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Mulching strategies and the significance of mulching in improving soil fertility and soil physical properties: A review

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Abstract: The population growth has increased the demands on food and resources like land and water, affecting crop productivity and yields in arid and semi-arid areas. Approximately 50 % of the land area on Earth is made up of arid and semi-arid areas. Optimizing agricultural field management techniques is crucial due to limited rainfall, but intensive cultural techniques like irrigation, weeding, fertilizers, and stress prevention make vegetable production expensive. This review has examined 118 recent published studies on mulching materials and procedures in vegetable farming, focusing on their impact on soil and environment. It suggests mulch can be a viable alternative to traditional methods, reducing irrigation and chemical inputs for weed control. The review also discusses the effects of organic mulching on soil temperature, moisture content, organic matter content, soil microorganisms, pest and insect control, and plant yield. The aim is to conduct a comparative analysis of the advantages and disadvantages of mulches in vegetable farming. Mulch techniques can enhance vegetable production by reducing cultivation costs, improving soil properties like temperature regulation, moisture, weed suppression, and structure, and providing habitat for insects and earthworms, thereby improving soil biological activities.

Key words: organic and inorganic mulches, soil properties, pros and cons of mulches, mulching and soil fertility

Načini mulčenja in pomen mulčenja pri izboljšanju rodovitnosti tal in njihovih fizikalnih lastnosti: pregled.

Izvleček: Rast človeške populacije je povečala zahteve po hrani in drugih virih kot sta obdelovalna zemlja in voda, kar je vplivalo na produktivnost gojenih rastlin in njihove pridelke v sušnih in polsušnih območjih. Na Zemlji je približno 50 % površin sušnih in polsušnih. Optimizacija tehnik upravljanja kmetijskih zemljišč je odločilna zaradi omejenih padavin, a intenzivni načini tehnik v kmetijstvu kot so namakanje, odstranjevanje plevelov, gnojenje in preprečevanje stresa delajo pridelavo zelenjave drago. V tem pregledu je bilo pregledanih 118 v zadnjem času objavljenih raziskav o načinih in pripomočkih mulčenja pri pridelavi zelenjave, ki se osredotočajo o vplivih na tla in okolje. Izsledki nakazujejo, da je mulčenje primerna alternativa tradicionalnim metodam, ker zmanjšuje potrebe po namakanju in vnosu kemikalij za zatiranje plevelov. Pregled komentira tudi učinke organskega mulčenja na temperaturo tal, vsebnost vode in organskih snovi v tleh, vpliv na mikroorganizme, uravnavanje škodljivcev in vpliv na pridelek. Namen je izvesti primerjalno analizo prednosti in slabostio mulčenaj pri pridelovanju zelenjave. Tehnike mulčenja lahko pospešijo pridelavo zelenjave z zmanševanjem stroškov pridelave, z izboljševanjem latnosti tal kot sta uravnavanje temperature in vlažnosti in z zatiranjem plevelnih združb. Tehnike mulčenja lahko pospešijo pridelavo zelenjave in zmanjšajo stroške, izboljšajo lastnosti tal kot so uravnavanje temperature in vlažnosti, zatiranje plevelov in zagotavljanje primernih habitatov za žuželke in deževnike in s tem izboljšanje biološke aktivnosti tal.

Ključne besede: organsko in anorgansko mulčenje, lastnosti tal, prednosti in slabosti mulčenja, mulčenje in rodovitnost tal

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1 BACKGROUND

Due to current globalization and health consciousness, there is a greater need than ever for upright horticultural crops, farmers are being forced to produce more and high-quality fruits and vegetables to survive in the global market due to the growing demand for these products, and market competition (Ranjan et al., 2017; Yaseen et al., 2023). The importance of managing soil as a non-renewable resource to promote sustainable development is becoming more widely acknowledged the health of the soil determines the productivity of arable systems farm management techniques, such as the use of pesticides, fertilizers, mulching, and manure, can have an impact on soil health and sustainable development (Ngosong et al., 2019).

Additionally, rapid urbanization and industrialization have raised global temperatures, upsetting the balance of agro-ecological systems all over the world for sustainable food production (Iqbal et al., 2020). The new environmentally friendly agricultural techniques are therefore required by lowering soil evaporation, preserving moisture, regulating soil temperature, inhibiting weed growth, and enhancing microbial activity, also mulching can also be affective. Mulching is the process of applying different covering materials to the soil's surface to increase crop yield, reduce weed growth and moisture loss (Iqbal et al., 2020). The microclimate surrounding a plant is directly influenced by mulching materials, and this can have beneficial or detrimental effects on the physiological metabolism of the plant (Kader et al., 2017).

Various mulching materials can be used for different agricultural and horticultural crop in different climates. Mulch can be a ground cover made of live plants, loose organic and inorganic matter particles scattered over the soil, or sheets of natural or artificial materials applied to the soil's surface. The primary benefits of using organic mulches are the organic matter and nutrients they provide for soil organisms as well as plants. The primary functions of organic mulches are to enhance crop plant growth conditions and shield the soil's surface from adverse influences. Although organic mulches are biodegradable, a temporary decrease in soil mineral nitrogen may occur during the decomposition process (Ranjan et al., 2017; Yaseen and Takacs-Hajos, 2022).

The application of mulches improves soil structure, provides organic matter, lessens the effects of wind and, water erosion, and cools the soil during the summer, all of which increase crop yields (Kosterna, 2014a). Mulching increases yield more when it comes to species that are cultivated for early harvest (Qin et al., 2015). The main reasons for increased plant growth in response to mulching have been identified as soil moisture conservation, improving microbial activities, soil temperature regulation, and decreased competition from turf and other plants (Iqbal et al., 2020).

Conversely, synthetic mulches can be applied mechanically and offer a strong defence against the majority of weeds; however, they need to be taken out at the end of the growing season. Furthermore, crop root zone penetration of rainfall or overhead irrigation can be impeded by non-porous plastic mulches. While most of the water runs off the mulch into alleys and may not reach crop roots, some of it does run into planting holes. The labour-intensive end-of-season removal, the production of non-biodegradable waste, and the lack of organic matter or nutrients added to the soil are additional drawbacks of synthetic mulches (Kosterna, 2014b). In ecological farming, it is advised that soil be covered with composts, chopped straw, and other organic residues to supply crops with nutrients, particularly nitrogen (Bajoriene et al., 2013).

The purpose of this study is to look into how important is mulching in increasing crop productivity and improving soil. In particular, it compares organic and non-organic techniques in an effort to highlight the advantages of mulching in vegetable production.

2 MAIN TEXT

2.1 ADVANTAGES OF MULCHING PROCEDURE INTEGRATION WITH SOIL

In various mulching techniques, it was discovered that adding organic mulch to the soil increases its organic matter (Bajoriene et al., 2013). Liu et al. (2021b) stated that among the used materials for mulching (organic and inorganic materials), straw mulching and dual mulching of the ridge (film) and furrow (straw) improved soil organic carbon (SOC) storage due to straw decomposition in the soil. Using a variety of materials for mulching has the potential to increase soil moisture, decrease evaporation losses, and suppress weed growth. Various mulching techniques showed notable effects on the quantity, quality, and growth of different crops (Iqbal et al., 2020). There are inconsistencies regarding mulching's effectiveness because various scientists have reported negative effects from the practice. Plastic film mulching, for example, contributes to an increase in net global warming potential (GWP) and greenhouse gas emissions. (gu Lee et al., 2022). Caboň et al. (2021) also discovered that mulching has a negative impact on vascular plant diversity due to competition and changes in plant reproductivity. Additionally, mulching reduced fungal diversity of mac-

Table 1: Benefits of organic mulches for soil properties.

Types of mulch	Benefits	References
Straw mulch	Water productivity rises while water usage falls.	Jat et al. (2015)
	Decreases the Colorado potato beetle's insect pest invasion and late blight in potatoes	Finckh et al. (2015)
	There are improvements in rice yield, grain quality, and recovery.	Jabran et al. (2015)
	Less runoff or erosion, better soil water management, and temperature control	Montenegro et al. (2013)
Compost mulching	Mulching and organic composting workable ways to lessen the detrimental effects of water stress and save irrigation water by 15 %.	Abd El-Mageed et al. (2018)
Newspaper	Lower soil temperature keep moisture in soil	Haapala et al. (2014b)
Sawdust	Sawdust, whereas the control preserved moisture and generated comparatively less 'Savoy' baby cabbage.	Masarirambi et al. (2013)

Here are some advantages of mulching strategies on soil content and soil microbiological improvements:

ro-fungi collectively, known as CHEGD fungi, in semi-natural grasslands of Europe due to the decomposition of plant litter by saprotrophic organisms, which causes changes in soil properties. Despite the fact that mulches have many advantages over these drawbacks, the disadvantages reported by various scientists are not as risky in actual field conditions (Iqbal et al., 2020). Nonetheless, the literature suggests that mulches are an inexpensive way to control weed growth and maintain a significant level of soil moisture content (Iqbal et al., 2020). One of the mulch's biggest benefits is that it adds organic matter to the soil, particularly nutrient-rich mulch, which has a positive impact on the soil's chemical and physical characteristics and ultimately, crop productivity. The amount of chemical plant protection and mineral fertilisers applied can be decreased thanks to this management system. Numerous studies have shown that keeping organic matter on the soil's surface promotes plant growth and development and increases vegetable yield (Kosterna, 2014b; NING et al., 2017). From an ecological standpoint, mulching offers numerous benefits. These benefits are particularly significant in places where water is scarce. Mulching has many advantages as it is shown in Table 1.

2.1.1 Effect of mulch on soil moisture

Since the 20th century, conserving water and soil has become a significant issue to the human life (Mekonnen et al., 2015). The need for agricultural land is growing as the world's population continues to rise, and soil and water losses are getting worse. This is especially true in developing countries (Thomaz and Luiz, 2012). Based on the reports by FAO (2015); IPCC (2019), the quarter of the word's agricultural land has been degraded in the last few decades. Farmers can actively maintain the residual soil health by farming in a healthy manner; mulching is one such method; however, in order to preserve the ecosystem, this requires direct support from national and international governments.

By absorbing and using rainfall, mulching can significantly alter the growing conditions of crops and lower the likelihood of crop failure in the field, particularly in arid or semi-arid areas (Wang et al., 2021). The soil's conversion to barren land due to moisture loss is caused by numerous abiotic factors. The main purpose of mulches in the cultivation of vegetable crops is to protect the soil surface from the influence of unfavourable factors and to improve the growing conditions for the crop plants (Iqbal et al., 2020; van Donk et al., 2012). Mulches also help maintain stable soil temperature, increase soil porosity, and suppress weed growth, reducing evapora-

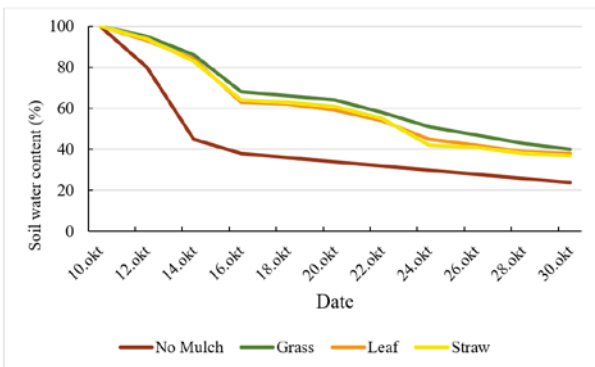

Figure 1: The effect of the three different mulch types on the soil water content. Source: McMillen (2013)

tion and conserve soil moisture and a significantly slow down soil water loss (Bajoriene et al., 2013; Kader et al., 2017). Consequently, a more consistent and elevated soil water regime is upheld, thereby decreasing the frequency of irrigation (Sajid et al., 2013). Narayan et al. (2017) have demonstrated that black double coated polythene mulch could significantly retain soil moisture by 16.74 % when compared to white double coated, black single coated inorganic mulch, and organic straw paddy mulch, this was because they increase retention and percolation while decreasing evaporation see (Figure 1).

Organic mulches have an impact on the soil water cycle. The exposed soil is more susceptible to the effects of rain, wind, and soil radiation. Mulches decrease rainfall water loses, which increases the soil's ability to absorb the precipitation water (Brunetti, 2014). Living mulch can grow alongside crops year-round, protect the soil layer over time with good coverage, and contribute significantly to soil and water conservation (Donjadee and Tingsanchali, 2016; Fracchiolla et al., 2020). Yin et al. (2016) have discovered that double mulching of organic and inorganic materials improves moisture retention in the soil by 4.6 %. Soil covered with plastic mulches can reduce evaporation and protect soil moisture in salt-affected reclamation soils. (Chen et al., 2023).

Table 2: Recent research works showing the effect the mulching types on soil temperature on different vegetables.

Mulch type	Materials	Effect on soil temperature	Reference
Organic	Biodegradable (eco-benign plastic)	Biodegradable mulches significantly reduced temperature by 2.04 °C-3.52 °C and 0.52 °C-0.88 °C ($p < 0.050$) throughout seedling and full growth periods, compared to plastic mulch.	Jia et al. (2020)
	Mushroom compost	maintained a higher temperature on the soil surface and a depth of 15 cm	Guo and Liu (2022), Yordanova and Gerasimova (2015)
	Barley straw	significantly increasing it in winter and then significantly decreasing it in spring and summer as well as regulating soil temperature	Ding et al. (2017), Song et al. (2024)
	Maize straw	lowest temperature was observed compared to plastic film, biodegradable film mulches	Li et al. (2013)
	Grass and pine needle mulch,	Helps regulating soil hydrothermal regimes	Sharma et al. (2024)
	Rice straw mulch	In comparison to without mulch (Mo), cover crops Arachis pintoi (Ma), rice straw mulch (Mj), and black silver plastic mulch (Mp), the rice straw mulch with a combination of organic and inorganic fertiliser produced the lowest soil temperature of 17.82 ^{0}C.	Nurzadeh Namaghi et al. (2018)
Inorganic	Black double coated, white double coated and black single coated polythene	Increased soil temperature was caused by the absorbing of solar radiation by plastic mulches and the transmission of heat into the soil deep of the first 20 cm.	Torres-Olivar et al. (2018), Gheshm and Brown (2020)
	Clear polyethylene mulch	The highest average temperatures were found for the clear mulch compared to blue plastic mulch.	Jia et al. (2020), Tesfaye et al. (2016), Pramanik et al. (2015)
	Coloured plastic mulches (silver, yellow and black)	Under greenhouse conditions, soil temperature at 20 cm depth decreased by 2-3 °C in summer and increased by 3–5 °Cin winter.	Laulina and Hasan (2018)
	Polythene film	increased the soil temperature by about 6 °C at 5 cm depth and by 4 °C and 1 °C at 10 cm depth	Gu et al. (2020), Yang et al. (2020)
	Orange plastic mulch (250 μm)	Soil temperature was increased compared to no mulch as the control, maize straw mulch, Grass mulch (Eragrostis lehmanniana Nees)	Malamba (2021)

2.1.2 Effect of mulch on soil temperature

Mulch is a type of soil cover that helps to keep the soil at a consistent temperature and humidity, prevent weed growth, and reduce soil erosion (Dvořák et al., 2012). Mulches are known to modify microclimatic conditions by influencing soil temperature through the transmission of light energy (Hu et al., 2011). Modifies the microclimate surrounding the grown plants, assisting it in adapting to climate change (Kasirajan and Ngouajio, 2012). Table 2 lists the most recent research publications on the effect of different mulch materials on soil temperature in growing plants.

2.1.3 Effect of mulch on improving soil organic matter

Due to its ability to restore degraded soils and provide the most basic energy substrate, soil organic matter (SOM) is essential to crop production (Guimarães et al., 2013). The primary benefits of organic mulches are their organic matter content and ability to supply nutrients to soil organisms as well as plants, the interplay of chemical, physical, and biological soil properties result in soil quality. According to a study by Hwang et al. (2020), inorganic mulch material (plastic film (PFM)) caused soil organic carbon (SOC) losses of 8–48 %, whereas organic mulch (green manure (GM)) could dramatically decrease SOC losses by 33-59 %. Additionally, after six years of applying organic mulch to the soil, SOM, soil fertility, and soil physicochemical properties improved. Cellulase, invertase, and dehydrogenase activities in the organic mulch-covered soil were 17.46 %, 78.98 %, and 283.19 % higher than those in the lawn, accordingly, at a depth of 0–20 cm (Liu et al., 2024).

The degree of soil alteration in both natural and agroecosystems can be assessed using specific soil properties, such as highlighted enzyme activities. Soil enzymes have the potential to function as early indicators of biological changes because they may react to modifications in soil management more quickly than other soil variables (Naorem et al., 2021). An essential function of soil enzymes is to catalyse processes related to the decomposition of organic matter and the cycling of nutrients (Jodaugienė et al., 2010). Additionally, mulch can enhance the quality of the soil. Short-term mulching can effectively reduce runoff and sedimentation, and long-term mulching can greatly increase the organic matter in the soil as a result of the mulching materials‘ deterioration, matter, and accessible nutrients (Jiménez et al., 2016). Fracchiolla et al. (2020) have reported that the mineral content in the soil covered with living mulch was significantly improved, such elements like Mg and Fe, whereas a reduction of Na, K, and Ca was observed. In addition to preventing weed growth, applying organic mulch to soils can improve soil fertility and supply plants with the necessary mineral elements (Mulumba and Lal, 2008).

Furthermore, a long-term nitrogen fertigation yield study by Ding et al. (2022) found that mulching with PFM reduced nitrogen fertiliser leaching, resulting in increased root biomass, SOC by 26 %, soil enzyme activities, and SOC mineralisation rates due to the diurnal internal water cycle within the mulch.

2.1.4 Effect of mulch on weed control suppression

Covering the soil with mulches helps prevent weed growth and weed competition. The mechanisms through which living mulches suppress weeds include competition for light and subsurface resources, and shading, which prevents weed seeds from germinating and allelopathy (Médiène et al., 2011; Petit et al., 2018). Mulching impact can be determined by a variety of parameters, including mulch material type, transparency, and thickness. van Donk et al. (2012) have measured a significant lower weed growth and number in the soils covered with wood chip mulch thicknesses of 5 and 10 cm compared to the same mulch but lower layer thickness at 0 and 2.5 cm. It is also found that when comparing mulch types, the best summer annual eclipta (*Eclipta prostrata* (L.) L.) weed control was achieved with hardwood at about 5 cm depth (Saha et al., 2019). Furthermore, Dragumilo et al. (2023) investigated organic mulching materials (sawdust of acacia and dry pine needles) and inorganic mulching materials (silver-brown and black „agrotextile“ film) to determine their impact on weed biomass and dry mass. The results show that inorganic materials had a significant better reduction of weed biomass using silver-brown film by 96.3-100 %, followed by black „agrotextile“ film at 74.6-95.9 %. Additionally, synthetic materials were able

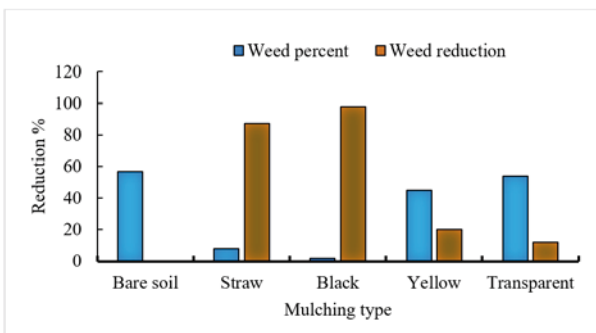

Figure 2: The typical percentage of weed growth for each treatment. **Source:** El-Shaih and Fouda (2008)

to substantially decrease total dry biomass by 84.6-100 %, while organic materials by 28.5-81.4 %.

In recent years, interest in living mulches has again increased because living mulch systems can contribute to agricultural sustainability through reducing herbicide inputs and improved soil health (Bartel et al., 2020). Sharma et al. (2024) have discovered that black mulch and mulch mat treatments provided 100 % weed control efficiency. Spreading mulch on the soil's surface penetration of light into soil, which slows the germination of small-seeded weed species. According to a research study by Mohtisham et al. (2013), there was no difference in the types of mulch used when comparing unmatched to mulched areas in fifteen districts; nevertheless, there was a noticeable difference in the number of weeds treated with bare soil. DeVetter et al. (2015) found straw and living mulches surpassed cultivation and herbicides in terms of weed control and reduction. Conversely, Dvorak et al. (2015) have found no consistent influence on weeds' aboveground biomass of potato field covered with grass mulch. In contrast, a research study discovered that prior to cabbage planting, oat and phacelia mulches drastically reduced fresh biomass and weed population (Franczuk et al., 2010). So that, many factors can influence of the effectiveness of mulches on weed control including mulch types, thickness, colour, the plant growth cycle and environmental factors. Narayan et al. (2017) noticed that mulching with hardwood chips recorded a better result in weed suppressing compared to pine bark and pine straw mulching. Figure 2 shows the percentage of weed growth for each treatment under black film, the percentage of weed was reduced to the lowest of 9 % and to the maximum of 98 % under transparent film. Because of the black film's significant reducing of light penetration into the soil, weed seedlings cannot grow under the mulch.

2.1.5 Influence of mulch on soil pest problem

Table 3: Different types of mulch effect of different insects and pathogens.

Type of mulch	Type of plant	Type of insect or pathogens	Effect	Source
Living mulch Red clover	Cabbage	Turnip root fly, *Delia floralis* (Fallén, 1824))	Decrease lying egg	Björkman et al. (2010)
Straw mulching	Kale (Brassicaceae)	*Myzus persicae* ( )	Decrease in population, and provide a better refuge for the natural enemies	Silva-Filho et al. (2014), Mochiah and Baidoo (2012)
plastic mulch	Okra (*Abelmoschus esculentus* (L.) Moench)	Beetle flea Podagrica species, roller of cotton leaves Cotton strainer with Notarcha derogate Whitefly, *Dysdercus* spp. *Oedaleus nigeriensis* Uvarov, 1926, the Nigerian grasshopper, and *Bemisia tabaci* (Gennadius, 1889)	Decreased insect pests and generated stronger yields	Ojiako et al. (2018)
Cowpea live mulch	Pepper (*Capsicum annuum* L.)	Aphids (*Aphis gossypii* Glover , 1877), thrips (*Thrips tabac*i Lindeman, 1889) and white flies (Bemisia tabaci (Genn., 1889)),	suppressing pest populations	Mochiah and Baidoo (2012)
Living mulch	Eggplant (*Solanum melongena* L.)	Colorado potato beetle, *Leptinotarsa decemlineata* Say, 1824 (Say): Flea beetles, Epitrix spp.	In comparison to the monoculture plots, fewer Colorado potato beetle adults, larvae, and eggs were discovered in the interplanted plots.	Hooks et al. (2013)
straw, walnut leaves, mixed leaves, compost	Potato tubers (*Solanum tuberosum* L.)	Potato tuber damage caused by soil-dwelling pests and soil-borne pathogens	mulch thickness (20 cm or more) can reduce damaging potato tubers caused by pathogens (e.g. Fusarium species).	Südiné Fehér and Zalai (2024)
Green plastic mulch increased in the planting and covered row	(tomato, cucumber, watermelon, strawberry, and vine)	the populations of fungevorous nematodes (*Aphelenchus* sp.) and Dorylaimida (omnivore nematodes) differed less between the soil mulching	Long-term growing of blueberries using green 100 % high-density polyethylene mulch did not significantly affect the presence of nematodes or the amount of Rhabditida (bacterial feeders).	Pedra et al. (2024)

Vegetables are extremely susceptible to pest and insect damage. It has been demonstrated that the distribution of pests in agriculture is significantly influenced by straw mulching (Phophi and Mafongoya, 2017). Organic and inorganic materials used as mulch have varying effects on pest populations in the soil. For instance, mulching straw increases the number of insects (Ma et al., 2021). Rice-straw mulching promotes natural enemies, while black polythene inhibits insect pest populations (Kumaratenna et al., 2022). In addition to other materials, organic mulches such peel and rice straw alter temperature and UV rays, which reduces the infestation of aphids (Silva-Filho et al., 2014). Plastic mulch is advised for optimal crop production and the management of *Abelmoschus esculentus* (L.) Moench insect pests (Ojiako et al., 2018). While straw mulch may offer a better haven for the natural enemies and is still a suggested choice for pest management in pepper production, cowpea mulch may be more successful at suppressing pest populations (Mochiah and Baidoo, 2012). Mulching can minimise pest population and crop damage by encouraging the activity of natural enemies in the soil and improving the micro-environment for pest disruption with natural enemy activity, and other reasons (Gill et al., 2011; Thomson and Hoffmann, 2007).

Table 3 shows some examples of how using various mulch types affects certain insects:

2.1.6 Influence of mulching on soil microorganisms

Mulching can change the biological content of the soil, reducing its sustainability and quality, and even causing soil alkalization, which can harm plants (Ni et al., 2016). Unlike other mulching methods, organic mulching is primarily made from plant residues, which have been shown to improve soil health (Kader et al., 2017). A research study by Sharma et al. (2024) indicated that grass and pine mulch had a substantial impact on total viable count, microbial activity, and microbial biomass carbon. Furthermore, mulching can increase the richness of the soil microecosystem (Kolota and Adamczewska-Sowinska, 2013). Tian et al. (2015) discovered that soil microorganisms greatly altered agroecosystem structure and nutrient cycling as soil fertility increased. Soil microorganisms are crucial to the soil's ability to maintain fertility and cycle nutrients, both of which are important for agroecosystem resilience and productivity (Liu et al., 2019; Yeboah et al., 2016).

Moreover, the movement of matter and energy within the soil ecosystem was facilitated by the diversity of soil microorganisms (Mori et al., 2018). The microbial community may change as a result of changes in the physicochemical characteristics of the soil during the mulching process (Qian et al., 2018). In addition to helping forecast changes in soil functions, soil microbial diversity and biomass showed sensitivity to changes in the physicochemical properties and management of the soil (Romaniuk et al., 2011). To take effective action to increase soil fertility and, productivity and guarantee the sustainable development of soil ecosystems, it would be beneficial to investigate the diversity and composition of microbial communities in soils that are being mulched.

Inorganic mulches may have a negative influence on soil microorganism activities. Pedra et al. (2024) have demonstrated that green plastic mulch was dramatically lower microbial activity in the planting row when compared to bare soil without mulching.

2.1.7 Influence of mulching on earthworm biomass

Earthworms have been identified as indications of soil biological health. Earthworms are typical ecosystem engineers because they significantly influence the physical qualities of soil in a variety of ways. Many research investigations indicate that mulching can boost biomass and population improvement, primarily with organic or biological mulches. Earthworms not only improve soil physical properties but also can improve soil water retention and reduce evaporation in lateritic red soil (Liu et al., 2021a). On the other hand, a 14-year study by Pelosi et al. (2015) examined organic and living mulch farming systems, and they discovered that organic and living mulch cropping systems had 1.5 and 2.3 times more earthworms than conventional systems. Radics et al. (2022) indicates that whereas irrigation greatly reduced earthworm biomass and abundance in the summer, organic mulching (made from wheat straw) significantly enhanced it.

Jodaugienė et al. (2010) have also indicate the activity of soil enzymes was not significantly affected by the thickness of the mulch layer, but the density and biomass

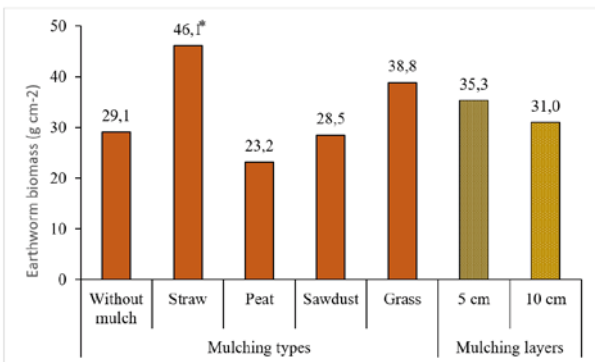

Figure 3: The influence of organic mulches and different thickness of mulch layer on the earthworm biomass. Source: Jodaugienė et al. (2010)

of earthworms were positively impacted by mulches made of grass and straw (Figure 3.). According to the findings, grass or straw mulch creates and maintains favourable conditions for earthworms (Jodaugienė et al., 2010).

2.2 TYPE OF MULCHES

2.2.1 Organic mulch

Natural plant or animal matters are used to make organic mulches which can decompose naturally. Applying organic mulch as soon as the crop germinates or when the vegetable seedlings are transplanted will maximize its benefits on yield and ecological surrounding the plant (Iqbal et al., 2020). In addition to reducing nitrate leaching, organic mulches also improve the physical properties of soil, stimulate biological activity, maintain the nitrogen cycle in balance, supply organic matter, regulate temperature and water retention, and lessen erosion (El-Beltagi et al., 2022). Applying natural ingredients to crops requires a lot of work and is challenging. Due to financial and practical constraints, the use of organic mulch in horticultural crop production has been limited, with very little large-scale commercial application (Wang et al., 2014). Organic mulch has the potential to control and enhance the soil's chemical, biological, and physical characteristics (Xu et al., 2022). It has been discovered that mulching with organic materials has numerous benefits, including reducing soil erosion, boosting nutrient cycling, improving biological processes and crop yield (Korkanç and Şahin, 2021; Ranjan et al., 2017).

Millions of metric tons of organic materials are sadly wasted annually in the Kurdistan region of northern Iraq due to a lack of organic businesses and recycling companies. Mulching is done solely for research purposes, using very little organic material. After use, paper mulches decompose organically and become incorporated into the soil (Haapala et al., 2014b). The use of organic mulching in organic farming has several goals, including improving crop productivity, encouraging sustainable farming methods, and strengthening soil health. In brief, using organic mulching techniques in organic farming is a comprehensive and sustainable strategy. Long-term, it improves the resilience and general health of the farming ecosystem in addition to increasing crop productivity. Mulches can be alive, synthetic, dead, organic, non-organic, biodegradable, or neither. They can also take on many forms and contents (Gul et al., 2022). In this section we will focus more on organic and non-organic mulches.

2.2.2 The most commonly used ingredients or components for organic mulching

Straw or crop remnants are easily accessible after harvest. Straw mulch is an easily applied and lightweight material. These days, field mulch made of paddy straw is widely used because it enhances crop cultivation conditions. However, using straw as mulch can lead to several problems. Because straw mulches are highly flammable and contain grain seeds that may germinate and reduce soil nitrogen levels as they decompose, they must be replaced annually (Goodman, 2020).

Tree bark is another material that is widely used as mulch, particularly in gardens and small places. Bark mulches work well because they retain moisture longer and give the crop more time to get water. It is frequently applied to vegetation and landscaping. However, it shouldn't be used in vegetable fields due to its acidity (Iqbal et al., 2020). However, this mulch is suitable for covering the paths that run between the beds (Bantle et al., 2014). They are two types of bark clipping sources which can be used as mulch (hardwood and softwood). The paper and lumber industries produce hardwood bark clipping, which comes in a variety of sizes from chips to larger nuggets. It is primarily utilized close to trees and shrubs. Bark comes in both naturally occurring and coloured varieties. Typically, coloured varieties are made of a combination of non-natural peroxides and recycled wood waste. Although hardwood bark clippings are more nutrient-dense than soft wood, they are not always easily accessible (Prem et al., 2020). Whereas, a softwood bark is a byproduct of the paper and wood industries. Pine bark is a typical example, and it's often used beneath big trees and shrubs. These barks come in a variety of sizes and are typically applied to a depth of two to four inches (Ranjan et al., 2017).

Wood chips are made from a variety of tree species and reprocessed wood. Wood chip mulches may limit the amount of soil nitrogen available for plant absorption during their decomposition because of their high C: N ratio (Bantle et al., 2014).

Sawdust in areas where sawdust is easily accessible, it is widely used mulch. It is discovered while doing wood finishing processes. With only half the nutrients of straw, it has a lower nutritional value. Because of the high C: N ratio, the breakdown occurs slowly. Because of its breakdown, the soil faces the nitrogen deficiency which later requiring frequent fertilizer application. Low soil pH shouldn't be used because of its acidic nature. Having said that, it does retain moisture for a long time (Tan et al., 2016).

Compost easily made at home from a variety of waste materials, including leaves, grass, straw, and plant

wastes, compost is a great mulch and soil conditioner. The availability and use of compost in agriculture have long been practiced. It increases the soil qualities and carbon content, which strengthens the soil's ability to hold water and promotes soil health. However, compost is not suggested to be used in vegetable fields due to its higher N content because of the increased likelihood of weed growth (Sofy et al., 2022).

Using newspaper mulch to suppress the germination of last season's fallen weed seeds is an inexpensive method of controlling weed growth. The layers of newspaper biodegrade into the soil rapidly. Newspaper breaks down over time, making it a better material Compare with organic mulch instead of plastic. It takes less time and is less costly (Haapala et al., 2014a).

Because leaves are abundant and easily accessible, they create excellent mulch ((Ranjan et al., 2017). The main issue with using leaves as mulch is that they are so light that they can be blown away even at low wind speeds. On the other hand, they are beneficial for keeping dormant plants warm and aiding in germination throughout the winter (Patil Shirish et al., 2013). In order to mitigate these issues, materials such as bark, stone, or any other substance that can lower wind speed should be used (Patil Shirish et al., 2013).

2.2.3 The most commonly used ingredients or components for inorganic mulching

Mulches composed of inorganic materials that are devoid of organic matter are called inorganic mulches. Stones and gravels, polyethylene films, landscaping materials, and rubbers are examples of inorganic mulches (Prem et al., 2020). Such as plastic mulch, make up the majority of mulch used in industrial crop cultivation. The plastics used as mulch are polyethylene films or polyvinyl chloride. Because of its increased permeability to longwave radiation, it may cause an increase in temperature around the plants at night in the winter (El-Beltagi et al., 2022). Therefore, it is advised to use polyethylene film mulch as a mulching material when cultivating horticultural crops (Gosar and Baričevič, 2011). Using plastic as mulch in farming is a practice known as „ Plasticulture," which is gradually producing fresh vegetables (Serrano-Ruiz et al., 2021). Since they are synthetic, they cannot break down. According to the most recent update, mulching with synthetic materials specifically plastic has evolved into a cutting edge, sophisticated, and efficient method in field agriculture output today (Somanathan et al., 2022) and cased a severe issue to the most agricultural lands (Lal, 2023). Plastic mulching can treat plants, get rid of pests, and make the soil drier (Zhang et al., 2020). Every year, more than a million tons of plastic film mulch are utilized worldwide (Yu et al., 2018) .

And inorganic mulching has many disadvantages like when utilized as mulch, dry materials increase the chance of fire, which could harm trees (Petratou et al., 2023). Because thick mulches can serve as havens for mice and other rodents to breed and survive, they face the risk of damaging tree trunks and roots through their nibbling of bark and burrowing into the ground (Iqbal et al., 2020). Because inorganic mulches do not break down in the soil, seasonal crops should remove them from the field when their fruiting season is over (Adnan et al., 2020).

2.3 DISADVANTAGES OF MULCHING

Farm's unique circumstances and organizational structure will determine whether mulching is practical and cost-effective as well as how to implement it (Finckh et al., 2015). Additionally, other significant problems with some organic mulching materials, like straw and grass, are weed growth and acid leakage (Patil Shirish et al., 2013). There are certain disadvantages to mulching, including the need for more labour, higher transportation costs, and challenging removal and disposal (By and Rivera, 2023).

Because the plastic mulch is generating pieces that come into direct contact with the soil, the soil becomes contaminated (Wang et al., 2016). Plastic film wreckages are buried or disposed of by farmers using onsite burning or landfilling, which seriously contaminates the soil and hinders crop development (Gonzalez-Dugo et al., 2014). Mulching increases soil moisture retention, which limits the flow of oxygen near the roots due to poor soil drainage. If mulching is done in close proximity to the stem, many pests, diseases, and microorganisms may find refuge in the moisture surrounding the stem of the plant. Mulches made of straw, hay, or other seeds and grass clippings, can encourage weed growth (Prem et al., 2020). With the exception of biodegradable plastic mulches, inorganic mulches do not break down and do not contribute any nutrients to the soil. In certain cases, the sun will degrade inorganic mulch and cause it to deteriorate over time. If it is dispersed throughout a large area, it may increase the temperature of the earth. Rubber is non organic mulch that is potentially harmful to plants, poisonous and damaging to the ecosystem (Prem et al., 2020). Some very common disadvantages of mulches are shown in table 4.

Utilizing one waste material to reduce pollution caused by another is crucial for the development of sustainability and for improving environmental issues.

Table 4: Disadvantages of using mulches on plants, soil properties

Inorganic mulch	Disadvantage	Reference
Rock	Although soil is absorbent, it lacks organic matter, can get heated and impact the roots of plants with shallow roots, and cannot be tilled.	Hussain et al. (2023)
Gravel	absorbent, doesn't add organic matter to the soil; might get heated and damage shallow-rooted plants' roots	Datta and Meena (2021)
Black and plastic mulch	Not air- or water-permeable; capable of suffocating plants with shallow roots non-biodegradable; provides no nutrients; weeds thrive under clear plastic; have to be covered with more mulch to shield it from UV ray harm.	Iqbal et al. (2020)

In this regard, straw have both been utilized as natural environmental adsorbents as well as after undergoing a variety of treatments to increase their sorption capabilities (Goodman, 2020). Additional useful for the findings regarding microbial activity and functional diversity indicated that the weather had a significant impact on them across all mulching treatments (Brunetti, 2014).

In other studies, examining the effects of various mulching techniques, it was discovered that most mulching techniques generally raise soil temperature, which has an impact on the germination, growth, flowering, and harvesting stages of cucumber plants, generally speaking, the temperature rises with soil depth (Iqbal et al., 2020). It has been demonstrated that mulching raises the surface temperature while decreasing the temperature beneath the soil (El-Shaikh and Fouda, 2008). Furthermore, paper mulches have the advantage of not posing the disposal issue that plastic films and partially degradable bio-films frequently do.

3 CONCLUSIONS

In conclusion, mulching is an essential practical need for the arid and semi-arid environments since it provides many advantages to the soil, plant yield and water shortages. Because organic mulching has so many advantages over inorganic mulching, it is a better choice for farmers who want to engage in ecologically responsible and sustainable agriculture. Mulching has a significant effect on several soil and plant health factors. Natural materials such as bark or compost are used to create organic mulch, which can also improve soil moisture retention, balances soil temperature, and encourages seed germination. It increases the organic matter in the soil, which supports the growth of bacteria, fungi, and microorganisms. This natural cover also helps suppress weeds by reducing competition for resources. Organic mulch provides ecosystem support, which frequently reduces pest problems. As a result, there is a synergistic impact that favourably affects vegetable yield.

On the other hand, inorganic mulches, which are usually composed of chemical-based materials, do not offer the same organic advantages and can even interfere with the natural processes occurring in the soil. Although they suppress weeds, they have disadvantages such as decreased soil fertility and the possibility of heat accumulation. Organic mulches are superior for supporting sustainable agriculture since they increase soil health and ecological balance.

4 ABBREVIATIONS

Ca: Calcium
CPB: Colorado potato beetle
Fe: Iron
GWP: global warming potential
GM: Genetically modified
K: Potassium
Mg: Magnesium
Na: Sodium
N: Nitrogen
PFM: Plastic film mulch
SOC: Soil organic carbon
SOM: Soil organic matter

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6 AUTHOR CONTRIBUTIONS

AAY worked as MKA's MSc supervisor in the organic farming field. As part of her MSc study, MKA re-

ceived guidance from AAY on how to conduct research for and write a review article pertaining to her master's work. AAY examined and made improvements to all of the used data, figures, and references. AAY revised and enhanced certain sections and provided valuable recommendations to enhance other sections. Both authors proofread and examined the completed manuscript.

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8 DATA AVAILABILITY DECLARATION

No new data were created or analysed in this study. Data sharing is not applicable to this review article.

9 DECLARATIONS

9.1 ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable. Concerns or personal details were not included in the current investigation.

9.2 CONSENT FOR PUBLICATION

The document doesn't contain any recordings, interviews, or other personally identifiable information. Thus, giving agreement for topics of a personal nature is not appropriate. Moreover, there are no competing interests that would keep the authors from publishing this study.

9.3 COMPETING INTERESTS

The authors confirm that no conflicts of interest exist.

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