, soil moisture availability, and soil productivity [26]. These effects are summarized in Figure 5. Mulching in crop fields has numerous benefits, including reduced soil water loss, weed germination, soil erosion, and water droplet kinetic energy [48,49]. Mulch can help improve soil structure and increase earthworm movement [50]. It also lowers the pH of the soil, increasing the availability of nutrients (Table 1). After breaking down, organic mulch gives nutrients to the soil and boosts the availability of nutrients in the soil for a longer period of time [25]. Plastic mulches can significantly improve soil health and pest management [23]. As a result, it helps to prevent fertilizer from leaching and keeps nutrients close to the plants' roots so they can be used effectively. The mulched landscape has a more appealing uniformity of appearance [1]. Additionally, the appropriateness of soil moisture and temperature can change over the course of a crop's growth cycle. When organic mulch decomposes in the soil, the soil's organic content improves quickly, which improves the soil's ability to hold water [57]. Because mulches decrease evaporation, more moisture is accessible near the plant roots, extending the time for plants to absorb water. As a result, mulched areas require less water [58]. Both organic and biodegradable plastic mulches eventually collapse or boost nutrients to the soil's surface, enhance moisture retention, or increase the humus layer. Mulches control the temperature variation in the plants' root zones, causing soil to become colder in summer or warmer in winter [59].

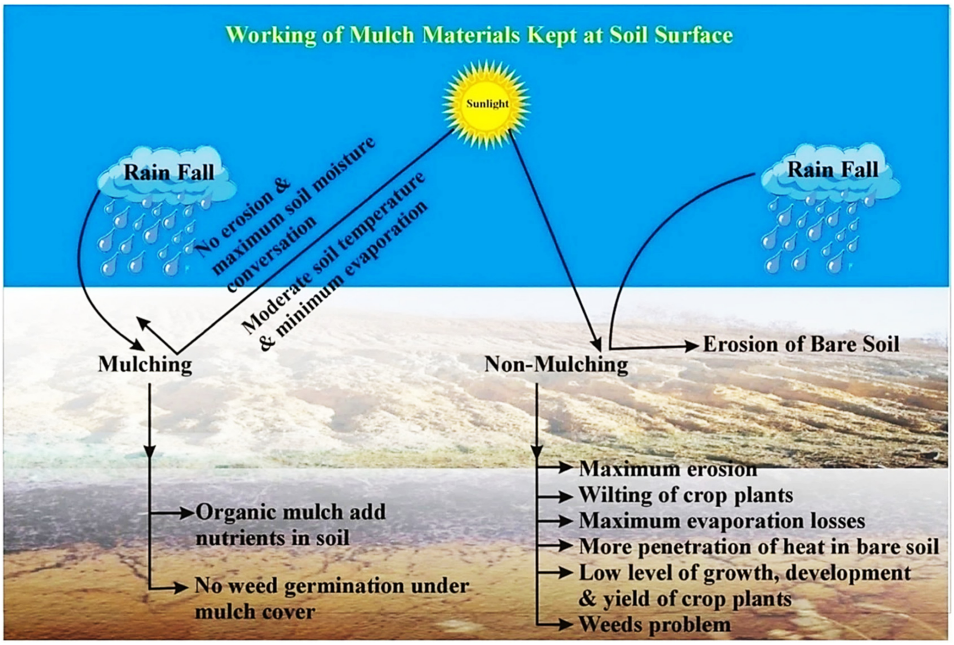

Figure 5. The effects between mulching and non-mulching.

Mulch reduces the germination of seeds by preventing sunlight from reaching the top surface of the soil. After forming a protective surface on the soil, plastic films or landscape fabrics also stop weeds from germinating [60]. Underneath the plant leaves, sand and clay soil reflect heat and light. Due to their multidimensional faces, organic mulches exhibit less light reflection. Therefore, organic mulch slows the rate of evaporation. However, inorganic mulches, particularly rocks, increase reflectivity and are suitable for some plants but harmful to more delicate ones [61]. Mulch prevents runoff or provides soil more time to absorb rainwater by lowering the kinetic energy of rain or by slowing the movement of rainwater. The additional moisture promotes plant root expansion, which further stabilizes the soil by encouraging root growth. Furthermore, mulch protects soil from wind erosion [62–64].

Table 1. Beneficial aspects of various mulch types.

Type of Mulch	Benefits	References
Straw mulch	Water usage is decreased and water productivity is increased.	[65]
	In potatoes, a probable decline in the insect pest invasion caused by the Colorado potato beetle.	[66]
	Rice yield, grain quality, or recovery are all enhanced.	[67]
	Decreased erosion or runoff, and soil water management or temperature control is improved.	[68]
	Soil water is boosted.	[67,69]
Aluminum/black and silver/black mulch	Plant growth as well as soil temperature improved in *Cucumis sativus*.	[70]
	Boosted plant length.	[71]
	Growth and yield of lettuce improved with silver polyethene mulch.	[72]
Paddy straw	Boosted leaf area.	[73]
Plastic and straw integrated	Reduction in evaporation and boosted soil moisture.	[74]
Black-colored plastic	More fruits, roots, tubers, and bulbs were found.	[75]
	In aerobic rice production, gross income and net returns have improved.	[76]
	Growth and yield of rice improved.	[67]
	Soil moisture and temperature increased.	[77]
	An enhancement in the yield of *Triticum aestivum.*	[78]
Degradable film	Early in the growing season, the soil was warmer and had more water, and maize productivity and water use efficiency had increased by 30%.	[79]

Table 1. *Cont.*

Type of Mulch	Benefits	References
Degradable mulch made of polycaprolactone, starch of maize, adjuvants, or grease (60:30:5:5)	*Brassica napus* L. has a 10% reduction in evapotranspiration and boosts in water usage efficiency and seed productivity by 54% and 38%, respectively.	[80]
Jatropha and Sesbania remains	An enhancement in yield.	[65]
Almond shell mulch	Upregulation of dehydrogenase, phosphomonoesterase, and protease, as well as a rise in soil enzyme activities and organic carbon.	[81]
Bark chips and manure mulches	Toxicity of hazardous chemicals (polycyclic aromatic hydrocarbons) in the soil is decreased.	[82]
Plastic mulch	Maize yields have increased as a result of increased moisture supply and maintained temperature.	[83]
	Higher water productivity and soil moisture content.	[67,69]
	Boosted soil moisture.	[79]
	Boosted soil water content in maize.	[84]
Gravel mulch	Enhanced soil moisture.	[85]
Ryegrass (*Lolium multiflorum* L.)	Rice increased the activity of alkaline phosphatase, glucosidase, arylsulfatase, and arylamidase.	[86]
Transparent plastic mulch	Radish growth improved significantly.	[87]

4. Disadvantages of Mulching

Mulching has some drawbacks as well, such as increased labor needs, higher transportation costs, and difficult removal and disposal. The soil is contaminated due to the plastic mulch producing fragments that are in direct contact with it [88]. Weed growth and acid leakage are also major issues with some organic mulching materials such as straw and grass [89]. Mulched soil has better aeration and temperature that tends to support increased microbial activity in the soil, resulting in more thorough nitrification in mulched soil [90]. Farmers use onsite burning or landfilling to dispose of or bury plastic film wreckages in cultivable soil sheets, which severely contaminates the soil and impairs the development and growth of crops [91].

Because mulching causes the soil to retain more moisture, it restricts the oxygen supply close to the roots because the soil has poor drainage. If mulching is done close to the stem, the surrounding moisture in the plant's stem can serve as a haven for a variety of microorganisms, pests, and diseases. Mulches containing seeds, such as hay, straw, and grass clippings, can promote the growth of weeds [92]. Inorganic mulches do not add any nutrients to the soil because they do not disintegrate, except for biodegradable plastic mulches. In some circumstances, inorganic mulch will be destroyed by the sun and will begin to deteriorate over time. If it is spread out over a vast region, it can raise the temperature of the soil. Rubber is an organic mulch that can damage plants because it is toxic and hazardous to the environment [92].

5. Methods of Application of Mulching Materials

In agricultural fields, a variety of mulching materials are used in a variety of ways and patterns as shown schematically in Figure 6.

5.1. Flat Mulching

A traditional type of mulching is called flat mulching, which involves covering the soil's top layer with organic, inorganic, or mixed mulching materials [93]. In the case of organic mulching materials, flat mulching can keep the layer thickness based on the intended function. A type of flat mulch, where part of the topsoil is coated, is plastic mulching with holes. Compared with conventional flat mulching, this mulching improves soil aeration and rainfall infiltration [94].

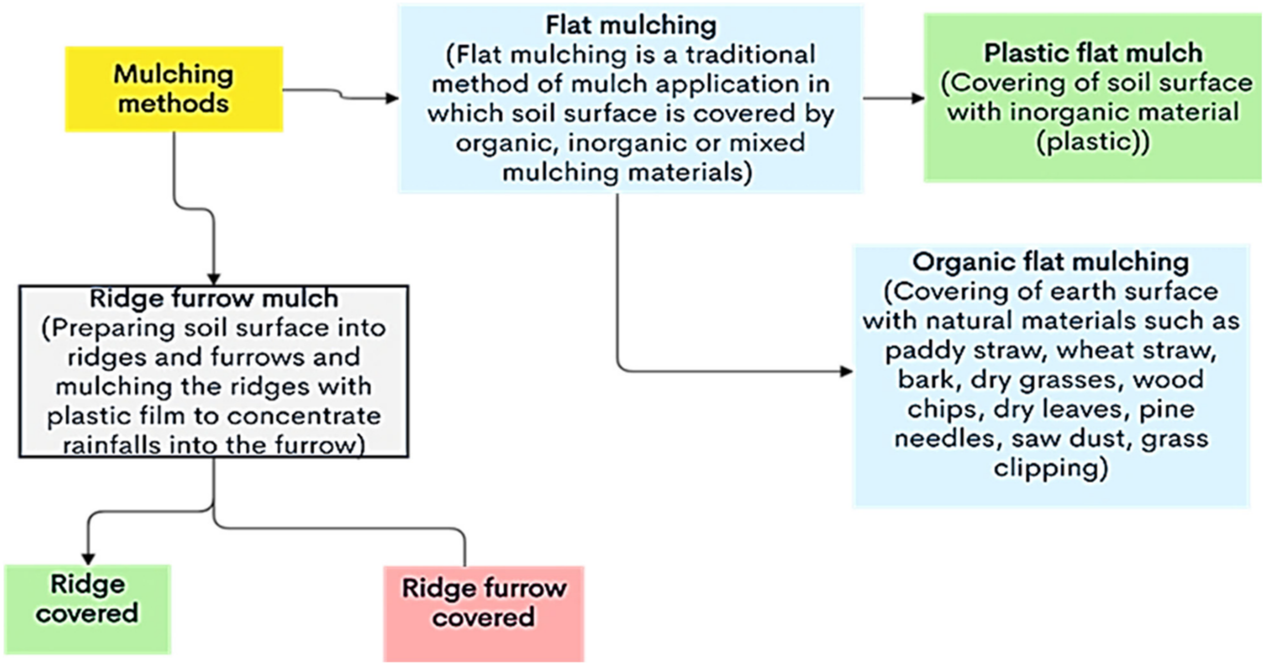

Figure 6. An illustration of the various mulching techniques.

5.2. Ridge Shape Mulching

In this type, the ridge is coated with a plastic film, which directs rainwater into furrows or lowers surface runoff [95], enhancing water use efficiency (WUE) [96]. Crops such as corn are typically grown on the ridge area of the field, which is mulched, but crops are also grown in the furrow, which can be mulched or not [97].

6. Mulching Material Selection

In general, the selection of a proper mulching material depends on the material type, the type of crop, environmental locations, and the availability of mulch, as well as their cost effectiveness [98]. Table 2 illustrates a comparison between organic and plastic mulching.

Table 2. Explained comparison of different organic and inorganic mulches.

Subject	Organic Mulching	Plastic Mulching
Material type	Bio-based cellulose, chips, leaf, paper	Acetate, polyethylene, polymeric material
Durability	Temporary or decays over time	Long lasting, two–three crop seasons
Thickness	3–5 cm, controlled by application rates	15–20 µm; 15 µm is most effective
Colors	Natural	Black, silver, white, red, blue, yellow, etc.
Weed control	Effective, but grass material grows weeds	High weed competition except transparent color
Pest management	Reduces thrips or fungal disease	Reduces thrips, spider mites, or whiteflies
Fragments	Degradable to soil	Problematic or contaminated after one–two seasons
Priority mulch	Straw (rice and wheat)	Black plastic
Priority mulch	Straw (rice and wheat)	Black plastic

7. Role of Mulching on Soil Conservation

7.1. Mulching Effects on Soil Moisture

Frequently, mulching is believed to be beneficial to stressed environments (heat, drought, and salinity) as it changes the rate of evaporation and transpiration [99,100]. The effect of mulching depends on the climatic conditions and the amount of rainfall. It influences the moisture content of soil by reducing the evaporation of water from the surface of the soil. Mulches improve soil moisture retention and structure while inhibiting weed growth [101]. However, under various mulching materials, the soil moisture difference depends on the various soil types or climatic circumstances that affect the efficacy of various mulching materials to conserve moisture. When compared with bare soil, mulching treatments generally hold more soil moisture [97]. The changes in soil moisture in top surface layers (0–10 cm) are caused by water vapor fluxes throughout the soil surface and layers. Mulching, on the other hand, reduces the variability of soil moisture or temperature [102].

Other mulches and bare treatments displayed bigger fluctuations, but plastic mulching (without holes) treatments consistently conserved soil moisture during soybean growing phases [94]. The other mulch-covered treatments hindered direct infiltration, but the bare treatment allowed rain to directly penetrate the soil surface. Because paper is porous and hygroscopic by nature and extends and contracts in response to moisture levels, paper mulching treatments showed maximum soil moisture levels [34]. When organic mulch is applied to the topsoil, it hinders weeds from growing, increases rainwater infiltration, and reduces evaporation [103]. Additionally, the addition of organic mulch puts plants in competition for moisture, resulting in a decrease in soil moisture. However, organic mulch or paper mulch on sesame and other crops showed a higher moisture content in comparison with the soil without mulching [104]. Stagnari et al. [105] indicated similar outcomes by incorporating straw mulch at a depth of 5–15 cm. Gravel mulch slows evaporation and retains moisture in the soil [12,106]. Most visible, UV, and infrared sunlight is absorbed by black polyethylene mulch, which then re-radiates the radiation. The color of mulch determines its energy-radiating behavior or impact on a plant's microclimate [107]. In comparison with black polyethylene mulch, full film mulching systems have markedly increased moisture content up to deeper soil depths [108]; it depends on a particular material's thermal characteristics, such as its reflectivity, absorptivity, or conductivity, in relation to incoming solar radiation. Black polyethylene mulch absorbs solar radiation, which is then lost to the atmosphere due to radiation or forced convection. By optimizing conditions for transferring heat from the mulch to the soil, the efficiency with which black mulch raises soil temperature can be increased. Because soil has a higher thermal conductivity compared with air, much of the energy absorbed by black plastic can be transferred to the soil via conduction if contact between the plastic mulch and the soil surface is good. When compared with bare soil, soil temperatures under black plastic mulch are generally 5° F higher at a 2-inch depth and 3° F higher at a 4-inch depth during the day [109]. It has been discovered that using dark colored mulch is the safest solution, because the soil does not warm to a harmful degree even in the presence of high air temperatures and solar radiation [110]. Mulch significantly improved total soil water holding capacity, soil moisture retention, soil porosity, and, thus, water-use efficiency [111].

On the other hand, Jenni et al. [112] discovered that plastic film was more effective than paper mulches at conserving soil moisture during lettuce crop cultivation during dry periods. According to McMillen [113], mulching with grass clippings, wheat, or leaf debris at a depth of 5–10 cm enhanced soil moisture by 10% over bare soil. In contrast to organic mulch treatments, which retain more moisture than bare soil, plastic mulch treatments hold the most soil moisture [114]. Surface runoff is reduced, infiltration is improved, and soil loss is reduced with compost mulching [115]. On the other hand, Ashrafuzzaman et al. [116] found non-significant variations in soil moisture content between various mulch treatments, but they reported higher moisture levels with mulches over bare soil. The results revealed that, after 90 days, soil under transparent plastic mulch had a higher moisture content (21.1%), followed by black (20.4%) or blue plastic mulch (19.2%), respectively, whereas minimum soil moisture was observed at the control (14.6%).

7.2. Reduce Infiltration Rate

Water infiltration is an important process in which rainwater, irrigation water, surface water, soil water, and groundwater all interact with one another. Irrigation amounts, precipitation characteristics, canopy interception capacities, and soil hydraulic characteristics all influence water infiltration [117]. In general, because of the low initial soil water content (SWC), a large amount of rainwater infiltrates the soil and is converted into soil water when it rains. If the rainfall amount is large, soil water gradually becomes saturated as infiltration progresses, the infiltration rate gradually becomes lower than the rainfall intensity, rainwater gathers on the soil surface to form surface water and runoff, and is eventually lost. Furthermore, surface runoff degrades soil and reduces sustainable production through soil erosion and nutrient loss [117].

Mulch has a direct impact on rainwater infiltration and evaporation by blocking solar radiation from reaching the soil and thus increasing total water intake due to the creation of a loose soil surface. Crops can use water absorbed into the soil, resulting in higher agricultural yields. In semi-arid agriculture, infiltration or evaporation are two of the most important processes that determine soil water availability to crops. According to Abu-Awwad [118], coating the soil surface lowered the amount of irrigation water used by a pepper crop by 14–29% and an onion crop by 70%.

7.3. Mulch Effects on Soil Temperature

Mulched soil dries out more quickly than bare soil in the late stage. Overall soil moisture is determined by the porosity, texture, and structure of the soil [119,120] and organic mulching can assist them in development. With increasing machining rates, the soil wetting depth also increases. Raised mulch rates enhance the depth of soil wetness. Straw mulching, according to these studies, can store more soil water from tiny amounts of precipitation [121–124]. Mulching lowers the temperature of the soil in summer, raises it in winter, or avoids high temperatures. Sarolia and Bhardwaj [125] recorded a temperature increase of 2–30 °C after treatment with wheat straw mulched soil. When compared with bare soil, the temperature of the ground beneath clear mulch might be up to 7 °C higher. Park et al. [126] found that at a depth of 15 cm, black film raised the soil temperature by 0.8 °C, while transparent film raised the soil temperature by 2.4 °C. Condensation on the mulch's underside absorbs long-wave radiation in the evening, delaying the cooling of the soil [127].

The role of mulching in affecting the temperature that will lead to an increase or decrease in crop production depends on the material type of mulching as illustrated in Table 3. The ability of mulches to influence soil temperature also depends on the ability of mulches to transmit or absorb solar radiation [127]. In the summer, mulch cools the soil, while in the winter, it warms it. Mulches change the thermal regime of soil by changing its temperature [128,129]. Although polyethylene film mulches have a higher temperature than biodegradable mulches [130], the former may be detrimental in hot climates, resulting in early decomposition, or favorable in cool weather due to the ability to maintain a warm temperature at night, which allows for faster seed germination. The daily soil temperature fluctuates due to various mulching materials in the surface (5 cm) soil layer. However, in the deeper layers, the soil's temperature is essentially constant.

When contrasted with black plastic mulching or bare soil, paper mulching minimizes soil temperature [94] and gives the minimum soil temperature [34]. Higher soil temperatures accelerated crop establishment and boosted growth in black polyethylene mulch by absorbing a higher amount of solar radiation [37,131]. By storing incoming solar energy, organic mulches limit heat transfer to the surface soil [36]. These mulches reduce the higher temperatures and vice versa [132], while lowering soil temperatures considerably [133]. At 10 cm of soil depth, a 4 °C decrease in soil temperature during the warmer phase or a 2 °C increase during the cooler time were also detected. Soil temperature variations are also caused by the timing of soil temperature observations or the thickness of mulching [134]. Xiukang et al. [77] observed a rise in soil moisture or temperature under plastic mulch, which enhanced crop growth or yield. On the other hand, the effects of soil temperature on crop growth are dependent on the climate where the crop plants are grown. Chakraborty et al. [135] discovered that an elevated soil temperature under mulch did not boost wheat production in India. Farmers in some areas must reduce soil temperature to increase yield, while farmers in others must increase soil temperature to increase production [34].

The temperature of the soil is significantly influenced by the color of plastic mulch. Photo-selective mulch films raised the soil temperature more than bare soil [136]. Their findings revealed that blue plastic mulch has a higher temperature than red. In addition, Farias-Larios and Orozco-Santos [137] found that transparent plastic mulch had the maximum temperature, while black plastic mulch or bare soil had the same temperature. Similarly, Gordon et al. [138] discovered that colored plastic mulches and row cover cause variations in soil temperature. Black plastic mulch with a row cover recorded the greatest temperature, while bare soil recorded the lowest. The most significant way that mulch use affects crop yield is generally thought to be through the effects of the mulch films on the soil temperature. Mulch films modify the energy flow in the soil by allowing various wavelengths of incident solar radiation to pass through the film and reach the soil (depending on the type of film used), preventing the loss of lower energy infrared radiation. The most frequently reported effect (for black and clear films) is an improvement in the average temperature relative to the bare soil temperature, allowing for earlier germination and longer growing seasons. Some reports on the effects on soil temperature suggest that the use of white and reflective films can lower the maximum temperature experienced by the soil [139,140].

Table 3. Impact of various mulch types on the soil temperature in different crops.

Type of Mulch	Impact on Soil Temperature	Crop	Reference
Coupled plastic or straw mulch	Reduce soil temperature	Maize and wheat	[74]
Straw mulch	Reduce soil temperature fluctuations	Alfalfa	[85]
	Decrease soil temperature	Maize	[79]
	Decrease soil temperature	Wheat–maize	[141]
Black plastic mulch	Boost soil temperature	Cucumber	[70]
	Boost soil temperature	Maize	[77]
	Increase soil temperature	Maize	[79]
	The soil temperature increased more in black polyethylene mulched plots than white-on-black polyethylene or bare ground plots	Lettuce	[142]
Transparent plastic mulch	The soil temperature boosted in plastic film mulching	Maize	[143]
	Decrease soil temperature	Maize	[143]
	Boost soil temperature	Potato	[144]
	Boost soil temperature	Maize	[145]
Degradable film as mulch	Increase soil temperature	Maize	[79]
	Decrease soil temperature	Tomatoes	[146]
	Increase soil temperature	Different crops	[147]
Compost mulch	Increase soil temperature	-	[148]
Silver/black plastic mulch	Increase soil temperature	Cucumber	[70]

7.4. Mulch Effects on Soil Properties

The composition of soil moisture and temperature has an impact on soil and crop interactions [149]. Mulch application rates can change soil attributes such as organic matter, moisture content, salinity, texture, porosity, or subsurface characteristics, all of which have a significant impact on crop productivity [64,150]. According to Huang et al. [151], the application of organic mulches to soil improved soil health or consequently gave a higher yield. In addition, soil chemical properties such as cation exchange capacity (CEC) and electrical conductivity (EC) were also improved [147]. In hardwoods, mulching practices increased soil organic matter (SOM) over the control [148]. Likewise, in an arid climate, Zhang et al. [152] found significantly greater SOM in straw mulch at the soil surface layer (0–15 cm); however, Tian et al. [153] showed a significant increase in dissolved organic carbon beneath black polyethylene mulch in a humid environment. Compared with polyethylene film mulch (PM), Zhang et al. [154] discovered that biodegradable mulches (BM) increased the soil's microbial, urease, or catalase activities. Although BM can reduce soil bulk density, it has no lasting negative effects on the nutrient or the microbial activity of the soil. Instead, it may improve the soil's quality. The use of mulch modifies the bulk density according to the climatic factors, the characteristics of the soil, and the mulch used [155]. Mulching increases the water holding capacity, while no mulching has no effect on the water capacity. The use of various kinds of mulch decreased electrical conductivity when compared with bare soil. [156]. Black polyethylene mulch improves soil fertility by reducing nitrogen or organic carbon exhaustion in soil, as described by Liu et al. [157]. Figure 7 illustrates the effect of mulch on productivity, growth, or nutrients of crops.

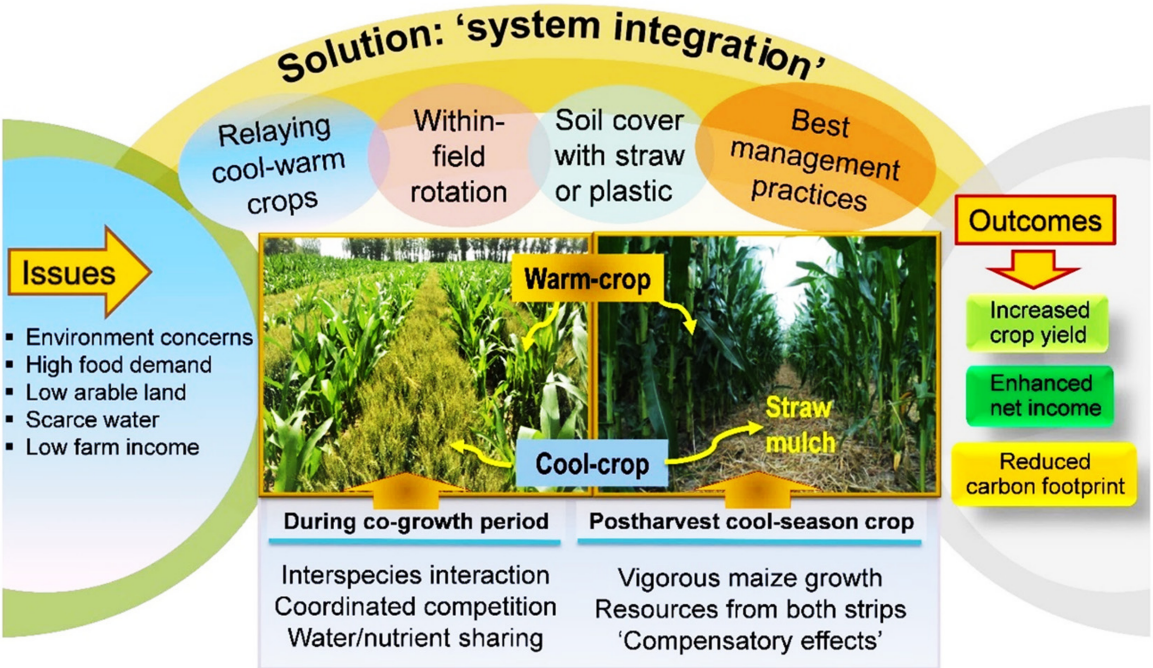

Figure 7. Effect of mulch types on growth, productivity, or nutrients of crops.

7.5. Mulch Effects on Soil Thermal Regimes

Mulches appear to be effective at changing water or heat balances on the soil's surface or improving the growing environment for plants. By delaying evaporation, mulches preserve soil moisture, although their capacity to affect soil temperature varies according to the composition and optical characteristics of the mulch. In general, organic mulches reduce maximum soil temperatures but boost minimum soil temperatures, whereas polyethylene mulches enhance maximum or minimum soil temperatures compared with un-mulched soil [158,159].

Because solar energy directly heats air or soil beneath mulch through penetration, mulch is known to increase soil temperature. The heat is then holed up by the greenhouse effect. Crop growth throughout the growing season is determined by the genetic or environmental factors that regulate the duration or speed of plant development. Temperature is considered the most crucial environmental factor. Soil temperature is a measure of the intensity of heat in the soil. Heat flows in soil, or the generation or usage of heat in soil, both have an impact on the temperature of the soil [160]. The microclimate, which affects seed germination, seedling emergence, and root growth, is greatly affected by the thermal properties of soils [161,162]. Crops are exposed to sub-or supra-optimal temperatures at various points in their growth cycles. Summer crops are subjected to higher temperatures than those cultivated in the winter. Crop production can be improved by altering hydrothermal regimes through the use of mulches or appropriate management practices.

In terms of crop growth, the soil temperature is more important than the aerial temperature in agriculture [20]. One of the most critical elements affecting soil heat storage, soil heat flow, soil water flux, seed germination, nutrient cycling, or plant growth is soil temperature. Plant root functional activity can be influenced by either minimum or maximum soil temperatures. The response of plants changes when the temperature changes, having lower and upper threshold values as well as a conspicuous optimum. The ideal temperature for the optimum utilization of N-fixing bacteria is between 20 and 25 °C. The ideal soil temperature for wheat is 15–27 °C, and 25–30 °C for sorghum, rice, or corn [163].

7.6. Mulch Effects on Microbial Count

Microorganisms in the soil have a significant role in the agriculture system, nutrients, and soil quality. Soil organisms feed on soil organic substrates positively affecting plant growth [164–167]. Mulching increases the number of microbes in the soil, which leads to better aerobic conditions, adequate soil moisture, or temperature, which in turn causes microbial decomposition to occur quickly, which improves soil fertility due to the abundance of nutrients that affect plant growth and productivity [168–170]. The microbial population and activity are affected differently by different types of mulch [171–174].

Excessive application of synthetic fertilizers overall in the agricultural sector has led to contiguous health issues and ecological damage worldwide [175]. Mulches enhance soil biota by ensuring the availability of nutrients and play a significant part in nutrient cycling activities, allowing the crop to harvest a healthy product for long time [147,176]. Proteobacteria and actinobacteria populations rose when plastic film mulch was applied relative to control [172], but soil invertebrate populations decreased [177]. Mycotoxigenic fungus was increased by the use of plastic mulch [178]. In addition, under mulching circumstances, Chen et al. [147] discovered an increment in the microbial community. Microbial activity varies with the type of temperature present during the mulching process. As a result, microbial activity is increased when the soil temperature is below the microbial optimal range. Conversely, when the soil temperature is above the microbial optimal range, the mulch may raise the temperature, which would decrease the number of microbes present [119]. Using biodegradable mulch has been shown to boost bacterial and fungal populations [179].

When contrasted with black polyethylene mulch, biodegradable mulch boosted microbial populations, enzyme activity, and respiration [179]. According to Yan et al. [180], black polyethylene mulch reduces porosity, which changes air exchange and hence microbial population, resulting in reduced soil fertility. Black polyethylene mulch raised the temperature of the soil, which accelerated the decomposition of organic matter or encouraged the activity of soil microbes [88]. The decomposition process, nutrient mineralization, or soil carbon sequestration are all significantly influenced by the physicochemical characteristics of the soil. The high microbial biomass and activity frequently lead to the highest nutrient availability to crops [88].

7.7. Mulch Effects on Weed

One of the most difficult aspects of farming is weed control [181]. Weeds compete with crops for light, food, water, nutrients, or space in agricultural fields, and they also discharge allelopathic chemicals into the soil, reducing crop productivity and quality [169]. According to agronomic research, light can only reach the soil for a few cm, so mulching at a depth of 5 cm is the most often advised method for reducing weed development [182]. The microclimatic conditions of the soil surface are changed by the use of any form of mulch, which in turn influences the weed spectrum. Mulch prevents the growth of undesired weeds by reducing the amount of solar radiation available [183]. Weeds are suppressed by black polyethylene and straw mulch [184]. Table 4 illustrates the impact of different mulches on weed control.

Table 4. The impact of different mulches on weed control.

Types of Mulches	Effects	References
PE (polyethylene) mulch	PE mulch increased saffron growth and productivity while successfully reducing weed populations.	[185]
Barley straw mulch (BSM) and mulch from spent mushroom compost (SMCM)	BSM and SMCM decreased weed populations.	[186]
Wheat straw, pine needle, or black plastic mulch	Mulch decreased the weed biomass and weed density.	[187]
Both organic and inorganic mulches	Treatment of tomato lines with black polythene mulch boosted fruit yield and decreased weed density. Transparent polythene could not inhibit the weed population.	[188]
Three mulch treatments, i.e., plastic mulch (PLM), sorghum mulch (SM), or paper mulch (PM)	The PLM and PM decreased weed flora and increased morphological criteria of maize.	[189]
Cereal rye mulch biomass	Mulch decreased weed community that related with soybean.	[190]
Black– black, Black–silver, Black–white, organic mulches such as paddy straw, paddy husk, ground nut shells	Black–black polythene mulch exhibited maximum weed control efficiency while the minimum was registered with paddy straw mulch.	[191]
Peanut straw mulch	Peanut straw mulch decreased weed biomass.	[192]

Mulches are more effective than pesticides or manual weed control methods [193]. Hjelm et al. [194] reported that weed control could be effective when mulching is used and it could be a cost-effective and sustainable alternative. According to Abouziena et al. [195], broad-leaved weeds are more sensitive to mulching coatings than grassy weeds. The inhibiting effect of weeds under organic mulch was observed by Oliveira et al. [196], and may be related to decreased solar radiation, temperature, or allelopathic effects produced by straw mulch, which may have lowered emergence. *Eucalyptus grandis*, *Pinus patula*, and *Acacia mearnsii* are examples of organic mulches that contain hydroxylated aromatic compounds and produce allelopathic compounds with hydrophobic nature that rapidly decrease the supply of water, influencing weed species such as *Trifolium* spp., *Lactuca sativa*, or *Echinochloa utilis* [172,197].

The influence of black or clear plastic mulches on weed infestation has been reported to be positive. This effect is due to their ability to warm the soil or raise the root zone temperature. However, black plastic mulch has a greater impact on suppressing weed competition than clear plastic mulch because it spreads across the soil or around the crop, lowering the amount of light reaching the soil. It reduces the efficacy of weed germination or suffocates growing weeds [38].

8. Role of Mulching on Water Conservation

Because water-usage efficiency is a modern technique of farming, it focuses on increasing production while using a scarce amount of water. It is vital to save water and increase crop output in arid or semi-arid locations. Crop output is proportional to the amount of accessible water and the efficiency with which it is used throughout the production period [198]. Land that is not mulched loses more water than land that is covered with plastic. This is due to increased exposure to water-losing factors such as solar radiation, wind, or heat [199]. Plastic mulching has a better effect on plant production or water-use efficiency (WUE) than traditional tillage patterns. Black and white plastic mulching improves WUE in potato plants by 31% compared with the un-mulched ground [200]. Table 5 summarizes the role of various mulches on soil water content.

Table 5. Effect of various mulches on soil water content.

Mulch Type	Effect on Soil Water	References
Plastic mulch	Boosted soil water contents Boosted soil water contents and availability Boosted moisture contents and maize productivity	[79] [67,69] [201]
Degradable film mulch	Raised soil water contents	[79]
Straw mulch	Increased soil water contents Enhanced soil water storage Boosted soil moisture contents Reduced water needs and enhanced water productivity	[79] [202] [67,70] [65]
Gravel mulch	Boosted soil water content	[202]
Compost made from municipal waste	Increase (85%) in water percolation	[203]
Oat straw and olive twigs as mulches	Reduced water loss from rainfall	[204]
Transparent plastic mulch	Boosted soil water content and canopy air humidity	[139]
Black plastic mulch (BM)	Boosted soil moisture, temperature, and morphological criteria of maize	[205]
Straw strip mulching	Straw strip mulching and plastic film mulching boosted water use efficiency of grain yield (WUEr) or biomass yield (WUEb).	[206]
Transparent film (W), black film (B), or straw mulching (S)	W, B, and S mulch boosted soil water content	[207]

Mulch involves maintaining soil moisture by covering the soil's surface. This method can be utilized to prolong crop production in regions with insufficient water supplies. To conserve soil and water, ridge-furrow farming has been integrated with plastic mulching in some regions of the world. For instance, compared with a flat-sown crop with no soil protective coating, the technique (covering ridge furrows with plastic mulch) could improve soil water supplies, root density, energy and water conservation, plant dry weight, and maize productivity [208]. In comparison with a control, the water-use efficiency, yield attributes, and yield and quality improved by about 50% when ridge furrows and a plastic covering were used to conserve water in the wheat crop in China (flat planting) [209].

The use of black plastic mulch has been reported to improve water efficiency. Because of its impact on reducing evaporation and transpiration, such efficiency is achieved. This emphasizes the importance of black plastic mulch in preventing moisture loss, improving protected agriculture, or lowering plants' need for more water [210]. However, a study of black or white plastic mulches revealed that black plastic mulch (202–442.6 mm) has a higher maximum rate of evaporation and transpiration than white plastic mulch [211].

The ability of bare soil to absorb irrigation or rainfall decreases when it is subjected to high temperatures, wind, and compaction. Mulch helps the soil retain more water, evaporate less, and suppress weed growth. The application of straw mulch reduced evaporation by about 35%, according to Goodman [29]. Permeable mulching materials come in a wide range of options. Organic mulches are more effective at conserving water and do not obstruct soil water infiltration and retention. The suitable mulch can decrease the frequency of irrigation and, in some cases, completely remove it. Mulch can also assist in shielding trees and plants from drought and winter damage. In semi-arid regions of the world, mulching is a water-saving technique that maintains soil moisture, manages temperature, and lowers soil evaporation [48]. In a rainfed agricultural system, surface mulching is frequently employed as a water-saving technique [212–215].

Water is the scarcest natural resource for the farming system out of all the natural resources. However, it is well known that different plant species have different water needs [216]. Water use efficiency (WUE) in a cropping system is the total biomass or yield produced per unit of water used by the plant or the soil surface [169]. As a result, understanding how to improve WUE in both irrigated and rainfed areas to improve crop quality and yield is essential. Zhou et al. [216] found that mulching improves yield and WUE by reducing evaporation and increasing soil transpiration [217]. Plastic mulch increases WUE by 20–60% and decreases the evaporation rate [201], which improves soil water retention and infiltration or creates a favorable environment for root proliferation or seed germination [218].

In rainfed dryland areas, black plastic mulch could improve soil moisture and WUE, consequently boosting apple yield [219]. Under the Chinese drip irrigation technique, black or transparent plastic could enhance WUE and productivity of potatoes [220]. The black plastic mulch outperformed the other two mulches (white and rice straw) in terms of boosting tomato leaf area index, fruit production, or water productivity while lowering evapotranspiration [221]. The latter was more successful than the degradable film and plastic mulches in reducing evapotranspiration and enhancing the yield or WUE of winter oilseed rape [80]. In rice farming, mulch treatment has been shown to improve water retention and grain yield. According to a study of 36 rice farming sites, covering rice fields with mulch enhanced yields by 18%. Black plastic mulch could boost water productivity, rice yield, and quality while also conserving soil moisture [67,69].

The efficiency of mulch depends on soil properties as well as the climatic conditions of the site. The Egyptian clover mulch was successful in retaining soil water content and promoting crop growth during the summer season, however it did not outperform the black plastic mulch [67,69]. On the other hand, rice husk produced better soil water retention, water utilization, and production benefits for wheat, which is considered a winter crop, by plastic mulch [133]. In water-saving rice mechanisms, the Egyptian clover mulch reduced the number of ineffective tillers or excessive water productivity [67,69].

Various types of straw mulches were all similarly successful in decreasing the rate of water loss from the soil surface, with a 5 cm depth of these mulches minimizing evaporation by 40% [113]. An enhancement in mulch depth to 10 cm increased soil moisture by 10%, while a further boost (to 15 cm) provided no additional benefit [113]. Wheat straw (2–16 t/ha) could improve soil moisture [155]. Black plastic and wheat straw mulches could help cucumber plants recover from drought stress by reducing evaporation [222]. The mulches not only enhanced the cucumber leaf area and the biomass yield but also improved its water usage efficiency. Furthermore, mulching has been shown to improve fruit production and plant nutrient availability [222].

Because of their beneficial effects on photosynthesis and crop yield [223], fruit phytochemical quality [224], and indirect pest protection, photo-selective (PS) mulching films have recently been proposed for use in agriculture [224]. In addition to these beneficial effects, PS mulching films may be able to keep the soil cooler than conventional black mulch due to their high level of reflectivity [225]. In light of this, PS mulching films have the ability to lower crop water needs through two complementary mechanisms: decreasing direct soil evaporation and boosting root efficiency by fostering a favorable microclimate in the root zone [224].

9. Role of Mulching on Crop Production

Most research has focused on the impact of mulches on crop production or yield (Table 6). For example, López-Tolentino et al. [226], in cucumber, and Zhang et al. [227], in maize, found that utilizing black plastic mulch can improve early crop yield. According to Berglund et al. [228], strawberry establishment is more rapid and successful when degradable plastic mulches are used. In crops, it appears that layer mulches have received more research than other forms of mulches. Furthermore, pine bark produced higher output than live sedum mulch in a study on the effects of mulch types on vegetable production in a green roof system [229]. Thermal transmission efficiency might have resulted in better heat conservation under black mulch during the night, a reason for greater morning temperatures compared with midday temperatures under black polythene mulch. Black polythene mulch was also discovered to be better compared with other mulches for vegetables such as lettuce [230], okra, and squash [231] by either raising soil temperature or preserving soil moisture.

Table 6. The impact of mulching on yield and crop production.

Crop	Economic Yield Tons ha^{-1}		% Increase in Yield	References
	Un-Mulched	Mulch		
Pickling cucumber	2.45	4.50	83.7	[70]
Maize	4.18	7.18	71.77	[77]
Brassica napus	3.97	5.90	48.4	[80]
Sesamum indicum	0.21	0.73	16.55	[104]
Apple trees	27.9	34.7	24.4	[117]
Watermelon	22.8	48.3	111.8	[138]
Potato	3.20	5.81	81.5	[144]
Beetroot	2.62	6.42	145	[186]
Tomato	6.02	8.27	27.20	[232]
Chickpea	5.91	7.32	19.26	[233]
Cotton	1.67	2.22	24.77	[234]
Mustard	0.41	0.61	32.78	[235]
Rice	5.39	6.83	21.08	[236]
French beans	12.73	14.10	9.71	[237]
Lentil	0.80	0.89	10.11	[238]
Wheat	5.261	5.863	89.7	[239]
Maize	2.49	4.76	47.68	[240]
Mung beans	1.02	1.36	25.00	[241]
Soybean	1.32	1.57	15.92	[242]

Temperatures in the soil between 16 and 20 °C are necessary for potato tubers to develop properly [243]. The formation of tubers is negatively impacted by dry conditions and temperatures that are higher than ideal. These unfavorable vegetation conditions can lead to malformation of tubers or chain-like growth of new small tubers. A change in tuber quality, particularly a change in the amount of storage substances such as starch, is the next unfavorable consequence of high temperatures [244]. Mulching is one method to address these issues. All over the world, people use organic materials such as compost, straw, and other agricultural waste as mulch. A readily available and useful mulch material is cereal straw. A simple application, a drop in soil temperature, a reduction in daytime temperature fluctuations, and an increase in soil moisture are the primary advantages of straw mulch treatment [245–247]. The effects of various mulches on a variety of plants, including eggplant [248] and tomato [249], have been studied. Abdrabbo et al. [24] stated that the plant response to the plastic mulch depends on the plant cultivar, the materials used, and the environmental conditions. Mulch application improved the water status of sweet cherry crops, according to Yin et al. [249]. Mulches also create the ideal environment for root growth, which promotes plant growth and productivity [103].

10. Strategies for Optimum Water Usage in Urban Green Spaces and Landscaping

Trees, flowers, turfgrass, and other plants cover urban green spaces, which are open spaces in the city with natural or manufactured arenas covered by turfgrass, flowers, trees, or other plants [250]. The value of green spaces to minimize air pollution, improve human health, reduce violence in society, moderate urban heat islands, minimize urban runoff by minimizing hard surfaces, and regulate soil erosion in urban areas has been widely addressed [251]. The global standard for green spaces per capita is between 5 and 50 m^2. In Iran, this threshold is set at 30 m^2. However, none of Iran's major cities have the resources to create green spaces that meet international standards. One of the biggest limiting issues in building green areas in Iran is a lack of water resources [252]. Turfgrasses are an important part of creating urban green zones. Turfgrass has covered more than 20 million hectares of public spaces around the world (sports fields and parks, for example) [253]. Water makes up roughly 80% of turfgrass weight; obviously, this varies depending on the type or species of lawn, the density or placement of lawn plantings, and the climate. Most of the water is found in turfgrass species' stems, leaves, and roots, in that order. Reduced watering causes wilting and eventually death of turfgrass plants in various areas. When describing the function of water in turfgrass physiology, Ansari and Azimi [253] added that energy, carbon dioxide, and water are required for photosynthetic processes in lawns. Living cells use water as a solvent or a catalyst in their metabolic processes. Temperature variations in the protoplasm can be managed with the help of the specific heat capacity of the water in plant cells. This characteristic in turn helps to protect the grass from unexpected temperature changes. Water is crucial for cell inflammation and keeping the stomata open, which allows for gas exchange. The resistance of grasses to footing can also be increased by cellular inflammation.

The conservation of greenbelts is the most everlastingly fruitful and basic need today to preserve the ecological landscape, open green space, green gardens, and to save green land on the urban fringes [254]. In urban landscaping, they are now planning to shift toward low-management landscapes such as low-water-using landscapes [255], either by altering the method or the system of landscaping [256,257] or xeriscaping [258], which includes mulching as one of its principles [241]. Despite their high upkeep requirements, decorative flower beds add beauty and color to urban landscapes, making it difficult to persuade people to remove them in favor of low-maintenance landscaping [259,260]. A strategy to combine mulch with bedding flowers to achieve lower inputs, including maintenance and water resources, should be discussed in light of the significance of bedding plants in urban landscapes, as shown in Figure 8. There has not been a lot of research done in this field, despite the fact that the work of Pakdel [261] can be explored. Pakdel [261] examined the growth of *Tagetes patula*, *Platanus orientalis*, and *Rosa masquerade* using four different types of mulch: gravel, sawdust, wood chips, and municipal compost.

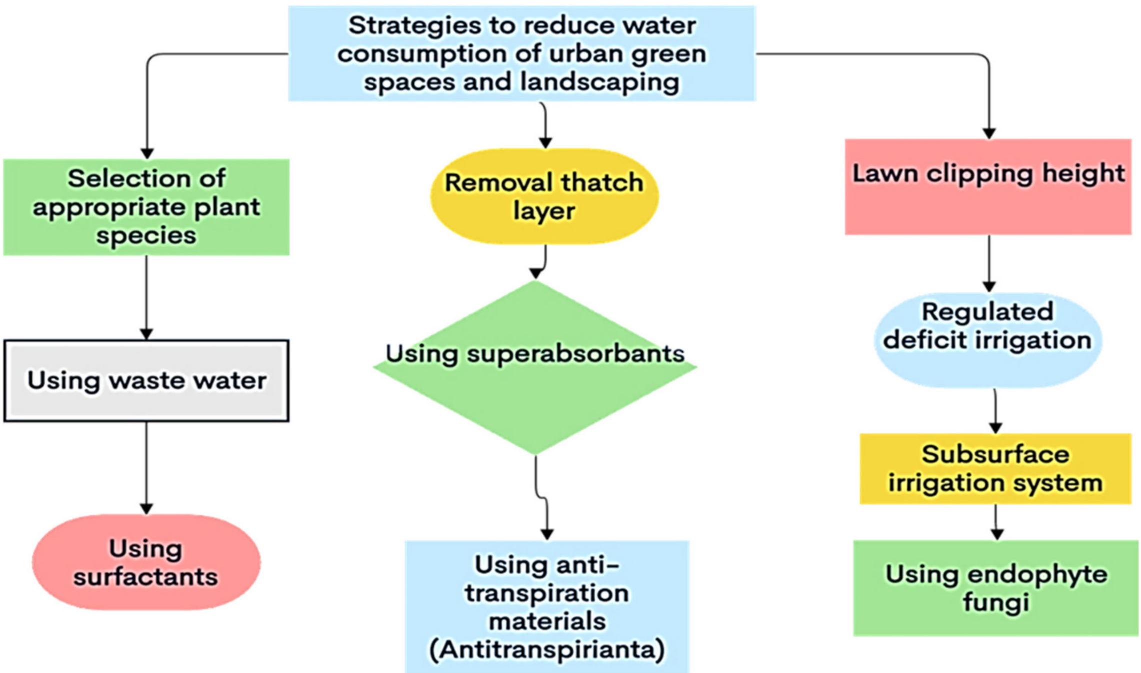

Figure 8. Schematic diagram of strategic water consumption methods.

Many bedding plants have different growing conditions. Those with a tolerance to cool weather can include *Lobularia maritima*, *Antirrhinum* sp., and *Calendula* sp., while others, such as *Catharanthus roseus* and *Celosia* sp., tolerate and flourish in warmer weather conditions [259]. It has been demonstrated that mulches have the ability to mitigate adverse weather conditions, which in turn could extend the survival and performance of a large variety of bedding plants. Likewise, mulches improve water retention capacity in the soil and weed control, which reduces the maintenance requirements of bedding plants in ornamental landscapes. However, despite these assumptions, evidence on the performance of bedding plants in the presence of mulch continues to be limited, and this research was conducted to fill in this important research gap. *Zinnia elegans* is recognized as a commonly utilized drought-tolerant bedding plant in ornamental landscaping in many places around the world. However, the performance of this plant species in conjunction with mulches as a soil cover has been less investigated. Therefore, in this study, the effect and evaluation of four mulch types on the growth or morpho-physiological traits of *Zinnia elegans* were evaluated.

Mulches can help with root establishment and plant performance because their higher water retention stimulates roots to expand or establish beyond the trunk compared with bare soil roots. As a result, plants with stronger root systems establish themselves more quickly. Organic mulches promote root development more than bare soil [262–265].

11. Conclusions

The hydrothermal regime of the soil is affected by various mulching materials that change soil moisture and temperature. These changes in the soil environment have an impact on soil microbiology, which is critical for creating a suitable environment for plant growth. Mulching materials have a substantial impact on water conservation in agriculture by altering the microclimate and lowering the soil evaporation. However, each form of mulch has its own set of advantages and disadvantages, making it appropriate for some conditions but not for others. The availability, durability, or pricing of materials are all key factors to consider when choosing mulching materials. However, minimizing the detrimental effects of mulching should be the main priority. The soil surface is physically covered with mulches such as crop straw, plastic film, sand, and gravel that insulate the soil surface from the atmosphere. Recently, there has been an increase in the use of these methods. One of the many benefits of mulching the soil surface is that it reduces soil evaporation or erosion brought on by wind or water. Straw mulch moderates soil temperatures in the hot summer by preventing topsoil temperatures from reaching levels that inhibit plant growth. In the early spring, when soil temperatures are low, plastic mulch encourages plant growth by increasing the topsoil temperature. As a result, farmers will employ this unique technology in the future to help them preserve moisture, eliminate weeds, and greatly increase soil health while producing more. This will also contribute significantly to the world's long-term food security.

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