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Review Paper

Effect of Mulching On Crop Production under Rainfed Condition: A Review

Sarolia Deepak Kumar[1], *Bhardwaj Raju Lal[2]
SMS (Horticulture), Krishi Viyan Kendra, Sirohi, INDIA
Maharana Partap University of Agriculture and Technology, Udaipur (Rajasthan), INDIA

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Abstract- *In water deficit area (rainfed area), judicious use of water is essential for increasing area under crop production with limited water supply. Therefore, uses of moisture conservation measures are essential under such situation. Mulching has been advocated as an effective means for conserving soil moisture. It works as an insulating barrier which checks evaporation from soil surface. Mulching is an agricultural and horticultural technique in which the use of organic materials (plant residues-straw, hay, groundnut hulls, leaf and compost, peat, wood products-saw dust and animal manures), and synthetic materials (paper, polyethylene, wax coated papers, aluminium, steel foils and asphalt spray emulsions etc.) with or without shallow tillage, for the purpose of increasing soil productivity is involved. This technique is very useful in protecting the roots of the plants from heat, cold or drought or to keep fruit clean. It checks evaporation and modifies the soil and air microclimate in which a plant is growing. Mulch is used to cover soil surface around the plants to create congenial condition for the growth. This may include temperature moderation, salinity and weed control. It exerts decisive effects on earliness, yield and quality of the crop. Mulching is also applicable to most field crops. However, it is preferred in fruit orchard, flower and vegetable production, nurseries and forest where frequent cultivation is not required for raising the crops. Most commonly used agricultural mulch is black plastic. Clear plastic mulch is used in some areas due to its increased soil warming characteristics. Weed control beneath the mulch is a deterrent to its use. White or aluminum reflective mulch is used where soil cooling is desired, such as establishing fall crops during the heat of summer. Research has shown that white or aluminum reflective mulch also repels aphids which spread some virus diseases in vine crops such as squash.*

Keywords: Soil conservation, Soil erosion, Mulch, Polyethylene, Microclimate, Crop residue, Organic matter.

Introduction

Any material used (spread) at surface or vertically in soil to assist soil and water conservation and soil productivity is called mulch. The word mulch has been probably derived from the German word “molsch” means soft to decay, which apparently referred to the use of straw and leaves by gardeners as a spread over the ground as mulch [85]. Rowe-Dutton and Patricia (1957) defined mulching as an application of layer of covering material on the soil surface. As quoted by Bhavani (1960), mulching appears to be a very ancient Chinese practice employed to conserve the scanty supply of moisture available for growing melons.

To achieve optimum advantage from the mulch, the mulch should be applied immediately after germination of crop @ 5 ton/ ha (organic mulch). The practice of applying mulches to soil is possibly as old as agriculture itself. Mulches are used for various reasons but water conservation and erosion control are the most important objective for it’s use in agriculture in dry regions. Other reason for high mulching use includes soil temperature modification, soil conservation, nutrient addition, improvement in soil structure, weed control and crop quality control. Mulching reduces the deterioration of soil by way of preventing the runoff and soil loss, minimizes the weed infestation and checks the water evaporation. Thus, it facilitates more retention of soil moisture and helps in control of temperature fluctuations, improves physical, chemical and biological properties of soil, as it adds

nutrients to the soil and ultimately enhances the growth and yield of crops [48].

Mulches are either organic or inorganic. Organic mulches are those derived from plant and animal materials. Those most frequently used include plant residues such as straw, hay, peanut hulls, leaf mold and compost, wood products such as sawdust, wood chips and shavings and animal manures. Organic mulch properly utilized can perform all the benefits of any mulch with the possible exception of early season soil warming. However, natural mulch materials are often not available in adequate quantities for commercial operations or must be transported to the place of use.

Natural materials can not be easily spread on growing crops and require considerable hand labour. Expense and logistical problems have generally restricted use of organic mulch in crop production and gardening of fruit plants with only limited use on a large commercial scale. Inorganic mulch includes plastic mulch and accounts for the greatest volume of mulch use in commercial crop production. The plastic materials used as mulch are poly vinyl chloride or polyethylene films. Owing to its greater permeability to long wave radiation it can increase temperature around the plants during night in winter. Hence, polyethylene film mulch is preferred as mulching material for crop production.

Now a day application of black plastic mulch film is becoming popular and very good results have been achieved particularly in rainfed agriculture. Use of polyethylene mulch has been reported to conserve soil moisture appreciably. Hence, under prevailing drought and water scarcity conditions, conservation of soil moisture and to ensure availability of soil moisture to crop is of much importance. The black polyethylene mulch also checks all types of weeds in addition to soil moisture conservation, therefore, black plastic mulch is more beneficial [114]. Plastic mulches have various beneficial effects on crop product in arid regions, including an increase in soil temperature the conservation of soil moisture, texture and fertility and the control of weeds, pests and diseases. The beneficial effects of organic and synthetic mulches for crop production have been widely discussed by Ravi and Lourduraj (1996).

Organic mulches have the advantage of being biodegradable, but decomposition may result in a temporary reduction in soil mineral nitrogen. In addition, the natural phytotoxins released when organic materials decompose may not only inhibit the growing of weeds but also the crop plants [169]. Black polyethylene mulches are used for weed control in a range of crops under the organic system of crop production. The use of black polypropylene woven mulch is usually restricted to perennial crops. Various colours of woven and solid film plastics have been tested for weed control in the field [80]. There are additional environmental benefits if the mulch is made from recycled materials [39].

Murugan and Gopinath (2001) verified the efficacy of organic mulches (dried leaves, coconut fronds and coir pith) and inorganic mulches (black polyethylene 25, 50 and 100 μ) on growth of 'Saundrya' cv of crossandra at Bangalore. The growth attributes were significantly influenced by organic and inorganic mulches. The black polyethylene mulch was found to be superior to other mulches. Likewise, different cultivars of carnation in poly house significantly improved plant height, number of branches, flower size and yield with the application of black polyethylene mulch [11].

Effect of mulches on soil and plants: Conserve soil moisture: The conservation of soil moisture through mulching is one of the important purposes. The micro-climatic conditions are favourably affected by optimum degree of soil moisture. When soil surface is covered with mulch helps to prevent weed growth, reduce evaporation and increase infiltration of rain water during growing season. Plastic mulch helps prevent soil water loss during dry years and sheds excessive water away from the crop root zone during periods of excessive rain fall. This can reduce irrigation frequency and amount of water, it may help reduce the incidence of moisture related physiological disorders such as blossom end rot on tomato, fruit cracking in lime and pomegranate. Research has shown that mulch provides many benefits to crop production through soil and water conservation, enhanced soil biological activity and improved chemical and physical properties of the soil (Cooper, 1973). Menezes *et al.* (1974), Chung (1987) and Aliudin (1986) reported that mulches conserved more soil moistures, enhances vegetative growth and yield contributing characters of garlic.

Adeoye (1984) recorded high moisture content up to a depth of 60 cm in grass-mulched soil together with good infiltration and reduced evaporation. Chen (1985) also reported high water content in the top 5 cm of soil (an increase of 4.7 per cent in clayey, 3.1 per cent in loamy and 0.8–1.8 per cent in sandy soil) with polythene mulch from sowing to the emergence of groundnut seedlings. According Bhelia (1988) increased plant dry weight for mulched plants is due to the capabilities of mulch to maintain soil moisture as well as increased efficiency in water uptake by plants.

The growth and leaf yield of mulberry appears to be direct reflection of the soil moisture status[43,133]. Orzolek et al. (1993) observed that use of polyethylene mulch in the field, increase in the soil temperature especially in early spring, reduced weed problems, increased moisture conservation, reduction in certain insect pest, higher crop yield and more efficient use of soil nutrients. Sood and Sharma (1996) reported similar beneficial effects of mulching through improvement of soil

environment resulting in better plant growth and tuber yield of potato.

Crop residues or mulch at the soil surface act as shade, serve as a vapour barrier against moisture losses from the soil, causing slow surface runoff. Rathore et al. (1998) reported that more water conserves in the soil profile during the early growth period with straw mulch than without it. Higher water use efficiency was caused by lower evaporation in *Rosa indica* by using black polythene sheet (0.18 mm thick) as mulch [139].

Thakur et al. (2000) observed that different mulching materials like grass, lantana leaves and plastic helped bell pepper (*C. annuum* cv. California Wonder) to perform better at water deficits from 25 per cent to 75 per cent and plastic mulch had highest water use efficiency. Sutagundi (2000) reported that treatment receiving straw mulch recorded significantly higher net returns (Rs. 30,894 ha^{-1}) and B: C ratio (1.80) compared to control as result of soil water conservation. Hatfield et al. (2001) reported a 34-50 per cent reduction in soil water evaporation as a result of crop residue mulching. Mulch slows down evaporation and reduces the irrigation requirement [9]. Liu et al. (2002), Chawla (2006), Khurshid et al. (2006) and Muhammad et al. (2009) stated the same results that mulching improves the ecological environment of the soil and increases soil water contents.

Reduce infiltration rate: Mulching increase the total intake of water due to formation of loose soil surface. The rain drops on mulched soil do not seal the particles as they do on unmulched soil. This sealing effect of rain drops results in more loss of water through erosion. The water infiltrated in soil can be utilized by crops there-by crop yields are increased. Mulches obstruct the solar radiation reaching to soil. Infiltration and soil evaporation are among the key processes that determine soil water availability to crops in semi arid agriculture. The presence of crop residue mulch at the soil-atmosphere interface has a direct influence on infiltration of rainwater into the soil and evaporation from the soil. Mulch cover reduces surface runoff and holds rainwater at the soil surface thereby giving it more time to infiltrate into the soil.

Straw mulch conserved higher soil moisture to an extent of 55 per cent more compared to control [134]. Average available soil moisture stored up to 1.5 m depth of soil increased significantly by mulching of wheat residue @ 6730 kg/ha compared to bare soil [21]. Koni (1983) found that sorghum stubbles, cotton stubbles and maize stubbles as mulch in chilli conserved more moisture compared to control. Abu-Awwad (1998) and Abu-Awwad (1999) showed that covering of soil surface reduced the amount of irrigation water required by the pepper and the onion crop by about 14 to 29 and 70 per cent respectively. Trials conducted in the higher potential areas of Zimbabwe between 1988 and 1995 indicated that mulching significantly reduced surface runoff and infiltration [54].

Reduce run-off and soil erosion: Soils from dry region are highly susceptible to water erosion and wind erosion because rainfall occurrence is frequent during intense storms and surface is not adequately protected by vegetation which effectively retards runoff. Therefore to reduce erosions by wind and water is an important reason for using mulches in dry regions. Crop residues when applied at adequate level increase infiltration rate. Decomposition of these residues results in improving soil aggregation and suitability for crop production. Mulching the soil surface reduce velocity of runoff, evaporation and increase the amount of water stored in the soil profile [17, 61,108]. Mulch can effectively minimize water vapour loss, soil erosion, weed problems and nutrient [38,113,165].

Reduce weed growth and keep the crop clean: By providing a physical barrier, mulching reduces the germination and nourishment of many weeds. If somehow weeds are growing they become pale and ultimately die. Mulching materials such as wheat straw, dry grasses and saw dust are good in this respect. Pimpini (1974) found that the plastic mulching benefitted the crop, black and photo selective plastic being preferable to the transparent type in eggplant for weed control. The mulching favours the reduction of evaporation leading to higher soil moisture content, a reduction in weed growth and the decomposition of added mulches might have also contributed to increase the supply of nutrients and moisture for overall increase in crop yields [68,69,166]. Covering or mulching the soil surface can prevent weed seed germination or physically suppress seedling emergence. Loose materials like straw, bark and composted municipal green waste can provide effective weed control [112]. Saw dust is a wonderful soil improver and weed suppressor as it conserves soil moisture, decreases run-off, increases infiltration and percolation, decreases evaporation, etc. and weed growth can be substantial under clear mulch [172]. White and green covering had little effect on weeds, whereas brown, black, blue or white on black (double color) films prevented weeds emerging [22]. Daisley et al. (1988) and Ossom et al. (2001) also observed significant differences in weed control between mulched and unmulched plots of eggplant, cowpea and sweet potato. Mulching operation also keeps the weed under control [9].

Pest control: Transparent polyethylene mulch reduced whitefly populations, aphids caught in yellow traps and virus diseases incidence, in comparison to bare soil. The reflective plastic mulches can reduce the incidence of aphid-borne viruses and exclude some species of pest [148]. Transparent mulch reduced the incidence of virus disease, and delayed by 2 weeks the onset of virus symptoms compared with the bare soil [119]. Transparent polyethylene mulch has a repellent effect on pest and vector insects, such as aphids [25, 86], whiteflies [88], and thrips [67]. Transparent mulch has a reflective effect and reduces the incidence of

virus diseases by confusing aphids, which vector the virus [26,123]. The mode of action of the transparent mulch is probably the result of high reflectance of UV light [94]. These results agree with those of several other investigators [26,99,123]. A beneficial effect of clear mulch on reduction of aphid population was recorded by Farias-Larios and Orozco-Santos 1997a, Farias-Larios and Orozco-Santos 1997b. Other reported benefits of mulch include microclimate and texture improvement, conservation of soil moisture and fertility [72], and the control of weeds, pests and diseases [81]. The success of living mulches is the suppression of pests and weeds population [128,151].

Maintain soil temperature: Mulching reduces soil temperature in summer and raises it in winter. It prevents the extremes of temperatures. During summer, mulching conserves the soil moisture due to reduced evaporation. The cooling effect of soil promotes root development. In general, the effect of mulching on the temperature regime of the soil varies according to the capacity of the mulching material to reflect and transmit solar energy. Mulches results in greater water content and lower the evaporation. However effects on soil temperature are highly variable. White mulches decrease soil temperature while clear plastic mulches increase soil temperature. Chen and Yin (1989) reported that the plastic mulching increased soil temperature by 0.9 to 4.3ºC at the seedling stage, 1.6 to 2.3ºC at the bud initiation stage and 0.8 to 1.9ºC at the flowering stage.

The findings of Duhr and Dubas (1990) showed an increase of 2.9–3.3^{0}C in soil temperatures with transparent, photodegradable polythene film mulching. Wheat straw mulch raised the soil temperature by 2–3^{0}C [46]. The soil temperature can be higher up to 7°C under clear mulch compared to bare soil [71]. Park et al. (1996) observed an increase of 2.4 ^{0}C in average soil temperature at 15 cm depth under transparent film and an increase of 0.8^{0}C under black film. Choi and Chung (1997), who have observed that thermostats placed at soil surface recorded increase in soil temperatures by 2.8–9.4^{0}C and 0.9–7.3^{0}C at 5 cm depth. In regions with a longer growing season, it may be possible to grow two or more crops on the mulch within a single calendar year [73]. Plastic mulching has many advantages for agriculture including maintaining soil temperature and humidity, preventing soil borne diseases and attack by soil pests and speeding up growth [149]. At night, condensation on the underside of the mulch absorbs the longwave radiation emitted by the soil thereby slowing cooling of the soil [97]. The ability of clear mulches to produce soil temperatures high enough to control weeds, plant pathogens and nematodes forms the basis for the soil solarization process [154].

Plant growth and development: The effects of mulches on plants are operative through the effects of mulches on soil water, soil temperature structure and erosion. Reduced evaporation is major reason for the growth of the plants and there by high crop production due to mulch. Mulching provides a favourable environment for growth. A combination of the above, and perhaps other factors, results in more vigorous, healthier plants which may be more resistant to pest injury. Therefore, mulched plants usually grow and mature more uniformally than unmulched plants. It was observed that different mulching materials highly influenced the plant height and bulb diameter [84] as well as the yield [111] of garlic. Wojtaszek and Lisiewska (1977) reported that plastic mulch increased soil water content, soil temperature and plant growth, advanced flowering and increased the number of flowers on the 2nd truss in tomato. Increase in soil temperature and moisture content stimulate root growth which leads to greater plant growth [86]. Mulching along plant rows with 80-100 cm wide polythene film was also found to cause remarkable improvement in growth and flowering of roses [129]. Using black plastic mulch for growing dahlia is also beneficial as it improves growth, flowering and tuberous root formation, as well as cuts down weeding [101]. Hassan et al.(1994) and Yamaguchi et al. (1996) revealed that combination of reflective film mulching (RFM) and shading treatments increased plant height, length of primary and secondary branches of carnation seedlings.

Lourduraj et al. (1996) obtained highest plant height (81.5 cm) and number of laterals (8.6 per plant) in tomato cv. “CO-3” with the application of black LLDPE mulch as compared to organic mulch and no mulch. Kim et al. (2000) obtained maximum plant height and number of flower stems increased particularly in polyvinyl mulched treatments in *Crocosmia crocosmiiflora*. Hong et al. (2001) reported that the foliage weight of lilies was found higher with mulching materials than control. Mulching with saw dust and reflective film stimulate foliage growth and root development. Gao et al. (2001) the nutrient paper mulch (NPM) advanced plant growth as compared to plastic mulch and no mulch in tomato. Barman *et al*. (2005) recorded significant improvement in number of days taken to first floret opening, spike length and rachis length with the application of paddy straw mulch in gladiolus. Chawla (2006) obtained maximum plant height (70.91 cm), plant spread (53.05 cm) and highest number of branches (18.54) at harvest in marigold cv. “Double mix” with application of black plastic mulch compared to other mulching treatment and control.

Improved quality and yield: Mulch helps keep fruits such as tomato from contacting the ground. This reduces soil rot and helps keep the product clean. Fruit cracking and blossom end rot are reduced in many cases. Fruits tend to be smoother with fewer scars. Properly installed plastic mulch helps keep soil from splashing onto the plants during rainfall, which can reduce grading time. The yield and chemical composition to tomatoes, cucumbers, muskmelons, eggplant, etc. were found to be improved. The yield and keeping quality of early potatoes, cabbage and other vegetables may be improved by straw mulch.

This is probably due to better plant growth which is governed by soil temperatures with minimum fluctuations, and soil moisture as well. The leaf yield of mulberry increased significantly due to better soil moisture retention, creation of favorable soil temperature, suppression of weed growth, improved soil structure, high status of nutrient in soil and well development of root system [85]. Clarkson and Frazier (1957) and Chen and Katan (1980) have reported a significant increase in vegetation and yield of different crops using mulch. Improved flower quality of gladiolus due to polyethylene mulch was also reported by Beck et al. (1970). Rylski and Kempler (1972) reported that the double layer cover induced more vigrous plant development, good fruit set on lower nodes, resulting in higher early yields of large fruit was obtained. Yield increase may be attributed to more favourable soil moisture and nutrient utilization[29]. Okra production was significantly higher under straw mulch followed by dust mulch over control [13]. Grass mulching increased grain yield by 15–22 per cent in maize and by about 10 per cent in millet in northern Guinea and Sudan savanna regions of Nigeria [6]. Application of straw mulch @ 6 t ha^{-1} increased yield of tomato and okra by 100 and 200 per cent, respectively over control [69].

The most common response to mulch is an increase in total yield [104,165,175]. Marketable fruit yield from mulched plot was significantly higher than those produced on bare soil. This difference can be attributed to moisture conservation, higher soil temperature, weed control, and increased mineral nutrient uptake in the mulched plot through improved root temperatures, according to Decoteau et al. (1990), Tindall et al. (1991), Al-Assir et al. (1992), Brown et al. (1993), Ham et al. (1993), Wien et al. (1993) and Orozco et al. (1994).

Ramakrishna et al. (1991) reported that effective weed control resulted in improved yield parameters and yield of groundnut. Orzolek et al. (1993) obtained the highest yield of tomato fruit in blue plastic mulch. Gollifer (1993) reported that application of organic mulch @ 40 t/ha produced 2500 kg of chilli dry fruits compared to control. Rose et al. (1994) and Hassan *et al*. (1994) reported that organic mulch gave highest fruit yield of bell pepper over control. Chakraborthy and Sadhu (1994) reported that water hyacinth mulch was better than rice straw mulch for increased fruit number and size of tomato. The yield (27.9 per cent) and starch content (18.18 per cent) of potato was increased with paddy straw mulch than unmulched plot [49]. Cheong *et al*. (1995) observed highly positive correlation of proportion of sound seeds, 100-seed weight and shelling ratio with seed yield of groundnut, while Choi and Chung (1997) recorded more flowers, pegs, pods and kernels and greater 100-kernal mass in polythene mulched plots than on the unmulched plots in Suwon, Korea.

Park *et al*. (1996) recorded seed yield increase in soybean by 18 per cent with transparent film and by 15 per cent with black film. Aref et al. (1996) reported that application of hairy vetch mulch recorded significantly higher yield of tomato (32 per cent) than bare soil. Ravi and Lourduraj (1996) observed significantly higher mean number of symbodia per plant (7.0), number of bolls per plant (7.8) and kapas yield (673 kg ha^{-1}) in black LLDPE mulch compared to coir pith, organic mulch and no mulch. Lourduraj *et al*. (1996) obtained highest number of fruits (42), average fruit weight (31.8 g) and yield (12735 kg ha^{-1}) in tomato cv. 'CO-3' with application of black LLDPE mulch compared to organic and no mulch. Mulching increased crop weight by 16 per cent compared with non mulched plots in leek [18]. Li et al. (1999) investigated the positive effects of clear plastic film on spring wheat yield. Black polythene sheet (0.18 mm) mulching also increased 29 and 56 per cent flower yield of Anna and Sari varieties of roses, respectively [139].

Thakur et al.(2000) reported that the use of different mulches on the performance of *Capsicum annuum* L. under the water deficit of 75 per cent, the lantana mulch gave the highest fruit yield of 73.36 quintals per hectare over unmulched plots (36.90 q/ha). Similar are the findings of Aref et al. (1996) and Ossom et al.(2003). Thakur et al. (2000) also reported that plastic, lantana leaves and grass mulches significantly maintained higher growth and yield parameters as compared to unmulched treatments and yield levels increased by 198 per cent in plastic mulch, 164 per cent in lantana leaves and 141 per cent in grass mulched plants over unmulched plants of capsicum.

Acharya and Kapur (2000) reported that the beneficial effect of pine needle mulching on tuber yield. These findings are in agreement with Gangwar et al. (2000) who reported that paddy straw mulch to mulberry showed maximum leaf yield (46%) compared to sorghum (32.4%) and blackgram mulching (23.08%) over control. Murugan and Gopinath (2001) obtained maximum duration of flowering and advanced flowering in crossandra cv. 'Saundrya' by using black polyethylene mulch as compared to organic mulches (dried leaves, coconut fronds and coir pith). Gao et al. (2001) reported that the nutrient paper mulching (NPM) promoted flower bud differentiation, enhanced yield and improved fruit quality in tomato as compared to the plastic mulch or no mulching.

Tamilselvan et al. (2001) observed that press mud mulching ultimately recorded the highest cane and sugar yield in sugarcane. Uppal et al. (2001) observed that mulched tubers of potato contained about 46 per cent less reducing sugars compared to normal crop. Proline content was significantly enhanced due to polythene mulch in groundnut [107]. On the other hand, growing of perennial rye grasses and white clover as living mulches considerably reduced the marketable yield of leeks by upto 45.1 per cent [91]. Nagalakshmi et al. (2002) obtained the maximum number of fruits per plant (97.67), length of fresh fruit (6.93 cm), circumeferance of fruit (3.57 cm) and yield of chilli (8602 kg ha^{-1}) with the application of black LLDPE

mulch compared to organic mulch and no mulch. Plastic (polyethylene) mulches have the potential to alter soil temperatures, reduce crop water use, improve crop quality and control weeds, thereby improving crop development and increasing yields [97,171,172,120]. Black mulch warms the soil by absorbing light then transferring heat by conduction to the underlying soil, provided that the mulch is in close contact with the soil [97,160].

Gandhi and Bains (2006) observed that mulches modified the microclimate by modifying soil temperature, soil moisture and evaporation and the modified microclimate affected the yield contributing characters of tomato. Crop under straw mulch produced higher number of branches (8.7), fruit weight (28.08 g) and total yield (496.3 q ha^{-1}) as compared to no mulch (8.1, 27.86 g and 478.5 q ha^{-1}, respectively). Chawla (2006) obtained highest number of flowers per plant (53.45), average flower weight (47.21 g/ 10 flowers), maximum flower diameter (5.47 cm) and highest flower yield (11.66 tonn/ha) in marigold cv. 'Double mix' with application of black LLDPE mulch compared to white LLDPE mulch, organic mulch and no mulch. Wicks et al.(1994) and Khurshid et al.(2006) pointed out that maize grew taller under greater mulch levels, because of availability of more soil moisture contents for plant growth. Shashidhar et al. (2009) reported that the total leaf yield of mulberry was found maximum in paddy straw mulched plots (15201.36 kg/ha) as compared to control plots (11785.32 kg/ha).

Besides beneficial effect on earliness, polyethylene film as a mulch can enhance plant growth and development, increase yield, decrease soil evaporation and nutrient leaching, reduce incidence of pests and weeds, and improve fruit cleanliness and quality [47, 55, 62, 83, 88, 98,170].

Promote earlier harvest: Mulch can be used effectively to modify soil temperature. Black or clear mulch intercept sunlight which warms the soil. White or aluminum mulch reflects the sun's heat and keeps the soil cooler. Black mulch applied to the planting bed prior to planting will warm the soil and promote faster growth in early season, which generally leads to earlier harvest. First harvest acceleration of 7 to 14 days is not uncommon, depending on weather conditions. Clear mulch warms the soil more than black and usually provides even earlier harvest. Warm season vegetable, such as cucumbers, muskmelons, watermelons, eggplant, peppers, usually respond well to mulching in terms of early maturity and more yields. An earlier maturity is probably due to maintenance of favourable temperatures during growing season. Benkenstein et al. (1976) observed that flowering in gladiolus and tulip was advanced due to mulching.

Devi Dayal et al. (1991) observed early flowering (by 5 days) in mulch treated groundnut crop. Earlier harvest is among the most important advantages of polyethylene mulch application [53,140]. Organic mulches induced earliness in flowering, less days to fruit set and days to harvest, also increased number of flowers and per cent fruit set in tomato crop over control [138]. Niu et al. (1998) showed that improved soil water and temperature with polythene mulches enhanced seedling emergence in spring wheat, while Hu et al. (1995) recorded earlier seedling emergence, improved crop growth and nodule development in groundnut. Hu et al. (1995) also reported increased crop growth (3.2–4.0 cm), dry root mass (12.2–50.1%), nitrogen-fixing activity (3.3–128.7%), chlorophyll content of the fresh leaves (41–78%) and more reproductive buds (63.3–94.1%) in polythene mulched plots than unmulched plots and thereby advanced peak flowering stage by 9 days. Applications of polyethylene films as mulch have shortened growing season and enhanced earliness and yield [66,110,145]. Beneficial effect of polyethylene mulch on the increase of the early yield was also found for watermelon [141], zucchini [170], tomato [1,25,41,83] and pepper [83]. Mulching helps to maintain an even soil temperature, induce early flowering and better blooms [9].

Reduced fertilizer leaching: As excessive rainfall is shed from the root zone, fertilizer loss due to leaching is reduced. This is particularly true in sandy soils. This allows the grower to place more pre plant fertilizer in the row prior to planting the crop. Patil and Singh (1983) observed that application of sunflower stover mulch @ 20 t/ha in hot and dry season significantly increased the N, P and K uptake over no mulch. In okra, the highest uptake of N, P and K was observed in sugarcane trash mulched plots over unmulched [167]. Borthakur and Bhattacharya (1992) reported that the influence of mulches on soil pH was found to be highest in water hyacinth and paddy husk mulch (5.56 pH) and lowest in no mulch (4.98). Mulching with coconut fronds increased leaf N, P and K content in chilli [74].

Vos and Sumarni (1997) indicated faster plant growth, early fruiting, reduced P concentration and increased N concentration in leaves and fruits and also increased fruit weight and yield of hot pepper with straw mulching compared to control. Further, they reported that rice straw mulch increased K- content and decreased P-concentration in leaves of bell pepper over no-mulch. Hundal et al. (2000) reported that concentration of nitrogen and phosphorus and nutrient uptake was significantly higher in mulched plots over unmulched plots in tomato. According to Worthington (2001), an increase in available nitrogen contents stimulates protein production, in cabbage following serradella and vetch mulches which, living in symbiosis with nitrogen-fixing bacteria, are additional sources of available nitrogen. Tolk et al. (1999) and Liu et al. (2002) concluded that mulch increases soil moisture and nutrients availability to plant roots, in turn, leading to higher grain yield. Mulch protects the surface of the soil against unfavourable factors, reduces nutrient leaching and improves growing conditions for vegetables [14,91]. Annual legumes, grasses and *Brassica* species are mostly recommended for mulching purpose and used in the

practice [24,79,100,121]. They are also efficient in reduction of nitrates leaching and contamination of surface and ground waters by these compounds. The influence of plants left as a mulch has many positive aspects: mulches improve soil physical properties, prevent erosion, supply organic matter, regulate temperature and water retention, improve nitrogen balance, take part in nutrient cycle as well as increase the biological activity [52,115,153].

Add organic matter: Organic mulches return organic matter and plant nutrients to the soil and improve the physical, chemical and biological properties of the soil after decomposition, which in turn increases crop yield. Soil under the mulch remains loose and friable. Aeration and soil microbial activity are enhanced. In heavy black soil also, application of mulches like coir pith @ 20 t/ha, press mud @ 10 t/ha decreased the bulk density over control [109]. The organic mulches not only conserve the soil moisture, they also increase the soil nutrients through organic matter addition [48]. Organic mulches have the advantage of being biodegradable, but decomposition may result in a temporary reduction in soil mineral nitrogen [169]. Gajri et al. (1994) reported that both soil strength and bulk density decreased by increasing mulch levels. Lal et al. (1996) reported decrease in bulk density under straw mulch (1.42 g/cm) compared to bare soil (1.50 g/cm).

Mulching increased soil moisture, organic matter contents leading to suitable environment for root penetration. Ghuman et al. (2001) concluded that mulching decreases bulk density of the surface soil. The soil organic matter increased due decomposition of applied mulch. Applications of crop residue mulches increase soil organic carbon contents (Havlin et al.1990, Paustin et al. 1997, Duiker and Lal 1999, Saroa and Lal 2003). Lal et al. (1980) and Khurshid et al.(2006) concluded that organic matter was significantly higher when more mulch was applied. Acharya and Sharma (1994) and Muhammad et al. (2009) observed that mulched treatments show significantly greater total uptake of nitrogen, phosphorus and potassium than corresponding unmulched ones. Higher organic carbon content of soil recorded with sunhemp mulch (0.71%) followed by silkworm bed waste (0.68%) and paddy straw (0.66%) mulched plots. Least organic carbon content was recorded in no mulched plot (0.48%) [150].

Stimulate soil micro-flora: Mulching stimulates soil micro-organisms such as algae, mosses, fungi, bacteria, actinomycetes and other organisms like earth worms etc., owing to loose, well aerated soil conditions, uniform moisture and temperatures thus resulting in a more rapid breakdown of organic matter in the soil and release of plant nutrients for crop growth. Under the mulch layer earth worms proliferate and help to improve the soil aggregate stability and infiltration etc. Mulching conserves moisture, suppresses weed growth, protects the upper fertile soil from erosion, minimise variation in soil temperature and affords winter protection. In addition mulches are also reported to enhance soil microbial activity [65]. The variation in the microbial load of the different organic mulches on bacterial population could be due to their different chemical composition and their decomposition rates [116,178].

The greater soil profile moisture under mulch has important implications on the utilization of water by crop and on soil reactions that control the availability of nutrients and biological nitrogen fixation [157]. Brown et al. (2001) mentioned that mulching practices gave positive effect on the soil biota. Important role of mulch to support existence of most species of soil macroinvertebrates [106,146]. Soil biota increase under mulched soil environment thereby improving nutrient cycling and organic matter build up over a period of several years [77]. Organic mulching technology support diversity of beneficial soil macroinvertebrates. Crop residue mulch supplied a lot of food for soil macroinvertebrates and nutrient to ensure the vegetation growth and created suitable environment for soil macroinvertebrates [155]. Sugiyarto (2009) showed that application of maize residue as mulch enhanced diversity index of surface and deep soil macroinvertebrate, i.e: 0.215 and 0.214 (by 44% and 73% respectively as compared to no mulching). Shashidhar et al. (2009) reported more number of bacterial, fungal and actinomycetes colonies found in *Cassia sericea* (32 CFU x 105/g), paddy straw (53 CFU x 104/g) and sunhemp (53 CFU x 103/g) mulched plots over other treatments respectively.

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