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ADVANTAGES OF STRAW MULCHING IN FRUIT CULTIVATION: A COMPREHENSIVE REVIEW

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ABSTRACT:
Straw mulching has emerged as a sustainable cultivation practice with multifaceted benefits for fruit cultivation systems worldwide. This comprehensive review synthesizes empirical evidence, theoretical frameworks, and practical insights to elucidate the advantages of straw mulching in fruit cultivation. Soil conservation and erosion control are primary benefits of straw mulching, mitigating soil erosion, promoting soil aggregation, and enhancing water infiltration rates. Weed management is facilitated by straw mulching, suppressing weed growth. Additionally, straw mulching contributes to soil moisture conservation, drought resilience, and water use efficiency in fruit orchards. Soil fertility and nutrient management are enhanced through the decomposition of straw mulch, enriching soil organic matter. Pest and disease management benefits from straw mulching include habitat provision for natural enemies, and creation of a less favorable microclimate for disease development. Biodiversity conservation and ecosystem services are promoted by straw mulching, supporting diverse flora and fauna. While the efficacy of straw mulching depends on various factors, including mulch thickness, application timing, and management practices, its potential for enhancing fruit yield, quality, and sustainability is evident across diverse agro ecological contexts. Further research is warranted to optimize straw mulching techniques such as mulch type, their thickness, mulch temperature, mulch effect on climate change and time of application, quantify its long-term effects on soil health and ecosystem services, and assess its economic viability and scalability in fruit cultivation systems. Overall, straw mulching represents a promising strategy for promoting sustainable fruit cultivation practices that prioritize environmental stewardship, social equity, and economic viability in a changing world.
KEYWORDS: Straw Mulching, Soil Conservation, Nutrient Cycling, Biodiversity Conservation.

INTRODUCTION
Fruit cultivation plays a pivotal role in global agriculture, providing essential nutrients, economic livelihoods, and environmental benefits to millions of people worldwide. However, fruit production is often challenged by various biotic and abiotic stressors, including soil erosion; weed competition, moisture loss, temperature fluctuations, and nutrient depletion. In this context, the adoption of sustainable cultivation practices such as straw mulching offers promising solutions to enhance fruit yield, quality, and resilience while minimizing environmental impact and resource use. This comprehensive review explores the multifaceted advantages of straw mulching in fruit cultivation, drawing upon empirical evidence, theoretical frameworks, and practical insights from diverse agro ecological contexts (Borthakur and Bhattacharya, 1992).
Mulching, defined as the application of organic or inorganic materials on the soil surface, has been practiced for centuries to improve soil health, conserve moisture, suppress weeds, and regulate soil temperature in agricultural systems. Among various mulching materials, straw, derived from cereal crops such as wheat, rice, barley, and oats, has gained widespread popularity due to its abundance, affordability, biodegradability, and agronomic benefits. Straw mulching involves spreading a layer of straw residue on the soil surface around fruit trees or vine crops, thereby creating a protective barrier that mitigates soil erosion, retains soil moisture, moderate's temperature extremes, and enhances nutrient cycling in the orchard ecosystem. One of the primary advantages of straw mulching in fruit cultivation is its role in soil conservation and erosion control. Fruit orchards are often established on sloping terrain, where soil erosion poses a significant threat to soil fertility, water quality, and ecosystem integrity (Asghar *et al.* 1987). By covering the soil surface with a layer of straw mulch, farmers can reduce the impact of rainfall and surface runoff, thereby minimizing soil erosion and sediment loss from orchard slopes. Moreover, straw mulching promotes soil aggregation, enhances soil structure, and increases water infiltration rates,

thereby reducing surface runoff and enhancing soil moisture retention, particularly in sandy or degraded soils prone to water stress, working on straw mulch and finding similar results by (Demo and Asefa Bogale, 2024)

Straw mulching serves as an effective weed management strategy in fruit cultivation systems. Weeds compete with fruit trees for essential resources such as water, nutrients, and sunlight, thereby reducing crop yield, quality, and profitability. Traditional weed control methods, such as tillage and herbicide application, can be costly, labor-intensive, and environmentally harmful. In contrast, straw mulching acts as a physical barrier that suppresses weed germination, growth, and seed dispersal by blocking sunlight, inhibiting root penetration, and creating a microenvironment conducive to beneficial soil organisms that compete with weeds for resources. Additionally, straw mulching promotes the decomposition of organic matter, releasing allelochemicals and microbial metabolites that inhibit (Arora *et al.* 2024) weed growth while enhancing soil fertility and nutrient availability for fruit trees (Li *et al.* 2023) Straw mulching contributes to soil moisture conservation and drought resilience in fruit cultivation systems. Water scarcity is a major limiting factor for fruit production in arid and semi-arid regions, where erratic rainfall patterns and prolonged droughts can severely impact crop yield, quality, and survival. By reducing evaporation, minimizing soil surface crusting, and enhancing water infiltration rates, straw mulching helps retain soil moisture and extend the availability of water for plant uptake during dry periods. Additionally, straw mulch acts as a reservoir for rainwater, capturing precipitation and directing it to the root zone of fruit trees, thereby reducing irrigation requirements and improving water use efficiency in orchard systems (Sharma *et al.* 2006).

Furthermore, straw mulching contributes to soil fertility and nutrient management in fruit cultivation systems. Fruit trees require adequate nutrients, including nitrogen, phosphorus, potassium, and micronutrients, for optimal growth, development, and fruiting. Conventional fertilizer applications can lead to nutrient imbalances, soil acidification, and environmental pollution if not managed properly. In contrast, straw mulching promotes the recycling of organic matter, enhances microbial activity, and improves nutrient cycling in the orchard ecosystem. As straw mulch decomposes, it releases organic carbon, nitrogen, and other essential nutrients into the soil, thereby enriching soil fertility, stimulating root growth, and enhancing nutrient uptake by fruit trees (Das *et al.* 2007). Additionally, straw mulching fosters the development of symbiotic relationships between fruit tree roots and mycorrhizal fungi, which facilitate nutrient acquisition, improve soil structure, and enhance plant resilience to biotic and abiotic stressors. Straw mulching contributes to pest and disease management in fruit cultivation systems. Fruit orchards are vulnerable to a wide range of pests and pathogens, including insects, nematodes, fungi, bacteria, and viruses, which can cause significant yield losses and economic damage if not controlled effectively. Conventional pest management strategies, such as chemical pesticides and fungicides, can have adverse effects on human health, beneficial organisms, and environmental quality. In contrast, straw mulching creates a habitat for natural enemies of pests, such as predatory insects, and microorganisms, which feed on harmful pest populations and regulate their abundance in the orchard ecosystem (Jasrotia *et al.* 2023). Additionally, straw mulch acts as a physical barrier that inhibits the spread of soil-borne pathogens, reduces splashing of pathogens onto fruit trees, and creates a drier microclimate that is less favorable for disease development and proliferation (Blume *et al.* 2016 and Weinmann *et al.* 2023). Straw mulching contributes to biodiversity conservation and ecosystem services in fruit cultivation systems. Fruit orchards provide important habitats and resources for a diverse array of flora and fauna, including pollinators, beneficial insects, birds, mammals, and soil organisms, which contribute to ecosystem functioning, resilience, and sustainability. However, intensive monoculture farming practices, pesticide use, and habitat destruction have led to declines in biodiversity and ecosystem services in many agricultural landscapes. In contrast, straw mulching promotes habitat heterogeneity, enhances food availability, and creates refuge areas for beneficial organisms, thereby supporting biological diversity, ecological balance, and ecosystem resilience in fruit orchards. Additionally, straw mulching reduces the need for external inputs such as synthetic fertilizers and pesticides, thereby minimizing environmental pollution and conserving natural resources for future generations (Awasthi *et al*. 2006).

In straw mulching offers a myriad of advantages for fruit cultivation, including soil conservation, weed management, moisture retention, nutrient cycling, pest and disease control, biodiversity conservation, and ecosystem resilience. By harnessing the agronomic benefits of straw mulching, farmers can enhance fruit yield, quality, and profitability while minimizing environmental impact and resource use. However, the efficacy of straw mulching depends on various factors such as mulch thickness, application timing, crop type, soil conditions, climate, and management practices. Moreover, further research is needed to optimize straw mulching techniques, quantify its long-term effects on soil health and ecosystem services, and assess its economic viability and scalability across diverse agro ecological contexts.

Overall, straw mulching represents a promising strategy for promoting sustainable fruit cultivation practices that prioritize environmental stewardship, social equity, and economic viability in a changing world (Gupta *et al.* 1986). Strawberry perform better and quality fruit and color when they applied just after 41 to 45 days after transplanting (DAP) at sandy loam soil and subtropical climatic condition (Ariza *et al.* 2021).

1. Soil Conservation and Erosion Control

In different type of straw mulch used in horticulture crops like wheat, maize, and Pearl millet and rice mulch, reported that rice mulch is easily available and have high water retention capacity so conserve moisture content, for different fruit crops orchard because rice is the main crop such as in citrus orchard perform better results (Visconti *et al.* 2024)

Soil erosion poses a significant threat to fruit cultivation, leading to loss of soil fertility, reduced water-holding capacity, and diminished crop productivity. Traditional agricultural practices, such as intensive tillage and bare soil cultivation, exacerbate soil erosion by exposing the soil surface to erosive forces such as wind and water. In this context, the adoption of straw mulching represents a sustainable solution to mitigate soil erosion and preserve soil health in fruit cultivation systems. Straw mulching creates a protective barrier on the soil surface, shielding it from the erosive effects of rainfall and surface runoff. By covering the soil with a layer of straw residue, farmers can reduce the impact of raindrops, minimize soil detachment, and prevent sediment loss from orchard slopes (Maitra *et al*. 2020). Moreover, straw mulch promotes soil aggregation, enhances soil structure, and increases water infiltration rates, thereby reducing surface runoff and enhancing soil moisture retention, particularly in sloping terrain prone to erosion. Studies have shown that straw mulching can significantly reduce soil erosion in fruit cultivation systems. For example, research conducted in apple orchards demonstrated that straw mulching reduced soil erosion by up to 50% compared to bare soil conditions (Webber *et al.* 2022). Similarly, studies in citrus orchards found that straw mulching reduced sediment loss by up to 70% and decreased runoff volumes by up to 60%, thereby preserving soil fertility and protecting downstream water quality (Osman *et al.* 2014). Furthermore, straw mulching promotes the establishment of vegetation cover, which further contributes to soil conservation and erosion control in fruit orchards. As the straw mulch decomposes, it provides organic matter and nutrients to support plant growth, thereby enhancing vegetation establishment and root development. The presence of vegetation cover stabilizes the soil surface, reduces the impact of raindrops, and increases soil stability, thereby minimizing erosion risk in fruit cultivation systems (Oliver, 2020).

In addition to mitigating soil erosion, straw mulching helps to prevent soil compaction and crusting, which can further exacerbate erosion risk in fruit orchards. By maintaining a porous and friable soil structure, straw mulch facilitates water infiltration, root penetration, and gas exchange in the root zone, thereby improving soil aeration, nutrient uptake, and plant growth. Moreover, straw mulch creates a favorable microenvironment for soil organisms, such as earthworms and beneficial microbes, which contribute to soil aggregation, organic matter decomposition, and nutrient cycling in fruit cultivation systems. While the efficacy of straw mulching in soil conservation and erosion control is well-documented, its effectiveness may vary depending on various factors, including mulch thickness (25 microns in strawberry), application timing, crop type, soil conditions, and slope gradient (Rannu *et al.* 2018). Therefore, optimal mulching practices should be tailored to specific agroecological contexts and production goals to maximize soil protection and erosion control benefits in fruit cultivation systems. Straw mulching represents a sustainable strategy for mitigating soil erosion and preserving soil health in fruit cultivation systems. By creating a protective barrier on the soil surface, straw mulch reduces the impact of erosive forces, promotes soil aggregation, enhances vegetation cover, and improves soil structure and fertility (Singandhupe *et al.* 2003). Moreover, straw mulching contributes to water conservation, and ecosystem resilience in fruit orchards, thereby supporting sustainable fruit production practices that prioritize soil conservation, environmental stewardship, and long-term productivity in a changing climate.

2. Weed Suppression and Management

Mulching is a common practice in agriculture, particularly in fruit cultivation, aimed at enhancing soil health, moisture retention, and weed suppression. Among various mulching materials, straw stands out for its numerous advantages, showed table -1, especially in weed suppression and management. This article delves into the benefits of straw mulching in fruit cultivation, focusing on its efficacy in weed control (Indurthi *et al.* 2023).

TABLE 1. Effect of mulching on fruiting and yield of wonderful cv. pomegranatetrees during 2012 and 2013 seasons.

Treat	Av. Fruit weight (g.)		Total No. of fruits/tree		Yield/tree (Kg.)	
	2012	2013	2012	2013	2012	2013
Control	375.8D	381.9D	44.00B	42.67C	16.54D	16.30E
Rice straw	557.1A	556.8B	54.33A	61.33A	30.27A	34.15B
Palm frands	481.8B	539.2B	54.67A	53.33B	26.34B	28.76C
Transparent	431.6C	476.0C	54.33A	49.33B	23.45C	23.48D
Gravel	575.2A	609.8A	57.33A	64.33A	32.98A	39.23A

Source: El-Taweel (2015) *Egypt Journal Horticulture*

2.1. Natural Weed Suppression:

Straw mulch creates a physical barrier that obstructs weed growth by depriving them of sunlight. This shading effect impedes weed seed germination and inhibits the growth of existing weeds. Additionally, straw mulch acts as a natural weed suppressor by smothering emerging weed seedlings, preventing them from establishing a foothold in the soil (Singh *et al.* 2006).

2.2. Moisture Conservation:

One of the primary advantages of straw mulching is its ability to conserve soil moisture. By covering the soil surface, straw mulch reduces water evaporation, thereby maintaining soil moisture levels essential for fruit tree growth. Adequate soil moisture promotes vigorous root development in fruit trees, enabling them to better compete with weeds for resources (Soni *et al.* 2017).

2.3. Nutrient Retention and Soil Health:

As straw mulch decomposes, it enriches the soil with organic matter, thus enhancing soil fertility and structure. The gradual breakdown of straw releases essential nutrients into the soil, providing a steady supply of nourishment to fruit trees. Moreover, the decomposition process fosters microbial activity, contributing to improved soil health and nutrient cycling (Singh *et al.* 2011) and (Ding *et al.* 2024).

2.4. Temperature Regulation:

Straw mulch acts as an insulating layer, moderating soil temperature fluctuations. In hot climates, it helps to keep the soil cool, mitigating heat stress on fruit trees. Conversely, in cooler climates, straw mulch provides insulation, preventing soil temperature from dropping excessively. These stable soil temperatures create optimal growing conditions for fruit trees w while suppressing weed growth, as some weeds are sensitive to temperature variations on shallow rooted fruit crop such as strawberry (Du *et al.* 2022) and (Ahmad *et al.* 2024).

2.5. Erosion Control:

By covering the soil surface, straw mulch prevents erosion caused by wind and water. Erosion not only leads to loss of topsoil but also facilitates weed colonization in bare soil. The use of straw mulch helps to stabilize the soil, because of the conserve soil, reducing erosion and the subsequent influx of weed germination in fruit crops (Bakshi *et al.* 2015)

2.6. Cost-Effective and Sustainable:

Straw mulch is a cost-effective and renewable solution for weed management in fruit cultivation, particularly for small-scale farmers, offering a sustainable alternative to synthetic methods (Iqbal *et al.* 2020), in table-2 showed that straw much get higher yield as compare plastic mulch, so there are cost effective over plastic mulch (Prem *et al.* 2020).Straw mulching is a cost-effective solution for fruit growers, offering numerous benefits such as reduced irrigation, weed control, and synthetic fertilizers, reduced pest and disease pressure, enhanced fruit yield, and potential niche markets. Its positive cost-benefit ratio makes it a financially viable strategy for fruit cultivation (Thakur *et al.* 2021).

Straw mulching effectively manages weeds in fruit cultivation, promoting health and productivity through its natural weed suppression properties, moisture conservation, nutrient retention, and erosion control (Ray *et al.* 2016).

Table 2: Increase in Yield of Fruit Crops through Plastic Mulching

Crop	**Yield (T/ha)**		**Increase inyield (%)**
	Un-mulched	**Mulched**	
Banana	53.99	73.32	33.95
Papaya	73.24	120.29	64.24
Ber	7.02	8.92	27.06
Mango	4.93	7.16	45.23
Guava	18.36	23.12	25.93
Litchi	111.0	125.0	12.61
Pineapple	10.25	11.75	14.63

(Source: NCPAH, New Delhi (National Committee on Plasticulture Applicationsin Horticulture)

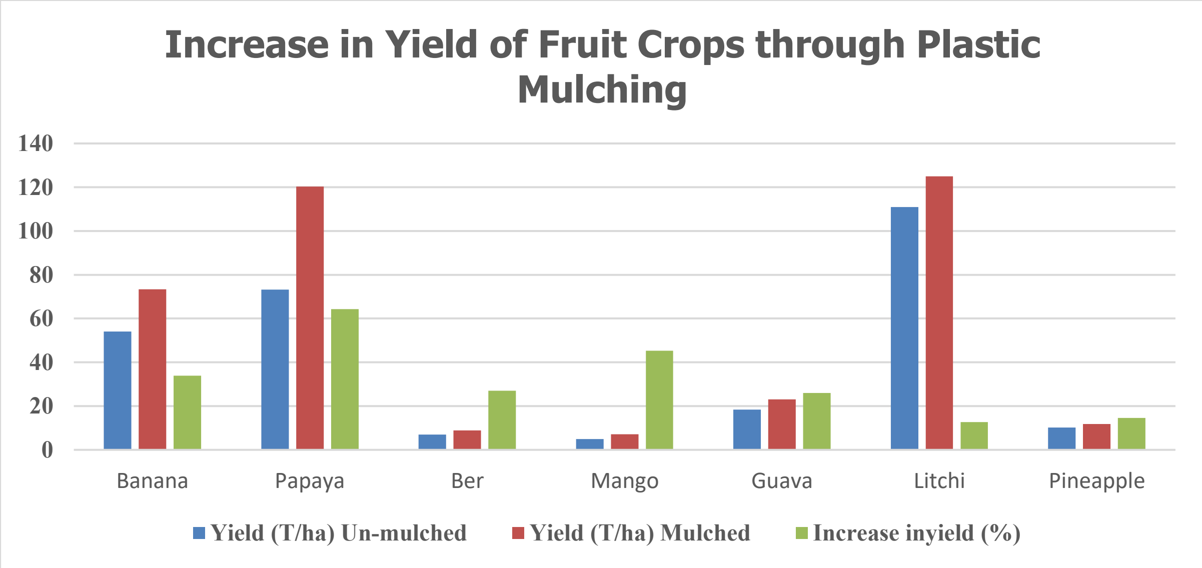


Fig-1- Show that effect of different type of much on different fruit crops

3. Soil Moisture Retention and Drought Resilience

In the realm of fruit cultivation, maintaining adequate soil moisture levels is paramount for sustaining healthy growth and maximizing yields, especially in regions prone to drought. Straw mulching has emerged as a highly effective technique for enhancing soil moisture retention and bolstering drought resilience in fruit orchards. This method is a practical agronomic entrance to reduce water scarcity and raise the chance of water conservation, notably in arid and semiarid regions (Ravichandran *et al.* 2022).

3.1. Reduced Soil Erosion:

Straw mulch prevents soil erosion, stabilizes soil structure, and minimizes surface disturbance, preserving soil moisture profile essential for fruit cultivation, especially during drought periods.
(Memom *et al.* 2017).

3.2. Enhanced Water Infiltration:

The presence of straw mulch improves soil porosity and aggregate stability, facilitating better water infiltration and retention within the soil profile. This enhanced water-holding capacity allows for more efficient utilization of irrigation or rainfall, as water infiltrates deeper into the soil, reaching the root zones of fruit trees. Improved water distribution within the soil matrix ensures consistent moisture availability to support plant growth and development (Zhang *et al.* 2021).

3.3. Temperature Regulation:

Straw mulch acts as an insulating layer, buffering against extreme temperature fluctuations that can exacerbate moisture stress in fruit orchards. During periods of intense heat, straw mulch helps to keep the soil surface cooler, reducing water loss through evaporation. Conversely, in colder conditions, straw mulch provides insulation, minimizing soil temperature fluctuations that can impair root function and water uptake in fruit trees (El-Beltagi *et al.* 2022).

3.4. Soil Health Promotion:

The decomposition of straw mulch contributes organic matter to the soil, fostering a healthy soil ecosystem conducive to moisture retention. Organic matter improves soil structure, increasing its capacity to hold water and nutrients. Moreover, the microbial activity stimulated by the breakdown of straw enhances nutrient cycling and availability, supporting the resilience of fruit trees to drought stress (Kader *et al.* 2019).

3.5. Sustainable Resource Management:

Straw mulch, derived from agricultural residues, is a renewable, cost-effective, and sustainable resource for fruit growers, promoting organic matter recycling and drought-resilient cultivation strategies (Iqbal *et al.* 2020).
Straw mulching in fruit cultivation offers benefits beyond weed suppression, including soil moisture retention and drought resilience. It helps mitigate drought impacts and optimizes water use efficiency, offering a sustainable solution for agricultural productivity (Li *et al.* 2021). Straw mulching in fruit cultivation enhances sustainability by recycling organic materials, reducing waste, improving soil health, reducing soil erosion, conserving water, and mitigating greenhouse gas emissions. It also minimizes chemical runoff into water bodies, safeguarding aquatic ecosystems. This practice aligns with sustainable agriculture principles, promoting ecosystem resilience and long-term environmental stewardship (Kader *et al.* 2019).

Straw mulching enhances microbial dynamics and soil health in fruit cultivation by providing a substrate for diverse microbial communities. These communities play crucial roles in nutrient cycling, organic matter decomposition, and plant pathogen suppression. Straw mulching promotes soil aggregation, structure, water infiltration, root penetration, and nutrient release, promoting soil resilience and productivity (Prosdocimi *et al.* 2016).

Straw mulching enhances fruit cultivation by promoting the growth of beneficial microorganisms like bacteria, fungi, and actinomycetes. These microorganisms play crucial roles in nutrient cycling, organic matter decomposition, and disease suppression, promoting soil fertility and resilience. Straw mulch also improves soil structure, water retention, and aeration, enhancing fruit yield and ecosystem resilience (Jabran *et al*. 2019)..

4. Nutrient Cycling and Soil Fertility Enhancement

Straw mulching improves nutrient cycling and soil fertility in fruit cultivation by releasing organic matter, promoting microbial activity, and enhancing soil fertility, supporting robust growth and long-term sustainability. The extensive use of inorganic plastic mulch can cause a series of soil and environmental effects that may affect agricultural productivity and jeopardies sustainable development. Therefore, inorganic mulching materials such as plastic films should be carefully selected in relation to specific needs of farmers and local environmental conditions, while organic mulching is a viable sustainable option to improve soil health and productivity (Ngosong *et al.* 2024).

5. Pest and Disease Suppression

Straw mulching offers pest and disease suppression benefits in fruit cultivation. By creating a physical barrier, it deters pests like aphids and beetles, reducing their access to fruit trees. Additionally, straw mulch moderates soil moisture, preventing conditions conducive to certain fungal diseases. Furthermore, as the mulch decomposes, it fosters beneficial microbial activity, which can antagonize harmful pathogens. This integrated approach to pest and disease management promotes orchard health and reduces the need for chemical interventions, aligning with sustainable agricultural practices (Prosdocimi *et al.* 2016).

6. Impact on Fruit Yield and Quality

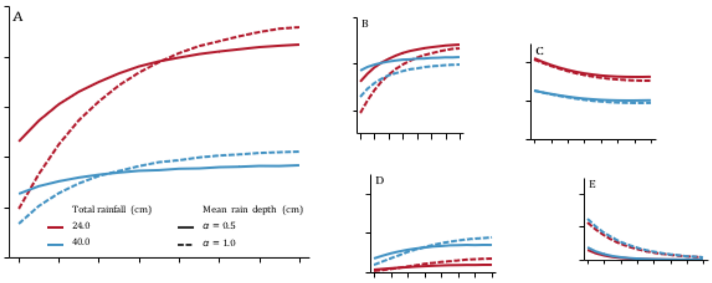
Straw mulching in fruit cultivation significantly impacts fruit yield and quality. By maintaining optimal soil moisture levels and enhancing nutrient availability, straw mulching supports vigorous growth and development in fruit trees throughout the growing season. Consistent soil moisture reduces water stress on trees, minimizing fruit drop and promoting uniform fruit size and ripening. Moreover, the gradual decomposition of straw mulch enriches the soil with organic matter and nutrients, fostering robust root development and nutrient uptake in fruit trees. This nutrient-rich environment enhances fruit development, leading to larger, tastier, and more nutritious yields. Additionally, the improved soil structure resulting from straw mulching promotes aeration and drainage, preventing waterlogging and root suffocation, which can compromise fruit quality (Qin *et al.* 2015). Furthermore, the pest and disease suppression properties of straw mulching contribute to higher fruit yields and improved quality. By creating a physical barrier against pests and moderating soil moisture to discourage disease proliferation, straw mulch helps to protect fruit trees from common threats. This reduced pest and disease pressure translates to healthier trees and higher fruit quality, as fruits are less prone to blemishes, scars, and deformities caused by pest infestations or fungal infections. In essence, straw mulching acts as a multifaceted tool in fruit cultivation, positively influencing both yield quantity and fruit quality. By providing a conducive environment for fruit tree growth, while simultaneously mitigating environmental stressors and pest pressures, straw mulching enables fruit growers to achieve more abundant harvests of superior quality fruits, contributing to the overall success and profitability of orchard operations (Ranjan *et al.* 2017)

7. Environmental Impacts and Sustainability

Straw mulching in fruit cultivation has favorable environmental impacts, enhancing sustainability. By utilizing agricultural residues as mulch, straw mulching promotes the efficient recycling of organic materials, reducing waste and reliance on synthetic inputs. This practice contributes to soil health by enhancing organic matter content, fostering microbial activity, and improving nutrient cycling. Additionally, straw mulching reduces soil erosion, conserves water, and mitigates greenhouse gas emissions by sequestering carbon in the soil. Moreover, the avoidance of synthetic pesticides and fertilizers minimizes chemical runoff into water bodies, safeguarding water quality and aquatic ecosystems. Overall, the adoption of straw mulching aligns with principles of sustainable agriculture, promoting ecosystem resilience, resource conservation, and long-term environmental stewardship in fruit cultivation. By prioritizing environmental sustainability, fruit growers can mitigate their ecological footprint while cultivating healthy, productive orchards for future generations (Kader *et al.* 2019).

8. Mulch Thickness and Application Strategies

In fruit cultivation, the thickness and application strategies of straw mulching significantly impact its effectiveness and the overall benefits it provides. The optimal 3–5 cm mulch thickness typically ranges from 5 to 10 centimeters, ensuring adequate coverage without suffocating plant roots or impeding water penetration. Thicker mulch layers offer better weed suppression and moisture retention but require more material and may increase the risk of rodent activity. Fruit growers often employ uniform application methods, spreading the mulch evenly around the base of trees while leaving a small gap to prevent direct contact with the trunk. Additionally, mulch replenishment may be necessary periodically to maintain the desired thickness and effectiveness, especially as the straw decomposes over time. Strategic placement and management of straw mulch contribute to maximizing its benefits, including weed control, moisture conservation, soil health improvement, and overall enhancement of fruit cultivation practices (Smets *et al.* 2008).



Source: Souza et al. (2022): *Journal of Hydrology*
Figure 1: Effects of mulching thickness on transpiration efficiency [(TSM − TNM)/TNM] (A) and the ratio of transpiration (B), evaporation (C), leakage (D), and runoff (E) to rainfall for four different rainfall regimes for a growing season of 120 days: total rainfall of 24 or 40 cm and mean rainfall depth of 0.5 or 1 cm. From total rainfall (R) and mean rainfall depth (α), the respective mean rainfall frequency (λ) can be computed as $\lambda = R/(\alpha \cdot 120)$.

9. Climate Resilience and Adaptation Strategies (Yes, straw mulch can reduce the upward movement of salt in coastal zones by conserving soil moisture and suppressing vertical evaporation,

Straw mulching offers crucial advantages in fruit cultivation, particularly in bolstering climate resilience and adaptation strategies. Firstly, it acts as a protective barrier, shielding the soil from extreme temperature fluctuations, conserving moisture, and reducing erosion risks. This insulation fosters a stable microclimate, vital for fruit trees' health and productivity amidst changing climate patterns. Secondly, straw mulch enhances soil structure and fertility by promoting microbial activity and organic matter decomposition, fostering healthier root systems and nutrient uptake. Moreover, its biodegradability ensures minimal environmental impact, aligning with sustainable cultivation practices. Straw mulch can reduce the upward movement of salt in coastal zones by conserving soil moisture and suppressing vertical evaporation (Zhang *et al.* 2022). Additionally, the practice reduces weed competition, minimizing the need for herbicides, thus further mitigating environmental harm. Overall, straw mulching not only fortifies fruit cultivation against climate-induced stresses but also promotes long-term sustainability, making it a valuable component of adaptive agricultural strategies (Chopra *et al.* 2020).

10. Interactions with Soil Microorganisms

Straw mulching profoundly influences soil microorganisms, offering numerous advantages in fruit cultivation. By providing a conducive environment, straw mulch promotes the proliferation of beneficial microorganisms like bacteria, fungi, and actinomycetes. These organisms play pivotal roles in nutrient cycling, organic matter decomposition, and disease suppression, fostering soil fertility and resilience. The decomposition of straw mulch by microbial activity enriches the soil with essential nutrients, enhancing the availability of nitrogen, phosphorus, and potassium for fruit trees. Moreover, the increased microbial diversity and activity stimulated by straw mulching contribute to soil structure improvement, promoting better water retention and aeration. This symbiotic relationship between straw mulch and soil microorganisms not only enhances fruit yield and quality but also fortifies the ecosystem's resilience to environmental stressors. Overall, integrating straw mulching into fruit cultivation practices fosters a harmonious interaction with soil microorganisms, facilitating sustainable and resilient agricultural systems (Jabran *et al.* 2019).

11. Long-Term Effects on Soil Productivity

Straw mulching exerts long-term beneficial effects on soil productivity in fruit cultivation systems. Over time, the gradual decomposition of straw mulch enriches the soil with organic matter, enhancing its fertility and structure. This process facilitates improved soil water retention, aeration, and nutrient availability, creating an optimal environment for root development and overall plant growth. Additionally, straw mulch acts as a protective barrier, shielding the soil from erosive forces, temperature fluctuations, and compaction, which can degrade soil health over time. By fostering a stable and favorable soil environment, straw mulching supports sustained fruit productivity and quality over multiple growing seasons. Furthermore, the incorporation of organic matter through straw mulching promotes soil biodiversity and microbial activity, contributing to enhanced nutrient cycling and ecosystem resilience. Thus, the long-term integration of straw mulching in fruit cultivation systems offers enduring benefits for soil productivity and ecosystem sustainability (Bogunovic *et al.* 2023.

12. Farmer Adoption and Extension Strategies

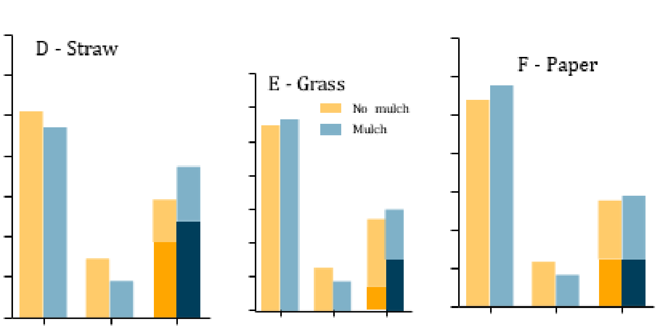
Effective farmer adoption and extension strategies are crucial for realizing the advantages of straw mulching in fruit cultivation. Extension services play a pivotal role in educating farmers about the benefits of straw mulching, demonstrating its effectiveness through field trials and practical workshops. Providing farmers with technical guidance on proper mulch application techniques, including timing and thickness, enhances adoption rates and ensures optimal outcomes. Moreover, facilitating access to affordable straw mulch sources and equipment encourages widespread adoption among farmers. Tailoring extension programs to address specific regional challenges and agricultural practices further enhances relevance and effectiveness. Collaborating with local agricultural cooperatives and organizations can amplify outreach efforts and foster peer learning networks. By empowering farmers with knowledge and resources, effective extension strategies promote the widespread adoption of straw mulching, enhancing soil health, crop productivity, and resilience in fruit cultivation systems (Haapala *et al.* 2014).

13. Impact on Fruit Tree Growth and Development

Straw mulching significantly impacts fruit tree growth and development in cultivation systems. By conserving soil moisture and moderating temperature extremes, straw mulch creates favorable conditions for root development and overall plant growth. The insulation provided by mulch promotes uniform soil moisture levels, reducing water stress on fruit trees and fostering robust root systems. Enhanced soil structure resulting from mulch decomposition facilitates nutrient uptake, promoting healthy foliage, blossoms, and fruit set. Furthermore, straw mulch acts as a natural weed suppressant, minimizing competition for resources and allowing fruit trees to allocate energy towards growth and fruit production. This management of soil moisture, temperature, and nutrient availability through straw mulching ultimately translates into improved fruit quality, yield, and resilience to environmental stresses, ensuring sustainable and productive fruit cultivation over the long term (Fan *et al.* 2023).

14. Water Use Efficiency and Irrigation Management

Straw mulching offers significant advantages in water use efficiency and irrigation management within fruit cultivation systems. By creating a protective layer over the soil, mulch helps to minimize evaporation and reduce water loss from the root zone, thus enhancing water retention in the soil. This leads to more efficient water utilization by fruit trees, particularly during periods of drought or limited water availability. Additionally, straw mulch acts as a barrier against surface runoff, allowing for better infiltration of irrigation water into the soil and reducing the need for frequent watering. Moreover, the improved soil structure resulting from mulch decomposition enhances water distribution and root penetration, further optimizing water use efficiency. Overall, integrating straw mulching into fruit cultivation practices not only conserves water but also promotes sustainable irrigation management, ensuring the long-term viability and productivity of orchards while mitigating water-related challenges in agriculture (Daryanto *et al.* 2017).



Source: Souza et al. (2022): *Journal of Hydrology*

Figure 2: Temporal dynamics of rainfall (A) and observed and modeled soil moisture (B) for different soil cover materials (straw, grass, and paper). Correlation between observed and modeled soil moisture (C). Percentage of rainfall converted into leakage, *L*, evapora- tion, *E*, transpiration, *T* (D, E, and F), with gray bars for the fluxes for the no mulching condition and darker color bars for the fraction of transpiration under non-stressed con- dition ($s^* \leq s$). Data retrieved from (Kader et al., 2017).

15. Effects on Soil Temperature and Microclimate

Straw mulching exerts profound effects on soil temperature and microclimate dynamics in fruit cultivation. Acting as an insulating layer, mulch regulates soil temperature by moderating heat fluxes, reducing temperature extremes, and promoting thermal stability. This buffering effect is particularly beneficial during periods of temperature fluctuations, safeguarding fruit trees from stress and optimizing physiological processes. Additionally, straw mulch mitigates moisture loss through evaporation, maintaining soil moisture levels and creating a more conducive microclimate for root growth and nutrient uptake. Moreover, mulch alters surface albedo, reflecting sunlight and reducing heat absorption, further tempering soil temperatures. These combined influences enhance the overall microclimate within orchards, fostering conditions conducive to healthy fruit development and productivity. By regulating soil temperature and microclimate, straw mulching contributes to improved fruit quality, yield consistency, and resilience to environmental stresses, thereby enhancing the sustainability and profitability of fruit cultivation practices (Zhang *et al.* 2017).

16. Mulch Decomposition Dynamics and Nutrient Release

In fruit cultivation, straw mulching offers advantages through its decomposition dynamics and nutrient release processes. As straw mulch breaks down over time, it releases organic matter into the soil, enriching it with essential nutrients such as nitrogen, phosphorus, and potassium. This gradual nutrient release aligns with the fruit trees' growth and development stages, ensuring a steady supply of nutrients for optimal health and productivity. Additionally, microbial activity stimulated by mulch decomposition further accelerates nutrient cycling, enhancing soil fertility and structure. The breakdown of straw mulch also improves soil aeration and water retention, promoting root growth and nutrient uptake by fruit trees. This symbiotic relationship between mulch decomposition and nutrient release fosters sustainable fruit cultivation practices, reducing the need for synthetic fertilizers and minimizing environmental impact. Overall, the integration of straw mulching in fruit cultivation systems enhances soil health, nutrient availability, and long-term productivity, supporting resilient and sustainable orchard management (Prem *et al.* 2020).

17. Integration with Fruit Orchading and Permaculture Practices

Integration of straw mulching with fruit orchading and permaculture practices offers multifaceted advantages in fruit cultivation. In fruit orchading systems, straw mulch serves as a key component in enhancing soil fertility, moisture retention, and weed suppression, thereby supporting the growth of fruit trees alongside other crops or woody perennials. By mimicking natural ecosystems, permaculture principles emphasize the importance of utilizing organic materials like straw mulch to create self-sustaining and resilient agricultural systems. The incorporation of straw mulch in these practices promotes biodiversity, soil health, and ecosystem resilience, contributing to the overall sustainability of fruit cultivation. Furthermore, straw mulch aids in conserving water, minimizing erosion, and improving soil structure, all of which are fundamental aspects of fruit orchading and permaculture designs. By synergistically integrating with these practices, straw mulching enhances the productivity, biodiversity, and ecological integrity of fruit cultivation systems, fostering sustainable fruit production and environmental stewardship (Patil *et al.* 2013).

18. Influence on Fruit Ripening and Shelf Life

Straw mulching exerts a notable influence on fruit ripening and shelf life in cultivation systems. By moderating soil temperature and moisture levels, mulch promotes more consistent and optimal conditions for fruit development. This controlled environment can enhance the uniformity of fruit ripening, resulting in a more synchronized harvest and improved fruit quality. Additionally, straw mulch helps reduce soil compaction and erosion, which can negatively impact root health and nutrient uptake, thus indirectly influencing fruit ripening processes. Furthermore, by minimizing weed competition and soil-borne diseases, straw mulching supports healthier fruit development, potentially extending shelf life by reducing post-harvest losses due to spoilage. Overall, the adoption of straw mulching practices in fruit cultivation contributes to more predictable and higher-quality fruit yields, enhancing marketability and ensuring consumer satisfaction while promoting sustainable agricultural practices (Qin *et al.* 2015).

19. Conversation of different mulch and their effect

Straw mulching in fruit cultivation enhances productivity, sustainability, and resilience by conserving soil moisture by forming a protective layer over the soil surface. This is particularly beneficial in regions prone to drought or erratic precipitation patterns, where maintaining adequate soil moisture levels is essential for sustaining fruit tree health and productivity (Haapala *et al.* 2014).

Moreover, straw mulch helps to moderate soil temperature by insulating the soil surface. This moderating effect mitigates temperature extremes, protecting fruit trees from heat stress during hot weather and frost damage during cold spells. By creating a more stable microclimate around the roots, straw mulch promotes optimal conditions for root growth and nutrient uptake, thereby supporting overall tree health and vigor. In addition to regulating soil moisture and temperature, straw mulching contributes to improved soil structure and fertility (Daryanto *et al.* 2017). As the mulch decomposes, it gradually releases organic matter and nutrients into the soil, enriching it with essential elements such as nitrogen, phosphorus, and potassium. This nutrient cycling process not only enhances soil fertility but also promotes microbial activity, which further facilitates nutrient availability to fruit trees. The improved soil structure resulting from mulch decomposition also enhances water infiltration and aeration, promoting root development and resilience to environmental stresses (Prem *et al.* 2020).

Another significant advantage of straw mulching in fruit cultivation is its role in weed suppression. The dense layer of mulch effectively blocks sunlight, inhibiting weed germination and growth. This reduces competition for water, nutrients, and sunlight, allowing fruit trees to allocate more resources towards growth and fruit production. Furthermore, by minimizing the need for mechanical or chemical weed control methods, straw mulching helps to reduce labor and input costs, making fruit cultivation more economically viable and environmentally sustainable

(Gnanavel *et al.* 2014). Moreover, straw mulch serves as a natural barrier against soil erosion. By protecting the soil surface from raindrop impact and runoff, mulch helps to maintain soil structure and prevent soil loss, particularly on sloping terrain. This erosion control function is crucial for preserving soil fertility and preventing nutrient runoff into water bodies, thereby promoting environmental conservation and ecosystem health. Additionally, the integration of straw mulching in fruit cultivation aligns with principles of fruit orchading and permaculture practices. In fruit orchading, straw mulch can be utilized alongside fruit trees to enhance soil fertility, moisture retention, and biodiversity, thereby promoting sustainable land use and diversified income streams for farmers. Similarly, in permaculture designs, straw mulch is incorporated as part of holistic strategies to create self-sustaining and resilient agricultural systems that mimic natural ecosystems (Baradia *et al.* 2021).

Overall, the advantages of straw mulching in fruit cultivation are manifold and contribute to the sustainability and resilience of orchard systems. From conserving soil moisture and moderating soil temperature to improving soil structure and fertility, straw mulching enhances fruit tree health and productivity while reducing environmental impact and input costs. By integrating straw mulching with fruit orchading and permaculture practices, farmers can further optimize the benefits of this technique, promoting sustainable food production and environmental stewardship for future generations (Singh and Nath 2020).

CONCLUSION:

Straw mulching is a sustainable and effective method for fruit cultivation, enhancing productivity and resilience. It conserves soil moisture, moderate's temperature, and improves soil structure, reducing water stress and nutrient deficiencies. It also promotes weed suppression, erosion control, and environmental conservation. When integrated with fruit orchading and permaculture practices, it enhances soil fertility, moisture retention, and biodiversity, enhancing resilience to environmental stresses. Straw mulch also fosters self-sustaining agricultural systems that mimic natural ecosystems, promoting long-term sustainability.

Straw mulching enhances fruit cultivation systems' resilience and viability by promoting sustainable land management, reducing input costs, and enhancing ecosystem services, extending beyond immediate agronomic benefits. However, it is essential to recognize that the successful adoption and implementation of straw mulching require careful consideration of site-specific factors, including climate, soil type, crop species, and management practices. Effective mulch application techniques, such as proper timing, thickness, and mulch material selection, are critical for optimizing the benefits of mulching while minimizing potential drawbacks, such as pest and disease risks. Furthermore, continued research and extension efforts are needed to further refine mulching practices and address knowledge gaps related to its long-term impacts on soil health, nutrient cycling, and ecosystem functioning. They are required more research regarding different mulch type, time of application thickness and temperature of mulch and soil. By advancing our understanding of the mechanisms underlying the benefits of straw mulching and developing innovative approaches to its implementation, we can continue to harness the full potential of this valuable technique for sustainable fruit cultivation.

Straw mulching holds great promise as a practical and effective strategy for enhancing the sustainability, productivity, and resilience of fruit cultivation systems. By leveraging its numerous advantages and integrating it with complementary agricultural practices, farmers can promote sustainable land management, conserve natural resources, and secure the long- term viability of orchard ecosystems for generations to come.

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