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Case Study

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Benefits of Mulching in Dry Land Agriculture

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A B S T R A C T

Dry land agricultural crops are characterized by very low and highly variable and uncertain yields. Crop failures are quite common at these areas because of inadequate and uneven distribution of rainfall, prolonged dry spells during the crop period, low moisture retention capacity and low fertility of soils. To overcome the constraints of dry land agriculture, mulching is gaining a considerable attention worldwide as agronomic measures for water and soil conservation. Mulching is the process of forming the protective layer, organic and inorganic material, around the plant. It is beneficial for plant health by creating a microclimate around the plant root zone. Mulching improves the soil quality by preventing the runoff of soil, reduces the weed growth and also limits the evaporation of water. Mulching improve water holding capacity of soil, conserve soil moisture, and improves physical, chemical and biological properties of soil. Thus, enhances the soil fertility by generating nutrients to the soil and increases the growth and yield of crops. The paper has information of all the aspect of mulches with reference to their types, origin and beneficiary effects. The paper also discusses the advantages of these mulches in terms of soil environment, water conservation, weed control, crop growth and yield.

Key words: Mulch, Plant growth, Soil health, Water conservation

Dry land is the areas which receives annual rainfall of approximately 750mm or less and where there is no irrigation facilities to raise the crops. Dry lands are also characterized by high rate of evaporation, hot summers with high day temperature, low humidity rate, high run off with extreme problem of soil erosion. The soils of dry land area are also low in nutrients and with high salinity. About 72% of the global dryland are in the developing nations and rest 28% falls in industrialized nations (Millennium Ecosystem Assessment 2005). Geographically dry-land agriculture area in India includes the north western desert regions of Rajasthan, the plateau region of central India, the alluvial plains of Ganga Yamuna river basin, the central highlands of Gujarat, Maharashtra and Madhya Pradesh, the rain shadow regions of Deccan in Maharashtra, the Deccan Plateau of Andhra Pradesh and the Tamil Nadu highlands (Rao and Ryan 2004, Singh *et al*. 2004).

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In our country, of 8 million 129 hectares of cultivated land 33% irrigated area are dry land and 67% are rain-fed. Dryland agriculture contributes about 44% of total national food grain production and thus play very important role in nation's food security. It may contribute up to 75% of total food grain production if we fully utilize the all the source of irrigation (Arun Katyayan 2009, Magray *et al*. 2014). With the increase in population in India, the need of food production is also increasing. Thus, there is need to adopt soil and water management practices, that can enhance crop yield (food production) in dry areas limiting conditions. To overcome the constraints of dry land agriculture mulching is gaining a considerable attention worldwide as agronomic measures because of its low cost and rapid effect. Mulching is ancient traditional practice in dry land agricultural field. Mulch is a protective covering of organic and inorganic matters, to be placed around plants to prevent the evaporation of moisture, and the growth of weeds (Kader *et al*. 2019). The word mulch has probably derived from the German word "molsch" means soft to decay, which apparently referred to the gardener's use of straw and leaves as a spread over the ground as Mulch (Jack *et al*. 1955).

Mulching preserves soil moisture, regulates soil temperature, and also reduces soil evaporation. Mulching shows tragic effect on soil health (by improving physical chemical and biological properties), water conservation, crop growth and yield (Ranjan *et al*. 2017, Kader *et al*. 2019). Further, reported that mulching boosts the yield by 50-60 per cent over no mulching under rain-fed situations (Dilip *et al*. 1990).

Practice of mulching application in dry land agriculture, like India, will surely boon to dry-land farmers and will bring revolution in agricultural soil and water management. The paper summarizes and reflects all the aspect of mulches with reference to their types, origin and beneficiary effects. The paper also discusses the advantages of these mulches in terms of soil environment, water conservation, weed control, crop growth and yield.

Mulches and their types

Mulch is defined as any organic and inorganic material applied to the soil surface as cover (Kasirajan and Ngouajio 2012). Mulches may broadly be categorized into live mulch and dead mulch.

Live mulch: Live mulch is a living cover of a crop. The species for live mulch must be quick emergence and soil covering, short height, low water and nutrients demands such legumes, cereals especially *Secale cereale* L (rye). Usually a non-competing legume crop (green crop) is the best choice for live mulch planted around the desired crop (Feil 2001). It is practiced in fruit and plantation crops. Intercrop having good weed smothering ability can also be introduced in an inter-row of an economic crop. The living mulches are considered more environmentally friendly than plastics and add nitrogen to the primary crop (Durham 2003). The living mulch not only provides for the effective management of weeds but also for the decrease of insect pest pressure resulting in lower requirement for pesticide use (Tyagi *et al*. 2017). Subabul (*Leucaena leucocephala*) and Gliricidia (*Gliricidia sepium*) when used as live vegetative barriers by cutting and spreading these on the ground surface on contour key lines act as effective mulch by improving soil moisture and supply nitrogen to the extent of 25 to 30 kg/ha (Tyagi *et al*. 2017).

Dead mulch: Dead mulch is further of four types' organic mulch, inorganic mulch, synthetic mulch, and soil-dust mulch.

Organic mulches: These are natural origin from plant and animal materials. Organic mulches can decompose naturally, examples soft and hard bark chips, grass clippings, agricultural residue straw (rice and wheat straw), leaves, compost and sawdust, etc. (Iqbal *et al*. 2020). Organic mulch has a number of positive attributes (Table 1). It conserves soil moisture by reducing water lost through evaporation, minimizes soil erosion, moderates soil temperatures, inhibits weed growth, encourages the growth of beneficial soil microorganisms, and reduces the spread of soil-born pathogens by preventing soil from splashing onto plants during rainstorms and watering (Ranjan *et al*. 2017). Mulch can also eliminate mowing around trees and shrubs, preventing mechanical injury to trunks. When used as winter protection, mulch prevents heaving (plant roots pushed upward out of soil) during periods of freeze and thaw. It can also be used to stabilize eroded areas, preventing erosion from wind and water. Organic mulches decompose over time, improving soil structure and quality, and returning nutrients to the soil (Teame *et al*. 2017). Suthar (2009) reported that the total production of organic waste by human, livestock and crops are approximately 38 trillion metric tons worldwide, and agricultural wastes (as well as 272 million metric tons of crop residues) are about 600 to 700 million metric tons/year in India and most of which remains unutilized.

Table 1 Types of organic mulches along with their origin and function

Name	Origin	Function	References
Hardwood / Softwood Bark Mulch	By product of lumber and paper industry	Provides nutrients, aeration to soil, holds water	Telkar *et al*. (2017)
Cocoa Bean Mulch	By product of chocolate industry	Adds nutrients, increase soil fertility	Arentoft *et al*. (2013) Balentic *et al*. (2018)
Leaf Mulch	Composting shredded leaves	Protect dormant plant	Ngala *et al*. (2019)
Grass clipping	Grass bed	Provide nitrogen to soil	Hellqvist (1996)
Compost (Plant and Animal)	Animal manure, straws, leaves and plant residue	Reduce growth of plant pathogen, improve water holding capacity of soil, improves physical, chemical and biological properties of soil	Palada *et al*. (1992) Tyagi *et al*. (2017)
Paper	Layer of newspaper	Suppress weeds	Ranjan *et al*. (2017)
Peat Mulch	Incomplete decomposition of plant residues	Soil conditioner, good moisture retention capacity, supply oxygen to pant root	Kitir *et al*. (2018)
Straw mulch	Stubbles, ground nut shells, cotton shells	Weed control, Moisture conservation, reduce evaporation, improve soil enzyme activity	Sri Lakshmi *et al*. (2012)
Sawdust	Finishing operation of wood and furniture	Retain moisture, improves organic matter content, stimulating plants growth and yield	Salahudeen and Sadeeq (2019) Lima *et al*. (2016)

Inorganic mulches: Inorganic mulches are non-living materials applied to the soil surface such as rock, stone, gravels, and rubber etc. (Table 2). These products do not break down and must be removed after each growing season when used in farm land (Chopra and Koul 2020). Inorganic mulch, such as rocks or gravel, does not readily decompose. These are generally used to create barriers to weeds (Patil *et al*. 2013).

Table 2 Types of inorganic mulches along with their function

Name	Function	References
Landscape Fabric	Suppress weeds	Feldman *et al*. (2000)
Pebbles/Gravels	Reduce evaporation, reduce runoff of water, improves infiltration and temperature of soil	Li (2003) Tejedor *et al*. (2003)
Rubber	Retain soil moisture, reduce fungus and weed growth	Iqbal *et al*. (2020) Tyagi *et al*. (2017)

Synthetic mulch: It includes polythene film/polyester sheet, latex, starch resin spray and petroleum mulch etc. (Table 3). Mulches-latex and starch resin mulch technique may eliminate polythene from the solarization process. The spray mulch performs well in sandy loam soil than in clay loam soil due to less cracking of sandy soil (Parker and Riches 1993, Kwambe *et al*. 2015). Plastic film (polyethylene) is the most common synthetic mulch. Plastic film is impermeable as water and nutrients cannot pass through it. Spreading polyethylene sheets over the seed bed provides warmth for germination and seedling growth (Kasirajan and Ngouajio 2012). The use of clear plastic mulch allows sunlight to heat the soil, stimulating growth and fostering early yield. Advancement in plastic technology has been reported for improved plastic films with optical properties that are ideal for a growing of specific crop in a particular location (Steinmetz *et al*. 2016).

Dust mulch: Dust mulching is the practice of repeatedly and shallowly cultivating the soil surrounding the crop to create a pulverized (dust) layer of soil (James 1945). It reduces evaporation of water by interrupting channels that move water from the ground into the atmosphere. It also conserves soil moisture and moderates the soil temperature. It makes soil warmer in winters and cooler in summers (Barche and Reena 2014, Chalker-Scott 2015).

Table 3 Types of synthetic mulches along with their function

Name	Function	Reference
Polythene film/ Polyester sheet	Improves seed germination and seedling growth, minimize weed problem, improves soil moisture, reduces outgoing radiations, cools down the root-zone temperature	Kasirajan and Ngouajio (2012) Telker *et al*. (2017)
Petroleum mulch	Promotes early germination and seedling growth, improved soil water conditions, improved soil temperature conditions.	Takatori *et al*. (1963) Kowsar *et al*. (1969)
Latex coating	Soil warming effect, control weeds	Haapala *et al*. (2015)
Starch resin spray	Weed and pathogen control	Vox *et al*. (2013)

Advantages of mulching in dry land agriculture

Impact on plant growth and crop yield: Plant roots are highly sensitive to the high temperatures of the soils. Mulch by lowering the temperature of the soil and also by conserving the water in soil profile, makes the soil hydrated and cool. Thus, assist the plant in anchoring in the soil (Haapala *et al*. 2014). Plastic mulch film builds the high levels of carbon dioxide inside it, which is important for photosynthesis. This abundance of CO_2 imports positive impact on growing leaves (Kader *et al*. 2019). Organic mulches have also shown the earliness in flowering, fruits loom increase in the number of flowers and fruits, earliness in harvesting period and increase in tomato crop yield overall (Kumar and Srivatsava 1998). Wheat straw mulch has reported for increase in number of leaves and plant height (Khan *et al*. 2005). Conservation of soil moisture by mulching enhances water use efficiency by reducing evaporation from soil surface as a result of cutting supply of heat energy to the evaporating site and lowering its thermal conductivity. Such practice helps in minimizing fruit drop (Qu *et al*. 2019).

Paddy straw mulch increases starch content and potato crop yield by 18.18 and 27.9% respectively, in compare to un-mulched plots (Dixit and Majmudar 1995). Soybean straw mulch, wheat straw mulch, sugarcane trash mulch and inter culturing operation has reported for increase in grain yield by 12.64%, 9.06%, 7.46% and 3.74%, respectively (Chavan *et al*. 2009). Rice husk mulch was reported to enhance specific leaf weight, root length density and dry biomass of wheat (Chakraborty *et al*. 2008). They also reported that under limited irrigation condition, rice husk mulch was found beneficial for wheat as this mulch was reported for improved quality and water status of soil. Thus, leading to improved crop cultivation and increased grain yield.

Ni *et al*. (2016) found improved plant growth by increasing root activity, soluble sugar, and chlorophyll a content, as well as by providing suitable moisture conditions and nutrients in the root zone by applying round gravel and wood chips for the cultivation of *Osmanthus fragrans* L. 'Rixianggui' plants. Also reported increased plant height and trunk diameter. Pawar *et al*. (2019) reported higher number of branches and leaves in watermelon crop with

black plastic mulch than the control. Watermelon yield with black plastic mulch was reported as 28.90 t/ha and was higher than the crop obtained with other or no mulch. They found positive correlation between the watermelon yield and average root zone temperature. A similar observation for watermelon was reported by Ban *et al*. (2009). They stated that increased growth of plant and cultivation of watermelon is due to increased root-zone temperature.

Impact on soil environment

Soil health: Decomposition of organic and living mulches under appropriate conditions of water and soil temperature releases nutrients into the soil and which is than uptake by plant root. Round gravel and Wood chip mulching increased available nitrogen in the soil (Ni *et al*. 2016). Li *et al*. (2019) reported increased organic matter, total N, mineral N, available P and available K contents of the soil mulched with organic material. The wood chips increased K and Na, whereas the vermi-compost increased Mg and K (Lotze and Kotze 2014).

Soil structure: Plastic mulch makes the soil loose, friable and well aerated. Thus, plants roots easily access the oxygen, which results in enhanced microbial activity. Organic mulch such as bark or jute restores the soil aggregation and porosity (Kwambe *et al*. 2015). Ngosong *et al*. (2019) reported improved total porosity, macro-porosity and micro-porosity of the soil mulching with pine bark, green waste compost and turf grass.

Soil temperature: Plastic mulching has the capacity to trap heat, which results to increased soil temperature. Light-coloured mulches reflect sunlight, thus lowers the temperature whereas dark mulch absorbs it increasing the soil temperature. The temperature of soil with white plastic mulching was found 1.17°C, 3.78°C and 2.48°C in compared to black plastic mulching, grass mulching and no mulch, respectively. The both types of plastic mulching (white and black) increases soil temperature crops in winter season and grass mulching reduce soil temperature during hot season (Tegen *et al*. 2015). Mulches (black poly-geotextile PT110, wood chips, compost, and a thin wood chip layer on top of a thin vermi-compost) changed the minimum temperature in the top 50 mm by 1°C and as much as 5°C for maximum temperature during summer (Lotze and Kotze 2014).

Soil erosion: Improved soil structure results to increased water absorption in mulched soil. In summer, mulched soils are less likely to form a crust, allowing the soil for better water percolation when irrigating, and reduces the soil erosion. Straw prevents strong winds from eroding the soil due to the protection it provides for the soil particles (Woodruff *et al*. 1977, Ven *et al*. 1982). Straw mulch reduces runoff from 65.6% to 50.7% and soil erosion rates up to 2.6 Mg/ha/ h (Keesstra *et al*. 2019). Joao *et al*. (2019) reported 90% soil loss reduction with smaller sizes of rice straw mulch and 80% with bigger size.

Weed growth: Mulch prevents annual weeds from germinating by blocking sunlight from hitting the soil surface. Mulches cover the soil surface and act as physical barrier and thus prevent the germination of weeds. Polythene and straw mulch has been reported for control over weeds (Ramakrishna et al., 2006). Organic mulch applied immediately after a final cultivation often suppresses later-emerging weeds until the crop has passed through its minimum weed-free period. Jayawardana *et al*. (2019) reported effectiveness of shade net and polythene for weed management. Oil palm EFB (Empty Fruit Bunches) was also reported as natural mulch for weed control with labour saving technique.

Soil moisture: Moisture in the soil is gained by applying two to four inches of mulch on planting beds. Cover of mulch shades the soil, thus reduces the loss of water by evaporation. Mulch acts as an insulator by maintaining constant root temperature. Mulch retains moisture of soil, thus reduces irrigation needs for farming. Li (2000) reported the high potential of gravel-sand mulch for soil conservation in the upper soil layer (20-60 cm depth). Rice husk was reported as efficient mulch by improving soil moisture condition for crop (wheat) (Chakraborty *et al*. 2008). Mkhabela *et al*. (2019) reported grass mulching for improved moisture retention and high yields.

Pathogen / insect and pest control: Plastic mulching has the capacity to trap heat, which causes increase in soil. The high temperature in turn destroys some soil pathogens. Mulch is a physical barrier between soil and the above-ground portions of the plant thus reduces the risk of disease in plant. Traps (polyethylene sticky sheets mulches) play a good role in reduces or eliminate pathogen's inoculums. Highly reflective or metalized plastic mulches have been used in agriculture for many purposes and are particularly effective in reducing the entry of insect's whitefly and thrips. The reflective plastic mulch reduces the incidences of attack of aphid-borne viruses and some pest (Ranjan *et al*. 2017). All the organic mulches (wood chips, compost, and a thin wood chip layer on top of a thin vermi-compost) decreased the percentage of pathogenic nematodes (Lotze and Kotze 2014).

Impact on water conservation

Water runoff: Dry regions lands are not protected by the plant cover and rainfall during intense storms leads to soil erosion by wind and water. Adekalu *et al*. (2007) applied elephant grass (*Pennisetum purpureum*) as mulching material and observed decreased runoff and soil loss with the amount of mulch used and increased with slope. Gholami *et al*. (2014) reported significant conservation effects of straw mulching on splash erosion, runoff coefficient, sediment concentration and soil loss and also found enhancement effects on infiltration and drainage, compared with bare treatments. Plastic film mulching along with drip irrigation has been reported for retard runoff, conserve soil water and increased productivity of crop (Chen *et al*. 2019).

Water Infiltration: Tejedor *et al*. (2003) reported fast infiltration velocity in the mulched soils than was in un-mulched soil. Zhang et al. (2016) observed enhanced water infiltration by 31% and reduced soil loss by 49% with maize straw mulching of 30%, compared to the un-mulched treatment. Plastic Mulching method based on the ridges cover with plastic sheet has been observed to enhance the soil water infiltration and also water availability to the crop (Li *et al*. 2018).

Water evaporation: Application of mulch can significantly reduce evaporation and conserve moisture. Cover crops or ground cover also reduce evaporation from the soil. Application of plastic and straw mulching without tillage treatment reported the reduced soil evaporation by 9.0-17.3% and the proportion of evaporation to evapotranspiration by 8.6-17.5% compared to conventional tillage without any mulching (Yin *et al*. 2019). Abdelraouf *et al*. (2019) observed increase in crop yield with the rice straw mulch; the reason was attributed for the lowering of evaporation rate compared with non-mulching.

Water holding capacity: Mulching cover on soil surface reduces evaporation of water and increases soil water retention. Similarly, the presence of a ground cover improves water retention. Donk *et al*. (2011) evaluated that addition of mulch at any thicknesses can conserve the soil water content compared to when no mulch was used. Liu *et al*. (2018) revealed increased soil water storage from 0-40 cm with Ridge Furrows Plastic Mulching, and straw mulch slightly increased soil water storage from 0-60 cm compared with un-mulched plots.

CONCLUSION

In agriculture, mulching is the practice of leaving crop residues or other materials on the soil surface and keeping favourable and stable environments for plant growth and crop yield. The mulches used in dry land agricultures have significant effects on the soil properties, plant growth and yield. Mulching enhances water holding capacity, conserves the water in soil, reduces runoff water, and conserves the soil moisture. It poses variable effect on soil such as prevents the soil erosion, maintains the temperature, provides nutrients to the plants. It also enhances the beneficial microbial activity and helps in fighting pathogens and pests. Certain non-degradable polythene mulch or plastic mulch is of great matter of concern as cause's long-term environmental pollution. Researchers are investigating over this problem and have developed biodegradable mulch films as an alternative to non-degradable mulches. Various studies have revealed that practice of mulching application in dry land agriculture, like India, will surely boon to dry-land farmers and will bring revolution in agricultural soil and water management. It can be helpful in the development of agroforestry, horticulture, social forestry, etc.

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