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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 required. This review paper focuses on multiple significant influences of mulches for the improvements of soil physical properties. It is well known that Adding mulch to the soil improves its qualities, in particular the soil physical properties, most likely via bringing the soil's temperature into balance, raising the soil's moisture level, preventing weed growth, and enhancing microbial activity. Covering the soil surface promotes aggregate stability, prevents raindrop impact, and reduces erosion and evaporation. Mulches, especially those made of organic materials, enhance soil structure by creating conditions that encourage soil aggregation, such as increased soil water content and temperature as well as the mineralization of organic matter. Therefore, the proper mulching method could give the soil ecology the aforementioned advantages. Therefore, future research should focus on the effects of low-cost, environmentally friendly, and biodegradable mulching materials on soil microorganisms, nutrient balance, plant development, and soil erosion.*

Keywords: *Mulch, Soil, Soil Physical Properties*

1. INTRODUCTION

Mulch is a soil management strategy used in agriculture. It is any material that is deposited on the soil's surface to protect it from water, sunlight, or evaporation as well as to prevent weed germination and growth (Bell, 2009). Its protect soils from extreme temperatures through maintaining soils cooler in hot conditions (McMillen 2013).

Mulches can be broadly classified into three key categories: living, inorganic, and organic mulches. Organic materials such as crop waste (straw and rice husks), trash from the logging industry (sawdust and bark), and green waste (leaves and wood chips) are used to make green mulches. (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).

In various regions of the world, mulching has been employed extensively in agricultural lands, orchards, forests, and landscapes. (Kader, 2017). Additionally, they can shield soils from erosion and compaction brought on by wind, water, and traffic. Mulch can also improve soil quality, which can enhance crop yield by enhancing soil biological activity, soil chemical composition, and soil physical features. Globe and Kulig, (2008); Bhatt and Khara, (2006) reported that by mulching agricultural soil, you can reduce runoff and soil erosion while increasing soil porosity and water infiltrations during heavy rain. Similarly, Zhao *et al.*, (2014); Fini *et al.*, (2016) revealed that Mulches improve early tree growth, seed germination, root growth, water availability, maintain good soil structure and porosity, reduce soil erosion, lessen weed competition, maintain soil temperature, lessen soil evaporation, improve root establishment and transplant survival, and improve overall plant performance. Agele *et al.*, (2000) reported that Mulching is reported to ameliorate soil moisture deficits and extremely high soil temperature regimes, and eliminate compaction of ridges and mounds.

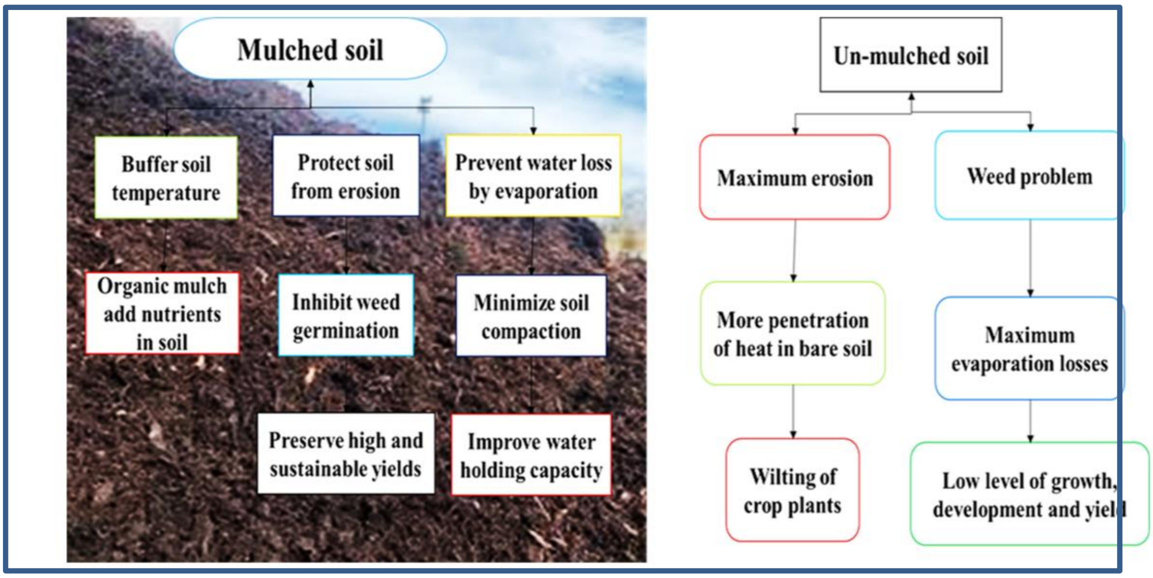

Figure 1: Comparative approach to the mulched and un-mulched soil (source: El-Beltagi *et al.*, 2022)

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. The main objective of this review is to review the effects of different mulching types on soil physical properties improvements.

2. Effects of Mulch on Soil Physical Properties

Bulk density

Bulk density is a sign of healthy and compacted soil. It has an impact on critical soil processes and productivity such as infiltration, rooting depth/restrictions, available water capacity, soil porosity, plant nutrient availability, and soil microbial activity. Because it affects soil porosity, the availability of nutrients to plants, and the activity of soil microorganisms, soil bulk density is an essential indicator of soil degradation. (Recha *et al.*, 2022). Additionally, Shaheb, Venkatesh & Shearer (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) 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 Control treatment without any cover had the highest level of soil compaction, and the Coconut mulching treatment had the lowest level. 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

Table1. Effect of mulch on soil bulk density

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	

Soil moisture

Soil moisture is the water held in pores in the soil in liquid and vapor phase (Scott and Maitre 1998). Soil moisture is the source of water for plant use in particular, in the rainfed agriculture. There are a number of factors that affect the growth and performance of crop like soil, water and evapotranspiration. Evaporation from soil accounts for 25-50% of the total quantity of water used in cropping activity (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. Kader *et al.*, (2017) reported that mulching the soil improves soil properties, soil moisture availability. Additionally Jiménez *et al.*, (2017) indicated that use of mulching is believed to be beneficial to stressed environments (heat, drought, and salinity) as it changes the rate of evaporation and transpiration. Other studies demonstrated that the application of mulch could keep the soil cool during very hot climate condition (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. 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.

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

The quantity of voids or open spaces in the soil is referred to as soil porosity. It is an essential characteristic of soil, as it affects the soil ability to hold water and air, which are necessary for the growth of plant and other organism. 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 rate 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. (Mulumba *et al.,* 2008). The increase porosity is especially important to crop developments since it may have 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 function related to aggregate stability (He *et al.,* 2020; Ma *et al.,* 2020). Aggregates impact soil stability and quality as the fundamental component of a structure (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). 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 macro aggregates 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.

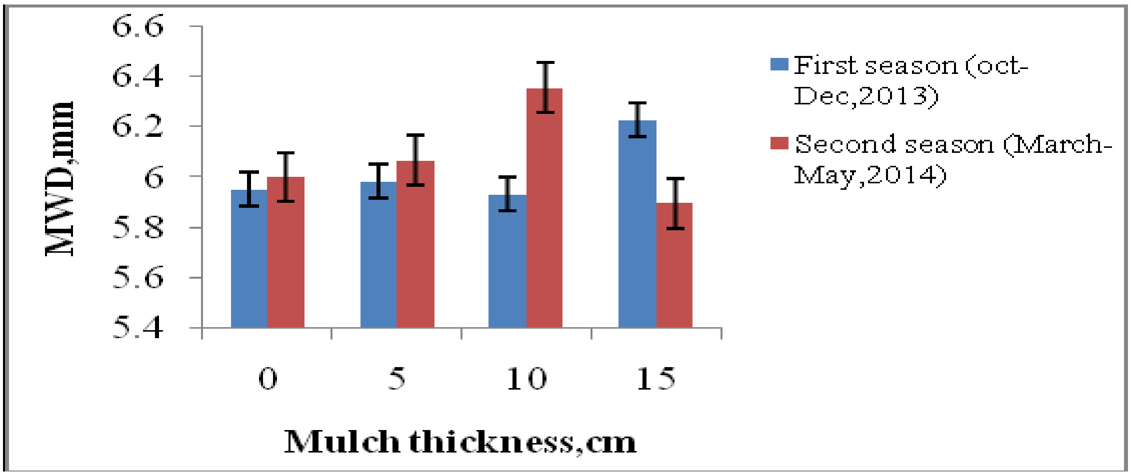

Figure 2. Interaction between porosity and mulch thickness. Source: Kakaire *et al.*, (2015).

3. Conclusion

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.

References

[1] Fini, C. Degl'Innocenti, and F. Ferrini, "Effect of mulching with compost on growth and physiology of Ulmus "FL634" planted in an urban park," *Arboriculture & Urban Forestry*, vol. 42, pp. 192–200, 2016.

[2] Chen, H., Liu, J., Zhang, A., Chen, J., Cheng, G., Sun, B., Pi, X., Dyck, M., Si, B., Zhao, Y. and Feng, H., 2017. Effects of straw and plastic film mulching on greenhouse gas emissions in Loess Plateau, China: A field study of 2 consecutive wheat-maize rotation cycles. *Science of the Total Environment*, *579*, pp.814-824.

[3] El-Beltagi, H.S., Basit, A., Mohamed, H.I., Ali, I., Ullah, S., Kamel, E.A., Shalaby, T.A., Ramadan, K.M., Alkhateeb, A.A. and Ghazzawy, H.S., 2022. Mulching as a sustainable water and soil saving practice in agriculture: A review. *Agronomy*, *12*(8), p.1881.

[4] H. Zhao, R.-Y. Wang, B.-L. Ma et al., "Ridge-furrow with full plastic film mulching improves water use efficiency and tuber yields of potato in a semiarid rainfed ecosystem," *Field Crops Research*, vol. 161, pp. 137–148, 2014.

[5] Hu, W., 1995. High yield technology for groundnut. *International Arachis Newsletter (Supplement)*, *15*, pp.1-22.

[6] Jiménez, M.N., Pinto, J.R., Ripoll, M.A., Sánchez-Miranda, A. and Navarro, F.B., 2017. Impact of straw and rock-fragment mulches on soil moisture and early growth of holm oaks in a semiarid area. *Catena*, *152*, pp.198-206.

[7] Kader, M.A., Senge, M., Mojid, M.A. and Ito, K., 2017. Recent advances in mulching materials and methods for modifying soil environment. *Soil and Tillage Research*, *168*, pp.155-166.

[8] Kader, M.A., Senge, M., Mojid, M.A. and Ito, K., 2017. Recent advances in mulching materials and methods for modifying soil environment. *Soil and Tillage Research*, *168*, pp.155-166.

[9] Kader, Mohammad Abdul, Singha, A., Begum, M. A., Jewel, A., & Khan, F. H. (2019). Mulching as water-saving technique in dryland agriculture : review article. 7.

[10] Kakaire, J., Makokha, G.L., Mwanjalolo, M., Mensah, A.K. and Emmanuel, M., 2015. Effects of mulching on soil hydro-physical properties in Kibaale Sub-catchment, South Central Uganda.

[11] Kakaire, J., Makokha, G.L., Mwanjalolo, M., Mensah, A.K. and Emmanuel, M., 2015. Effects of mulching on soil hydro-physical properties in Kibaale Sub-catchment, South Central Uganda.

[12] Khan, G.D., Din, S., Ramzan, M., Hanif, M. and Hameed, M., 2014. Influence of tillage and mulching practices on soil physical properties under semi-arid environment. *Journal of Environment and Earth Science*, *4*(9), pp.120-124.

[13] Khan, G.D., Din, S., Ramzan, M., Hanif, M. and Hameed, M., 2014. Influence of tillage and mulching practices on soil physical properties under semi-arid environment. *Journal of Environment and Earth Science*, *4*(9), pp.120-124.

[14] Khan, I., Chen, T., Farooq, M., Luan, C., Wu, Q., Wanning, D., Xu, S. and Li-xue, W., 2021. The residual impact of straw mulch and biochar amendments on soil physiochemical properties and yield of maize under rainfed system. *Agronomy Journal*, *113*(2), pp.1102-1120.

[15] Kumar, A., Naresh, R.K., Singh, S., Mahajan, N.C. and Singh, O., 2019. Soil aggregation and organic carbon fractions and indices in conventional and conservation agriculture under vertisol soils of sub-tropical ecosystems: A review. *International Journal of Current Microbiology and Applied Sciences*, *8*(10), pp.2236-2253.

[16] Larkin, R.P. Soil health paradigms and implications for disease management. Annu. Rev. Phytopathol. 2015, 53, 199–221.

[17] M. A. Kader, M. Senge, M. A. Mojid, and K. Ito, “Recent advances in mulching materials and methods for modifying soil environment,” *Soil and Tillage Research*, vol. 168, pp. 155–166, 2017.

[18] M. McMillen, *The Effect of Mulch Type and 7ickness on the Soil Surface Evaporation Rate*, California Polytechnic State University, San Luis Obispo, California, 2013.

[19] Magdoff, F.; Van Es, H. Building Soils for Better Crops, 3rd ed.; Sustainable Agriculture Research and Education: Waldorf, MD, USA, 2009.

[20] Mohammed, T., Wapa, J.M., Lawal, B.A. and Ibrahim, H., 2021. Effect of mulch material on soil physical properties, yield and yield components of tomato (Lycorpersicum esculentum L.) in Mokwa, Niger State, Nigeria.

[21] Mulumba, L.N. and Lal, R., 2008. Mulching effects on selected soil physical properties. *Soil and Tillage Research*, *98*(1), pp.106-111.

[22] Mutetwa, M. and Mtaita, T., 2014. Effects of mulching and fertilizer sources on growth and yield of onion. *J. Glob. Innov. Agric. Soc. Sci*, *2*(3), pp.102-106.

[23] Ni, X., Song, W., Zhang, H., Yang, X. and Wang, L., 2016. Effects of mulching on soil properties and growth of tea olive (Osmanthus fragrans). *Plos one*, *11*(8), p.e0158228.

[24] Pervaiz, M.A., Iqbal, M., Shahzad, K. and Hassan, A.U., 2009. Effect of mulch on soil physical properties and N, P, K concentration in maize (Zea mays L.) shoots under two tillage systems. *International Journal of Agriculture and Biology*, *11*(2), pp.119-124.

[25] Samuel, H., Hamoudu, R. and Nepo, N.J., 2021. Effect of mulching on soil physico-chemical properties of soil under semiarid of rain fed fersiallitic soil condition in Eastern of Rwanda. *Int J Progressive Sci Technol*, *25*(1), pp.468-75.

[26] Shaheb, M.R., Venkatesh, R. and Shearer, S.A., 2021. A review on the effect of soil compaction and its management for sustainable crop production. *Journal of Biosystems Engineering*, pp.1-23.

[27] Wang, L., Li, X.G., Lv, J., Fu, T., Ma, Q., Song, W., Wang, Y.P. and Li, F.M., 2017. Continuous plastic-film mulching increases soil aggregation but decreases soil pH in semiarid areas of China. *Soil and Tillage Research*, *167*, pp.46-53.

[28] Wu, C., Ma, Y., Wang, D., Shan, Y., Song, X., Hu, H., Ren, X., Ma, X., Cui, J. and Ma, Y., 2022. Integrated microbiology and metabolomics analysis reveal plastic mulch film residue affects soil microorganisms and their metabolic functions. *Journal of Hazardous Materials*, *423*, p.127258.

[29] X. Qian, J. Gu, H.-j. Pan et al., “Effects of living mulches on the soil nutrient contents, enzyme activities, and bacterial community diversities of apple orchard soils,” *European Journal of Soil Biology*, vol. 70, pp. 23–30, 2015.

[30] Agele, S.O., Iremiren, G.O. and Ojeniyi, S.O., 2000. Effects of tillage and mulching on the growth, development and yield of late-season tomato (Lycopersicon esculentum L.) in the humid south of Nigeria. *The Journal of Agricultural Science*, *134*(1), pp.55-59.

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