



# Effect of Mulching on Vegetable Production: A Review

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## ABSTRACT

Vegetables have much importance as economic, nutritional, medicinal and industrial and also have employment opportunities. However, vegetable production is a costly enterprise as it requires heavy cultural practices such as irrigation, weeding, fertilizers and protection from biotic and abiotic stress. Many times the farmers lose the entire crop in rabi and summer due to inadequate irrigation facility. In addition, seedling establishment is a tedious job in arid and semi-arid climatic conditions due to water scarcity. To improve the productivity of vegetables where either particularly non-irrigated rainfed conditions, proper moisture management of the soil is necessary. Thus, in an attempt to reducing number of irrigation and chemical inputs for weed control, mulch may be a good alternative of conventional cultivation practice. It reduces the water evaporation by interfering the radiation falling on the soil surface and thus delays the drying of the soil and reduces the soil thermal regime during the day time. It also reduces the weed population and improves the microbial activity of the soil by improving the environment around the root zone. Therefore, the practices of mulching in vegetable production have been advised to cut-down the cost of cultivation and obtain quality produce with increased profits.

**Key words:** Mulch, Organic mulch, Plastic mulch, Soil, Moisture, Vegetable, Weed.

India has been bestowed with wide range of climate and physico-geographical conditions and as such is most suitable for growing various kinds of vegetables. They are important food and highly beneficial for the maintenance of health and prevention of diseases. Vegetables contain valuable food ingredients which can be successfully utilized to build up and repair the body. Adequate vegetable consumption can be protective for some chronic diseases such as diabetes, cancer, obesity, metabolic syndrome, cardiovascular diseases, as well as improve risk factors related with these diseases. Vegetables may be edible roots, stems, leaves, fruits or seeds. Each group contributes to diet in its own way (Robinson, 1990). Most of the vegetables are quick growing and ready for harvest within a short time enabling the grower to practice succession cropping and inter cropping and thus provide more profit compared to cereals. Although, the production cost of vegetables is high and needs heavy inputs like fertilizers, insecticides-pesticides, irrigation water, weeding and other cultural operations. Even though, the establishment of seedlings in agricultural field is a tedious job in water limited regions which is considered as a dwindling natural resource. In hot dry and semi-arid regions, use of mulching in vegetable cultivation has been prompted in order to cut-down the expense of production and acquire quality produce, return boost with increased benefits.

The word mulch has been derived from the German word *molsch* means "easy to decay," and mulches have widely been used for vegetable production since ancient times (Lightfoot, 1994). Mulching is referred as spreading various covering materials on the surface of soil to minimize moisture losses and weed population and to enhance crop yield (Nalayini, 2007; Kader *et al.* 2019), i.e., it is the process or practice of covering the soil/ground to make more favourable conditions for plant growth, development and

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efficient crop production. Organic-based mulches such as plant waste, straw, sawdust and manure have also been used to a great extent for vegetable production. Traditionally, organic mulches have consisted of materials which are locally plentiful (Coolong, 2012). Organic mulches are cheap materials; therefore, the cost of mulching is also economical (Ranjan *et al.*, 2017). Continuous use of mulches is helpful in improving the organic matter content of the soil, which in turn improves the water holding capacity of the soil (Agrawal *et al.*, 2010). It prevents rapid evaporation from the soil surface and reduces quick drying thereby conserving soil moisture. The purpose of this review is to provide a comprehensive analysis of the scientific research on the benefits of mulches used in vegetable crops.

## Types of mulches

The type of mulch to be used depends on the type of weed, type of soil/topography, prevailing weather conditions of the

area, crop to be cultivated and the availability of mulch. Basically, there are two types of mulches depending upon the material used as mulching. They are as under:

### Organic mulches

In organic mulching, suitable animal or plant residue such as bark, wood chips, dry grasses, paddy/wheat straw, dry leaves, saw dust, grass clipping, farm yard manure *etc.*, is used to cover soil so that it will enhance the growth of crop and also improve the condition of the soil. As these mulches slowly decompose, they provide organic matter which helps keep the soil loose. They serve as food for many microorganisms in the soil. These organisms are necessary for maintaining and promoting soil granulation (Barche *et al.*, 2015). This organic matter becomes food for the beneficial earthworms and other soil micro-organisms in the soil and create a very good porous soil (Patil *et al.*, 2013). Expense and logistical problems have generally restricted the use of organic mulch in vegetable crop production with only limited use on a large commercial scale. Natural materials cannot be easily spread on growing crops and require considerable human labour (Bhardwaj, 2011).

### In-organic mulches (Plastic mulches)

Plastic mulches are one of the important components of plasticulture and have been used commercially for the production of vegetables since the early 1960's, and their usage is still increasing throughout the world. Polyethylene is one of the most commonly used plastic materials for mulching, due to the fact that it is easy to process, has excellent chemical resistance, high durability, flexibility and is odorless as compared to other polymers (Helaly *et al.*, 2017). As far as color of the plastic film used for mulching is concerned, black color film (black plastic) was found to be the best in most the crops and seasons (Solia *et al.*, 2018 and Kumar and Sharma, 2018). Different plastic mulches *i.e.*, red, black, yellow, green, brown *etc.* are used in vegetables (Orzolek and Lamont, 2015). By proper selection of plastic mulch composition-colour and thickness, it is possible to precisely control the soil environment.

### Limitation of mulching

Mulching also shows some limitations beyond many advantages as it may harbor some insects, pests and

diseases and also create some weed problems sometimes. Plastic mulches, especially black plastic, do not break down and should never be disked or incorporated into the soil. Many types of organic mulching such as grass and straw contain seeds that may allow to grow weeds and release acid to soil (Chalker, 2007; Patil, *et al.*, 2013). Juglonic acid is mostly isolated from the bark of black walnut and used in the inhibition of many weeds and non-desirable plants. This acid can also destroy the seedlings and shallow-rooted plants though it has no effect on established plants (Harris *et al.*, 2004).

## Effect of mulching on soil and vegetables

### Improve soil health

The practice of applying or retaining crop residues in the field as mulch is imperative to prevent soil erosion, maintain soil quality and improve crop productivity (Mgolozeli *et al.*, 2020). Mulch is categorized as inorganic or organic with the latter being more commonly favored due to its biodegradable nature (Lalljee *et al.*, 2013). Organic mulching like crop straw, grasses, sawdust, *etc.*, improve soil physical, chemical and biological quality by adding organic matter into the soil during the decomposition process (Yadav *et al.*, 2017). Organic mulches serve as food for many microorganisms in the soil. These organisms are necessary for maintaining and promoting soil granulation (Barche *et al.*, 2015). Furthermore, it can increase soil organic matter content and plant nutrients. It can also provide an ideal environment for earthworms and useful for soil micro-organisms (Dickerson, 2000). The practice of applying or retaining crop residues in the field as mulch after harvest is imperative in maintaining soil health and productivity (Dube *et al.*, 2012). Organic mulch materials are commonly used in arable systems to improve soil health, but the use of inorganic plastic mulch has gained global importance in recent decades (Ngosong *et al.*, 2019).

### Conserve soil moisture

Water is a major input for agricultural production. In the current situation, it is a scarce resource and there exists a large gap in terms of water available and its requirement for irrigation. It is therefore, necessary to minimize the loss due to evaporation and to conserve the moisture. Evaporation

**Table 1:** Different colour of plastic mulches and their uses.

Colour of plastic mulches	Uses
Black mulches	Conserve moisture and controlling weed growth
Clear or transparent	Soil solarization for disinfecting the soil in order to reduce soil borne diseases and some weeds.
<b>Two side colour mulches</b>	
Yellow/black	Attracts certain insect & thus acts as a trap for them, which prevents diseases
White/black	Cools the soil and control weeds
Silver/black	Cools the soil, though not to be extent of white/black film & repels some aphids & thrips
Red/black	It warms the soil, alters plant vegetative, flower development and metabolism to early fruiting and increased yield in some vegetables.

Source: Lyengar *et al.* (2011). Practical Manual on Plastic Mulching. NCAPH, New Delhi.

from soil is mainly due to the degree of saturation of soil surface, temperature of air and soil, humidity and wind velocity. Several factors are greatly influenced only by the vegetative cover. Therefore, the only way to conserve the moisture in such condition is to spread mulch over the crop (Agrawal *et al.*, 2010). Adoption of innovative irrigation techniques can also increase the efficiency of water usage by minimizing deep percolation losses. Mulches could potentially minimize water runoff, improve infiltration capacity of soil, restrain weed population *via* shading, and perform as obstacle in evapotranspiration (Rathore *et al.*, 1998). In addition plastic mulch helps in shedding excessive water away from the crop root zone during periods of excessive rain fall. This can reduce irrigation frequency and amount of water used. The mulching techniques were being used widely in irrigated crop production worldwide. Ramakrishna *et al.* (2006) noted that evaporation from the soil accounts for 25-50% of the total quantity of water used. The notable advantage of the use of plastic mulch is its impermeability which prevents direct evaporation of moisture from the soil and thus reduces the water losses. Mulching experiment conducted on brinjal crop with black polyethylene revealed that it conserved 29-56 and 22-107% more moisture as compared to straw mulches and control, respectively (Singh *et al.* 2006). Likewise, Agrawal *et al.* (2010) found that among the mulch covers the water use efficiencies of 0.57, 0.42, 0.37 and 0.21 q/ha-mm was observed in red, black, white mulch and control plots respectively. In that treatments water use efficiency was increased by 63, 50 and 43% in red, black and white mulch respectively as compared to the no mulch plot.

Leaf mulch of local grasses like sevan (*Lasiurus indicus*), kheep (*Leptodenia pyrotechnica*) and lasoda (*Cordia myxa*) with brinjal under hot arid conditions conserved higher moisture content in the range of 33-100% compared to un-mulched plots (Awasthi *et al.*, 2006). Manyatsi and Simelane (2017) also observed that significant difference between the treatments in terms of the moisture retention properties. Organic compost mulch recorded the highest mean percentage moisture retention (22.9%), followed by treated sewage mulch (20.9%) and no mulch recorded the lowest percentage moisture retention in the soil (14.4%). Similarly, Mahadeen (2014) examined that water use efficiency in agriculture is mostly increased by mulching process. Covering of soil with different mulch materials is an efficient method for soil and water conservation along with weed management; it was examined by Bobby *et al.* (2017). Ashrafuzzaman *et al.* (2011) observed that transparent polythene mulch apparently showed highest moisture (21.1%), followed by black (20.4%) and blue (19.2%) polythene mulch. The lowest moisture (14.6%) was recorded in the control plot. Increased moisture retention capacity due to mulching with polythene could be attributed to less evaporation from the soil.

#### Maintain soil temperature

Agricultural management practices, such as mulching and irrigation can change the characteristics of the soil surface

and hence influence the hydrothermal properties of the soil. Straw mulching system can conserve soil water and reduce temperature because they reduce soil disturbance and increase residue accumulation at the soil surface (Zhang *et al.*, 2009). Mulch is an excellent insulator and prevents drastic fluctuations in soil temperature. It keeps the soil cooler in summer and warm in winter (Musie *et al.*, 2015). Wheat straw mulch raised the soil temperature by 2-3°C in peak winter season (Sarolia and Bhardwaj, 2012). At night, condensation on the underside of the mulch absorbs the long wave radiation emitted by the soil thereby slowing cooling of the soil (Lamont, 2005). Similarly, Maida and Kumar (2020) study indicate that soil temperature under the various coloured mulches was 2 to 4°C warmer compared to bare soil. The highest soil temperature was recorded under black mulch (20.63). Experiment conducted in the hot arid conditions of western Rajasthan, opined that in general, straw mulches applied curtailed soil temperature by 1.1-5.6°C during warmer months, while an increase in soil temperature by 0.6-3.2°C at 20 cm depth was recorded during the winter months of December-January (Awasthi *et al.*, 2006). Rajablariani *et al.* (2012) also studied the effect of coloured plastic mulches (black, blue, clear, red, silver on black) on tomato and they reported that that soil temperature increased under the various colored plastic mulches about 3 to 6°C more than it in bare soil. Soil temperature was highest under blue mulch followed by red and clear plastic silver on black had the lowest soil temperature among all the plastic mulches.

#### Improve plant growth parameters

Increase in soil temperature and moisture content stimulate root growth which leads to greater plant growth. The retention of moisture also leads to higher uptake of nutrients for proper growth and development of plants. Therefore, mulched plants usually grow and mature more consistently than un-mulched plants (Bhardwaj *et al.*, 2011; Sarolia and Bhardwaj, 2012). In brinjal crop maximum leaves/plant, plant height, no. of shoots/plant, shoot length and plant spread was found in black polyethylene mulch as compared to control (Kumar *et al.*, 2019). Similarly, Maida and Kumar (2020) observed best results of chilli grown on silver/black mulch. Ashrafuzzaman *et al.* (2011) reported the tallest plant (78.45 cm) in transparent, followed by black (77.58 cm) and blue (77.03 cm) plastic mulch in chilli crop, while, the smallest plant (61.15 cm) was observed in control plot. Tyagi and Kulmi (2019) obtained maximum plant height and number of structural branches/plant in chilli with the application of silver/black plastic mulch as compared to no mulch. Agrawal *et al.* (2010) observed that plant height (90.74 cm), no. of primary branches (7.31), stem thickness (1.87), no. of flowers/cluster (7.02), no. of locules (5.17) were greatest in red plastic mulch followed by black plastic, white mulch, whereas, the same characteristics was obtained lowest in control plot.

#### Promote early harvest

The greatest benefit from plastic mulch is that the soil

temperature in the planting bed is raised; promote faster crop development and earlier harvest. Black plastic mulch can give a harvest earlier by some 7-14 days, while clear plastic may advance the harvest date by 21 days (Parmar *et al.*, 2013). Warm season vegetables such as cucumbers, muskmelons, watermelons, eggplant, peppers, usually respond to mulching in terms of early maturity and higher yields. An early maturity is probably due to maintenance of favorable temperatures during growing season (Bhardwaj, 2013). Applications of polyethylene films as mulch have shortened growing season and enhanced earliness and yield in different vegetable crops (Goreta *et al.*, 2005; McCann *et al.*, 2007). Similarly, El-Nemr (2006) reported earliness in cucumber with use of clear and black polyethylene mulches, compared to no mulch. Soleymani *et al.* (2015) noted earliest maturity with use of polyethylene mulch (black and clear). Beneficial effects of mulches on early harvest were also found by Singh *et al.* (2017) and Agrawal *et al.* (2010) in tomato; Kumar and Sharma (2018) in summer squash.

### Improve quality and yield

Plastic mulches are adopted on large scale in commercial vegetable production due to their large scale effects on gaining higher yield with better quality which might be due to decreased water evaporation, increased soil temperatures and less weed infestation (Coolong, 2010 and Gordon *et al.* 2008). Black plastic mulch is effective in increasing soil temperature (Mahadeen, 2014) and thereby improved the yield of summer squash by 74% over control (Bhatt *et al.* 2011) and transparent mulch helps in soil solarization by increasing soil temperature that lead to yield gain of 25-28% in melon crop over control (Patil *et al.* 2013; Ekinci and Dursun, 2009). Black polythene mulch produced significantly 19.0% and 50.3% more fruit yield of brinjal crop over wheat straw mulch and without mulch, respectively (Kumar *et al.*, 2019). Similarly, Tyagi and Kulmi (2019) reported significantly maximum fruit length (16.48 cm), fruit girth (1.29 cm), green chilli weight (8.19g), number of fruits/plant (212.80), dry chilli weight/plant (267.50g) and dry chilli yield (53.50q/ha) in chilli.

Kayum *et al.* (2008) reported that water hyacinth and straw mulches have potentiality effect on increase the yield of tomato, which involves minimum cost of production. The black polyethylene mulching material was noted with significantly enhanced fruit length and fruit weight, whereas, white plastic mulch significantly improved the number of fruit/plant, fruit diameter and total yield of cucumber at both early and late seasons followed by grass-mulch, whereas control consistently produced the highest number of nonmarketable fruits (Ajibola and Amujoyegbe, 2019). Similarly, Maida and Kumar (2020) also recorded maximum fruit length (8.74 cm), fruit diameter (0.88 cm), average weight of fruit (4.49 g), number of fruits/plant (155.25), fruit yield/plant (744.14 g), fruit yield/plot (11.82 kg) and ascorbic acid (269.07 mg/100 g) in chilli grown on silver/black mulch. Chandra *et al.* (2002) found that potato yield increased with the use of mulches.

Tuber weight was 0.23 kg/plant for no mulch but increased to 0.29 kg/plant and number of tubers/plant increased to 6.5 from 5.4 when pine mulch was used. Total yield was 165.0 q/ha for no mulch and 222.7 q/ha for pine mulching. Nijamudeen and Dharamasena (2002) also observed 32% increase in yield and 28% lower water consumption in chilli due to the application of mulch. Vankar and Shinde (2007) reported statistically higher yield of fruit (22.06 t/ha), leaves and stem dry matter, number of fruits/plant, weight of fruits/plant, length of fruit and total biomass production in okra with use of white polythene mulch than black, straw and no mulch treatments. Beneficial effect of polyethylene mulch on higher yield was also found for watermelon (Parmar *et al.* 2013) and tomato (Agrawal *et al.*, 2010).

### Reduce weed population

Weeds provide major challenge in the cultivation of any crop, universal. They decrease crop productivity by interfering with crop growth. Apart from reducing yield, weeds contaminate and taint farm product to reduce their market values and change their end use. Mulching is an effective method of manipulating crop growing environment to increase yield and improve product quality by controlling weed growth. Mulches typically function by blocking light or creating environmental conditions which can prevent germination or suppress weed growth shortly after germination (Coolong, 2012). By providing a physical barrier, mulching reduces the germination and nourishment of many weeds (Vander Zaag *et al.*, 1986). Luqman *et al.* (2013) noted that among different forms of mulch (*Rumex crispus*, *Silybum marianum*, newspapers and sawdust) and herbicide, stomp 330 EC (pendimethalin) the efficiency of mulching treatments was substantially more successful.

Polyethylene mulches are widely used in vegetable production and contributed significantly for reduction of losses due to weeds (Ngouajio and Ernest, 2004). Black plastic films do not allow sunlight to pass in to the soil. Hence, it arrests weed growth completely because photosynthesis do not completed in absence of sunlight (Barche *et al.*, 2015). In contrast, transparent and blue plastic mulches allow sunlight to pass through therefore it encouraged weed

**Table 2:** Response of plastic mulch on the yield of vegetables.

Crop	Yield (t/ha.) Increase in		
	Mulched	Unmulched	yield (%)
Brinjal	47.06	36.73	28.12
Broccoli	25.14	15.64	60.74
Bitter Gourd	25.63	20.12	27.39
Cabbage	19.9	14.3	39.16
Cauliflower	25.02	18.58	34.66
Chilli	19.71	16.79	17.39
Okra	8.56	6.91	23.88
Tomato	94.85	69.10	37.26

Source: NCPAH, New Delhi (National Committee on Plasticulture Applications in Horticulture).



population. Ashrafuzzaman *et al.* (2011) recorded highest number of weeds/m<sup>2</sup> in transparent plastic mulch (186.5) and the lowest in black plastic mulch (54.25). The weed population increased 11, 5 and 3 times in transparent plastic, blue plastic and control, respectively compared to black, indicating black plastic mulch was more effective than the other mulches in suppressing weed growth. Mahajan *et al.*, (2006) also observed significant effect of black polythene mulch on weed control in red chilli in respect of rice straw mulch.

#### Effect of mulching on insect and micro-flora

Pest and diseases are the major limitations for the crop because of labor and the high costs needed to manage them (Davis *et al.*, 2008; Sapkota *et al.*, 2010). Plant mulches can be an effective way to provide shelter for predatory insects (Johnson *et al.*, 2004). Mulch application reduced the severity of some above ground diseases of plants in crops such as tomatoes (Abbasi *et al.* 2002). Cookey *et al.*, (2016) observed that plastic mulch was significantly effective to the control of root gall nematode infection on cucumber than the control plots. 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 (Sciortino, 2001 and Stapleton *et al.* 2005). Santos *et al.* (1995) tested transparent polyethylene mulch for its efficacy in reducing insect populations, virus diseases and increasing soil temperature and yield of cantaloup (*Cucumis melo* L.) in a tropical region. They observed that transparent mulch reduced whitefly populations, aphids caught in yellow traps and virus incidence, with respect to bare soil (control). Also, soil temperatures in the morning, midday, and afternoon were significantly increased in the transparent mulch.

#### Improve economics

Whenever we use synthetic chemicals, fertilizers and mulches, they estimate the cost and benefit which comes out from the investment. The mulching can be used to solve the problem of weed infestation, it stimulates the microbial activity in soil through improvement of soil properties, it minimizes the requirement of nitrogen fertilizer, warms the soil and suppresses weed growth and as a result increases yield. Kumar *et al.* (2019) observed that black polyethylene mulch and wheat straw mulch earn 106.4% and 70.4% more net return, respectively over without mulch in brinjal crop. B:C ratio was also 37.0% and 33.3% more with black polyethylene mulch and wheat straw mulch, respectively over control. Similarly, Tyagi and Kulmi (2019) stated that treatment receiving 30 micron silver on black plastic mulch resulted in higher gross returns, net returns and cost: benefit ratio as compared to without mulch in chilli. Narayan *et al.* (2017) reported the higher B:C ratio with double coated black polythene mulch in chilli. Parmar *et al.* (2013) also observed that highest net return with maximum CBR in silver on black mulch treatment followed by black on white mulch, whereas, it was lowest in control (no mulch) in water melon. Kundu *et al.*

(2019) noted that among all the inputs for tomato production technology, labour alone accounts for more than 70% of the cost of operations and it was observed that maximum return can be fetched from black poly mulch followed by jute felt and straw mulch. Similarly, rice straw mulch recorded significantly higher benefit cost ratio (5.65) followed by water hyacinth (5.56), wastage of rice straw (5.01) and no mulch (4.51) in tomato by Rahman *et al.* (2006). Lourduraj (2003) also observed that gross return and net returns favorably influenced by plastic mulching compared to unmulched in chilli.

## CONCLUSION

The green revolution is responsible for paradigm shift in agriculture in the world ensuring food security. This led to heavy use of synthetic inputs to fulfill the demand of high yielding fertilizer responsive crops which over a long run questioned sustainability of the agricultural system. In the present scenario of globalization and health consciousness, demand for vegetable crops has increased world over. Therefore, new eco-friendly agricultural practices for sustainable food production are needed. Mulching is an effective method of manipulating crop growing environment to increase yield and improve product quality by controlling weed growth, ameliorating soil temperature, conserving soil moisture, reducing soil erosion, improving soil structure and enhancing organic matter content. The beneficial effect of different mulching reported by different researchers has been summarized above. Mulches greatly retard the loss of moisture from the soil. As a result, higher and uniform soil moisture regime is maintained reducing the irrigation frequency. Under plastic mulch, soil properties like soil temperature, moisture content, bulk density, aggregate stability and nutrient availability improved. Black, white and clear plastic mulches are most commonly used in commercial production with black being the dominant colour used for vegetables. Even though it has many advantages, high initial cost, removal and disposal of plastic materials are some of the limitations experienced by the farmers.

## REFERENCES

- Abbasi, P.A., Al-Dahmani, J., Sahin, F., Hoitink, H.A.J. and Miller, S.A. (2002). Effect of compost amendments on disease severity and yield of tomato in organic and conventional production systems. *Plant Disease*. 86: 156-161.
- Agrawal, N., Panigrahi, H.K., Sharma, D. and Agrawal, R. (2010). Effect of different colour mulches on the growth and yield of tomato under Chhattisgarh region. *Indian Journal of Horticulture*. 67: 295-300.
- Ajibola, O.V. and Amujoyegbe, B.J. (2019). Effect of seasons, mulching materials, and fruit quality on a cucumber (*Cucumis sativus* L.) variety. *Asian Journal of Agricultural and Horticultural Research*. 3(2): 1-11.
- Ashrafuzzaman, M., Halim, A., Ismail, M., Shahidullah, S. and Hossain, A. (2011). Effect of plastic mulch on growth and yield at chilli. *Brazilian Archives of Biology and Technology*. 54(2): 321-330.

- Awasthi, O.P., Singh, I.S. and Sharma, B.D. (2006). Effect of mulch on soil hydrothermal regimes, growth and fruit yield of brinjal (*Solanum melongena* L.) under arid conditions. *Indian Journal of Horticulture*. 63: 192-194.
- Barche, S., Nair, R. and Jain, P.K. (2015). A review of mulching on vegetable crops production. *Ecology, Environment and Conservation*. 21(2): 859-866.
- Bhardwaj, R.L. (2013). Effect of mulching on crop production under rainfed condition - A review. *Agriculture. Reviews*. 34(3): 188-197.
- Bhardwaj, R.L. (2011). Bench Mark Survey on Effect of Mulching Material on Crop Production. *Krishi Vigyan Kendra, Sirohi, MPUAT Udaipur*, pp.12-15.
- Bhardwaj, R.L., Meena, C.B., Singh, N., Ojha, S.N. and Dadhich, S.K. (2011). Annual Progress Report of Krishi Vigyan Kendra, Sirohi, MPUAT Udaipur, pp. 45-46.
- Bhatt, L., Rana, R., Uniyal, S.P. and Singh, V.P. (2011). Effect of mulch material on vegetative characters, yield and economics of summer squash (*Cucurbita pepo*) under rainfed mid-hill condition of Uttarakhand. *Vegetable Science*. 38(2): 165-168.
- Bobby, A., Prashanth, P., Seenivasan, N. and Mishra, P. (2017). Effect of different mulch materials on weed control in cucumber (*Cucumis sativus* L.) hybrid Multistar under shade net conditions, *International Journal of Pure and Applied Biosciences*. 5(5): 1246-1251.
- Chalker, S. (2007). Impact of mulches on landscape plants and the environment-A review. *Journal of Environmental Horticulture*. 25: 239-249.
- Chandra, A., Singh, R.D., Bhatnagar, V.K., Bisht, J.K. (2002). Effect of mulch and irrigation on tuber size, canopy temperature, water use and yield of potato (*Solanum tuberosum*). *Indian Journal of Agronomy*. 47: 443-448.
- Cookey, C.O., Agu, C.M., Uwaga, E.C., Keyagha, R.E. and Ogwudire, V.E. (2016). Effects of plastic mulch colour and cucumber cultivars (*Cucumis sativus*) on root-gall nematode (*Meloidogyne* spp) infection in a Nigerian ultisol. *Journal of Global Biosciences*. 5(5): 4149-4157.
- Coolong, T. (2010). Performance of paper mulches using a mechanical plastic layer and water wheel transplanter for the production of summer squash. *HortTechnology*. 20: 319-324.
- Coolong, T. (2012). Mulches for Weed Management. In: *Weed Management*. In: *Weed Control*, Dr. Andrew Price (Ed.): 57-74.
- Coolong, T. (2012). Mulches for Weed Management. In *Book: Weed Control*. Andrew Price (Ed.): 57-74.
- Davis, A.R., Perkins-Veazie, P., Sakata, Y., Lopez-Galarza, S., Maroto, J.V., Lee, S.G. and Cohen, R. (2008). Cucurbit grafting. *Critical Review in Plant Science*. 27(1): 50-74.
- Dickerson, G.W. (2000). Commercial vegetable production with plastic mulches. Cooperative Extension Service, New Mexico State University, Las Cruces, N.M. Guide, 245.
- Dube, E., Chiduza, C. and Muchaonyerwa, P. (2012). Conservation agriculture effects on soil organic matter on a Haplic Cambisol after four years of maize-oat and maize-grazing vetch rotations in South Africa. *Soil Tillage Research*. 123: 21-28.
- Ekinci, M., Dursun, A. (2009). Effect of different mulch materials on plant growth, some quality parameters and yield in melon (*Cucumis melo* L.) cultivars in high altitude environmental condition. *Pakistan Journal of Botany*. 41: 1891-1901.
- El-Nemr, M.A. (2006). Effect of mulch types on soil environmental conditions and their effect on the growth and yield of cucumbers plants. *Journal of Applied Sciences Research*. 2: 67-73.
- Gordon, G.G., Foshee, W.G., Reed, S.T., Brown, J.E., Vinson, E. and Woods, F.M. (2008). Plastic mulches and row covers on growth and production of summer squash. *International Journal of Vegetable Science*. 14(4): 322-338.
- Goreta, S., Perica, S., Dumicic, G., Bucan, L. and Zanica, K. (2005). Growth and yield of watermelon on polyethylene mulch with different spacing and nitrogen rates. *HortScience*. 40: 366-369.
- Harris, R.W., Clark, J.R., Matheny, N.P. (2004). *Arboriculture: integrated management of landscape trees, shrubs, and vines*, 4<sup>th</sup> Edition. Prentice Hall, Inc, Upper Saddle River.
- Helaly, A.A., Goda, Y., Abd El-Rehim, A.S., Mohamed, A.A. and El-Zeiny, O.A.H. (2017). Effect of polyethylene mulching type on the growth, yield and fruits quality of *Physalis pubescens*. *Advances in Plants and Agriculture Research*. 6(5): 154-160.
- Johnson, J.M., Hough-Goldstein, J.A. and Vangessel, M.J. (2004). Effects of straw mulch on pest insects, predators and weeds in watermelons and potatoes. *Environmental Entomology*. 33(6): 1632-1643.
- Kader, M.A., Singha, A., Begum, M.A., Jewel, A., Khan, F.H., Khan, N.I. (2019). Mulching as water-saving technique in dry land agriculture. *Bulletin of the National Research Centre*. 43: 1-6.
- Kayum, M.A., Asaduzzaman, M. and Haque, M.Z. (2008). Effects of indigenous mulches on growth and yield of tomato. *Journal of Agriculture and Rural Development*. 6(1&2): 1-6.
- Kumar, D. and Sharma, R. (2018). Effect of mulching on growth, yield and quality in different varieties of summer squash (*Cucurbita pepo* L.). *International Journal of Current Microbiology and Applied Sciences*. 7(6): 2113-2119.
- Kumar, R.R., Singh, R., Nityanand, Sohane, R.K and Singh A.K. (2019). Effect of different type mulch on growth, yield attributes and yield of brinjal (*Solanum melongena*). *Current Journal of Applied Science and Technology*. 37(6): 1-6.
- Kundu, P., Adhikary, N.K., Saha, M., Ghosal, A. and Sahu, N.C. (2019). The effects of mulches on tomato (*Lycopersicon esculentum* L.) in respect of yield attribute in ecosystem of coastal Bengal. *Current Journal of Applied Science and Technology*. 35(4): 1-8.
- Lalljee, B. (2013). Mulching as a mitigation agricultural technology against land degradation in the wake of climate change. *International Soil and Water Conservation Research*. 1: 68-74.
- Lamont, J.W.J. (2005). Plastics: modifying the microclimate for the production of vegetable crops. *Hort Technology*. 15: 477-481.
- Lightfoot, D.R. (1994). Morphology and ecology of lithic-mulch agriculture. *Geographical Review*. 172-185.
- Lourduraj, A.C. (2003). Effect of mulching and irrigation regimes on chillies (*Capsicum annum* L.). *Agricultural Science Digest*. 23(3): 208-210.
- Luqman, Hussian, Z. and Fahad, S. (2013). Integrated weed management in bitter melon in the agro-ecological conditions of Peshawar. *The New Developmental Farm*. 19(3): 341-347.

- Lyengar, K.S., Gahrotra, A., Mishra, A., Kaushal, K.K. and Dutt, M. (2011). Practical Manual on Plastic Mulching. NCAPH, New Delhi. pp 2-6.
- Mahadeen, A.Y. (2014). Effect of polyethylene black plastic mulch on growth and yield of two summer vegetable crops under rain-fed conditions under semi-arid region conditions. *American Journal of Agricultural and Biological Sciences*. 9(2): 202-207.
- Mahajan, G., Sharda, R. and Singh, K.G. (2006). Weed management in red chilli through different weed management practices and planting methods. *Environment and Ecology*. 24: 1100-1103.
- Maida, P. and Kumar, U. (2020). Combination effect of mulch and irrigation schedule on performance of chilli under drip irrigation condition. *Journal of Pharmacognosy and Phytochemistry*. 9(5): 2639-2644.
- Manyatsi, A.M. and Simelane, G.R. (2017). The effect of organic mulch on the growth and yield of Spinach (*Spinacia oleracea* L.). *International Journal of Environmental & Agriculture Research*. 3(6): 53-56.
- McCann, I. Kee., E. Adkins, J., Ernest., E. and Ernest, J. (2007). Effect of irrigation rate on yield of drip-irrigated seedless watermelon in humid region. *Science Horticulture*. 113: 155-161.
- Mgolozeli, S., Nciizah, A.D., Wakindiki, Isaiah I. C. and Mudau, F.N. (2020). Innovative pro-smallholder farmers' permanent mulch for better soil quality and food security under conservation agriculture. *Agronomy*. 10(605): 3-16.
- Musie, S., Mohammed, A., Bel, D. and Getachew, E. (2015). Growth response of hot pepper varieties to different mulch types at Jimma, South Western Ethiopia. *American-Eurasian Journal of Agricultural and Environmental Sciences*. 15(5): 733-743.
- Nalayini, P. (2007). Poly-mulching a case study to increase cotton productivity. Central Institute for Cotton Research. Regional Station, Coimbatore.
- Narayan, S., Makhdoomi, M.L., Malik, A., Nabi, A., Hussain, K. and Khan, F.A. (2017). Influence of plastic and organic mulching on productivity, growth and weed density in chilli (*Capsicum annum* L.). *Journal of Pharmacogn Phytochem*. 6(6): 1733-1735.
- Ngosong, C., Okolle, J.N. and Tening, A.S. (2019). Mulching: A sustainable option to improve soil health. Panpatte, D.G. and Jhala, Y.K. (eds.), *Soil Fertility Management for Sustainable Development*. 231-249.
- Ngouajio, M. and Ernest, J. (2004). Light transmission through colored polyethylene mulches affected weed population. *Hort Science*. 39(6): 1302-1304.
- Nijamudeen, M.S. and Dharamasena, P.B. (2002). Performance of chilli under drip irrigation. *Ann Sri Lanka Department of Agriculture*. 4:89-94.
- Orzolek, M.D. and Lamont, W.J. (2015). Summary and recommendation for the use of mulch color in vegetable production. Penn State Extension.
- Parmar, H.N., Polara, N.D. and Viradiya, R.R. (2013). Effect of mulching material on growth, yield and quality of watermelon (*Citrullus lanatus* thunb) cv. Kiran. *Universal Journal of Agricultural Research*. 1(2): 30-37.
- Patil, S.S., Kelkar, T.S. and Bhalerao, S.A. (2013). Mulching: A soil and water conservation practice. *Research Journal of Agriculture and Forestry Sciences*. 1(3): 26-29.
- Rahman, M.J., Uddin, M.S., Bagum, S.A., Mondol, A.T.M.A.I. and Zaman, M.M. (2006). Effect of mulches on the growth and yield of tomato in the coastal area of bangladesh under rainfed condition. *International Journal of Sustainable Crop Production*. 1(1): 06-10.
- Rajablariani, H., Hassan Khan, F. and Rafezi, R. (2012). Effect at colored plastic mulches on yield at tomato and weed biomass. *International Journal of Environmental Science and Development*. 3(6): 590-593.
- Ramakrishna, A., Hoang, M.T., Wani, S.P. and Long, T.D. (2006). Effect of mulch on soil temperature, moisture, weed infestation and yield of groundnut in northern Vietnam. *Field Crops Research*. 95: 115-125.
- Ranjan, P., Patle, G.T., Prem, M., Solanke, K.R. (2017). Organic mulching- a water saving technique to increase the production of fruits and vegetables. *Current Agriculture Research Journal*. 5(3): 371-380.
- Rathore, A.L., Pal, A.R. and Sahu, K.K. (1998). Tillage and mulching effects on water use, root growth, and yield of rain-fed mustard and chickpea grown after lowland rice. *Journal of the Science of Food and Agriculture*. 78: 149-161.
- Robinson, D.S. (1990). *Food Biochemistry and Nutritional Value*. Longman scientific and technical publisher, New York, USA.
- Santos, M.O., Zamora, O.P. and Arriaga, O.L. (1995). Effect of transparent mulch on insect populations, virus diseases, soil temperature, and yield of cantaloup in a tropical region. *New Zealand Journal of Crop and Horticultural Science*. 23: 199-204.
- Sapkota, R., Dahal, K.C. and Thapa, R.B. (2010). Damage assessment and management of cucurbit fruit flies in spring-summer squash. *Journal of Entomology and Nematology*. 2(1): 7-12.
- Sarolia, D.K. and Bhardwaj, R.L. (2012). Effect of mulching on crop production under rainfed condition: A Review. *International Journal of Research in Chemistry and Environment*. 2: 8-20.
- Sciortino, A. (2001). Mulching, in what conditions. *Culture Protette*. 30: 39-43.
- Singh, H., Sharma, P., Kumar, P., Dhillon, N.S. and Sekhon, B.S. (2017). Influence of mulching on growth and yield of tomato (*Solanum lycopersicum* L.) under protected environment. *Biotechnology Journal International*. 19(2): 1-6.
- Singh, I.S., Awasthi, O.P. and Meena, S.R. (2006). Influence of mulch on soil hydrothermal regimes, leaf and soil nutrient concentrations, growth and fruit yield of brinjal grown under arid ecosystem. *Agropedology*. 16: 112-116.
- Soleymani, R., Hassandokht, M.R. and Abdoosi, V. (2015). Mulch and planting method on quantitative traits of cucumber. *International Journal of Agronomy and Agricultural Research*. 6(1): 28-35.
- Solia, B.M., Patel, R.B., Patel, J.M., Savani, N.G., Sonvan, S.S. and Patil, R.G. (2018). Mulching technologies for increasing crop yield. *Plasticulture technologies related publish paper Compiled by Solia, B.M., Usadadiya, V. P., Mansuri, R.N., Mistry P.S. and Zinzala M.R., Precision Farming Development Centre, NAU, Navsari, Gujarat.*

- Stapleton, J.J., Molinar, R.H., Lynn-Patterson, K., McFeeters, S.K. and Shrestha, A. (2005). Soil solarisation provides weed control for limited resource and organic growers in warmer climates. *California Agriculture*. 59: 84-89.
- Tyagi, S.K. and Kulmi, G.S. (2019). Effect of plastic mulch on growth, yield and economics of chilli (*Capsicum annuum* L.) under Nimarplains conditions of Madhya Pradesh. *Journal of Krishi Vigyan*. 8(1): 105-108.
- Vander Zaag, Demagante, A. Acasi, R. Domingo, A. and Hagerman, H. (1986). Response of solanum potatoes to mulching during different seasons in an isohyperthermic environment in the Philippines. *Tropical Agriculture (Trinidad)*. 63: 229-239.
- Vankar, R.R. and Shinde, P.P. (2007). Effect of micro irrigation systems and polythene mulches on yield and yield attributes of okra var. Arka Anamika. *The Orissa Journal of Horticulture*. 35(1): 22-26.
- Yadav, M.R., Parihar, C.M., Kumar, R., Yadav, R.K., Jat, S.L., Singh, A.K., Ram, H., Meena, R.K., Singh, M. and Meena, V.K., (2017). Conservation agriculture and soil quality-an overview. *International Journal of Current Microbiology and Applied Sciences*. 6: 1-28.
- Zhang, G., Breuer, M., Förster, A., Egger-Adam, D. and Wodarz, A. (2009). Mars, a Drosophila protein related to vertebrate HURP, is required for the attachment of centrosomes to the mitotic spindle during syncytial nuclear divisions. *Journal of Cell Science*. 122(4): 535-545.