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Influence of Mulch on Soil Physical Properties Improvement - A Review

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Abstract

Know a day soil properties affected by different agricultural practice, consequently disturbing the balance of soil ecosystem worldwide. Therefore, eco-friendly agricultural practices for sustainable food production are needed. This review paper focuses on multiple significant influences of mulches for the improvements of soil physical properties. It is well known that mulching the soil increases the soil properties, in particular the soil physical properties, most likely by balancing soil temperature, increasing soil moisture, and inhibiting weed growth and improving microbial activities. Soil surface covering decreases erosion, reduces evaporation, protects against raindrop impact, and increases aggregate stability. Mulches, particularly from organic materials, improve soil structure by favorable conditions for soil aggregation, e.g. through higher soil water content and temperature and the mineralization of organic matter in the soil. Therefore the appropriate mulching technique could provide the aforementioned benefits to the soil ecosystem. Therefore, the impacts of low-cost, eco-friendly, and biodegradable mulching materials on soil microbes, nutrient balance, plant growth, and soil erosion should be explored in the future.

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Keywords

Mulch, Soil, Soil Physical Properties, gravel, film, bricks.

Introduction

Mulch is an agricultural technique and any material spread on the surface of soil as soil management practice, they are used to protect it against rain drop, solar radiation or evaporation, inhibit weed germination, and suppress weed growth (Bell, 2009). Its protect soils from extreme temperatures through maintaining soils cooler in hot conditions (McMillen, 2013).

Mulches are widely divided into three important groups: organic, inorganic, and living mulches. Green mulches are obtained from organic products such as crop waste (straw and rice husks), waste from the timber industry (sawdust and bark), and green waste (leaves and wood chips) (Kader *et al.*, 2017). Inorganic mulches involve gravel, film, bricks, and cobblestones made of polyethylene. Clover, Manila grass, dwarf lily turf, ryegrass, and other kinds of grasses include living mulches (Qian *et al.*, 2015).

Mulching has been widely used in agricultural lands, orchards, forests, and landscapes in many parts of the world (Kader, 2017). Further, they can protect soils from wind, water, and traffic-induced erosion and compaction. Finally, mulch can improve crop production by enhancing soil quality by conserving soil moisture, enhancing soil biological activities, and improving the chemical and physical properties of soil. Globe and Kulig (2008); Bhatt and Khara, (2006) reported that mulching agricultural soil increases soil porosity and water infiltrations during intensive rain, and control run-off and soil erosion. Similarly, Zhao *et al.*, (2014); Fini *et al.*, (2016) revealed that mulches have beneficial effects such as improved early growth of trees, seed germination, increased root growth, higher water availability, maintaining good soil structure and porosity, minimizing soil erosion, reducing weed competition, maintaining soil temperature, reducing soil evaporation, enhanced root establishment and transplant survival, and increased overall plant performance.

Many materials have been used as mulch, such as plastic film, crop residue, straw, paper pellets, gravel-sand, rock fragment, volcanic ash, poultry and live-stock litters, city rubbish, etc. Returning crop residues to the soil improves soil quality and productivity through favorable effects on soil properties. Favorable effects of residue mulching on soil organic carbon, water retention and percent water-stable aggregates have been reported for the surface layer (Saroa and Lal, 2003). The main objective of this review is to review the effects of mulching and application different organic amendment on soil properties and crop productivity.

Effects of mulch on soil physical properties

Bulk density

Soil BD is a vital indicator of soil degradation because it influences soil porosity, plant nutrient availability, and soil microorganism activity (Recha *et al.*, 2022). According to Shaheb, Venkatesh and Shearer (2021), soil conservation measures decreased soil compaction, resulting in increased root development and length. Additionally, Shaheb *et al.*, (2021) revealed that soil compaction reduced root biomass significantly. The decreased crop growth and yield due to soil compaction were likely due to poor nutrient availability and uptake, thus limiting/preventing root growth (Gürsoy, 2021).

Returning crop residues as mulching to the soil improves soil quality and productivity through favorable effects on soil properties (Lal and Stewart, 1995). Mulching effects on soil bulk density are often variable. In some cases high bulk density has been observed under mulch relative to conventional tillage (Bottenberg *et al.*, 1999) and in other instances low bulk densities have been reported (Oliveira and Merwin, 2001). The mixed results may be due to differences in management practices, soil type and the type of mulch material used (Mulumba *et al.*, 2008).

Mulch has definite role in conserving soil physical health. Mulching reduced soil bulk density, Pervaiz *et al.*, (2009) reported that higher bulk density was observed in under Mo control (no mulch) (1.41 Mg m^3), followed by M1 (7Mg) (1.39 Mg m^3) and minimum in M2 (14Mg) (1.35 Mg m^3). Mulching increased soil moisture, organic matter contents leading to suitable environment for root penetration. Ghuman *et al.*, (2001) and concluded that mulching decreases bulk density of the surface soil. Similarly, Khan *et al.*, (2014) reported that the maximum bulk density (1.31 g cm^{-3}) was observed in no-Mulch followed by barseem straw mulch (1.29 g cm^{-3}) and minimum in wheat straw mulch (1.26 g cm^{-3}). Additionally, Van Dung *et al.*, (2022) reported that, at the topsoil (0–10 cm), bulk density rise straw mulch treated soil were lower than in the control plots.

In particular, the mean value of bulk density in rice straw mulch was 1.15 g cm^{-3}, lower than that in the treatments of control 1.22 g cm^{-3}. Likewise Mohammed *et al.*, (2021) indicated that the lowest bulk density value was recorded at the plot treated with plant residue 1.32 g/cm^3 while the values reported before planting, plant residue mulch and no mulching are 1.43, 1.38, 1.40g/cm^3 respectively. Rahmani *et al.*, (2021) indicated that there has been a significant difference in soil compaction for various types of mulching. The maximum value of soil compaction was shown in Control treatment without any cover, while the minimum value was in Coconut mulching treatment. In another word, Control treatment without any cover showed higher (2.46 kg/cm3) compacted soil than Plastic mulching treatment (2.05 kg/cm3), Oil palm mulching treatment (1.79 kg/cm3), and Coconut mulching treatment (0.94 kg/cm3) treatments, respectively.

Soil moisture

Evaporation from soil accounts for 25-50% of the total quantity of water used in cropping activities (Hu *et al.*, 1995). Mulching is one of the major soil and water conservation measures applied for conserving soil moisture and modifying soil physical and chemical environment (Kakaire *et al.*, 2015). Mulch prevents soil moisture; optimum soil moisture ensures good emergence and seedling growth. Mulching the soil improves soil properties, soil moisture availability (kader *et al.*, 2017). Use of mulching is believed to be beneficial to stressed environments (heat, drought, and salinity) as it changes the rate of evaporation and transpiration (Jiménez *et al.*, 2017). Likewise, Mulches can potentially reduce weed infestation and evaporation losses and enhance the percolation and retention rate of soil. Mulching covers the soil surface, and hence, it is helpful in maintaining the soil temperature which is beneficial for overall crop growth. Many studies demonstrated that the application of mulch could keep the soil cool during very hot climatic conditions (Kader *et al.,* 2019). Yin *et al.,* (2016) reported that mulches conserve soil moisture and reduce water evaporation from the soil surface in arid environments.

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 (Mutetwa and Mtaita, 2014). Pervaiz *et al.,* (2009) reported that Soil mulching significantly affected soil moisture contents, which is the maximum soil moisture contents were observed in wheat straw mulch M2(14Mg) (17.0%), followed by wheat straw M1(7Mg) (15.8%) and minimum in Mo control or no mulch plot (14.0%). Khan *et al.*, (2021) revealed that the straw mulch and biochar levels showed significantly improved soil temperature during 2018 and 2019 year.

The highest soil water content was seen in the straw mulch plot relative to no mulch plot at different stages of the maize crop in 2018 and 2019. Liu *et al.*, (2002) and Khurshid *et al.*, (2006) stated the same results that mulching improves the ecological environment of the soil and increases soil water contents. Mulumba *et al.,* (2008) stated that moisture content at saturation varied and were the highest for 16 and 8 Mg/ha mulch rate and the least under unmulched treatment. Ni *et al.,* (2016) reported that organic mulch, an approximated 1 cm layer of wood chips showed higher average soil moisture (21.7%) at the 5–10cm depth than unmatched control soil (19.2%).

Likewise Samuel *et al.,* (2021) indicated that Mulching has significantly affected the soil moisture content where the maximum moisture was observed to be 39.25% in a treatment mulched with rice straw and it is 1.3 times for rice straw, 1.25 times for beans straw and 1.24 times for cut grass than control in the top soil of the depth between (0-10) cm.

Likewise Nilim Kalita *et al.*, (2022) stated that mulching had a significant effect on the soil moisture content at 30 cm depth at the harvesting stage. Highest soil moisture at the 30cm depth at harvesting in the black polythene mulching (14.2%), additionally indicated on his research work Organic mulched materials evaluated significantly recorded higher soil moisture storage.

Soil porosity

Soil porosity refers to the amount of open space or voids within the soil. It is an essential characteristic of soil, as it affects the soil's ability to hold water and air, which are necessary for the growth of plants and other organisms. Understanding soil porosity is critical for farmers and gardeners, as it helps them make informed decisions about soil management practices. Mulching the soil increases soil porosity and water infiltrations during intensive rain, and control run-off and soil erosion (Globe and Kulig, 2008; Bhatt and Khara, 2006). Both bulk density and porosity are good indicators for soil permeability and suitability for root growth refers to soil-plant-atmosphere system (Samuel *et al.*, 2021).

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 (Wu *et al.*, 2022; Chen *et al.,* 2017). Total porosity increased with increase in mulch rate and was significantly lower under the 0 mulch treatment. 95% of the maximum porosity (obtained under 16 Mg/ha of farmyard) was obtained with 8 Mg/ ha of mulch. Increased porosity due to mulch application was also reported by Mulumba *et al.*, (2008). The increased porosity is especially important to crop development since it may have a direct effect on soil aeration and can enhance root growth (Mulumba *et al.,* 2008). Van Dung *et al.,* (2022) showed on his work rise straw mulch enhanced soil porosity by ~5% and ~3% at 0–10 and 10–20 cm after 3 years of experiments, respectively. Similarly (Khan *et al.,* 2014) stated that the mean data for mulches showed that porosity increased significantly by mulches, maximum porosity of 52.22% was observed in wheat straw mulch followed by Barseem straw mulch (51.31%) and minimum value for porosity (40.79%) was recorded for No-mulch.

Aggregate stability

Soil structure is a key factor influencing soil characteristics and ecological functions related to aggregate stability (He *et al.*, 2020; Ma *et al.*, 2020). As the basic unit of structure, aggregates affect soil quality and stability (Ma *et al.*, 2020). Soil aggregates are the fundamental core to regulate the soil properties (Wang *et al.*, 2017). Stable aggregates produce favorable conditions for plant growth and soil quality improvement by maintaining the water infiltration, moisture content, nutrient cycle, and especially the carbon storage (Kumar *et al.,* 2019).

Table.1 Effect of mulch on soil physical properties

Treatment	Soil bulk density (Mg m^{-3})	Source
Mulch 0 Mg ha^{-1} (Mo)	1.41a	(Pervaiz *et al.*, 2009)
Mulch 7 Mg ha^{-1} (M1)	1.39ab	
Mulch 14 Mg ha^{-1} (M2)	1.35b	

Fig.1 Comparative approach to the mulched and un-mulched soil (source: El-Beltagi *et al.*, 2022)

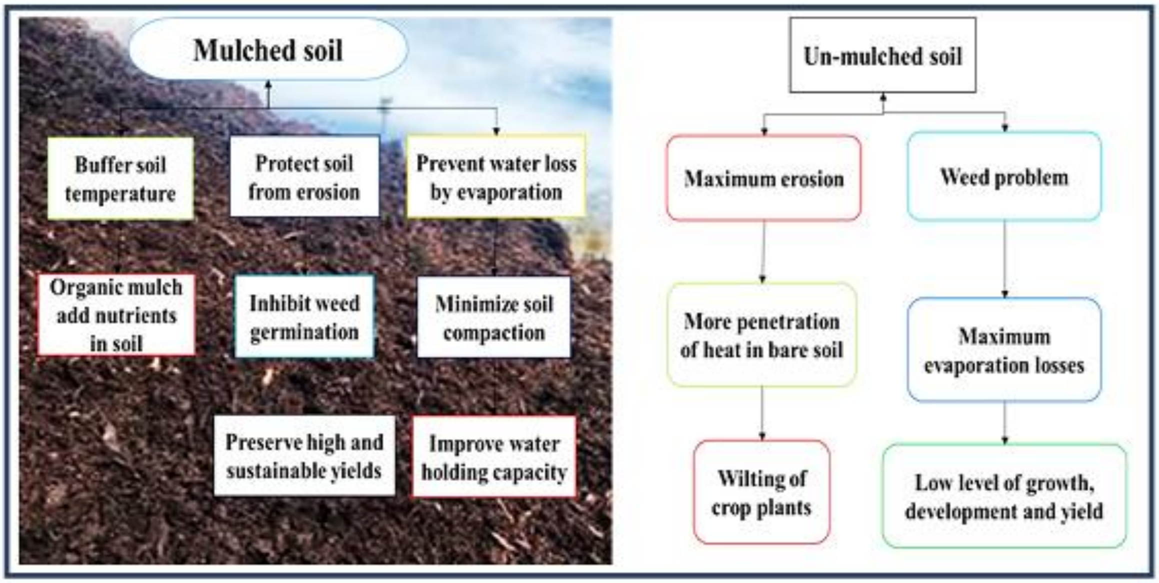
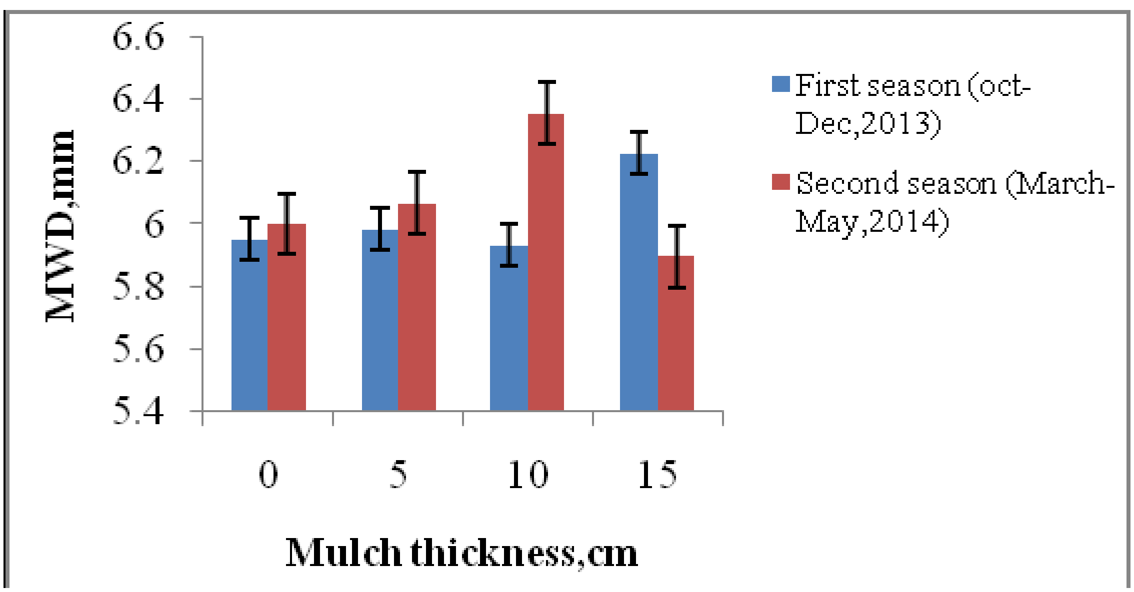


Fig.2 Interaction between porosity and mulch thickness.



Source: Kakaire *et al.*, (2015).

Soil aggregates are composed by binding the mineral and organic substances that came from the decomposition of organic matter. Mulching is effective for improving soil quality and aggregate stability. Organic mulches have been known as a material useful in soil structure stability and soil organic carbon improvement (Kader *et al.*, 2017). Soil aggregates maintain and supply organic carbon and nutrients, impacting biogeochemical reactions (Wei *et al.*, 2020). Large amounts of macroaggregates and low proportions of silt + clay promote aggregate stability (Dai *et al.*, 2019). Macroaggregates play an important role in maintaining aggregate stability. The higher proportion of macro aggregates, the stronger the soil aggregate stability (Zhang *et al.*, 2019; Liu *et al.*, 2020).

Mulumba and Rattan, (2007)indicated that the water-stable aggregates ranged from 38% to 67% and were the highest under the 16 Mg ha^{-1} $year^{-1}$mulch rate, the lowest under the 0 Mg ha^{-1} $year^{-1}$ mulch rate. Likewise Zhou *et al.*, (2021) stated that proportion of large macroaggregates was significantly higher, and micro aggregates (0.25 − 0.053 mm) were markedly lower under wood chips + wood compost than in the controls and wood chips ($P < 0.05$). Likewise he indicated that Wood chips + wood compost significantly increased mean weight diameter and geometric mean diameter compared to the controls and wood chips ($P < 0.05$). This means wood chips + wood compost increased the proportion of large and small macroaggregates and decreased the ratio of microaggregates and silt + clay fractions, contributing to larger mean weight diameter and geometric mean diameter than wood chips and controls.

Aggregate stability, a measure of the soil's resistance to externally imposed disruptive forces, therefore increased with increase in mulch rate (Mulumba *et al.*, 2008). Mean weight diameter ranged from 0.47 to 1.59 mm and was the highest under the 16 Mg ha^{-1} $year^{-1}$ mulch rate and lowest under the 0 Mg ha^{-1} $year^{-1}$ mulch rate. A strong correlation (R2 = 0.84 and 0.87) of mulch rate was observed on water stable aggregates and the mean weight diameter, respectively (Mulumba *et al.*, 2008). Kakaire *et al.*, (2015) reported that mean weight diameter ranged between 5.97 at control to 6.176 mm at 10 cm thickness of mulching.

Soil management affects the physical and chemical parameters of the soil. Mulching and direct soil covering are important agricultural practices used to improve soil properties and crop productivity. Under cool soil conditions, covering warms the soil and advances harvest maturity, preserves moisture, and decreases nutrient leaching. Mulch with organic material covers soils and creates a physical barrier to soil water evaporation, preserves a beneficial soil structure, soil aggregate stability, and protects plants from soil contamination. It was concluded that mulching the soil with different mulching material positively influence soil physical properties, that is decreased bulk density and penetration resistance, while increasing soil moisture contents and porosity.

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