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Mulches and Their Impact on Floor Management and Performance of Fruit Crops: A Review

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Apart from the various innovations and technologies developed, productivity of most of the fruit crops in India remains at a lower level when compared to the major producers and developed countries. In the present era of health awareness, demand of the quality fruits, classified as protective foods, has increased globally. The ever-growing demand for the quality fruits and market competition has been compelling the farmers to produce more but quality fruits. Use of mulches is an age old practice and also one the cheapest methods under protected cultivation technologies which could help the orchardists to increase the production with higher quality. Looking to the several biotic and abiotic challenges in fruit production, adoption of mulching technique at large scale might be helpful to mitigate several problems considering the advantages of mulching. Several studies have shown that mulching in fruit crops has positive impact on soil moisture status, soil temperature along with weed suppression thus on rhizosphere of the plants. These rhizospheric conditions favour the vegetative as well as yield and quality parameters of the fruit crops. In this paper, an attempt has been made to review the impact of mulching on floor management (soil moisture status, soil temperature and weed suppression) as well as growth, yield and quality characteristics in fruit crops with the help of appropriate findings available in literature.

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1. INTRODUCTION

The horticulture sector contributes about 30 per cent of the agriculture GDP indicating economic importance of horticultural produce. The demand of quality horticultural produce has been increasing over the years due to ever growing demand in domestic and international markets. India is the second largest producer of fruits (97.55 million MT) obtained from 6.50 million ha area with the average productivity of 14.96 MT/ha [1] and contributed about 10.5 per cent share in global fruit production. Fruits play an important role in our diet. Fruits are rich sources of antioxidants and considered as 'protective food'. India occupies first place in the production of mango, banana, guava, papaya, pomegranate, sapota and aonla. However, the productivity of most of the fruit crops is quite low as compared to the other major producers and world averages. The main cause behind low productivity is poor orchard management practices which results into biotic and abiotic stresses in fruit crops. This high stress adversely affects the growth and productivity of fruit crops. If proper management and care is provided then the productivity might be increased in substantial manner [2]. This compels to adapt the technique that despite of conserving natural resources also influences plant growth and yield parameters positively. In this regard mulching is the most appropriate as well as cheapest method to be adopted.

Mulching can be defined as a protective covering of the soil surface around the base of plants with organic or synthetic materials to make the micro-climate more favourable for plant growth and development thereby increasing yield and quality of produce. Mulches are also known as the grower's first line of defense in providing ideal conditions for plants with highly cost efficient [3]. The term 'mulch' has probably been derived from the German word 'molsch' meaning soft to decay [4], as earlier only organic materials were used to spread over the soil surface as mulch. These provide temperature moderation, moisture conservation, weed control etc. [5]. It exerts decisive effects on nutrient use efficiency, earliness, yield and quality of the crop [6,7,8,9]. Mulching is very effective in improving water productivity and reducing in water loss hence an integral component of water conservation in horticulture production [10]. Apart from these benefits, it also reduces labour requirement and drudgery [11,12,13]. Owing to multi-benefits of mulching and sizeable amount of work on this aspect in fruit crops, a comprehensive review with appropriate findings is very much desired. The present review encompasses brief knowledge about mulches and their effect on various soil parameters, weed growth, plant growth and yield as well as quality of various fruit crops.

2. TYPES OF MULCH

There are two basic kinds of mulch- organic and inorganic. Organic mulches include formerly living materials or natural substances such as chopped/ dry leaves, straw, sugarcane trash, grass clippings, compost, wood chips, shredded bark, saw dust, pine needles and paper etc. Besides providing other advantages of mulching, organic mulches improve the condition of the soil by adding organic matter after decomposition. It improves infiltration rate as well as water holding capacity of the soil by enhancing porosity of the soil [14]. However, organic mulches provide almost all the benefits of mulching but the non availability in adequate quantity, difficulty in application [3], multiplication of harmful pests beneath it, threat of fire hazard [15] and scope for reuse as mulch are some of the major limitations. Due to these limitations of organic materials, inorganic mulches, preferentially plastic mulches, came up with the advent of polyethylene as a plastic film in 1938 and its subsequent introduction as a clear and black plastic mulch in the early 1950s revolutionized the commercial horticulture production [16]. Plastic film, as easily available, easy to handle, transport and lay, has become the most preferred material as mulch [17]. Plastic mulches directly impact the microclimate around the plant by modifying the radiation budget of the surface and decreasing the soil water loss [18]. A wide variety of plastic films are now available for mulching of fruit crops. LDPE, HDPE and flexible PVC have all been used for mulching. Today the vast majority of plastic mulches are based on LLDPE because it is more economical in use. LLDPE mulch film is most popular, owing to the twin properties of down-gauging and better puncture resistance. While down-gauging leads to availability of thinner film at a lower cost, the puncture resistance and opacity check the weed growth under the film [19]. The plastic mulches are also available in different colours and thickness to obtain precise control over the soil

environment as per the need of crop grown. These are available in various colours viz., black, transparent/ clear, white, silver, blue, red, green, yellow etc. with specific advantages and also especially beneficial to a particular crop. Bicolour mulches (silver-black, yellow-black, white-black, Red-black, yellow-black etc.), with mostly black on lower side, are also available to attain twin advantages of colour with black [20]. Above side colour absorbs specific wavelengths of the sun's radiation that changes the spectrum of sunlight passing through the film or being reflected back into the plant canopy. These light changes can have marked effect on plant growth and development such as root development, plant height, branching, internal growth, size of fruit and quality. Whereas, black colour does not allow the sunlight to pass through on to the soil and restricts photosynthesis in plants below the film thus restricts weed growth [20]. Now-a-days photodegradable (gets decompose under sunlight) and biodegradable (gets decompose under natural environmental conditions) mulch films are also available to avoid the environmental challenges originated with the use of plastic mulches [19]. Further thickness of the mulch film is also an important consideration while mulching of fruit crops as it directly influences the production economics. The recommended thickness for organic mulches is 2-6 inches (5-15 cm) as per the material used and the quantity required might be approximately 10 tons (dried hay) to 200 tons (compost) per hectare or more. The recommended thickness, extent of surface to be covered under plastic film (Table 1) for different fruit crops and calculation of film requirement (Table 2) are given here under.

3. EFFECT OF MULCHES ON SOIL AND FRUIT PLANTS

3.1 Soil Moisture Content

Conservation agriculture more precisely water conservation will be a key concern for future agriculture as in India more than 80 per cent of water resources have been exploited for agricultural production [21]. The other forces (industrialization, urbanization, house hold needs etc.), competitors for water demand, have been creating tremendous pressure on water budget and compelling to reduce water share to agriculture. Thus it is necessary to adopt water-saving techniques and mulching is the cheapest method which is primarily used for it. Mulching has manifold advantages, however, the prime objective of using organic and inorganic mulches is to conserve soil moisture by reducing soil evaporation and this conserved moisture can be used more effectively by the crops towards transpiration [10]. Various studies conducted in fruit crops suggested its role in moisture conservation and improved soil moisture status. Srinivas et al. [22] stated that black polyethylene conserved more soil moisture in 15-30 cm and 30-45 cm depths compared to 0-15 cm soil depth in grapes. Accordingly, Reddy and Khan [23] observed higher soil moisture under black plastic film (400 guage) at 0-30, 30-60 and 60-90 cm depths after 12 and 18 months of treatment imposition which increased the transpiration

Table 1. Recommended thickness and extent of surface to be covered under film for different fruit crops [19]

Thickness (µ)	% coverage	Recommended fruit crops
20-25	30-50	Strawberry
40-50	40-60	Papaya, Pineapple, Initial stage of fruit crops (upto 5 years)
100	50-70	Fruit crops (more than 5 years)

Table 2. Calculation of approximate mulch film requirement [19]

Thickness			Area coverage (m^2/kg)
Micron	Gauge	Mm	
20	80	0.02	54
25	100	0.025	42
40	160	0.04	26
50	200	0.05	21
100	400	0.10	11

with reduced stomatal resistance in sapota cv. Kalipatti under rainfed condition. An increase in soil moisture content with plastic mulches (black and white) was reported in Nagpur mandarin from 4.23 per cent to 12.36 per cent at 15 cm and 30 cm depths, respectively, due to reduced soil surface evaporation and weed intensity [24]. Mulch colour also influenced the soil moisture retention in various months as Mal et al. [25] announced that black plastic mulch recorded maximum soil moisture from December to March while, white plastic gave higher moisture retention in the months of April and May in pomegranate cv. Ganesh during the experimental years 2001 and 2002. A study in aonla cv. NA-7 suggested that organic mulches improved soil moisture content from 50 to 260 days with highest in paddy straw followed by maize straw and grasses at both depths of soil i.e. 0-15 cm and 15-30 cm [26]. Similar findings were also enunciated by Rao and Pathak [27] and Shukla et al. [28] in aonla. However, in grape vineyards, surface soil water content (0–15 cm) was higher under the composted mulch at the rate of 7.5 cm depth (153 m^3/ha) when compared to the control in the beginning of the season only whereas the difference in soil water content among the treatments were not significant in the later parts [29]. Shirgure [30] studied the efficacy of plastic (black and white) and organic mulches on soil moisture conservation in acid lime and found that black polyethylene mulch conserved 26.55 per cent and 31.84 per cent while grass mulch conserved 25.40 per cent and 30.16 per cent higher moisture contents over control at 20 cm depth during 2000-2002. Significantly higher soil moisture contents at 0-15 cm and 15-30 cm depths were observed with black polyethylene in kinnow [31] and Eureka lemon [32] under rainfed condition.

Maximum moisture content in the soil was observed from the plants mulched with rice straw (19.70%), however, among the inorganic mulches, black polyethylene mulch (18.30%) conserved more moisture as compared to white polyethylene mulch (15.70%) in pomegranate cv. Ruby [33]. Further, Lalruatsangi and Hazarika [34] observed maximum soil moisture content (36.06%) in polyethylene mulch with black side facing upward followed by polythene mulch with silver side facing upward (35.25%) in acid lime. Similarly, higher surface soil moisture (0-15cm) by 1.0 to 3.5 per cent was noted under plastic mulches in strawberry [35] and it might be due to reduced exposed surface area resulting to reduced evaporation (10, 63, 92]. Bons et al. [36] reported maximum moisture savings in polythene mulching (28%) followed by paddy straw (20.05%) in soil profile up to 100 cm in kinnow mandarin. In general plastic mulch demonstrated higher soil moisture content over organic mulch as recorded by Ramakrishna et al. [37] in strawberry and Das and Dutta [38] in mango while working with various mulch materials and it was due to the fact that plastic mulch acts as an insulating substance that condenses the evaporating soil moisture inside the mulch and again drops it down to the soil surface [39] while some moisture is lost through porous organic mulch and moisture absorption by mulch itself and/or subsequent evaporation.

3.2 Water Use Efficiency

Water conservation through mulching reduces the water application rate thus enhances water use efficiency. It was confirmed by many workers in various fruit crops. Seidhom and Abd-El-Rahman [1] studied the impact of soil mulching along with drip irrigation on the water use efficiency of pomegranate trees and found maximum water efficiency in olive pomace mulch. Liu et al. [40] studied the effect of mulch and fertigation in young peach orchard and noted higher agricultural water use efficiency in mulch (2.72 kg/m^3) and mulch with fertigation (3.14 kg/m^3) treatments and these values were 64.4 per cent and 42.4 per cent higher over control (1.91 kg/m^3), respectively. In an experiment with guava cv. Lalit, Barman et al. [41] found that mulching with drip fertigation significantly enhanced water use efficiency (WUE) and noted 2.83 to 3.78 times higher WUE in different treatments of mulch and drip fertigation over control. Maximum (334.03 and 357.88 kg/ha-mm) and minimum (162.12 and 179.12 kg/ha-mm) water use efficiencies were observed with silver-black mulch and unmulch conditions in papaya variety Madhu bindu and Taiwan, respectively [42]. Diaz-Perez [43] studied the efficacy of soil moisture regimes and different mulching treatments on water use efficiency (WUE) of banana plant and found that WUE is increased with the mulching treatment and highest increase in WUE was observed under plastic mulch (6.40–6.36 kg/m^3) followed by banana leaves (5.78–5.62 kg/m^3). Maximum WUE (0.33 kg/ litre) was recorded in treatment having 0.3 PE and silver-black mulch and minimum (0.04 kg/ litre) in conventional method of irrigation without mulch in mango cv. Pant Sinduri [44]. Consistent with the above findings, Shirgure et al. [45] in mango and Tariq et al. [46]

in Sapota received the similar findings with higher WUE in mulched treatments.

3.3 Soil Temperature

Soil temperature has a direct influence on physiological activities of plants and it has more significance over aerial temperature [47]. Temperature range is critical for the main physiological functions of the plant i.e. photosynthesis and respiration. Temperature extremes can limit the plant growth and development by altering the balance between these two primary functions of plant. Beside this, extreme low and high temperatures also influence the soil microbial population and rate of organic matter decomposition [48]. Mulching regulates the soil temperature by avoiding extremes. Mulch type and colour have profound effect on soil temperature regime as the surface temperature of mulch and underlying soil temperature are greatly influenced by these. The thermal properties (reflectivity, absorbitivity or conductivity) of mulch material in relation to incoming solar radiation also affect the soil temperatures underneath it [49] by modifying the radiation budget of the surface [18]. The impact of various mulch colours (black, reflective, silver, white and clear) on soil temperature was compared with bare soil by Gupta and Acharya [50] and observed that the temperature difference was less than 5^0C at 10 cm soil depth. All mulches, except the white coloured mulch significantly increased the soil temperature in comparison to the unmulched soil. In general dark colour mulches increases the soil temperature, while lighter colours do not have much effect on temperature change as these reflect most of the solar radiation. This fact was further reinforced by Decoteau et al. [51] while working with broccoli as he also reported highest root zone temperature in case of dark coloured mulches (blue, black, red and gray) and lowest in light coloured mulches (silver and white). Specific mulch colours may produce qualitative and quantitative differences in reflected light wavelengths thereby affecting growth and yield parameters of plants [52]. Lamont [20] reported that increased soil temperature of 2.8^0C and 4^0 to 8^0C (5 cm depth) and 1.7^0C and 3^0 to 5^0C (10 cm depth) with the use of black and clear plastic films, respectively, compared to those of bare soil. Clear plastics enhances the soil temperature substantially than the other mulch colours as it absorbs little solar radiation and transmits most of it (85-95 per cent) which depends on the degree and opacity of the plastic [53]. However, under clear plastic mulch, weeds may pose problem and the use of other weed management options are advocated with it (as herbicide application and fumigation). It is primarily used for soil solarization with a limited use for winter season crops as in cooler climates. Black coloured mulches transmit less radiation (20-40 per cent) and soil heating is mainly due to energy transfer to the soil by conduction. On the other hand, white or white-on-black mulches slightly reduced the soil temperature (0.4^0C at 10 cm depth) as compared to unmulched surface as both reflected most incoming radiation. The higher temperature with mulching might expedite organic matter decomposition and mineralization which enhance the nutrient availability to the mulched plants [6]. Organic mulch regulates soil temperature as at 20 cm depth it lowers the soil temperature by 1.1-5.6^0C during warmer months, while it increases the temperature by 0.6- 3.2^0C during the winter months of December-January in brinjal under arid conditioms [54]. Soil temperature at 10 cm depth was reported to be higher with plastic mulches than straw or no mulch in young jujube trees [55].

Consistent with the above observations, mulches have also been reported to markedly modify the soil hydrothermal regimes in various fruit crops. Faber et al. [56] suggested that 10^0C drop in soil temperature would likely increased fruit size by 0.9-1.6 g in strawberry. Mulches considerably influenced the soil temperature in Plum cv. Santa Rosa under mid-hill condition of Himachal Pradesh with the transparent polyethylene recorded highest temperature both at 7.5 and 15.0 cm depths followed by black polyethylene, bi-colour polyethylene, field grass and pine needles at 07.30 hour when compared to control while at 14.30 hour unmulched plants showed higher temperature than the organic mulches (field grass and pine needles) but significantly lower than the plastic mulches [57]. Mehraj et al. [58] with the same crop and cultivar (Plum, Santa Rosa) observed that mulching with black polyethylene increased the soil temperature both at 0-15 cm and 15-30 cm depths (18.95^0C and 18.01^0C, respectively) as compared to unmulch plants (17.28^0C and 16.37^0C, respectively). Similar findings, while working with mango cultivars Chausa and Langra, were also reported by Singh et al. [59] with alleviated soil temperature under black plastic mulch treatment at Central Institute for Subtropical Horticulture, Lucknow.

Kumar and Dey [60] studied the impact of organic and inorganic mulches on soil temperature in strawberry. They reported that

hay mulch increased the minimum soil temperature (2.8–5.2^{0}C) and reduced the maximum soil temperature (2.7–5.8^{0}C) as compared to unmulched plot, whereas, black polyethylene mulch increased the minimum soil temperature from 0.4 to 2.5^{0}C (average 2^{0}C) and maximum soil temperature by 0.3–1.8^{0}C (average 1.3^{0}C) as compared to unmulched treatment. However, an increase in soil temperature to the tune of 1 to 6^{0}C under black polyethylene mulch covered strawberry was noticed by Pandey et al. [35] at Jhalawar, Rajasthan. Higher soil temperature under black plastic may be due to increased radiation absorption and better thermal conduct between soil surface and the polyethylene film. The effect of mulches on soil temperature in nectarine was studied by Negi (78) and found maximum temperature under black polyethylene mulch while minimum under grass mulch with an increase in average annual temperature by 3.3^{0}C by plastic film mulching.

3.4 Weed Growth

Weed management is the least cared part among the various orchard management practices in India. It is thought as trees are much larger than weed plants hence these do not affect the tree growth and productivity. But the fact is that most of the fruit trees have root systems that do not compete well with other plants [61]. Panigrahi et al. [62] reported that several studies had shown that full season competition due to unmanaged weeds could cause reduction in yield of up to 37 per cent. Weedicides are generally not applied in the orchards and tilling regularly enhances the root damage and soil erosion. The approachable and sustainable way to manage the weed problem in orchards can be offered by mulching. Mulching decreases the germination and nourishment of many weeds by providing a physical barrier. If weeds grow, they become pale and eventually die in the absence of light stimulus. Several workers have demonstrated the role of mulching in weed management and thereby enhancing moisture and nutrient availability to fruit plants. Black polyethylene mulch showed minimum weed count and dry weight in aonla orchard in sodic soils as compared to grass, paddy straw and sugarcane trash [27] as virtually no light is transmitted through black plastics. Consistent with it, Aulakh and Sur [63] observed reduced weed population in pomegranate from 19.7 to 26.4 per cent in black plastic mulch as compared to other mulching treatments. Black plastic mulch in combination with drip irrigation resulted in significantly higher weed control (60.15%) as compared to control (40.95%) in banana cv. Dwarf Cavendish [64]. Hassan et al. [65] compared black and transparent plastics in Flame seedless vineyard for mulching and studied that black colour efficiently controlled weeds due to lack of light and unfavourable conditions for growth whereas transparent colour encouraged weed growth during earlier months but weeds were gradually reduced after about two months as most of them were rot due to soil solarization and high humidity under plastic cover. Sharma and Kathiravan [24], in Nagpur mandarin, found similar results with the significant reduction in weed population in drip irrigated Nagpur mandarin covered with black polyethylene mulch followed by white polyethylene and dry grass. Weed growth was also substantially reduced with mulch in avocado and citrus [66] and pomegranate [25].

Melgarejo et al. [67] studied the effect of black and white geotextile mulch and observed both were effective in reducing weed cover and biomass substantially in grape cv. Pinot Noir throughout the experimental period of 2004 and 2005. Mulching not only provided weed control but also avoided herbicide pollution thus can be a sustainable management practice in mandarin orchards [68]. Abouziena et al. [69] also confirmed the higher efficiency of weed control (94-100%) by black plastic mulch (200 or 150 micron) over cattail or rice straw mulch (85-98 per cent weed control) in Balady mandarin. Further, black plastic mulch was found to be most effective in controlling (6.0/m^2 after 90 days) many of the weed species like *Cynodon dactylon* (L.) Pers., *Cyperus rotundus* L., *Sorghum halepense* (L.) etc. in Japanese plum (*Prunus salicina* Lindl.) orchard as it acts as a physical barrier on the surface of soil, which might create partially anaerobic conditions for the survival of weed species [70]. Mulching with black and bicoloured plastics significantly reduced the weed growth in plum [57]. In peach cv. Early Grande, covering soil with black polyethylene mulch (100 µ) resulted in 100 per cent control of weeds at six weeks after treatment, however, guinea grass, which had emerged out of the black polythene mulch, reduced the weed control efficiencies to 96.3 and 98.5% at 12 weeks after treatment [71]. Gan et al. [33] quantified the weed dry matter content under various organic and inorganic mulch materials in pomegranate and noted no weed growth in the plant basin of black plastic mulched plants. They further

recorded maximum weed dry matter content under white polyethylene mulching (898 g) followed by Napier grass mulching (186 g) and control *i.e.* no mulching (186 g). Contrary to it, Bakshi et al. [72], while comparing various mulch materials for strawberry cultivation, enunciated that transparent and black plastic mulches had not shown any weed growth, however, organic mulched beds (paddy straw, wheat straw, cut grass and saw dust) recorded weed populations but significantly lower than non-mulched plot. In pomegranate cv. Wonderful, plant basin mulched with bare soil (control) gave the highest values of cut grass weight (80.75 g) while mulching with rice straw, palm fronds, transparent plastic and gravel mulch were found effective in controlling weeds under semi arid conditions of Egypt [73]. Bons et al. [36] compared various organic and inorganic materials as mulch in kinnow for their efficacy in controlling weeds during the monsoon season (2nd fortnight of June to 2nd fortnight of September) in 2014-16 and found lowest weed dry weight in plants mulched with polyethylene mulches (black and silver) followed by paddy straw at all the growth phases of the plants.

3.5 Vegetative Parameters

Mulching influences the microclimate around the rhizosphere by providing optimum conditions for plant growth [18]. It enhances the growth of the plants and this may be because mulch reduces leaching of nutrients, reduces weed problems, reduces evaporation of soil water and reduces soil compaction [6]. Several workers in various fruit crops supported the view of positive impact of mulching on plant growth parameters.

Agrawal and Agrawal [64] observed maximum height (144.26 cm) and girth (50.58 cm) of pseudostem with number of functional leaves (15.20) in banana cv. Dwarf Cavendish treated with 60% irrigation + black polyethylene mulching. Canopy volume of Nagpur mandarin was substantially increased with black plastic mulch (8.67 m^3) followed by local grass mulch (7.37 m^3) as compared to unmulched control (6.05 m^3) as reported by Shirgure et al. [24]. Mukherjee et al. [74] studied the effect of water regime, mulch and kaolin on growth and yield of ber cv. Mundia and observed that black plastic mulch improved the plant height by 0.78 m as compared to 0.53 m in control. Further, dry grass and black polythene mulches were found equally effective in producing maximum extension of growth (26.70 cm) followed by dry leaf (26.40 cm) in apple cv. Red delicious which was due to higher soil moisture availability, addition of nutrients and less weed growth [75]. Mulching with black polyethylene significantly increased plant height compared to other mulches in strawberry cv. Chandler [76]. Mal et al. [25] studied the effect of various organic and inorganic mulches in pomegranate cv. Ganesh and observed maximum increase in plant height and basal girth with dry leaves and banana leaves, respectively, while maximum plant spread in East-West and North-South directions was observed with black polyethylene and sawdust, respectively. Singh et al. [77] noted that crown height (10.30 cm), plant spread (21.80 cm) and leaf area (79.60 cm^2) were significantly higher in strawberry plants mulched with black polyethylene than those mulched either with clear polyethylene or paddy straw. Paul et al. [78] indicated 6 per cent increase over the average height of plant (2.18 m), maximum stem girth (621 mm), more number of functional leaves (15.40), leaf area (1.47 m^2) with early emergence of flowers by 21 days in plants treated with 80% irrigation + black LDPE mulch in banana cv. G-9 when compared to basin irrigated unmulched plants. In Guava cv. L-49, mulching with paddy straw resulted in maximum increase in plant height (0.73 m), basal girth (0.94 cm) and canopy spread in both directions East – West (0.76 m) and North – South (0.74 m) as compared to control [79]. Similarly, Silva et al. [26] also observed paddy straw mulch to be more effective in producing more growth in terms of plant height, stock root girth, scion girth and plant spread followed by maize straw in NA-7 aonla. Paul et al. [80] reported that supply of 80% water need through drip coupled with plastic mulching (black LDPE mulch film) increased plant height by 35 per cent leading to the maximum height of 2.7 m, basal girth (27 cm), canopy area (5.20 m^2) in mango cv. Amrapalli. Bal and Singh [81] while studying the effect of mulching in ber obtained maximum tree volume of 45.13 m^3 under black polyethylene + gramoxone @ 1 l/ha followed by black polyethylene + glyphosate (44.18 m^3) as compared to only 33.04 m^3 under unmulch control. Mulching with black polyethylene resulted in significant increase in plant height, plant spread and tree volume in litchi cv. Rose scented which could be ascribed to higher uptake of nutrients under mulch as it conserves soil moisture and moderates evaporation from soil surface [82]. Kumar et al. [83] suggested that crown height, plant spread and leaf area were significantly higher in plants mulched with black polyethylene (50 µ) when compared to transparent polyethylene, paddy straw and pine mulch in strawberry. Among the organic

mulches, Ali and Gaur [84] observed maximum number of runners per plant (2.50), runner plantlets per plant (6.0), leaf area (27.15 cm^2 per plantlet) with paddy straw in strawberry cv. Sweet Charlie which might be attributed to optimum soil moisture, spare weed population and availability of nutrients. In passion fruit, maximum internodal length (8.00 cm) was seen in plants mulched with black polyethylene whereas length of the vine (129.15 cm) found highest with straw mulched plants [85]. Kumar et al. [31] recorded highest plant height, spread and girth in black polyethylene followed by farm yard manure and brankad in kinnow mandarin. Mage [86] also observed higher shoot length, leaf area and number of leaves/shoot under sub surface drip irrigation along with plastic sheet mulching in pomegranate. Similar observations in Strawberry cv. Chandler were noted by Bakshi et al. [72] as maximum increase in plant height, plant spread and number of leaves per plant were observed in the plants mulched with black plastic when compared to transparent plastic, other organic mulches (paddy straw, wheat straw and dry grass) and control. On the contrary, in an experiment to find the effect of organic and inorganic mulches in strawberry cv. Tioga under red and lateritic zone of West Bengal, Das et al. [87] observed highest plant height, canopy diameter, number of leaves, leaf breadth and chlorophyll content under transparent mulch rather than black plastic. Black plastic mulch was found superior over grass mulch in kiwi fruit cv. Allison as it measured highest shoot growth, internodal length, leaf area and leaf thickness [88]. These findings are in agreement with the result of Pandey et al. [89] who reported that strawberry plants mulched with black polythene had better growth than other mulches used like white polythene, straw mulch and control. It attributed to better soil hydrothermal regimes, better moisture conservation and suppression of weeds and further maximum root fresh as well as dry weight, volume, and length have also been recorded under black polythene mulch. El-Tawell and Farag [73] revealed that plant basin mulched with gravel produced the highest number of leaves (74.07), shoot length (37.62) and number of internodes (18.23) in pomegranate cv. Wonderful. While comparing black plastic with organic mulches and control in kinnow, Bhanukar et al. [90] suggested that maximum per cent increase in plant spread, plant height and plant girth were recorded in black polyethylene mulch (200µ). Black plastic mulch also proved superior in Eureka lemon as maximum increase in plant height, spread and girth size (51 cm, 35 cm and 2.20 cm, respectively) was recorded with it [32]. Pandey et al. [35] studied the effect of black plastic, white plastic and rice husk with control in strawberry and observed maximum plant spread, biomass, total chlorophyll content, root biomass, root volume and root length in black plastic mulch whereas maximum number of leaves and highest chlorophyll, content at the time of harvest was observed in case of white polythene mulch which might be related to better exploration of nutrients and water [91] in late stage of crop under modified radiation condition due to higher reflection from white polythene mulch as compared to other treatments. The maximum shoot length, number of leaves per shoot and leaf area at 30, 60, 90, 120 and 150 days after were recorded in plants mulched with black polythene film [92]. Higher vegetative growth in black polythene may be due to adequate moisture in the soil, which is vital for plant growth and in turn helps to increased intensive metabolic processes, better nutrient uptake and translocation of nutrients. The maximum shoot extension growth (51.80 cm), tree spread (2.60 m), tree height (2.66m) and tree volume (9.41 m^3) was also recorded in black polythene mulch in rejuvenated pomegranates (*Punica granatum* L.) cv. Seidhom and Rahman [93]. Further, Hieke et al. [94] observed maximum plant height (4.90 m and 5.02 m), plant spread (3.87 m and 3.89 m) and plant volume (40.00 m^3 and 40.19 m^3) in apple cv. Royal Delicious with paddy straw mulch, which is probably due to better moisture conservation and suppression of weed resulting in better translocation of nutrients in plants than other treatments. Mustaffa [95] observed maximum annual growth of the plant (29.62 and 35.44 cm) with black polythene mulching in apple. The availability of soil moisture and nutrient with less weed growth associated with mulch material can be attributed to maximum annual growth of the plant. Sakariya et al. [49] also reported that maximum plant height (1.50 m), stem diameter (84.30 mm), number of leaves (31.50) in silver black plastic mulch in papaya cv. Madhubindu and Taiwan. Lalruatsangi and Hazarika [34] evaluated efficacy of different mulches on growth of acid lime and reported that the highest increase in plant height (6.63%) as well as canopy spread in both East-West direction (9.90%) and North- South direction (7.60%) were recorded by polythene mulch with black side facing upward which is attributed due to ideal soil moisture and better water conservation along with lower weed intensity due to the mulching materials.

3.6 Yield and Quality Parameters

As stated earlier, by altering the microclimate in favour of the fruit plants viz., temperature regulation, maintenance of appropriate soil moisture status as well as reduced weed competition, soil compaction and erosion, mulching enhances moisture and nutrient availability to the fruit plants. These favourable factors undoubtedly improve the yield and quality of the economically important produce i.e. fruit. Several studies conducted in almost all the fruit crops advocated the positive response of mulching on yield and quality parameters of the fruit crops. Some appropriate findings to support the view are discussed here.

Mulched strawberry with plastic increased 68 per cent while with pine needle increased 33 per cent yield over control and mulched treatments also enhanced TSS [96]. Black plastic mulch recorded significantly higher yield of apple [97] and aonla [98] over unmulch control. Pomegranate yield also positively influenced by various organic and inorganic mulches and highest yield was noted under black plastic soil cover followed by saw dust, banana trash and control [99]. In ber, maximum yield with sugarcane trash mulch was observed by Jack et al. [100]. Kamal and Singh [101] obtained highest fruit yield (58 kg/tree) and TSS content (13.0^{0}Brix) in peach cv. Shan-e-Punjab under black polythene mulch. Reddy and Khan [23] assessed the response of various floor management practices in sapota cv. Kallipatti and showed 72.45 per cent and 65.05 per cent yield enhancement over control (78.02 kg/ tree) with the black plastic film of 200 guage (134.55 kg/ tree) and 400 guage (128.77 kg/ tree), respectively over the two years of experimentation period. Among the others, double cover crop (115.2 kg/ tree) produced the best result with respect to yield. Significant increase in yield was achieved in guava plants covered with paddy husk (13.6 kg/ tree) than control (8.7 kg/ tree) by Borthakur & Bhattacharya [102]. Highest fruit yield of apple cv. Starking Delicious was obtained with herbicide plus mulching along with hay followed by mulching with 10 cm hay and white netted polythene mulch [103]. Enhanced yield with higher quality parameters (TSS, vitamin C and lower acidity) was also found with black polythene mulch in strawberry cv. Oso Grand [104]. Significantly higher fruit yields were noticed in apricot cv. New Castle [105] and mango cv. Agrawal et al. [106] with drip irrigation and black plastic mulch than drip irrigation alone. Black plastic mulch also produced significantly higher fruit yield and TSS content in mango cv. Himsagar whereas maximum ascorbic acid content was found in dry leaf mulching [107]. Sharma and Kathiravan [24] investigated the effect of different mulches on yield and quality parameters of drip irrigated Nagpur mandarin and observed highest yield (73.7 kg/tree), which was almost 25 per cent higher over control, individual fruit weight, TSS content and lower acidity under black plastic mulch. Similarly, Patil et al. [108] assessed the effect of mulching on fruit yield of guava cv. Sardar and found maximum yield with black plastic mulched plants (44.32 kg/plant and 12.32 t/ha). The maximum fruit yield with dry grass mulch whereas quality parameters viz., TSS content (14.2 ^{0}Brix), total sugars (9.50%) and reducing sugar (6.90%) with black plastic mulch were observed in apple cv. Red Delicious by Neilsen et al. [75]. Schales and Sheldrake [76] reported that black polyethylene significantly increased the TSS (8.95 and 8.88%) and TSS: acid ratio (10.97 and 10.93) followed by bicoloured polyethylene during both the years of study. Das et al. [109] evaluated the effect of black plastic, paddy straw and Deenanath grass mulch on yield and quality attributes of strawberry and noted maximum yield with black plastic, however, other quality parameters viz., fruit weight, TSS, total as well as reducing sugars and ascorbic acid showed non-significant differences among the three mulch materials. Five year study with 'Lal Sundari' mango recorded higher yield and quality under dry grass mulching [110]. The effect of pre-harvest reflective mulching improved the quality attributes in plum as application of mulch 2-3 weeks prior to harvest indicated higher TSS by 0.3°Brix and lower fruit acidity with reduced fruit cracking compared to unmulched plants [111]. Ghosh et al. [112] opined that mulching of plant basin and watering in dry period significantly improved the yield and quality of sweet orange cv. Mosambi. Castaneda et al. [29] studied the effect of three mulches with three strawberry cultivars under temperate conditions of Brazil and concluded that black polyethylene mulch (used as control in the experiment) produced more fruits per plant and per unit area when compared to other tested material (black and white polypropylene) in all the tested cultivars (Oso Grande, Aromas and Camarosa).

Sharma and Kathiravan [57] during a two years study with plum cv. Santa Rosa recorded significantly higher mean fruit yield of 80.62 quintal/ha in black plastic mulched trees.

Significantly higher fruit yield in strawberry cv. Chandler was found under black polyethylene mulch followed by transparent polyethylene and paddy straw mulch [113]. Contrary to it, Kumar et al. [83] while studying the impact of different mulching materials on growth, yield and quality of strawberry reported significantly higher fruit yield under transparent polyethylene mulch followed by black polyethylene mulch with minimum in control. Among organic mulches, maximum fruit yield (41.50 kg/plant), TSS (8.25 ^{0}Brix) and vitamin C content (498 mg/ 100 g) in aonla cv. NA-7 were observed with paddy straw mulch followed by maize straw mulch [26]. The juice content of Nagpur santra (39.8%) was significantly higher in when plastic mulch was applied with drip system [114]. Bal and Singh [81] suggested that black plastic and black plastic + herbicides are the ideal choice for ber orchards as these were the best in respect of improving yield (fruit weight, size and total yield) and quality (TSS and ascorbic acid) parameters whereas, paddy straw was found to be the best organic mulch.

Saxena [1] revealed that pomegranate plants mulched with olive pomace gave a higher yield of 49.39 per cent over unmulched control and 11.39 per cent over bitumen emulsion mulch during three seasons of experiment. Rao and Pathak [115] reported that kinnow planted in continuous trench with mulch produced 68 per cent more fruit yield as compared to control treatment. Sharma et al. [30] observed higher TSS, acidity and juice content of acid lime with black plastic (100 micron) and grass mulches. Mehraj et al. [116] indicated that total sugars, organic acids and the total concentration of volatile compounds were slightly higher in plums fruits from trees with plastic mulching film, though the differences were not significant. Fruit yield and total soluble solids of kinnow was highest with black polyethylene mulch followed by farm yard manure [31]. Similarly, Bakshi et al. [72] also stated that mulching in strawberry cv. Chandler recorded higher TSS (7.63 ^{0}B), total sugar (7.0%) and lower acidity (0.64%) under black polythene mulch. In pomegranate cv. Ruby, highest fruit yield of 9.90 kg was obtained from the plant mulched with saw dust followed by 8.80 kg per plant mulched with white polyethylene, whereas, fruit weight was highest (178 g) in the plants mulched with rice straw followed by black polyethylene (172 g) and saw dust (170 g) which may be due to increased absorption of nutrients and moisture [33]. Maximum number of fruits per plant (33.6), yield per plant (536.6g), TSS (7.3^{0}B), total sugars (5.15 %), reducing sugar (4.10%), TSS: acid (4.40), vitamin C (52.5%), juice percentage (96.1 %) and anthocyanin content (38.9%) in black polyethylene mulch were observed by Pandey et al. [35] when compared with white plastic, rice husk and unmulched control. Das et al. [117] evaluated various organic materials (paddy straw, dry mango leaves, dry banana leaves and water hyacinth) as mulch in litchi cv. Bombai and recorded maximum fruit retention, yield (94.42 kg/ plant), total soluble solids (20.20 ^{0}B), highest TSS acid ratio (33.6:1), total sugars (14.80%) and ascorbic acid (37.20 mg/ 100 g) with minimum acid content (0.60%) when mulched with paddy straw. Yogaraj et al. [92] also conducted an experiment to compare the various organic and inorganic mulches on growth and yield of pomegranate cv. Bhagwa and revealed that maximum fruit yield (20.87 kg/plant) was recorded in plants mulched with black plastic mulch which was due to increase in number of fruits per plant (79.67), average fruit weight (299.42 g), fruit length and breadth (81.44 mm and 82.13 mm, respectively), total aril weight (193.78 g). Similar findings with pomegranate cv. Kandhari Kabuli were noted by Seidhom and Rahman [93] as they also found higher fruit set (53.40%), number of fruits/tree (51.66) and yield (kg)/plant (13.05) with black polyethylene mulch. Further, Mustaffa [95] found highest fruit yields (kg/plant) with black plastic mulch (43.40 and 54.57 kg/plant) followed by dry grasses (40.62 and 50.26 kg/plant) during both the years of study (2010-12) under hilly region of Uttarakhand. Pradhan [118] reported maximum fruit yield per plant with silver plastic mulch and 100% RDF in papaya. Maximum fruit weight and fruit number per tree (166.9 g and 371.7) with highest yield (62.8 kg/ tree) were recorded in plants mulched with silver plastic (50 µ thick) while highest TS.S (10.5%) and juice (49.6%) contents were noted with black plastic mulch in kinnow [36]. Further, Kumar [34] reported highest number of fruits per plant (161.85), fruit weight (50.22 g) and fruit yield per plant (7.81 kg) in acid lime with plastic mulch having black side facing upward.

4. CONCLUSION

In India**,** productivity of most of the fruit crops is quite low as compared to the other major producers and world averages. The main cause behind low productivity is poor orchard management practices which results into biotic and abiotic stresses in fruit crops. Further,

among orchard management practices, the floor management is least cared in India with just 2-3 times soil tilling per year to control weeds in most of the orchards, as its direct impact is not visible. It might be one of major causes of low productivity of fruit orchards in India. The cheapest way to manage optimally the orchard floor for soil hydro-thermal regime, weed suppression which ultimately favours optimum growth with higher yield and quality, is mulching. The present paper reviewed the effect of organic and plastic mulching on soil moisture status and water use efficiency, soil temperature, weed growth, vegetative parameters as well as yield and quality parameters with the brief account of types of mulch. From the review, in nutshell, it can be inferred that the mulching (either organic or inorganic) should be promoted in orchards to get higher yield with quality which can compete in national and international trade.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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