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**Jagrity Saini**  
School of Agriculture,  
Department of Horticulture,  
Lovely Professional University,  
Punjab, India

**Anis Ahmad Mirza**  
School of Agriculture,  
Department of Horticulture,  
Lovely Professional University,  
Punjab, India

## Impact of coloured plastic mulches on soil characteristics and strawberry crop productivity: A review

**Jagrity Saini and Anis Ahmad Mirza**

### Abstract

Mulches are materials applied in a soil surface for different roles and purposes. Plastic mulches with different colour have been developed and utilized in different crop production systems. Using coloured plastic mulches is mainly focused in modifying the radiation budget and decreasing the soil water loss. Besides, it helps to regulate soil temperature, water use efficiency, plant growth, yield, quality and weed and insect infestation. In this review, the knowledge and possible application of coloured plastic mulches, which can improve the soil physical properties, growth, yield, and quality of strawberries has been reviewed and discussed. The role of coloured plastic mulches to mitigate the harmful effect of environmental stress in crops is also examined. Various physicochemical processes leading to improved crop production under the effect of coloured plastic mulches are also discussed. The combined results indicated that, effect of coloured plastic mulches is highly significant on soil temperature, moisture and water holding capacity. While black and blue plastics increase soil temperature, clear and white decreases it. Higher number of fruits, number of roots, tubers and bulbs was recorded in use of coloured plastic mulches. Similarly, the TSS, Vitamin C and juice percentage of different plants also showed significant improvement. It is also reported that weed infestation and viral diseases is highly reduced. Coloured plastic mulches also have some negative impacts like, decrease growth and yield in some plants, increase pest infestation, micro plastics contamination, soil puddling, Soil structural loss and reduce activity of soil-microorganisms. Therefore, use of coloured plastic mulches require close inspection of interaction with factors like; cropping season, root zone temperature, crop type, insect pest infestation and water use efficiency factors.

**Keywords:** Coloured plastic mulch, insect-pest, soil quality, water use efficiency

### Introduction

A Germanic word ‘mulch’, which represents ‘molsh’ means soft. It doesn’t mean all mulches are soft, but it represents a soft, spongy layer found in forest ecosystems. Other definitions also define mulches as materials applied to or grow upon, the soil surface [1]. Mulches have a significant effect in preventing drought stress, protection from freezing, improving soil chemical, physical, biological properties, disease control, and enhancing crop productivities [2-4]. Mulches utilized in the farming systems vary in type and characteristics. The most known mulches are gravel, mulches, pebbles, polyethylene film, organic- straw, hyacinth, wood, bark, or leaves, used individually or in mixtures, or living- turf grass, rye, and clover materials [3-5]. Organic mulches mainly organic straws are the most common mulches utilized in developing countries. But, organic-mulches are subjected to decomposition, are less efficient, labour intensive, and weather dependent [6]. The development of polyethylene (PE) as a plastic film in 1938 and its introduction as a plastic mulch for vegetable crop production in the 1950s significantly enhances commercial crop production [7]. The world plastic production in the year 2018 was 360 million tonnes with a distribution percentage of Asia 51%, Europe 17%, NAFTA (North American Free Trade Agreement) 18%, Africa 7%, CIS (Commonwealth of Independent States) 3%, and Latin America 4% [8]. From the plastics fabricate agricultural production uses nearly 4% of it for different purposes, including mulching [8].

Regardless of their nature of the source of production, the plastics produced are polyethylene, polyamides, polypropylene, polycarbonate, expanded polystyrene, polyethylene terephthalate, etc. Various types of polyethylene-coloured plastic mulches have been utilized in the farming community with different formulations for a different purpose. Previously black, clear, and white plastic mulches were utilized for vegetable farming. The plastic colours known today are mainly, Black, white, green, brown, red, silver, and blue.

**Corresponding Author:**  
**Jagrity Saini**  
School of Agriculture,  
Department of Horticulture,  
Lovely Professional University,  
Punjab, India

These colours are formulated with their role in light absorption and crop physiology. The impact of these coloured plastic mulches is quantified by many researchers in different crops [9-12].

Black plastic mulch is the most available and most used of others. It absorbs efficiently UV(Ultraviolet), visible, and infrared wavelengths of solar radiation released from the sun. It showed significant impact in increasing soil heat by absorbing high amount of radiation. White plastic mulch is the reverse of the black one. It cools the soil and mostly used in crops that require less soil heating [7, 10, 13]. Red plastic mulch is the most efficient in absorbing global solar radiation than black, blue, green, and yellow plastic mulches. Based on the order of global solar radiation transmittance, black < blue < yellow < green < red < transparent plastic mulches [14]. There are also reports which describe the energy balance in the order of red > transparent > green > blue > yellow > black [15]. The variation in that colour of plastic mulches is designed to alter the micro-climate at the plant and soil levels. Variation in colour of plastic mulches affect spectral balance, quality, and quantity of light that affects many plants growth and developmental patterns including the yield of plants [16].

Plastic mulches also directly affect the microclimate around the plant by modifying the radiation budget and decreasing the soil water loss. It enhances crop production by increasing fruit quality, gross yield, and earlier production [17]. To increase crop production and productivity, field evaluation has been done on new formulations of wavelength-selective, biodegradable, and coloured plastic mulches [18, 19].

Coloured plastic mulches also significantly affect light absorptivity, light reflectivity, soil water loss, soil temperature, plant morphology, and weed control [20]. The purpose of variation of colours to impact the absorption and reflection of FR: R (far-red to Red) ratios result in phytochrome regulation. Plants receiving high FR: R light responds in increased plant height and above-ground biomass [20, 21].

The main kinds of coloured plastic mulches used in different parts of the world for different crops are, black, white, and clear plastic mulches. Black plastic mulch used to increase light and temperature absorption, white to reflect, and clear one to produce large heat [10, 20]. Recently, various plastic mulches with different colours and formulations have been developed. These coloured plastic mulches are used in the cropping system of different plants for different purposes. According to research reports different coloured plastic mulches impact crop production in different ways. Their level of impact is extended to the soil, water, and yield and quality of crops. Therefore, this review evaluates the impact of coloured plastic mulches on soil, light absorption, and crop yield and quality.

#### **Effect of coloured plastic mulches on soil temperature**

Any treatment or any technological application to enhance plant growth and development significantly affects the soil. The physical, chemical, and biological properties of soil were all affected by these technological inputs. Soil temperature is one of the main properties of soil which affects crop production. As expressed by different authors, systems and processes involved inside a soil mainly nutrient uptake, absorption of water root growth, and life of soil microorganisms depend on the level of soil temperature [22, 23]. Coloured plastic mulches significantly alter the soil

temperature. Franquera [20] reported a higher soil temperature due to colored plastic mulches than bare soil. Their result indicated that blue plastic mulch contains more temperature than red. According to Farias-Larios and Orozco-Santos [24], the highest temperature was recorded by clear plastic mulch and there was no difference in temperature by black plastic mulch and bare soil. Similarly, the experiment by Gordon *et al.* [12] showed there is a difference in soil temperature by coloured plastic mulches and row cover. The highest temperature (31.2 °C) was recorded by black plastic mulch with row cover and the lowest (31.2 °C) was recorded from bare soil.

The reported impact of coloured plastic mulches on soil temperature by different researchers is variable from area to area and from crop to crop. A research report by Shah Jahan *et al.* [25] indicated that higher temperature was recorded by black plastic mulches than olive, silver, white, and blue. But Ibarra-Jimenez *et al.* [26] reported that brown and blue plastic mulches were higher in soil temperature than the other mulches including black. This variation will be due to variations in soil type and climatic conditions of the areas. Confirming this, reports indicated that black plastic mulch is efficient in increasing minimum, maximum, and mean soil temperature than white/black, aluminum/black plastic mulching systems [27].

Covering the land with black and white plastic mulch during the production period increases the soil temperature significantly. The increase in soil temperature could reach to 60 °C by the trap of solar radiation in black and white plastic mulches. This increase in temperature specifically enhances weed suppression in weed-infested areas [28, 29]. On other reports, higher temperature was examined in black and brown plastic mulches than white [30].

Black and white plastic mulches were tested for their role in overwintering by protecting from the injurious cold temperatures. Their effect was not as expected, both plastic mulches reduce the overwintering capacity of shrubs rather than increasing survival ability [31]. Further reports also indicate that, black and brown plastic mulches are reported effective in increasing root zone temperature (RTZ). Increasing the root zone temperature by plastic mulches is highly required in areas with cold climatic conditions but not in warm areas [32, 33].

The temperature in the root zone decreased when the plant developed a full canopy. This event was recorded in tomato and radish plants. An increase in canopy increases shading on plastic mulch; this restricts direct interception of solar radiation and heat transfer from surrounding air and soil [34, 35]. It is eminent that using coloured plastic mulches enhance the temperature of the soil. There is a higher soil temperature by coloured plastic mulches than bare land. Any grower who intends to increase the soil temperature can use coloured plastic mulches. But, the decision on selecting the type of colours depends on the climate, soil type, crop type, and intended purpose.

#### **Effect of coloured plastic mulches on soil water and water use efficiency**

Water is one of the necessities of plants life in which all their processes during their lifecycle depends on. Inevitably, without water, living things are impossible to exist. The role of water in the plant's life is mainly on hydration, transpiration, and dry matter production of plants [36].

Decreasing water loss and irrigating to the level of optimum water availability enhances plant growth, development, and yield.

Many technologies were tested to enhance the availability of water for plants and to protect water loss. It is verified that mulches enhance the availability of water for plants by their impact on reducing erosion, evaporation, surface temperature, wind impact, and weed infestation [37–39]. Different researchers reported that coloured plastic mulches have a visible impact on effective water use, protection against water loss, and enhancing water use efficiency for different crops [15, 25, 39, 40].

As Water use efficiency is the new way of agriculture, its focus is in increased production by a limited amount of water. In arid and semi-arid areas, it is critical to saving water and enhancing crop productivity. Crop yield is linearly related with the available water and water use efficiency in the production period [41]. Mostly non mulched land shows higher water loss than the plastic covered lands. This is because there is an increase in exposure to water loss agents, mainly solar radiation, wind, and heat [42]. Plastic mulching shows a positive impact on yield and water use efficiency of plants than conventional tillage patterns. It was reported that black and white plastic mulching increases water use efficiency in potato plant by 31% than non-mulched land [43].

Efficiency in water use was reported to be improved through the use of black plastic mulches. Such efficiency is attained because of its impact in reduction of evapotranspiration from the soil surface. This signifies the role of black plastic mulch in reducing moisture loss, in enhancing protected agriculture and decreasing the plant requirement for higher irrigation water [44, 45]. But, comparison between black and white plastic mulches verified that the rate of evapotranspiration by black plastic mulch (202–442.6 mm), is higher than white plastic mulching (142.8–436.1 mm) [43]. In addition, early researches indicated that covering by black plastic mulch enhances the availability of moisture but less than straw and organic mulches. Whereas, under high rainfall, black plastic mulches are preferable than both organic and other coloured plastic mulches [46, 47].

Trapping black plastic mulches on the soil to modify the environment around it, is one of the common practices in farming community. Such trapping increases the water holding capacity of the soil, and enhance the nitrate in it. Besides, this practice can also improve the ability to hold moisture in reduced tillage production systems [48]. Photosynthetically active radiation (PAR) is mainly affected by the colours of plastic mulches. The variation in the colours of the plastic mulches will increase or decrease the transmittance, absorbance, and reflectance of both short wave and long wave radiations which affects PAR. Higher reflection in PAR creates a lower amount of soil temperature and higher moisture content in the root zone of the plants. Silver plastic mulches are higher in reflecting PAR than black and white plastic mulches. Such higher reflection of PAR by silver plastic mulches reduces root zone temperature and loss of water [48–50]. These important characteristics of this plastic mulch makes it efficient in conserving water and protecting the colours of the plastic mulches will increase or decrease the transmittance, absorbance, and reflectance of both short wave and long wave radiations which affects PAR. Higher reflection in PAR creates a lower amount of soil temperature and higher moisture content in the root zone of the plants. Silver plastic mulches are higher in reflecting PAR than black

and white plastic mulches. Such higher reflection of PAR by silver plastic mulches reduces root zone temperature and loss of water [48–50]. These important characteristics of this plastic mulch makes it efficient in conserving water and protecting water loss [48–51].

### **Effect of coloured plastic mulches on weed, diseases and insect pest control**

Weed suppression is reported as one of the positive impacts of plastic mulching. Mulching by its effect on shading, which reduced germination and seedling growth of weeds; and by acting as a physical barrier reduced weeds' existence [61]. Weed control has been practiced in crop farming systems by temporary, impermeable, black plastic tarps, solarization plastic covers, and long use plastic mulches [60, 92].

Better plant performance and less weed biomass were reported by coloured plastic mulching on a ginger plant than non-mulched lands. But according to this report, the impact of plastic mulches on reducing weed infestations and yield of the plant were lower than organic mulches like coconut leaves [6]. Other reports found that plastic mulch reduced weed dry matter by 63.8% compared with an un-mulched land [71] and black plastic mulch showed decreased weed dry weights by 91.3% and 94.7% [61].

On contrary to positive impact, reports indicated that plastic mulch increased insect pest attacks in some crops. In addition, black plastic film (lower PAR reflection) and silver plastic mulch (high Par reflection) also resulted in a non-significant difference to non-mulched lands in thrips and tomatoes spotted wilt infestation [51]. Similarly, bacterial soft rot (*Erwinia* spp) incidence exhibited an increase in plants covered by black plastic mulch [93]. Positive result was reported about the impact of black and clear plastic mulches in reducing weed infestation. This impact is a factor of their effectiveness at warming the soil and increasing root zone temperature. But the impact of black plastic mulch on reducing weed competition is better than clear plastic mulch as it lays across the soil and around the crop reduce the light reaching the soil. This inhibits the level of effectiveness of weed germination and smother emerging weeds [94, 95]. Aphids are one of the crop pests severely affected by plastic mulching. Clear plastic mulch is reported as highly effective in repelling this pest than black plastic and bare-root production [96]. On contrary to this, other reports also verified that, yellow plastic mulch have a negative impact on insect pest control. It attracts green pea aphids (*Myzus persicae*), striped (*Diabrotica undecimpunctata*) and spotted (*Acalymma trivittatum*) cucumber beetles [79, 97].

But, according to other reports, among coloured plastic mulches, white and clear are effective in reducing the incidence of viral diseases, whitefly population, and aphid population. In some crops repelling aphids reduces viral disease incidence [98, 99]. It was also reported that the infestation by thrips was reported as low in red, green, and black plastic mulches [100]. Therefore, from all the reports, there is a clear difference in the role of plastic mulches in reducing pest and diseases impact. But black and clear plastic mulches exhibited a positive impact in reducing pest and diseases attack in most crops [98, 99].

### **Drawbacks and damaging effect of coloured plastic mulches**

Agricultural practices by coloured plastic mulches could be

one of the major agents in terrestrial microplastic contamination [101, 102]. The projected increase in the use of plastic mulches for agriculture production is expected to grow at 5.6% per year through 2030. This increased rate indicates there will be further contamination of arable land by plastic mulching [103]. Microplastics retained from coloured plastic mulching negatively affect the activity of soil microorganisms [104], soil structure, soil chemical property [105], and plant performance [106].

Plastic mulch production is also labour intensive, require special equipment, costly as it incurs further cost in removal and disposal after the production period [107]. From the farmer's perspective, the cost for removal will not be appreciated and if there are remains left it can cause puddling and structural destruction on soils.

Furthermore, producing by black plastic mulch in hot climatic conditions may contribute to the high temperatures around the root zone. If the root zone temperature is above average, the growth of the plant will be curtailed significantly [25, 40]. Other investigations also revealed that the use of plastic mulch increases diseases and insect pest attacks in some crops. Polyethylene plastic mulches also create soil puddling, soil erosion, and reduced water holding capacity. In addition, use of coloured plastic mulches will impact the soil microbiota and will negate the natural functioning of terrestrial ecosystems by its direct and indirect impact on soil health [86, 108].

### Conclusion

In arid and semi-arid environments of the tropics and subtropics, moisture, temperature, precipitation, and other soil factors are the limiting factors in crop production. Lower root zone temperature, high rate of evaporation, and insufficient rainfall determine cropping systems. Using coloured plastic mulches is widely accepted and utilized in the farming community to solve above-lined problems. It is indicated that coloured plastic films affect the plant root zone temperature, microbial life, soil properties, and moisture levels. By improving the plant microclimate, coloured plastic mulches increase plant growth, development, quality, and yield of most crops. Black and silver-coloured plastic mulches are reported to enhance growth, yield, and quality in most crops than other coloured mulches. In some crops, even if there are beneficial roles by coloured plastic mulches, its use also exhibited a negative effect on yield and insect pest control. In addition, the fragments of plastic mulches pollute the arable land significantly. Therefore, even if the use of plastic mulch increases yield, quality of crop production, its use requires close inspection of factors like; cropping season/mulch interaction, root zone temperature/mulch interaction, the colour of plastic mulch/crop interaction, coloured plastic mulch/insect pest interaction and crop type/water use efficiency factors.

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