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Plastic mulching for crop production and protectionto mitigate climatic impact

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The word 'plastic' has its origin from the Greek word 'plastikos,' which means 'able to be moulded into different shapes' and the word 'mulch' has been possibly acquired from the German word 'molsc' meaning soft decay, which certainly indicates towards the use of straw and leaves as a spread over the ground.

Mulching is a technique that has been used by farmers for many years and refers to use of either organic or inorganic materials to cover the soilthatact as a physical barrier which checks soil waterevaporation,controls weeds, maintains a good soil texture, and protects cropsfrom pests and diseases. Organic mulches consist of naturally available plant or animal material. However, being of natural origin, oftenthey are not available in enough quantity, show inconsistency in their quality, and require morelabour for their lay out. Also, they may carry seeds of weeds and pests such as slugs, termites, snails, earwigsetc. Natural mulches are reported to reduce soil temperature and evaporation, often retard soil warming in spring, which can delay growth and ripening in warm season vegetables and usually do not produce higher yields.Therefore,natural mulches cannot be used efficiently in crop productionduring all the seasons. Plastic mulches have been used in agriculture industry to overcome some of these problems. Infact, plastic mulch has metamorphosed the age-old approach of mulching. Plastic mulch is now used globallyfor protecting crops from un-favourable growing conditions such as severe weather, insects, diseasesand birds. Earlier plastic was used in cold regions, mainly for protection of the crop from the cold. Now it is used in all kind of climates, soils, and seasons due to its numerous benefits. The use of plastic

mulch increased the production of peanut to the extent that it is called as white revolution in China.

Commercially, plastic mulches have been used for the production of vegetables since the 1960s. Various vegetables and fruit cropsgrown on plastic mulch include bell pepper, chilli, tomato, eggplant, muskmelon, cucumber, watermelon and strawberry.

Types of mulching material

Organic mulches

These are derived from plant and animal materials. The most frequently used organic mulches are rice straw, hay, peanut hulls, sugarcane leaves, banana leaves, compost, sawdust, wood chips, shavings and animal manures. The main drawbacks of using natural materialsisthat they require considerable human labour, are not easy to spread on growing crops and are often not available in required quantities for commercial operations or if available need to be transported to the place of use. Theselimitations have restricted the use of organic mulch in agriculture production.

Inorganic mulches

These are synthetic mulches which includes plastic mulch. They are the most popular mulch used in commercial crop production. The materials used for plastic mulch are polyethylene or poly vinyl chloride films. Most of plastic mulch used are linear low-density polyethylene (LLDPE) asthey are more economic in use.LLDPEresins have high puncture resistance and mechanical stretch properties. High-density polyethylene resins have reliable moisture and vapour barriers. These mulches are reported to improve microclimate around the plant, increase soil moisture content, temperature and minerals needed by plants therebybeing effective for crop plant growth and yield.

PLASTIC MULCH TYPES AND COLOURS

There are two basic types of plastic mulch,smooth plastic or embossed plastic based on the surface texture of the material. Theembossed plastic has visible patterns on the surface, which gives the plastic a wrinkled appearance. Theyare more tensile,and less vulnerable to wear out due to wind,cracking and damage due to punctures. They do not expand and contract under varying temperatures as much as smooth plastic, thus maintaining better plastic to soil contact throughout the day.

The common widths of the mulch are 36 to 60 inches, and the thickness varies from 0.6 to2.0mil (15-50µ).Thecost of the mulch increases with thickness. Thin plastics last only for one cropping season and are more prone to tearing. Thicker plastics can be reused and are recommended if double-cropping is planned. The commonly used plastic mulches in agriculture crops are of four colours- black, clear, silver and white. Selection of mulch colour mainly depends upon the conditions, purpose and the crop. Black plastic mulch is the most widely used, controlsweeds in cropped land and is the least expensive. Clear mulch is used when the aim is to increase soil temperature,but it will not control the weed growth, thus its usefulness is limited. White or aluminium reflective mulch reflects solar radiation and is used where soil cooling is desired and is

effective in summer cropped land. Silver mulch repels vectors of virus diseases especially in cucurbitaceous and solanaceous crops. Black and clear mulches have the greatest soil warming potential. Apart from these three colours, there are various other plastic mulch colours available such as red, yellow, blue, gray, and orange. Clear, black or coloured plastic mulch influence the soil microclimate differently based on their reflective properties. Thesemay also affect plant growth in a positive way. Plastic mulch silver on black with upper surface silver colour and lower surface black is now widely used.

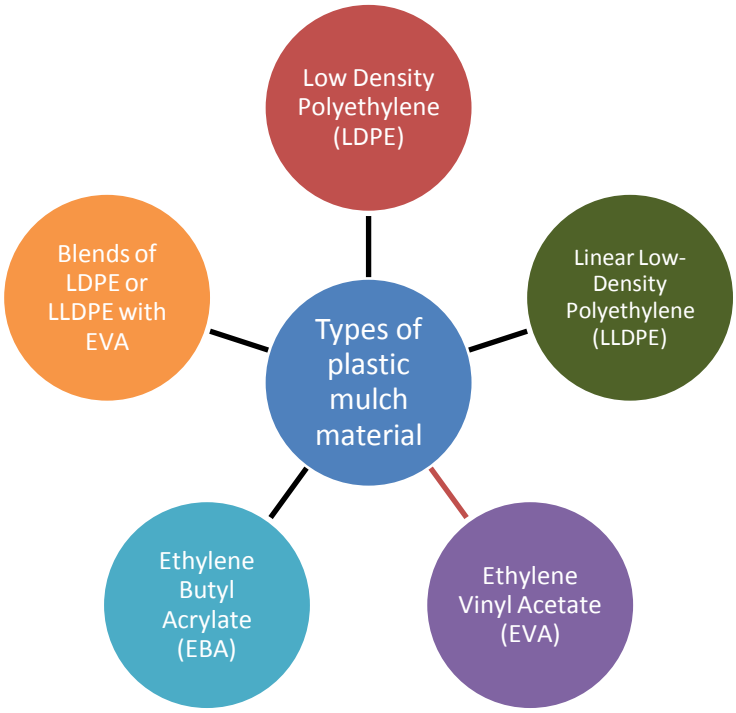

Fig. Commercially available plastic mulch materials.

The response of the crop to coloured mulches usually depends on season and region and so variations are often reported.Theyare able to effectively modify soil temperature. Black mulch is recommended during the spring to warm the soil and for the summer and fall; aluminium or white coloured mulches are preferred because these mulches heat the soil less than black mulch.

Sunlight is intercepted by black or clear mulches so they warm the soil whereas, white or aluminium mulch reflects the sun's rays and keeps the soil cooler. When black mulch is used it warms the soil and enhances the growth of the crop in early season,leading to earlier harvest. First harvest is usually accelerated from 7 to 14 days depending on weather conditions. Clear mulch impart greatest soil warming making them useful in certain situations.

STEPS INVOLVED IN MULCHING

a) Soil preparation

The soil should be tilled well and the required quantity of FYM and fertilizer should be applied before laying of mulching**.** Beds are prepared best when soil is friable,clod-freeand free from grass or weed residue otherwise it is difficult to lay plastic tightly on the bed and it can damage it. The raised bed must have the right moisture content to hold its shape. A too wet field will form clods and become compact during bed formation. The raised beds will not hold together and the sides will crumble, if the soil is too dry. When finished, the bed should be four to six inches high, about 30 inches to 34 inches wide (depending on mulch width) with about 1 1/2 -2 inches slope from thecenter to the edge. Plastic mulch is suitable for both flat and raised beds. The width of the bed depends on the crop and the rows on the bed. Usually crops such as chilli, tomatoes, capsicum, eggplant, muskmelon and melon are planted on3 foot wide plastic beds.

b) Application of fertilizers

The fertilizers can be applied mechanically as well as manually. Some plastic mulch laying equipment also incorporate fertilizer while the bed is formed and plastic is installed. Alternatively, fertilizer can be applied during soil preparation, before laying the plastic mulch. After the mulch is installed water soluble fertilizer can be given through the drip irrigation system.

c) Laying of drip line

Drip irrigation is the most effective and suitable method of irrigation when plastic mulch is used. Therefore, the drip lines are laid after preparation of beds with the help of tractor or manually prior to the laying of the mulch. If drip tape is to be used for irrigation, the tubing should be installed when the plastic mulch is being laid. Drip tape can either be laid on the soil surface under the mulch or buried 2-3 inches below the soil surface. Burial reduces the chance for movement of the tube and its damage which causes leaks. Care should be taken that orientation of the drip emitter holes is upward to avoid clogging. Tape placement on the bed will vary as per the row configuration. One center drip line is used for single-row crops - tomato, brinjal and cucurbits, two off-center rows are required for planting two rows on a bed e.g. in Cole crops or in very sandy soils and three lines are used for onion and garlic crops on an 80 to 90 cm wide bed.The drip tube should be installed approximately three inches off center of the row for crops grown in single rows. For the crops to be planted in two rows per bed, the drip tube should be in the center of the bed. This prevents the damaging of the tube during transplanting or seeding operation.

d) Laying of the mulch

After laying of the drip lines on beds, the plastic mulch is laid on the beds with the help of a tractor drawn machine or manually. Mulch should be laid on a non-windy condition and should not be laid on the hottest time of the day, when the film will be in expanded condition.The plastic mulch laying machine needs to be adjusted so that the press wheels hold the plastic firmly against the beds and the covering discs place soil only up to half way of the side of the beds and not on top of it. The plastic mulch can also be

covered manually by two persons holding the plastic roll and two persons covering the plastic by putting soil on the edges with spades. The mulch must be stretched tight and firmly secured at the edge, making good contact with the soil.However,it should be loose enough to overcome the expansion and contraction caused by temperature. The plastic must be in continuous contact with the soil. Soil warming occurs through conduction so contact between the soil and plastic is important. A loose plasticmulch allows it to 'whip' in the wind, causing tearing and can also damage young transplants. The mulch should be held tight without any crease and laid on the bed securely covering its sides with soil. Preferably, 6 inches of each edge of the plastic is covered with the soil. However, do not apply more soil than is needed, as this makes the mulch more difficult to remove. Once the mulch is laid, round holes (2 to 3 inches wide) are made on the plastic mulch using a punch or a hot cylindrical pipe with suitable diameter near to the drippers on the required planting distance and the seed are sown or the crop is transplanted.

Fig. Field with plastic mulch.

e) Planting

Planting on plastic mulch can be done either manually or mechanically, depending on the size of the operation. Mechanical transplanters are usedin the case of large-scale commercial operations. A water-wheel planter is one of the simplest and most common transplantersthat is used. It punches a hole in the mulch and fills the hole with water/starter solution,two workers ride the machine and set a plant into each hole. Fully-automated transplanters are also available. Such machines receive the plant into a pocket then punch a hole in the plastic, set the plant in the hole, press the soil around the plant and deliver water/starter solution onto each plant. A similar planter is used for direct seeding, which punches a hole and places the seed or a mix of potting soil and seed(s). The planters can be adjusted according to various spacings and are pulled with the help of a tractor.

f) Removal of plastic mulch

The plastic mulch should be removed at the earliest after its use as weeds tend to overgrow on unattended plastic. The field should not be ploughed until the plastic mulch is removed otherwise plastic residue problem will remain for years. To remove the mulch mechanically, machines are available which lift the plastic and throw off the

clingingsoil, leaving the mulch lying on the top of the row. The plastic can then be picked up by hand, removed from the field and taken to landfills.

Fig. Tomato crop on plastic mulching.

ADVANTAGES OF PLASTIC MULCH IN AGRICULTURE

There are many benefits of growing crops on plastic mulch. Although its use does not guarantee each benefit, the following advantages are generally recognised.

A) Effect of mulching on soil

Soil temperature

Plastic mulch was first noted for its ability to increase soil temperature in the 1950s.It depends on the capacity of the plastic mulch used to reflect and transmit solar energy.Heatingproperties of plastic such as transmittance, absorptivity and reflectivity, and their interaction with solar radiation directly affect soil temperature under the plastic mulch. Different types and colours of plastic mulch have distinct optical properties which have effect on the levels of light radiation reaching the soil, resulting into increases or decreases in the soil temperature. Application of clear plastic mulches increases soil temperature whereaswhite mulches lead to decrease in soil temperature. An increase of 2.4°C in average soil temperature at 15 cm depth under transparent mulch and an increase of 0.8°C under black film has been observed. The soil temperature can increase up to 7°C under transparent mulch as compared to bare soil. The use of clear plastic mulch in cold areas or seasons increases soil temperature and promotes germinationin many crops. Clear mulches are particularly usefulwhen warm

season vegetable crops are being cultivated in locations having a short and cool growing season. Higher soil temperatures enhance the availability of nutrients and their uptake by roots. It also promotes soil microorganism growth and activity along with speeding up of plant germination and growth.

The air temperatures were also found to be higher for mulch treatments compared to bare soil. Fluctuations in temperature in the first 20–30-cm depth of the soil is avoided through mulching. This favours root development, and the soil temperature in the planting bed is raised, promoting faster crop development and earlier harvest. When the crop canopy covers the surface of the mulch bed, soil temperatures among different mulch colours are approximatelyequal.Condensation occurring on the underside of the mulch at night, absorbs the long wave radiation emitted from the soil resulting into slow cooling of the soil.

Moisture conservation

Plastic mulches decrease the soil water loss and thus have effect on the microclimate around the plant. It acts as a barrier suppressing soil water evaporation and keeps themoisture levelbalanced in the root zone. It also reduces surface run-off,thusincreases infiltration of rain water in the soil andabdicate superfluous water away from the crop root zone during excessive rain fall. Plasticmulch prevents soil moisture from escaping as the water which evaporates from the soil surface beneath it, condenses on its under surface and falls back as droplets. This,preserves the moisture for several days, consequently increasing the period between two irrigations. This reduces irrigation requirement and helps in checking water and nutrient associated physiological disorder, for instance, blossomendrotin tomato, fruit cracking in lime and pomegranate. The irrigation requirement in bell pepper is reduced by 14-29% when the crop is grown on plastic mulch. In various types of soil, elevation in water content (4.7 %in clay soil, 3.1 % in loamy and 0.8–1.8 %in sandy soil)in the top 5 cm of soil has been reported under plastic mulch. Use of drip irrigation along with plastic mulch, further increases water savings.

Effects on plant microclimate

Plastic mulches have effect on plant microclimate as they modify the soil energy balance and slowdown the soil water evaporation. This in turn has an effect on soil temperature, which affects plant growth and yield. One of the main benefits of using plastic mulch is increase in the root-zone temperature. Several physiological processes in roots such as uptake of water and mineral nutrients are regulated by root-zone temperature hence it is considered important in inducing plant growth and development.

Enhanced nutrient management

Nutrient leaching is greatly reduced as irrigation schedule is better managed with plastic mulch which saves on fertilizer costs. Since leaching is reduced, so along with enhanced moisture regulation, mulch helps in checking nutrients and fertilizer loss thereby aiding in more efficient nutrient utilization by the plant.

Higher microbial biomass

Plastic mulch helps in maintaining moisture, increases soil temperature, and helps in better aeration of the soil which supports higher microbial biomass in the soil favouring not only N mineralization but also plant N uptake.

Reduced soil compaction

Plastic mulch protects the soil under it from foot traffic and rainfall. This helps keep the soil loose, friable, and well-aerated resulting into enhanced soil microbial activity. Plants that grow in non-compacted soils have better root growth leading to increased water and nutrient absorption.

Modification of light environment

Plastic mulches also modify the light environment around the plant. The light reflected from the mulch affect plant growth and morphogenesis, phytochrome regulation and increased PAR and development of flavour compound. Due to its high reflectance of UV light, it has repellent effect on pest and vector insects, such as aphids, whiteflies and thrips resulting into decrease in the incidence of viral diseases particularly in cucurbitaceous and solanaceous crops.

B) Effect of mulching on plants

Plant growth and development

Plastic mulch impartsconduciveenvironment for thegrowth of crop plantsresultingintomorevigorous and healthier plants which may be more resistant to pest and diseases. Plastic mulch helps in increasing soil temperature and moisture content which in turn stimulate root growth leading to greater plant growth. Therefore, plants cultivated on mulchgenerally grow and mature more uniformlyas compared to un-mulched plants. Increase in plant height and number of laterals in tomato has been observed when the crop was grown on black LLDPE as compared to no mulch.

Early harvest

Generally, crops grown on plastic mulch matures 2 to 3 weeks earlier as compared to those grown on bare soil. Vegetables grown on plastic mulch during summer season such as watermelons, cucumbers, muskmelons, chilli, eggplant, peppers, show early maturity and give higher yields. This occurs due to absorption of solar radiation by the mulch resulting into increased soil temperature under mulch. Black mulch is reported to keep the soil warm and promote faster growth of the plant during the early season of the crop, which generally leads to earlier harvest. Use of polyethylene films as mulch enable shortening of growing season and enhance earliness and yield in different vegetable crops. Beneficial effect of polyethylene mulch on early harvest and higher yield has been observed in watermelon, zucchini, tomato and pepper.

Improve quality and yield

Vegetable production has shown significant yield increases over the last several years. The use of plastic mulch along with drip irrigation has played a major role in the

increase in production. Reflectivemulch has been reported to increase soluble solids content, total phenolics, flavanols, and anthocyaninscontent in fruit crops such as wine grapes,plums, strawberries.

Plastic mulch helps keep fruits clean from direct contact with the soil surface. This reduces soil rot, fruit surface damage and blossom end rot in many cases.Hence,the quality of harvested fruits is improved. Marketable fruit yield quality from mulched plot is always significantly higher than those produced on bare soil. Mulch is reported to increase yield in many vegetables such as chilli,tomato,potato,brinjal,capsicum, okra, cauliflower,cucumber,muskmelon,watermelonand fruit crops e.g.strawberry,kinnowranging from 10 to 60%. This is due to moisture conservation, higher soil temperature, weed control, increased mineral nutrient uptake in the mulched plot through improved root temperatures and protection from diseases and pests.

C) Effect of mulching on micro-flora and insect-vectored viral diseases

One of the non-chemical methods for managing pathogens is soil solarisation using transparent mulches, such as PE, PVC, or EVA. In order to facilitate the maximum possible heating of the soil during the day and reduce heat loss at night, they must be mechanically strong and as transparent to sunlight as possible. The increase in the temperature of the soil causes many soil borne pathogens to die. An increase in the number of beneficial microorganisms (e.g.*Bacillus* bacteria or *Trichoderma* fungi) has been observed in the soils subjected to solarisation. This method is effective only in warm climatic regions.

In recent years, there has been increased attention to the use of coloured plastic mulches in preventing or delaying the onset of various insect-vectored diseases. Transparent polyethylene mulch also helps in reducing whitefly populations and virus diseases incidence. It also delayed the onset of virus symptoms by two weeks as compared with the bare soil. It has repellent effect on pest and vector insects, such as aphids, whiteflies and thrips probably due to its high reflectance of UV light. Several viral diseases in cucurbits are known to be transmitted by their aphid vectors.Mulching helps in limiting or delaying viral infection by repelling the insect vectors by emitting UV reflective rays.For example, in watermelon it is reported that use of silver mulch (30 µ)resulted in 24% less damage by the *Watermelon bud necrosis virus* (WBNV) by reducing the population of thrips (71.4%) as compared to the control. In the experimental trial conducted at IARI Regional Station, Pune reduction in percent disease and intensity of viral diseases mainly tomato leaf curl, cucumber mosaic, zucchini yellow mosaic and tospovirus was observed in muskmelon when silver mulch was used along with fortnightly alternate spray of insecticide and biopesticide.

D) Weed management

Mulch inhibits growth of weeds in many vegetable crops.Plasticmulchreduces weed emergence by 64% to 98% during the growing season.Mulching keeps the weed under control by suppressing weed seed germination and their growth. White or clear mulch

have little effect on weeds, whereas brown, black, blue or white on black (double colour) films prevent emergence of weeds.These films do not allow the sunlight to pass through on to the soil inhibiting photosynthesis and check weed growth.Thus,plastic mulch greatly reduces weed competition resulting into healthier crop. Further the cost towards labour and herbicide use is reduced. Some weeds also act as alternate hosts for insect pests and viruses, thus reduced weeds can reduce insect and disease pressure.

E) Maximizing farmers' income through double cropping

Plastic mulch increases the cost of production over bare soil, excluding the drip irrigation costs. In order to make full use of the additional inputs, some farmers augment the system by planting a second crop (double cropping). The success of double cropping is dependentupon the type of crops planted, their market demand, and length of the growing season. Ideally, crops are chosen which have short duration for maturation, are unrelated to reduce pest and disease problems, and practice good crop rotation. Since plant spacing often varies between crops, hence additional holes are required to be made in the plastic.

Alternatively, the plastic can be used for 2 years in a row for double cropping, but for this a heavier plastic is required. The durability of the plastic over the winter, and damage caused by animals and rodents by tearing and puncturing holes through and chewing holes in drip tape are some of the issues with this approach. A high value, high input crop in the first year and a lower value crop in the second is the best combination of crops for this method.

Limitations of plastic mulch

A) Economic limitations

Cost

Use of plastic mulch increases inputs to the overall production system, resulting in increased costs.The cost of one roll (400m) of mulching is aroundRs. 1200/- to 1800/- and the number of rolls required per acre depends on row spacing and bed width.

Installation

Apart from the cost of the plastic mulch, additional labour and field operations are required for their installation in the field.Installation of plastic mulch can be carried out by hand.However, forcommercial production of vegetables depending on the extent of the operation specialized equipment to prepare and shape the planting bed for mulch application, for mulch-laying and transplanting or seeding must be purchased or hired in order tosave time and increase labour efficiency.

Removal

Presently mostplastic mulch used are non-degradable hence they have to be removed and disposed-off at the end of the growing season. Completely degradable plastics are not yet available and partially degradable onesreadily break into small pieces which are difficult to remove. Machines are available to lift the plastic and hand labour and rolling devices are needed to remove plastic from the field. Their removal is time-consuming

and requires extra expenditure. Care needs to be taken to avoid leaving any pieces of plastic in the field as most of it does not decompose.

B) Environmental concerns

The most commonly used plastic mulches are polyethylene-based plastics which do not break down and cause a considerable waste disposal problem. Hence, their disposal raises environmental pollution problem that could persist for centuries. A large amount of this plastic enters the landfill system which requires extra expenditure towards its disposal. Theleft-over plastic mulch in thefieldusually interferes with the development of rooting system of the subsequent crop. In case of photodegradable mulches, the part exposed to the light undergoes decomposition and theremaining material is broken into pieces during soil preparation for the next crop, leaving some pieces buried and some left on the soil surface. The buried pieces are less affected by light and high temperatures making them more difficult to be decomposed. Thus, creating serioussoilproblems.

CONCLUSION

The application of plastic mulch in agriculture has increased significantly in the recent years worldwide. This increase is due to benefits such as increase in soil temperature, moisture conservation, more efficient use of soil nutrients, reduction of certain insect pests, reduced weed pressure, and higher crop yields with improved quality. However, despite multiple benefits, their removal and disposal after completion of the cropping season remains a major agronomic, economic, and environmental constraint. In some areas, agricultural plastic recycling is available. To overcome this problem several new photodegradable or bio-degradable mulches have been developed, which will solve the problem of plastic removal or disposal after completion of the cropping season.Currently however their adoption by farmers is limited by the high cost of these materials.