Effects of Mulching on Crop Growth, Productivity and Yield

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Abstract Mulching refers to the covering of bare land with organic or inorganic material for the betterment of soil and plants. Mulching not only improves the soil properties but also improves the growth and yield of many crops. Mulching improves the moisture status, temperature and nutrient status of the soil that are necessities for the better growth and yield of the crops. Ultimately mulching enhances the yield of many crops. This chapter will discuss the importance of mulching in agroecosystems-plants and soils. This chapter will highlight important aspects related to soil characteristics, the role of mulching in soil health and quality. It also includes important facters affecting the crop yield and impact of mulching for controlling these factors. It will also highlight the importance of mulching for vegetables, orchards and cereal crops relating to their yield characteristics.

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1 Introduction

Rainfed agriculture is responsible for 80% of the world's planted land and 60% of global grain production (Rockstrom et al., 2007; UNESCO, 2009). The inadequate water supply, degraded soil fertility and nutrient supplies are common causes of low productivity in the semi-arid and arid rainfed agricultural system; and crop yield can be improved by a range of methods, including plastic mulching and straw mulching (Li et al., 2013; Gan et al., 2013). Mulching is a process used by farmers and horticulturists to improve the quality of agricultural soils by coating the soil surface with various materials. This system prevents not only evaporation but also wind erosion and soil runoff from lands (Tan et al., 2015). Soil mulching management techniques can minimize degradation, evaporation, adjust soil temperature and reduce weed infestation, resulting in increased yield and possibly nitrogen use efficiency and water use efficiency as well (Qin et al., 2013).

Mulch is most likely derived from the German word "molsch," which means "soft to decompose," which refers to the use of straw and leaves spread around a field by a gardener (Jack & Diaconis, 1955). Mulching prevents soil erosion by avoiding soil degradation, runoff, water evaporation, and weed infestation, and as a result, it aids in the regulation of temperature variations, preservation of soil moisture and improvement in the physical, biological and chemical properties of soil, it also subsidizes nutrients to the soil, and eventually improves crop growth and yield (Akhtar et al., 2018; Nawaz et al., 2017; Nzeyimana et al., 2017). According to an estimate, mulching increases yield by 50–60% in rainfed conditions compared to no mulched area (Dilip et al., 1990).

Plant performance increases, as the physical condition of the soil changes (Chakraborty et al., 2008; Van der Putten et al., 2013). Mulch may help to introduce the organic matter to the soil, control weed growth, and mitigate or prevent erosion (Bot & Benites, 2005). Several types of organic mulches are often used in landscaping to combat weeds and improve plant quality (Ranjan et al., 2017). Though organic matter mulching was used in ancient agriculture, lithic (stone) mulches have a long tradition. Mulching can be done with a variety of materials in today's crop processing. Plant residues, various types of biodegradable films, plastics, and various types of paper mulches non-coated or coated with biodegradable films or plastic are all options available to farmers and horticulturists (Haapala et al., 2014). Due to differences in production methods, growing conditions, and crop types, the impact of mulch type on crop growth can vary (Ashworth & Harrison, 1983). Various factors that affect the growth and yield of the crop are given below.

2 Factors Affecting Plant Growth and Yield

Plant development is influenced by four key factors: temperature, water, light, and nutrients (Gondal et al., 2021; Gondal & Tayyiba, 2022). These four factors influence the plant's growth hormones, and other growth-related processes, causing it to develop slower or faster (Lauridsen et al., 2020). For instance, plants that are exposed to light deficiencies or obtain inadequate blue light have a number of effects on their growth and yield. According to Rhoades (2021) reduction in light leads to stem elongated or leggy, leaves become small enough, leaves with brown margins or tips, lower leaves tend to dry out and variegation on variegated leaves disappears. Similarly, many plants can survive in the majority of soil environments. There are several causes of nutrient deficiency that necessitate fertilization and/or soil amendment. Certain crops or plants have the potential to deplete the soil. Plants, like all living organisms, need nutrients and minerals to survive (Ann et al., 2011).

Most plant cycles, such as transpiration, photosynthesis, germination, respiration, and flowering, is affected by temperature by triggering chemical reactions within the plant's cells (Wahid et al., 2007). Temperature impacts the conversion from vegetative to reproductive development when combined with day length (Dorais, 2003). For example, cool-season crops like spinach can bloom if the weather is hot and the days are long and warm-season crops like tomatoes, on the other hand, cannot set fruit if temperatures are too cold (Abou-Hussein, 2012; Sohail et al., 2021). Water supports a plant's growth by carrying vital nutrients. The plant takes nutrients from the soil and uses them. Plants droop if there isn't enough water in their cells, so water makes them stand. The dissolved sugar and other nutrients are transported through the plant by water. The plant is not only malnourished without the correct water balance. Different plants necessitate various quantities of water (Armstrong, 2021).

3 Role of Mulching in Reducing Stress Factors

Due to all the above factors, possibly growth and yield of the various crops are affected and thus; mulching is the best way to cope with all these factors to maximize the growth.

3.1 Temperature

Mulching lowers the temperature of the soil in the summer, increases it in the winter, which avoids temperature extremes. In the peak winter season, wheat straw mulch increased soil temperature by 2–30 °C. When opposed to bare earth, the temperature of the soil under transparent mulch can be up to 7 °C higher (Lamont, 1993). Park et al. (1996) found a 2.4 °C rise in average soil temperature at 15 cm depth when the

clear film was used as mulch and a 0.8 °C increase was noticed with the use of black film. Condensation on the underside of the mulch absorbs the longwave radiation released by the soil at night, causing the soil to cool more slowly (Lamont, 2005).

3.2 Water

Mulching prevents unproductive evaporation from the soil surface, allowing more water to be required for transpiration (Chakraborty et al., 2008). This is beneficial in water-limited environments, as plant water status is sustained. Organic mulch also prevents nitrogen depletion by drainage and leaching by covering the soil surface (Erenstein, 2002). When compared to the monitor, straw mulch conserved 55% more soil moisture (Rajput & Singh, 1970). Mulching wheat residue @ 6730 kg/ha greatly improved usable soil moisture deposited up to 1.5 m depth of soil as compared to bare soil (Black, 1973). Over the control, okra production was substantially higher under straw mulch, followed by dust mulch (Batra et al., 1985).

3.3 Nutrients

Chilli leaf N, P, and K content improved after coconut fronds were mulched. Previous studies results revealed that plants grew quicker, ripened earlier, and had lower P and higher N concentrations in their leaves and fruits. Besides, they observed that rice straw mulch increased K-content and decreased P concentration in bell pepper leaves as compared to no-mulch leaves. In tomato, Hundal et al. (2000) observed that mulched crops had slightly higher nitrogen and phosphorus concentrations and nutrient absorption than un mulched plots. Mulch prevents the soil crust from erosion, reduces nitrogen leaching and defends against adverse influences leading to improved crop growing conditions.

4 Role of Mulching in the Improvement of Plant and Soil Health

Mulching is considered useful in moisture conservation and in improving crop productivity, Sharma et al. (2010) reported growth promotion trend in maize, wheat (Chakraborty et al., 2008), vegetables (Mahadeen, 2014) and other crops (Farrukh & Safdar, 2004). Weeds can be controlled through mulching (Erenstein, 2002) and soil moisture could also be retained. Combination of irrigation with mulching technology is advocated for better uptake of water by the spring wheat to reduce the number

of irrigations. All the results showed that conserved moisture through mulching is effective during stress for plants.

In sustainable agriculture crop rotations, the use of cover crops, mulching and good crop husbandry are very useful measures to suppress weeds (Erenstein, 2003). Therefore, environment-friendly weed control methods are required to be used for weeding management in crops to avoid the incidence of undesirable effects. Mulching also helps in the retention of soil moisture contents and suppresses weeds without herbicide application (Asif et al., 2020).

Mulch is a material that may be organic or inorganic which spread on the surface of the soil and provide shelter from raindrop damage, evaporation, and solar radiations. Mulches help to preserve moisture, suppress weeds, and improve soil stability and avoid insect pest attack. Organic mulches help to moderate soil temperature, provide efficient control of weeds, decrease the rate of evaporation, and add nutrients and humus to the soil (Iqbal et al., 2020). Mulching prevents soil erosion and can reduce soil-borne diseases. Chemical mulch offers a slow release of humic acids, nitrogen, phosphorus, and potassium in the soil which facilitate to increase their uptake and utilization. Biological mulch is the component of integrated management of pest which provides control to phytophthora root rot, against dual competitive and aggressive microbes (Ghorbani et al., 2009).

5 Role of Mulching in the Improvement of Plant Nutrition

Soil biota can be increased through mulching because it provides a compound of carbon, nitrogen, and other nutrients and this is the key role in the cycling of nutrients, these are also the prolonged resources to get healthy crop (Bot & Benites, 2005). Soil macro and microbiota get nutrients from organic mulches and provide suitable environmental conditions to improve crop growth (Lal Bhardwaj, 2013). Plastic mulch increased the population of actinobacteria and proteobacteria in comparison to the control treatment (Farmer et al., 2017), however, the population of the invertebrates decreased (Bandopadhyay et al., 2018). Microbial activity depends on the temperature, under low-temperature mulches brings soil temperature closer to microbial optima and vice versa. Under high temperature, it resulted in a reduced microbial population (Brodhagen et al., 2015).

6 Impact of Mulching on Plant Growth Mechanisms

It is well-known, mulches can improve plant growth through different aspects i.e. by conserving soil moisture and temperature. Nutrient availability increased because of weed and pest population reduction (Thakur & Kumar, 2020). The increased height of the tea olive (*Osmanthus fragrans* Lour.) was observed by using gravels and wood

chips mulch and the trunk diameter and also increased amount of chlorophyll, rhizospheric nutrients, development of roots and soluble sugar (Ni et al., 2016). Qayyum et al. (2020) noticed that paddy straw mulch improves the spike length of gladiolus. Rice straw mulch also increases the number of branches, root length, number of leaves, and plant height in patchouli (*Pogostemon cablin* Benth) as compared to black plastic silver mulch and without mulch. Aromatic plants like rosemary (*Rosmarinus officinalis* L.), lavender (*Lavandula officinalis* L.), thyme (*Thymus vulgaris* L.), and damask rose (*R. damascene* Mill.) produced maximum plant height and diameter with the applications of mulches (Hussain et al., 2019).

Xianchen et al. (2020) reported that black polythene mulch, increased the temperature of the soil, resulted in poor water and nutrients absorption, root growth, and consequently low yield returns. The Colour of the mulch also affects plant yield, as in sweet basil (*O. Basilicum* L.), the significantly higher yield was recorded under red colour mulch. Higher biomass was reported under organic mulch as compared to bare soil in basil (*O. Basilicum* L.), citronella (*Cymbopogon citratus* L.), and geranium (*P. graveolens* L.) (Mahadeen, 2014).

7 Mulching and Water Productivity

The most limiting source is water for the farming system among all-natural resources. Biomass produced per unit of water used is called water use efficiency (Farmer et al., 2017). The requirement of water is different depending upon the species of plants (Qayyum et al., 2020). The overall yield of crop plant depending upon rainfall, transpiration, drainage system and rate of evaporation (Bot & Benites, 2005). According to Qayyum et al. (2020), the mulching technique has proved to enhance the yield and WUE (Lal Bhardwaj, 2013). Plastic mulch enhanced WUE (20–60%) by decreasing evaporation rate (Bandopadhyay et al., 2020) and ultimately improves the soil water retention and infiltration and provide a favourable environment to root propagation and seed germination (Folino et al., 2020). Irrigation water requirement in bell pepper was decreased by 14–29% by covering with the plastic film due to limited moisture losses. Improved water use efficiency and yield potential of tomato were achieved in polyethylene mulched soil under all (surface and drip) levels of irrigation. In brinjal crop soil moisture of 29–56% and 22–107% conserved by using black plastic mulches over straw mulches and control, respectively (Sharma et al., 2010). It has been demonstrated that black polyethylene mulch is found to be useful in achieving the early harvest and yield of muskmelon. The yield of brinjal increased by 3.5–5.2 folds by white and black polyethylene over control probably because of slow water percolation and restricted nutrient loss from the top 15 cm of soil (Sharma et al., 2010).

Black polyethylene mulch boosted the soil moisture, reduced soil evaporation, altered microbial population, and hence produced higher quality and yield of production, which enhanced the economic value for farmers (Thakur & Kumar, 2020). There is mixed mulch which is a combination of organic and inorganic mulch. Phyto

degradable and biodegradable mulches are a new type of mulch for easy use and versatility (Folino et al., 2020). It has been developed to reduce the accumulation of low-density polyethylene (LDPE) and environmental pollution produced from plastic wastes (Kader et al., 2017).

8 Influence of Mulching on Crop Productivity and Yield

8.1 Mulching for Vegetable Crops

Ashrafuzza man et al. (2011) reported that mulch increased the yield and quality of fruit in chillies when mature, the tallest plant (78.45 cm) was observed in transparent mulch, followed by black (77.58 cm) and blue (77.03 cm) plastic mulch. The smallest observation was in the control plot (61.15 cm). Moreover, un-mulched chillies had fewer branches as compared to mulched chillies. The highest number of branches was observed in black plastic mulch as compared to transparent mulch and blue mulch. Similarly, mulched had good effects on the root elongation. This is due to better soil water use efficiency and the most suitable soil temperature. Rajablariani et al. (2012) performed an experiment on tomato grown on bare soil and polyethylene mulch film and reported that the number of leaves and branches in tomato plants observed better in the plastic film as compared to bare soil. The early production was attained from transparent plastic mulch due to light entrance and increasing soil temperature.

As the plants grown on silver/black plastic mulch suggested a 65% improvement in marketable mulch relative to control treatment, mulching improved marketable yield compared to the bare soil. The production of silver and black increased by 65% respectively, followed by black (50%), blue (40%), red (26%) and transparent plastic cover (24%). The increase in yield in the covered area may be related to the preservation of soil surface and surface soil moisture, the improvement of the microclimate and the control of a large number of weeds, especially in the silver and black plastic coverings. Singh et al. (2009) found that the use of black polyethylene shields and drip irrigation further increased tomato yield by 57.87 tons/ha.

The mulch helps prevent fruits such as tomatoes from touching the ground. This reduces decay and helps keep the product clean. In many cases, its cracking and flower end rot is reduced on fruits. It tends to be smoother and have fewer scars on fruits. The correct installation of plastic mulch helps prevent soil from splashing on the plants when it rains, which can reduce the grading time.

8.1.1 Plant Growth and Yield

It has been proven that black polyethylene mulch can be used to achieve early harvest and yield of melons. After applying white polyethylene and black polyethylene, the

yield of eggplant increased by 3.5–5.2 times compared with the control, which may be due to slow water leakage and limiting the nutrient loss of 15 cm from the soil surface (Singh et al., 2006).

Compared with white and reflective plastics, black plastic mulches were effective in promoting early tomato yields because of their high temperature inducing properties. Early tomato yields were often recorded as black and transparent plastic mulches because they prioritize the allocation of carbon to fruits rather than leaves. Conversely, when using plastic mulch in summer, high ambient temperature and high solar radiation often lead to poor growth and low yields.

8.1.2 Germination, Seedling Establishment and Growth

The mulch film produced some phytotoxic allelochemicals, which reduced the germination rate and seedling raising rate. Researchers founded that the effect of rice straw on the field to raise seedlings was better.

8.1.3 Effects on Plant Microclimate

The microclimate of the plant can be changed by changing the balance of energy in soil and by control the soil water evaporation. Root zone temperature (RZT) is one of the main advantages associated with the use of plastic coverings. Under controlled conditions, the growth of the root system increases with the increase of temperature until it reaches the optimum. Further increase in the temperature of the root zone may adversely affect the growth of the root system and stem. Under controlled conditions, the temperature and maximum root zone suitable for plant growth are considered to fluctuate under the conditions of air and root zone temperature field.

8.2 Mulching for Orchards

8.2.1 Banana

Mulch works as a 'lid,' allowing water to percolate into the soil while reducing evaporation. Because of this, your weekly watering will go a long way. Ensure that the mulch circle is well-watered so that the roots have plenty of room to grow. As a result, plants yield and growth increased. For instance, in banana orchards, the use of wheat straw and banana straw as a mulching material is very helpful to conserve the soil moisture and increasing the bunch weight of the banana plant and this mulching material applied at the start of the summer session, especially at February month. Stewart et al. (1926) evaluated the effect of asphalt-impregnated paper on pineapple weed control. In the experiment, the mulching film was unfolded with the mulch layer fixed by the tractor, much like the mulch layer currently used. In addition to

reducing weed pressure on crops, paper mulch usually raises the soil temperature by several degrees Fahrenheit on sunny days, with little effect on cloudy or rainy days. Moisture and nitrate levels are also usually higher under mulch than bare ground, leading to increased pineapple production.

The citrus fruit quality improves by the use of mulching covering but on fruit appearance has a negative influence. Zhang and Xie (2014) indicated that the use of mulching in mandarin during the early stages of plant and in cell division increased the reduced sugar and total sugars content. It has been reported that when transparent plastics are used in combination with soil fumigation of methyl bromide and clopyralid, the production of strawberries (*Fragaria* sp.) increases (Johnson & Fennimore, 2005). The de Araújo et al. (2022) and Wang et al. (1998) showed that different mulch types have a significant effect on the concentration of ellagic acid in strawberry fruits. Ali and Gaur (2013) used the rice straw mulching method to record the maximum number of strawberry runners per plant, the number of platelets per planter, and the number of runners per planter. Singh et al. (2005) found that the growth, fruit weight, yield and quality of the black polyethylene film in strawberries were the best. Cover the strawberry to protect the flower bud temperature below 15°F (Tyagi et al., 2015). Similarly mulching improve the soil properties, and yield of various horticultural crops as shown in Table 1.

8.3 Effect of Mulching on the Production of Cereal Crops

Maize and wheat are globally primary crop due to their importance in food security and food production. Seventy percent of the global cereal crop production are maize and wheat due to lean availability of nutrients and water significantly affected their yield especially in the semi-arid and arid area of the world (Rockstrom et al., 2010). Rice is mostly grown in heavily irrigated or in paddy field and mulching has not been generally practiced in rice crop therefore I excluded rice crop. The actual obtainable grain yield is just 30–80%. In a region where nutrient and water are sufficiently available, 8–10% losses of maize and wheat are observed due to suboptimal field practices (Zwart et al., 2004; Vitousek et al., 2009). In a dry environment where soil organic matter is generally less than two percent in this situation the availability of water and temperature are dominant factors and play a vital role in determining the yield of crops.

Mulching effects for maize and wheat crop are different, in maize absorbed more positive effect on yield as compared to wheat. Maize can use sunlight more efficiently for photosynthesis because maize is a C4 plant and wheat is a C3 plant (Long et al., 2006). During the growing season of maize crop evaporation and temperature are higher than wheat because maize grows in the summer season and wheat is a winter season crop that grows when evaporation and temperature are low as compared to maize. With the use of mulching 28% in wheat and 40% in maize temperature and evaporation can reduce (Zhang et al., 2013). The water requirement for the wheat

Table 1 Role of mulching in horticultural crops and yield

Mulching source	Orchard or plants	Crop growth and yield	Soil properties	References
Pruning mulching	Pear	Improved	–	Moniruzzaman et al. (2007)
Black plastic mulch	Mango	Improved	Increased	
mulch	Nectarine	Improved	–	Andreotti et al. (2009)
Black plastic mulch	Kiw	Improved	Increased	Pratima et al. (2016)
Black plastic sheeting and weed barrier grids	Olive	Improved		Camposeo and Vivaldi (2011)
Black polythene sheet mulch	Guava	Improved	Increased	Das et al. (2010)
Organic mulch	Guava	Improved	Increased	Das et al. (2010)
Straw mulching	Raspberry	Improved	–	Trinka and Pritts (1992)
Mulching	Peach	Improved	Increased	Lordan et al. (2015), Neri et al. (2022)
Black plastic mulch	Currants	Improved	Increased	Dale (2000)
Organic mulches	High bush blueberry	Improved	Increased	Mercik and Smolarz (1995), Spiers (1986)

crop is less than maize. Delta of water for wheat is 25–1000 mm and for maize 150–2000 mm. The nitrogen requirement for wheat ranged 20–200 kg/ha and for maize ranged 30–400 kg/ha. The efficiency to utilize of nitrogen and water increased in both crop maize and wheat with the use of mulching as compared to no mulching.

The plastic mulch effect in wheat crop vary with respect to the availability of water, 15% yield increased under the low water condition and 35% positive response on yield observed when water is available in sufficient quantity. In maize crop mulching of straw show 20% increase in yield and not affected by the input level of water. Maize crop perform better under the low water application with plastic mulch compared to plastic mulch with high water. When used plastic mulch 60 and 40% maize yield increase under the low and high water application respectively. The temperature of soil increase with the use of plastic mulch and mulching of straw decrease the temperature of soil. Germination of seed is effected by soil temperature, when we used straw mulch in wheat crop 5–7 decreased in yield observed due to decreased in soil temperature. Mulching with Plastic sheet favor the early seed germination and better growth of roots of maize crop and give positive response on yield (Li et al., 2013; Gan et al., 2013). However the use of plastic mulch in winter wheat crop increased soil temperature and favor the seed germination. Use of straw in

tropical region help in maintain the soil temperature and increase the yield of crops. Wheat grow at low temperature and has more growing time compared to maize crop. Therefore, the use of plastic mulch in wheat crop contribute in the increase of soil temperature than straw mulch. Conclude that mulching in wheat and maize crop prevent the losses of water and evaporation of nitrogen from field hence increase 60 and 20% yield of maize and wheat, respectively.

9 Conclusion and Remarks

From the above discussion, it is clear that mulching induces positive effects on soil quality as well as crop yield. Soil physical, chemical and biological characteristics are under the strong influence of mulching. As plants need proper temperature, moisture and nutrients for their survival and growth that is a necessity for better yield of the crops. Mulching induces these characters in the soil very efficiently. Mulching makes the soil a suitable medium for the proper growth and yield of many crops by improving the moisture and nutrient status of the soil. It also improves the structure of soil by increasing the organic matter concentration of the soil. Thus, all these characteristics bring maximum yield in vegetables, fruits and cereals.

References

Abou-Hussein, S. D. (2012). Climate change and its impact on the productivity and quality of vegetable crops. *Journal of Applied Sciences Research, 8*, 4359–4383.

Akhtar, K., Wang, W., Ren, G., Khan, A., Feng, Y., & Yang, G. (2018). Changes in soil enzymes, soil properties, and maize crop productivity under wheat straw mulching in Guanzhong, China. *Soil and Tillage Research, 182*, 94–102.

Ali, A., & Gaur, G. S. (2013). Effect of organic mulches on runner production of strawberry (Fragaria × ananassa Duch.). *Asian Journal of Bio Science, 8*(2), 175–179.

Andreotti, C., Ravaglia D., & Costa, G. (2009). Innovative light management to improve production sustainability, overall quality, and the phenolics composition of nectarine (Prunus persica cv. Stark Red Gold). *Journal of Horticultural Science & Biotechnology. ISAFRUIT Special Issue,* 145–149.

Ann, M., Clain, J., & Jeff, J. (2011). Plant Nutrient Functions and Deficiency and Toxicity Symptoms. *Nutrient Management Module, 9*.

Armstrong. S. (2021). How does water affect plant growth? https://www.gardeningknowhow.com/special/children/how-does-water-affect-plantgrowth.htm#:~:text=Water%20helps%20a%20plant%20by,other%20nutrients%20throuh%20the%20plant.

Ashrafuzza Man, M., Halim, A., Ismail, M., Shahidullah, S., & Hossain, A. (2011). Effect of plastic mulch on growth and yield at chilli. *Brazilian Archives of Biology and Technology, 54*(2), 321–330.

Ashworth, S., & Harrison, H. (1983). Evaluation of mulches for use in the home garden. *HortScience, 18*(2), 180–182.

Asif, M., Nadeem, M. A., Aziz, A., Safdar, M. E., Adnan, M., Ali, A., Ullah, N., Akhtar, N., & Abbas, B. (2020). Mulching improves weeds management, soil carbon and productivity of spring planted maize (Zea mays L.). *International Journal of Botany Studies, 5*, 57–61.

Bandopadhyay, S., Martin-Closas, L., Pelacho, A. M., & DeBruyn, J. M. (2018). Biodegradable plastic mulch films: Impacts on soil microbial communities and ecosystem functions. *Frontiers in Microbiology, 9*, 819.

Bandopadhyay, S., Sintim, H. Y., & DeBruyn, J. M. (2020). Effects of biodegradable plastic film mulching on soil microbial communities in two agroecosystems. *PeerJ, 8*, e9015.

Batra, S. K. (1985). Other long vegetable fibres: Abaca, banana, sisal, henequen, flax, ramie, hemp, sunn, and coir. *Handbook of fiber science and technology*, *4*, 727–807.

Black Jr, C. C. (1973). Photosynthetic carbon fixation in relation to net CO2 uptake. *Annual Review of Plant Physiology*, *24*(1), 253–286.

Bot, A., & Benites, J. (2005). The importance of soil organic matter. Key to drought-resistant soil and sustained food production. *FAO Soils Bulletin, 80*.

Brodhagen, M., Peyron, M., Miles, C., & Inglis, D. A. (2015). Biodegradable plastic agricultural mulches and key features of microbial degradation. *Applied Microbiology and Biotechnology, 99*(3), 1039–1056.

Camposeo, S., & Vivaldi, G. A. (2011). Short-term effects of de-oiled olive pomace mulching application on a young super high-density olive orchard. *Scientia Horticulturae, 129*, 613–621.

Chakraborty, D., Nagarajan, S., Aggarwal, P., Gupta, V. K., Tomar, R. K., Garg, R. N., Sahoo, R. N., Sarkar, A., Chopra, U. K., Sarma, K. S., & Kalra, N. (2008). Effect of mulching on soil and plant water status, and the growth and yield of wheat (Triticum aestivum L.) in a semi-arid environment. *Agricultural Water Management, 95*(12), 1323–1334.

Dale, A. (2000). Black plastic mulch and between-row cultivation increase black currant yields. *Hort Technology, 10*(2), 307–308.

Das B. C., Mahi S., & Mulieh, S. R. (2010). Response of soil covers on guava cv. L-49. *Journal of Crop and Weed, 6*(2), 10–14.

de Araújo, D. L., de Luna Souto, A. G., Cavalcante, A. G., Cavalcante, L. F., Pereira, W. E., & de Melo, A. S. (2022). Physiological aspects of yellow passion fruit with use of hydrogel and mulching. *Revista Caatinga, 35*(2), 382.

Dilip, K. G., Sachin, S. S., & Rajesh, K. (1990). Importance of mulch in crop production. *Indian Journal of Soil Conservation, 18*, 20–26.

Dorais, M. (2003). The use of supplemental lighting for vegetable crop production: Light intensity, crop response, nutrition, crop management, cultural practices. In *Canadian Greenhouse Conference* (Vol. 9).

Erenstein, O. (2002). Crop residue mulching in tropical and semi-tropical countries: An evaluation of residue availability and other technological implications. *Soil and Tillage Research, 67*(2), 115–133.

Erenstein, O. (2003). Smallholder conservation farming in the tropics and sub-tropics: A guide to the development and dissemination of mulching with crop residues and cover crops. *Agriculture, Ecosystems & Environment, 100*(1), 17–37.

Farmer, J., Zhang, B., Jin, X., Zhang, P., & Wang, J. (2017). Long-term effect of plastic film mulching and fertilization on bacterial communities in a brown soil revealed by high through-put sequencing. *Archives of Agronomy and Soil Science, 63*(2), 230–241.

Farrukh, I., & Safdar, A. (2004). Impact of different types of mulches on soil moisture. *Sarhad Journal of Agriculture, 20*(4), 571–573.

Folino, A., Karageorgiou, A., Calabrò, P. S., & Komilis, D. (2020). Biodegradation of wasted bioplastics in natural and industrial environments: A review. *Sustainability, 12*(15), 6030.

Gan, Y. T., et al. (2013). Ridge-furrow mulching systems-an innovative technique for boosting crop productivity in semiarid rain-fed environments. *Advances in Agronomy, 118*, 429–476. https://doi.org/10.1016/B978-0-12-405942-9.00007-4.

Ghorbani, R., Wilcockson, S., Koocheki, A., & Leifert, C. (2009). Soil management for sustainable crop disease control: a review. In *Organic farming, pest control and remediation of soil pollutants* (pp.177–201).

Gondal, A. H., & Tayyiba, L. (2022). Prospects of using nanotechnology in agricultural growth, environment and industrial food products. *Reviews in Agricultural Science, 10*, 68–81.

Gondal, A. H., Tampubolon, K., Toor, M. D., & Ali, M. (2021). Pragmatic and fragile effects of wastewater on a soil-plant-air continuum and its remediation measures: A perspective. *Reviews in Agricultural Science, 9*, 249–259.

Haapala, T., Palonen, P., Korpela, A., & Ahokas, J. (2014). Feasibility of paper mulches in crop production—A review. *Agricultural and Food Science, 23*(1), 60–79.

Hundal, R. S., Krssak, M., Dufour, S., Laurent, D., Lebon, V., Chandramouli, V., Inzucchi, S. E., Schumann, W. C., Petersen, K. F., Landau, B. R. & Shulman, G. I. (2000). Mechanism by which metformin reduces glucose production in type 2 diabetes. *Diabetes*, *49*(12), 2063–2069.

Hussain, A., Illahi, B. A., Iqbal, A. M., Jehaangir, I. A., & Hussain, S. T. (2019). Agronomic management of saffron (Crocus sativus)-A review. *Indian Journal of Agronomy, 64*(2), 147–164.

Iqbal, R., Raza, M. A. S., Valipour, M., Saleem, M. F., Zaheer, M. S., Ahmad, S., Toleikiene, M., Haider, I., Aslam, M. U., & Nazar, M. A. (2020). Potential agricultural and environmental benefits of mulches-a review. *Bulletin of the National Research Centre, 44*, 1–16.

Jack, J. R., & Diaconis, N. S. (1955). *Variation of boundary-layer transition with heat transfer on two bodies of revolution at a Mach number of 3.12* (No. NACA-TN-3562).

Johnson, M. S., & Fennimore, S. A. (2005). Weed and crop response to colored plastic mulches in strawberry production. *Hort Science, 40*, 1371–1375.

Kader, M. A., Senge, M., Mojid, M. A., & Ito, K. (2017). Recent advances in mulching materials and methods for modifying soil environment. *Soil and Tillage Research, 168*, 155–166.

Lal Bhardwaj, R. (2013). Effect of mulching on crop production under rainfed condition-a review. *Agricultural Reviews*, *34*(3).

Lamont, W. J. (2005). Plastics: Modifying the microclimate for the production of vegetable crops. *HortTechnology*, *15*(3), 477–481.

Lamont, B. B., Klinkhamer, P. G., & Witkowski, E. T. F. (1993). Population fragmentation may reduce fertility to zero in Banksia goodii—A demonstration of the Allee effect. *Oecologia*, *94*(3), 446–450.

Lauridsen, T. L., Mønster, T., Raundrup, K., Nymand, J., & Olesen, B. (2020). Macrophyte performance in a low arctic lake: Effects of temperature, light and nutrients on growth and depth distribution. *Aquatic Sciences, 82*(1), 1–14.

Li, S. X., Wang, Z. H., Li, S. Q., Gao, Y., & Tian, X. H. (2013). Effect of plastic sheet mulch, wheat straw mulch and maize growth on water loss by evaporation in dryland areas of China. *Agricultural Water Management, 116*, 39–49. https://doi.org/10.1016/j.agwat.2012.10.004

Long, S. P., Zhu, X. G., Naidu, S. L., & Ort, D. R. (2006). Can improvement in photosynthesis increase crop yields?. *Plant, cell & environment*, *29*(3), 315–330.

Lordan, J., Pascual, M., Villar, J. M., Fonseca, F., Papió, J., Montilla, V., & Rufat, J. (2015). Use of organic mulch to enhance water-use efficiency and peach production under limiting soil conditions in a three-year-old orchard. *Spanish Journal of Agricultural Research, 13*(4), e0904.

Mahadeen, A. Y. (2014). Effect of polyethylene black plastic mulch on growth and yield of two summer vegetable crops under rainfed conditions under semi-arid region conditions. *American Journal of Agricultural and Biological Sciences, 9*(2), 202–207.

Mercik, S., & Smolarz, K. (1995). Influence of fertilization and mulching on the growth, fruiting and chemical composition of soil and leaves of high bush blueberry. *Acta Horticulture, 383*, 323–329.

Moniruzzaman, M., Mozumde, S. N., & Islam, M. R. (2007). Effect of mulching and pruning on yield and quality of pear. *Bangladesh Journal of Agriculture Research, 32*(2), 225–233.

Nawaz, A., Lal, R., Shrestha, R. K., & Farooq, M. (2017). Mulching affects soil properties and greenhouse gas emissions under long-term no-till and plough-till systems in Alfisol of central Ohio. *Land Degradation & Development, 28*(2), 673–681.

Neri, D., Zikeli, S., Lepp, B., Malusa, E., Fernandez, M. M., Boutry, C., et al. (2022). Dynamic sod mulching and use of recycled amendments to increase biodiversity, resilience and sustainability of intensive organic apple orchards and vineyards (DOMINO).

Ni, X., Song, W., Zhang, H., Yang, X., & Wang, L. (2016). Effects of mulching on soil properties and growth of tea olive (Osmanthus fragrans). *PLoS ONE, 11*(8), e0158228.

Nzeyimana, I., Hartemink, A. E., Ritsema, C., Stroosnijder, L., Lwanga, E. H., & Geissen, V. (2017). Mulching as a strategy to improve soil properties and reduce soil erodibility in coffee farming systems of Rwanda. *CATENA, 149*, 43–51.

Park, C. L., Cohen, L. H., & Murch, R. L. (1996). Assessment and prediction of stress-related growth. *Journal of personality*, *64*(1), 71–105.

Pratima, P., Sharma, N., & Sharma, D. P. (2016). Canopy temperature and water relations of kiwifruit cultivar Allison in response to deficit irrigation and in situ moisture conservation. *Current Science, 111*(2), 375–379.

Qayyum, M. M., Hassan, I., Abbasi, N. A., & Khalid, A. (2020). Mitigation of low temperature stress by polythene for quality production of Gladiolus (Gladiolus hortulanus L.) during winter. *Applied Ecology and Environmental Research, 18*(3), 4469–4486.

Qin, W., Chi, B. L., Oenema, O. (2013). Long-term monitoring of rainfed wheat yield and soil water at the loess plateau reveals low water use efficiency. *Plos One, 8*, ARTN e78828, https://doi.org/10.1371/journal.pone.0078828.

Rajablariani, H., Khan, F. H., & Rafezi, R. (2012). Effect at colored plastic mulches on yield at tomato and weed biomass. *International Journal of Environmental Science and Development, 3*(6), 590–593.

Rajput, R. K., & Singh, M. (1970). Efficacy of different mulches in conserving soil moisture in cotton. *Indian Journal of Agronomy*, *15*(1), 41–5.

Ranjan, P., Patle, G. T., Prem, M., & Solanke, K. R. (2017). Organic mulching-A water saving technique to increase the production of fruits and vegetables. *Current Agriculture Research Journal, 5*(3), 371–380.

Rhoades, H. (2021). How light affects the growth of a plant & problems with too little light. https://www.gardeningknowhow.com/plant-problems/environmental/how-lightaffects-the-growth-of-a-plant-problems-with-too-little-light.htm.

Rockstrom, J., Hatlbu, N., Owels, T. Y., & Wani, S. P. (2007). Managing water in rainfed agriculture.

Rockström, J., Karlberg, L., Wani, S. P., Barron, J., Hatibu, N., Oweis, T., Bruggeman, A., Farahani, J. and Qiang, Z. (2010). Managing water in rainfed agriculture—The need for a paradigm shift. *Agricultural Water Management*, *97*(4), 543–550.

Sharma, A. R., Singh, R., Dhyani, S. K., & Dube, R. K. (2010). Moisture conservation and nitrogen recycling through legume mulching in rainfed maize (*Zea mays*)–wheat (Triticum aestivum) cropping system. *Nutrient Cycling in Agroecosystems, 87*(2), 187–197.

Singh, R., Sharma, R. R., & Jain, R. K. (2005). Planting time and mulching influenced vegetative and reproductive traits in strawberry in India. *Fruits, 60*, 395–403.

Singh, R., Jhorar, R. K., Van Dam, J. C., & Feddes, R. A. (2006). Distributed ecohydrological modelling to evaluate irrigation system performance in Sirsa district, India II: Impact of viable water management scenarios. *Journal of Hydrology*, *329*(3-4), 714–723.

Singh, R., Kumar, S., Nangare, D. D., & Meena, M. S. (2009). Drip irrigation and black polyethylene mulch influence on growth, yield and water-use efficiency of tomato. *African Journal of Agricultural Research, 4*(12), 1427–1430.

Sohail, S., Gondal, A. H., Farooq, Q., Tayyaba, L., Zainab, D. E., Ahmad, I. A., et al. (2021). Organic vegetable farming; a valuable way to ensure sustainability and profitability. In *Vegetable growing*. IntechOpen.

Spiers, J. M. (1986). Root distribution of 'Tifblue' rabbiteye blueberry as influenced by irrigation, incorporated peatmoss, and mulch. *Journal of American Society for Horticultural Science, 111*, 877–880.

Stewart, G., Thomas, E., & Horner, J. (1926). Some effects of mulching paper on Hawaiian soils. *Soil Science, 22*, 35–39.

Tan, C., Cao, X., Yuan, S., Wang, W., Feng, Y., & Qiao, B. (2015). Effects of long-term conservation tillage on soil nutrients in sloping fields in regions characterized by water and wind erosion. *Scientific Reports, 5*(1), 1–8.

Thakur, M., & Kumar, R. (2020). Mulching: Boosting crop productivity and improving soil environment in herbal plants. *Journal of Applied Research on Medicinal and Aromatic Plants,* 100287.

Trinka, D. L., & Pritts, M. P. (1992). Micropropagated raspberry plant establishment responds to weed control practice, row cover use, and fertilizer placement. *Journal of American Society for Horticultural Science, 117*(6), 874–880.

Tyagi, S., Ahmad, M., Sahay, S., Nanher, A. H., & Nandan, B. (2015). Strawberry: A potential cash crop in India. *Rashtriya krishi, 10*(2), 57–59.

UNESCO. (2009). The United Nations World Water Development Report 3: Water in a Changing World. Earthscan.

Van der Putten, W. H., Bardgett, R. D., Bever, J. D., Bezemer, T. M., Casper, B. B., Fukami, T., et al. (2013). Plant–soil feedbacks: The past, the present and future challenges. *Journal of Ecology, 101*(2), 265–276.

Vitousek, P. M., Naylor, R., Crews, T., David, M. B., Drinkwater, L. E., Holland, E., Johnes, P. J., Katzenberger, J., Martinelli, L. A., Matson, P. A. & Nziguheba, G. (2009). Nutrient imbalances in agricultural development. *Science*, *324*(5934), 1519–1520.

Wahid, A., Gelani, S., Ashraf, M., & Foolad, M. R. (2007). Heat tolerance in plants: An overview. *Environmental and Experimental Botany, 61*(3), 199–223.

Wang, S. Y., Galletta, G. J., Camp, M. J., & Kasperbauer, M. J. (1998). Mulch types affect fruit quality and composition of two strawberry genotypes. *Hort Science, 33*, 636–640.

Xianchen, Z., Huiguang, J., Xiaochun, W., & Yeyun, L. (2020). The effects of different types of mulch on soil properties and tea production and quality. *Journal of the Science of Food and Agriculture, 100*(14), 5292–5300.

Zhang, G., & Xie, S. (2014). Effects of plastic film mulching on quality and appearance of Statuma mandarin fruit. *American Journal of Plant Sciences, 5*, 3829–3835.

Zhang, X., Wang, H., He, L., Lu, K., Sarmah, A., Li, J., Bolan, N. S., Pei, J., & Huang, H. (2013). Using biochar for remediation of soils contaminated with heavy metals and organic pollutants. *Environmental Science and Pollution Research*, *20*(12), 8472–8483.

Zwart, P. J., Gerber, A. G., & Belamri, T. (2004, May). A two-phase flow model for predicting cavitation dynamics. In *Fifth international conference on multiphase flow, Yokohama, Japan* (Vol. 152).