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Savita Rani
Department of Horticulture, COA,
CCSHAU, Hisar, Haryana, India

Prince
Department of Horticulture, COA,
CCSHAU, Hisar, Haryana, India

Preeti Jha
Department of Horticulture, COA,
CCSHAU, Hisar, Haryana, India

Soil adaptation mechanisms to mitigate climate change effects on fruit crops

Savita Rani, Prince and Preeti Jha

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Abstract

Climate change presents significant challenges to agricultural output, particularly in fruit orchards. The distribution, phenology, fruit quality, and prevalence of pests and illnesses in perennial fruit crops are all significantly influenced by climate. The biochemical mechanisms that govern fruit trees are directly related to the physiological traits and yield of fruits, which are sensitive to changes in temperature, precipitation, and other climatic factors that comprise the world climate. Given the difficulties facing fruit production worldwide, a strategy-based scientific assessment of the impacts should be conducted, together with measures for adaptation and mitigation. Accordingly, orchard soil management is crucial for reducing these issues as it enhances soil health and climate variability resistance. This article examines how fruit orchards are affected by climate change and focuses on various soil management strategies that might be applied to adapt. Microbial inoculation, cover crops, organic amendments, integrated soil management, and improved irrigation techniques are all given careful consideration. To sustain fruit production in the face of climate change, these tactics can be implemented using the suggestions in the conclusion.

Keywords: Climate change, fruit orchards, soil management

1. Introduction

Climate change, which is typified by rising temperatures, altered precipitation patterns, and a rise in the frequency of extreme weather events, poses a major danger to global agricultural systems. According to the IPCC, the average temperature on the Indian subcontinent will rise by 0.88 to 3.16°C by 2050 and 1.56 to 5.44°C by 2080, depending on future events. The primary drivers of climate change are unpredictable high and low temperature regimes and unusual rainfall patterns, which have a significant effect on both horticulture and agriculture in general. Fruit orchards are particularly sensitive due to their long-term investment and sensitivity to environmental conditions (Shaffer *et al.*, 2018) ^[10]. Because resilient and productive soils are necessary to withstand the effects of climate change, fruit orchards must carefully manage their soils. For temperate fruit species to have good vegetative development and fruiting, there must be adequate cooling hours. These fruit harvests have irregular bud break and fruiting due to insufficient chilling hours (Viti *et al.*, 2010) ^[18]. In a warming climate, tropical fruit is projected to face significant challenges from increased irrigation demand, altered irrigation system efficiency, and altered water supplies. Soils have been severely degraded by intensive farming practices (such as continuous tilling, heavy mineral fertilizer inputs, poor irrigation, and irrigation technique water, removing any leftover pruning material) combined with unfavorable climate characteristics (such as low precipitation and high summer temperatures) (Lal, 2015) ^[6]. It is generally believed that advanced soil management is required in areas that are facing water shortages in order to limit competition between fruit crops and weeds for nutrients and water, which will greatly reduce the appeal of preservation tillage and hinder the restoration of soil fertility (Das, 2020) ^[4]. Therefore, managing soil-protecting approaches instead of traditional ones was the aim of this investigation. The fundamental premise of the work is that fruit crop yields are increased when soil fertility is increased by effective agricultural practices under a range of climatic circumstances. There has been extensive discussion on the present level of knowledge regarding soil management techniques that can aid in fruit orchards' adaptation to climate change.

Corresponding Author:
Savita Rani
Department of Horticulture, COA,
CCSHAU, Hisar, Haryana, India

2. Impact of Climate Change on Fruit Orchards

The productivity, blooming, and quality of tropical fruits are affected by annual variations in the pattern of precipitation distribution. The main ways that high temperatures affect crop output are by limiting vegetative development and reducing fruit set. Extreme transpiration coupled with high temperatures limits fruit crops that are susceptible to significant transpiration losses. (Sdoodeet *et al.*, 2010). The impact of climate change on fruit orchards may thus be divided into the following categories:

- **Elevated Temperature:** Heat stress brought on by temperatures above average may alter fruit development and perhaps reduce yields. Warmer winters could affect the chilling needs of some fruit trees, which could affect blooming and bud break (Sen *et al.*, 2015)^[12].
- **Modified Rainfall Patterns:** Changes in rainfall patterns can lead to either an abundance of moisture or dry spells, which can negatively affect the health of roots and their capacity to absorb nutrients (Pereira *et al.*, 2012)^[9].
- **Severe Weather Events:** High rainfall and more frequent storms can physically damage orchard trees and result in soil erosion and nutrient leakage (Viti *et al.*, 2010)^[18].
- **Degradation of Soil Health:** Long-term orchard management depends on microbial activity, soil organic matter, and overall soil health, all of which can be impacted by temperature and moisture content variations (Smith *et al.*, 2014)^[14].

3. Soil Management Strategies

3.1 Organic Amendments

These improvements increase fruit crops' resistance to climate change. The addition of organic matter raises the levels of soil organic carbon (SOC), which is essential for soil fertility and water-holding ability (Clara *et al.*, 2017)^[3]. Studies have indicated that soils supplemented with organic amendments are more resilient to drought circumstances because they hold onto moisture and give plants a consistent source of nutrients. Lal (2015)^[6] emphasizes that in order to sustain agricultural output in the face of shifting climatic circumstances, adding organic matter can improve water penetration, decrease erosion, and increase soil aggregation. Increasing the variety and activity of soil bacteria is another important function of organic additions. These amendments encourage the decomposition of organic materials by soil microbes and the restoration of vital nutrients in the soil by giving them food. Increased microbial activity may improve nutrient cycling and increase fruit crop availability of nutrients including potassium, phosphate, and nitrogen (Glick, 2012)^[5]. Additionally, the process of less compacted soil which is necessary for root growth and water absorption—can be aided by organic amendments (Lal, 2020)^[7].

Compost, manure, and biochars are examples of organic amendments that improve soil structure, water retention, and nutrient availability. Apply compost formed from plant waste, manure, and orchard trash to increase the amount of organic matter in the soil. This strengthens the soil's structure, increases its capacity to hold water, and provides essential nutrients for tree growth. Apply compost formed from plant waste, manure, and orchard trash to increase the amount of organic matter in the soil. This strengthens the soil's structure, increases its capacity to hold water, and provides essential nutrients for tree growth (Tejada *et al.*, 2016)^[16]. More people are realizing that biochar, a kind of charcoal derived from biomass, may improve soil health and mitigate the consequences of climate change. Its application increases the availability of nutrients and enhances the physical properties of the soil, including its porosity and

water retention, by reducing leaching losses (Lehmann & Joseph, 2024)^[8]. Additionally, biochar has the ability to retain carbon in the soil for extended periods of time, which aids in attempts to lessen the impacts of carbon dioxide (Van *et al.*, 2012)^[17]. Biochar-treated soils can significantly reduce agricultural fields' greenhouse gas emissions. Lehmann and Joseph (2015) assert that biochar may absorb and retain nutrients, making them more accessible to plants and reducing the need for artificial fertilizers. Furthermore, biochar improves the soil's pH, which is beneficial for fruit crops that are susceptible to soil acidity. The liming action of biochar can boost nutrient availability and microbial activity in acidic soils. Furthermore, it has been shown that biochar improves the water-use efficiency of agricultural systems. By keeping more water in the soil, biochar helps plants withstand dry spells, which are expected to happen more frequently as a result of climate change (Lal, 2020)^[7].

3.2 Cover Cropping

Growing cover crops is primarily done to enhance the soil, not to boost output. The practice of "cover cropping," which involves growing specific crops during off-seasons, is used to maintain and improve soil health. Cover crops increase the quantity of organic matter in the soil, decrease soil erosion, and enhance soil structure. They also promote healthy microbial activity, which is critical for nutrient cycling and plant health. By fixing atmospheric nitrogen, legumes and other cover crops can improve soil fertility and reduce the demand for synthetic fertilizers. Utilizing cover crops has been shown to improve soil moisture retention and reduce temperature swings, serving as a buffer against severe weather conditions. Blanco-Canqui *et al.* (2015)^[2] claim that because cover crops produce ground cover, which protects the soil's surface from the impacts of rainfall and reduces flow, they can reduce soil erosion.

Furthermore, cover crops reduce the demand for pesticides by suppressing weeds. Because cover crops outcompete weeds for nutrients, water, and light, they can help reduce weed pressure and produce better fruit harvests. Additionally, the root systems of cover crops can improve soil structure by producing macropores that allow water infiltration and root penetration (Blanco-Canqui *et al.*, 2015)^[2]. This is particularly useful in reducing the consequences of heavy rainfall events, as climate change is expected to exacerbate their effects.

3.3 Mulching

Mulching is the process of applying either organic or inorganic materials to the soil's surface. Mulching has the following advantages:

- **Moisture Conservation:** Mulch preserves soil moisture by lowering evaporation.
- **Temperature Regulation:** Mulch moderates temperature swings by insulating the soil.
- **Weed Control:** By obstructing sunlight, mulch prevents weeds from growing.
- **Soil Health:** As organic mulches break down, they enrich the soil with nutrients and organic materials (Das *et al.*, 2020)^[4].

3.4 Microbial Inoculants

Microbial inoculants, such as mycorrhizal fungi and plant growth-promoting rhizobacteria (PGPR), are crucial for enhancing soil health and plant resistance. These beneficial microbes increase resistance to soil-borne diseases, improve nutrient intake, and promote root growth. For instance,

mycorrhizal fungi expand the roots' surface area, which enhances their capacity to take up nutrients and water—a feature that is especially helpful during dry spells. PGPRs create phytohormones and other bioactive compounds that enhance plant growth and stress tolerance.

Microbial inoculants have been shown to improve agricultural yields and resilience to environmental shocks. PGPRs generate gibberellins, auxins, and cytokinins, which are known to enhance nutrient intake and promote root development (Glick, 2012) [5]. Mycorrhizal fungi help plants absorb more water and nutrients and extend the reach of their root systems by developing symbiotic associations with their roots. For fruit crops that are grown in arid or low-nutrient soils, this is especially important. The improved nutrient absorption may lead to greater plant development and higher fruit harvests. Additionally, mycorrhizal fungi can help plants that are stressed by salt and heavy metals, two factors that are becoming increasingly common due to pollution and climate change (Glick, 2012) [5]. These microorganisms also aid in soil aggregation, which improves soil structure and water penetration.

3.5 Integrated Soil Management

By using an integrated strategy that incorporates many soil management techniques, fruit crops may be shielded from the adverse impacts of climate change and their advantages can be optimized. For example, combining biochar and cover crops with organic amendments can increase soil health, increase water retention, and reduce greenhouse gas emissions (Van *et al.*, 2012) [17]. Furthermore, integrated soil management strategies can lead to improved biodiversity, agro-ecosystem resilience, and sustainable agricultural practices. Incorporating integrated soil management can yield several advantages, including higher resistance to climate change, better soil fertility, and enhanced carbon sequestration (Smith *et al.*, 2014) [14].

- **Gypsum:** Gypsum may decrease compaction, enhance drainage and soil structure in clay soils, and supply calcium and sulfur—two elements that are critical for plant growth.
- **Lime:** Lime improves nutrient availability and encourages healthy root growth by raising the pH of acidic soils.

Integrated soil management can also use precision agricultural techniques to optimize crop and soil management. Precision agriculture uses technology to monitor and manage the health of crops and soil, allowing for targeted treatments that can boost output while reducing their adverse environmental consequences. By combining modern technologies with conventional soil management methods, farmers may develop agricultural systems that are more robust and sustainable (Smith *et al.*, 2014) [14].

3.5.1 Fertilizer Timing and Application: You may improve nutrient usage efficiency and lessen your impact on the environment by applying fertilizers at the appropriate times and utilizing techniques like banding or fertigation that decrease nutrient runoff (Smith *et al.*, 2020) [15].

- **Banding:** Applying fertilizers in bands around the root zone improves the trees' ability to absorb nutrients and minimizes nutrient loss.
- **Fertigation:** By combining fertilization and irrigation, fertigation increases nutrient usage efficiency and decreases runoff by delivering nutrients straight to the root zone.

3.5.2 Soil Moisture Management

- **Irrigation Efficiency:** Making the switch to more effective irrigation methods, including drip or micro-sprinkler systems, will help cut down on water waste and guarantee that water gets to the root zone efficiently. Based on real-time soil moisture data, automatic irrigation and soil moisture sensors can assist maximize water utilization (Pereira *et al.*, 2012) [9].
- **Drip Irrigation:** By delivering water straight to the root zone, drip irrigation reduces runoff and evaporation. This technique is ideal for places with scarce water supplies and is quite effective.
- **Micro-Sprinkler Systems:** By uniformly distributing water throughout the soil surface, micro-sprinklers minimize water loss and guarantee consistent moisture levels in the orchard (Lal, 2020) [7].
- **Soil Moisture Conservation:** By conserving soil moisture through practices like mulching, no-till farming, and the use of water-absorbing polymers, orchards can become more drought-tolerant (Tejada *et al.*, 2016) [16].
- **No-Till Farming:** By avoiding tillage, soil moisture is preserved, erosion is decreased, and soil structure is maintained. Additionally, no-till methods increase microbial activity and soil organic matter (Blanco-Canqui & Ruis 2018) [1].
- **Water-Absorbing Polymers:** Large volumes of water may be absorbed and held by these polymers, often referred to as hydrogels, which then gradually release the water into the soil. During dry spells, this keeps soil moisture levels stable (Pereira *et al.*, 2012) [9].

3.5.3 Soil Structure and Health Improvement

- **Conservation Tillage:** Reducing the frequency of tillage contributes to the preservation of soil organic matter, erosion control, and soil structure. By reducing soil disturbance, conservation tillage techniques enhance water penetration and encourage stronger root systems (Shukla *et al.*, 2019) [13].
- **Reduced Tillage:** Only a piece of the soil is disturbed by techniques like zone tillage and strip tillage, leaving the remainder intact. This reduces erosion and preserves soil structure.
- **No-Till:** Tillage should be avoided at all costs in order to maintain soil structure, improve water penetration, and encourage strong root systems (Blanco-Canqui & Ruis 2018) [1].

Other Amendments: Soil additions like lime, gypsum, or charcoal can increase nutrient availability, decrease compaction, and improve soil structure. Additionally, these supplements might lessen the impacts of alkalinity or acidity in the soil.

Biochar: One type of charcoal that can strengthen soil structure, improve nutrient retention, and boost water-holding capacity is called biochar. Additionally, it encourages advantageous microbial activity (Lehmann & Joseph 2024) [8].

Gypsum: In clay soils, gypsum can enhance drainage and soil structure, lessen compaction, and supply calcium and sulfur—two elements that are critical for plant development.

Lime: In acidic soils, lime is utilized to increase the pH, which enhances nutrient availability and encourages strong root growth

(Tejada *et al.*, 2016)^[16].

3.5.4 Improved Irrigation Practices

In light of the changing climate, effective irrigation techniques are essential for managing water supplies. Some strategies are:

- **Drip irrigation:** By delivering water straight to the root zone, drip irrigation lowers water loss and increases water usage efficiency.
- **Scheduling:** Optimizing irrigation volumes and timing by utilizing meteorological information and soil moisture sensors.
- Gathering and storing rainwater for use in irrigation during dry spells is known as rainwater harvesting (Shukla *et al.*, 2019)^[13].

4. Case Studies

- **Organic Amendments in Apple Orchards:** In comparison to untreated orchards, apple orchards treated with compost demonstrated higher soil organic matter content, greater water retention, and higher fruit output and quality, according to a research done in Washington State, USA (Sen *et al.*, 2015)^[12].
- **Cover Cropping in Citrus Grove:** Leguminous cover crops in citrus orchards increased soil nitrogen levels, decreased erosion, and improved fruit quality, according to research conducted in Florida, USA (Blanco-Canqui *et al.*, 2015)^[2].
- **Mulching in Mango Plantations:** Mango plantations in India that were mulched with organic materials like wood chips and straw showed increased fruit output and quality, less weed pressure, and greater soil moisture retention (Das *et al.*, 2020)^[4].
- **Olive Orchard Drip Irrigation:** According to a research conducted in Spain, drip irrigation systems improved water usage efficiency, decreased water stress, and preserved consistent yields in drought-prone olive orchards (Pereira *et al.*, 2012)^[9].

4.1 Mediterranean Fruit Orchards: Techniques like mulching and effective irrigation have been effectively used to preserve soil health and conserve water in areas like the Mediterranean, where water shortage is a significant problem (Viti *et al.*, 2010)^[18].

4.1.1 Spain: To save water and raise soil moisture levels, olive groves there have embraced organic mulching and drip watering. Despite less water available, these methods have helped sustain output.

4.1.2 Vineyards in Italy: To improve soil organic matter and lessen erosion, Italian vineyards employ cover crops and decreased tillage. As a result, the soil is now healthier and more drought-resistant.

4.2 Tropical Fruit Orchards: Cover crops and agroforestry systems have shown promise in lowering soil erosion and increasing soil organic matter in tropical regions that are vulnerable to high rainfall and soil erosion (Smith *et al.*, 2020)^[15].

4.2.1 Costa Rica: To lessen soil erosion and enhance soil health, coffee and banana farms there have used agroforestry and cover cropping techniques. These methods have improved resilience to

climatic unpredictability and biodiversity.

4.2.2 India: To increase soil fertility and lessen erosion, mango plantations there employ organic mulching and leguminous cover crops. As a result, yields have grown and tree health has improved.

4.3 Temperate Fruit Orchards: Conservation tillage and the use of biochar have demonstrated potential in enhancing soil structure and nutrient retention in temperate climates, hence contributing to climate resilience (Sen *et al.*, 2015)^[12].

4.3.1 United States: To enhance soil health and boost water-holding capacity, apple orchards in the US have implemented conservation tillage and biochar application. Fruit quality and tree growth have improved as a result of these methods.

4.3.2 New Zealand: To improve soil organic matter and lessen erosion, kiwi orchards there employ cover crops and less tillage. As a result, soil health has improved and climate change resistance has grown.

5. Challenges and Considerations

A number of elements need to be taken into account when implementing soil management strategies:

- **Price and Availability:** Mulching materials and organic additions might be expensive and not always easily accessible.
- **Labor Requirements:** The application and upkeep of some methods, such mulching and cover crops, call for extra labor.
- **Knowledge and Assistance:** To successfully implement new soil management techniques, farmers require assistance and training.
- **Local Adaptation:** Plans need to be customized to the climate, soil, and agricultural needs of the area (Smith *et al.*, 2014 & Shukla *et al.*, 2019)^[14, 13].

6. Recommendations

The following suggestions are put forth to improve fruit orchards' resistance to climate change:

- **Integrated Soil Management:** Several soil management techniques can be combined to enhance overall soil health and provide synergistic effects.
- **Research and Development:** To create and improve soil management techniques for various fruit crops and geographical areas, further research is required.
- **Extension Services:** Improving extension services can facilitate the adoption of new methods by farmers and aid in the dissemination of information.
- **Policy fund:** Adaptation efforts can be aided by policies that fund research and extension services, encourage sustainable soil management, and offer financial incentives (Smith *et al.*, 2014 & Shukla *et al.*, 2019)^[14, 13].

7. Conclusion

The production of fruit orchards is severely threatened by climate change, although resilience and sustainability may be improved with good soil management techniques. Improved irrigation techniques, mulching, cover crops, and organic amendments are important tactics that can lessen the negative consequences of climate change. Fruit farmers may preserve soil health, increase water usage efficiency, and guarantee consistent

harvests despite climatic fluctuation by using these methods.

areas: Murcia (Spain) and Tuscany (Italy). *Sci Hortic* (Amsterdam). 2010;124(2):217-224.

References

1. Blanco-Canqui H, Ruis SJ. No-tillage and soil physical environment. *Geoderma*. 2018;326:164-200.
2. Blanco-Canqui H, Shaver TM, Lindquist JL, Shapiro CA, Elmore RW, Francis CA, *et al*. Cover crops and ecosystem services: insights from studies in temperate soils. *Agron J*. 2015;107(6):2449-2474.
3. Clara L, Fatma R, Viridiana A, Liesl W. Soil organic carbon: the hidden potential. Rome: Food and Agriculture Organization of the United Nations; 2017.
4. Das DK, *et al*. Mulching: an effective water conservation technique for sustainable agriculture. *J Soil Water Conserv*. 2020;75(1):1-9.
5. Glick BR. Plant growth-promoting bacteria: mechanisms and applications. *Scientifica*. 2012;2012:963401.
6. Lal R. Restoring soil quality to mitigate soil degradation. *Sustainability*. 2015;7(5):5875-5895.
7. Lal R. Soil organic matter and water retention. *Agron J*. 2020;112(5):3265-3277.
8. Lehmann J, Joseph S, editors. Biochar for environmental management: science, technology and implementation. 2nd ed. Boca Raton: Taylor & Francis; 2024.
9. Pereira LS, Cordery I, Iacovides I. Improved indicators of water use performance and productivity for sustainable water conservation and saving. *Agric Water Manag*. 2012;108:39-51.
10. Schaffer B, Andersen PC. Handbook of environmental physiology of fruit crops. Boca Raton: CRC Press; 2018.
11. Sdoodee S, Lerslerwong L, Rugkong A. Effects of climatic condition on off-season mangosteen production in Phatthalung Province. Songkla (Thailand): Prince of Songkla University, Faculty of Natural Resources, Department of Plant Science; 2010.
12. Sen V, Rana RS, Chauhan RC. Impact of climate variability on apple production and diversity in Kullu valley, Himachal Pradesh. *Indian J Hortic*. 2015;72(1):14-20.
13. Shukla PR, Skea J, Buendia EC, Masson-Delmotte V, Pörtner HO, Roberts DC, *et al*. Climate change and land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. Geneva: IPCC; 2019.
14. Smith P, Bustamante M, Ahammad H, Clark H, Dong H, Elsiddig EA, *et al*. Agriculture, forestry and other land use (AFOLU). In: Climate change 2014: mitigation of climate change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press; 2014. p. 811-922.
15. Smith P, *et al*. Soil management and climate change. *Soil Use Manag*. 2020;36(1):12-18.
16. Tejada M, *et al*. Use of organic amendments as a strategy for reducing the environmental impact of agriculture. *J Environ Manag*. 2016;181:357-366.
17. Van Zwieten L, Singh B, Joseph S, Kimber S, Cowie A, Chan KY. Biochar and emissions of non-CO₂ greenhouse gases from soil. In: Lehmann J, Joseph S, editors. Biochar for environmental management. London: Routledge; 2012. p. 259-282.
18. Viti R, Andreini L, Ruiz D, Egea J, Bartolini S, Iacona C, *et al*. Effect of climatic conditions on the overcoming of dormancy in apricot flower buds in two Mediterranean