Mulching as a Water-Saving Strategy and a Way to Increase Crop Productivity in Dryland Agriculture: A Review

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ABSTRACT

Owing to global warming and intermittent rainfall in arid and semi-arid areas, agricultural water supplies have been exhausted over time. Mulching has a vital effect as a water-saving technique in rain-fed crop cultivation to mitigate water stress in agriculture. It is primarily important for maintaining soil moisture, controlling soil temperature, and limiting soil evaporation, all of which have an effect on crop yield. In dryland agriculture, the most restricting factor is soil moisture. It evaporates from the soil surface and is lost by transpiration from plant surfaces. Evaporation must be stopped because it is unrelated to plant productivity, while transpiration may be decreased to a degree without impacting plant productivity. Mulching, antitransparents, and wind breaks can all help to minimize evaporation losses. Mulching has become a significant and decisive part of agricultural production in recent years. It decreases the use of herbicides and other chemical fertilizers, manages weeds, and keeps soil moisture and temperature stable. Mulches and their potential for resolving the problem in dryland agriculture are the subject of this review literature. Mulching is an effective water-saving technique in rain-fed cropping to help mitigate water shortage in agriculture. It is essential for maintaining soil moisture, preventing soil evaporation, and regulating soil temperature, all of which affect food production.

KEYWORDS: *Dryland agriculture , Mulching, Soil moisture and Crop productivity*

INTRODUCTION:

Agriculture is the largest water consumer in the world which accounts for 70% of total use (Qin et al. 2018). Among them, 80% of worldwide cropland is covered by rain-fed (non-irrigated) that produces 60–70% of the world's food (Chen et al. 2018). Considering the growing water shortage, rain-fed cultivation plays a prime interest in the worldwide food supply (Sun et al. 2012; Li et al. 2017). On the other hand, global warming and irregular rainfall patterns are responsible for the shortage of water resources which limit agricultural production in arid and semi-arid regions (Qin et al. 2015; Li et al. 2017). Thus, agriculture water management is a major concern to save water in cultivated land. It is becoming increasingly clear that the challenge of feeding tomorrow's population is to an outsized extend about improving productivity of water within present land use, as new arable land is relatively limited (Prem et al., 2017). In dryland farming rain-fed cultivation is being stressed which needed more effective consumption of water resources by using water-saving technologies (Qin et al., 2013).

Mulching helps to improve crop growth as well as yield and at the same time it optimizes water use (Yu et al. 2018). There are two types of mulches: organic or biodegradable made of organic materials and inorganic mainly made of plastic-based materials (Kader et al. 2017). These both are being popularized in recent years (Adhikari et al. 2016). Although it is still contradictory which one is best in agriculture; and research is still going on. In splash rainfall areas, plastic film mulching has been applied by ridge-furrow or raised bed system for harvest rainwater (Gan et al. 2013; Li et al. 2017). This ridge-furrow mulching system is very popular in Losses Plateau area

of China for successful cultivation of dryland crops like maize, wheat, potato, and cotton (Zhao et al. 2014; Yu et al. 2018). Moreover, erosion control is one of the important functions of mulch which is accomplished by the application of vegetative matter, such as grass, leaves, and prunings (Adekalu et al. 2007). The application of mulch can be classified as an effective soil conservation practice (Patil Shirish et al. 2013). Therefore, it is proven that the application of various organic and plastic mulches has an effect on crop production and soil hydrothermal environment in different climatic location under rain-fed conditions (Adeboye et al. 2017). Now, it is important to know the effectiveness of mulching which is equally useful and essential for soil and water conservation practices in the rainfed areas.

MULCHING :

Mulch is any covering material including either organic or inorganic applied on the soil surface to reduce evaporation losses. This material may be grown and maintained in place, or any material grown and modified before placement or any material processed or manufactured and transported before placement. Mulching is one cultural practice which can be used to addresses this problem. Mulch is any material applied on the soil surface to check evaporation and improve soil water. Application of mulches results in additional benefits like soil conservation, moderation of temperature, reduction in soil salinity, weed control and improvement of soil structure. Covering the ground with mulch saves water by preventing surface evaporation (Patil et al., 2013). The layer can also greatly reduce or eliminate weed propagation, which will also result in higher water use efficiency. Wheat straw, grass clippings and leaf debris are fairly abundant byproducts. Many producers already generate these mulching materials and currently spend resources to dispose of them. Mulching using this waste is a cost effective practice which would conserve water, moderate soil temperature, reduce waste and improve the soil health.

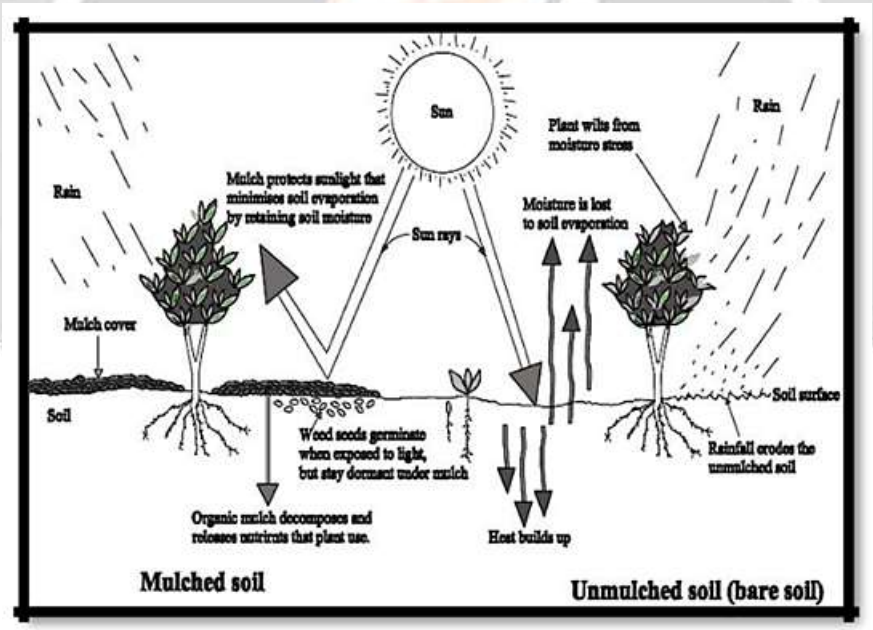

Fig 1: Advantage of mulched and un-mulched soil interactions with plant and environments (Kader et al., 2017)

SELECTION OF MULCHING IN DRYLAND AGRICULTURE :

Mulching is very helpful in conserving soil moisture in dryland areas after reducing the rate of evaporation (Kader et al., 2017; Zribi et al., 2015). Plastic mulch having moisture barricade properties does not allow escape of soil moisture, because the moisture evaporates beneath the mulch film, after condensing, gone back into the soil as water droplets. Thus, moisture is conserved for many days, that's why increases the irrigation period and lessens the irrigation demand during period of crop cultivation (Yang et al., 2015; Kader et al., 2017). Plastic mulching is much effective as compared to straw mulching for soil water conservation (Li et al., 2013).

EFFECTS OF MULCHING :

Mulching improvises soil productivity, soil ventilation around the plant, aggregates the soil particles and drainage of excess water (Kader et al., 2017). There is a lot of benefit of mulching in crop fields like reduction in loss of soil

water, soil erosion, growth of weeds, kinetic energy of water droplets and competition between the surrounding fields for nutrients and water (Yang et al., 2015; Kader et al., 2017). Mulch can be helpful in improvising soil structure and steering of nutrients due to movement of earthworm into the soil (Qin et al., 2015). It also let down the soil pH which augments availability of nutrients. Organic mulch adds nutrients in the soil after break down and increases the availability of nutrients for long time within soil (Larentzaki et al., 2008). Plastic mulch entertains as impermeable to the gassy movement which act as a greater wall for the process of solarization and fumigants. It can also show an astonishing role in increasing soil health and control of pests (Chalker-Scott, 2007). Consequently, it supports in keeping the nutrient around the root of plant for effective use of nutrient and also helps in reduction of leaching of fertilizer. The uniformity in look all over the mulched landscape are more appealingly (Li et al., 2013; Chen et al., 2018). Furthermore, in the different stages of growth of crops there is a viable changing in the appropriateness of soil moisture and temperature. After decomposition of organic mulch in the soil, the organic material of soil enhances rapidly and consequently increases the water holding capacity of the soil (Kader et al., 2017). Some other benefits are described below:

Moisture Retaliation in the Root Zone

Due to slow down in evaporation done by mulches, more moisture is being available nearby the plant roots and also more time available for plants to take the water. So, area covered with mulch requires less application of water (Ranjan et al., 2017).

Soil Structure Improvement

Organic mulches as well as bio-degradable plastic mulches ultimately collapse and augment nutrients to the soil surface, improvement in moisture retention capacity and increment in the humus layer.

Soil Temperature Stabilization

The fluctuation in temperature is governed by mulches in the plant's root zone, which resulted in the cooler soil in summer and warmer soil in winter season.

Soil water and nutrient storage

Ambient temperature and precipitation level during the two growing seasons were almost similar to the long-term average without large variations. Averaged across the soil depths, the soil water content gradually decreased in both treatments from the early growing season, irrespective of N fertilization rates. However, the soil water content was more efficiently preserved in the mulching treatment as compared with CT. The soil water content increased dramatically during irrigation, thereafter, the soil water content fell dramatically particularly in the top 0–20 cm soil layer across treatments. At the flowering stage of cotton, soil water content was higher by 16.4–13.5% under the mulching treatment than that of the CT. Similarly, at the boll formation period, the preserved water content in the soil was greater under mulching treatment than that of the CT. The soil water storage under mulching treatment tended to be higher by 59.8, 47.3, 40.0 mm in the flowering, boll formation and ripening stages of cotton, respectively compared to the CT. There was no significant difference in the soil water storage values between the two treatments after boll ripening period. After the long-term experiment on the impact of crop residue mulching under arid condition, Boboev et al. (2019) revealed considerable higher moisture storage in the root zone of cotton. While working on the effect of mulch in the dryland cropping system, Yan et al. (2019) found that mulch substantially decreases water evaporation from soil surface.

Water saved by mulching

Mulching is a water-saving technique in dryland areas for conserving soil moisture, regulating temperature, and reducing soil evaporation (Yang et al. 2015; Kader et al. 2017). Surface mulching is widely practiced as water conservation technique in rain-fed farming systems (Zribi et al. 2015). Plastic sheet mulch is more effective for conservation of soil water than that of wheat straw mulch (Li et al. 2013). The main strength of mulching is to conserve soil moisture by reducing surface evaporation and controlling soil erosion (Qin et al. 2015). Basically, mulching conserves soil water by reducing soil evaporation and regulating soil temperature which decreases irrigation demand during crop cultivation periods (Kader et al. 2017). Soil water and heat transfer mechanism under the mulching is important to increase the availability of the system for efficient use of mulching (Li et al. 2017; Kader et al. 2019). It is still unknown in what amount of water saved by mulching which is critical due to interaction of microclimate, soil environment, and plant growths (Steinmetz et al. 2016).

Impact of mulching in crop productivity:

Gangwar et al.(2000) reported that paddy straw mulch on mulberry showed maximum leaf yield (46%)compared to sorghum (32.4%) and blackgram mulching (23.08%) over control. Gao et al. (2001) reported that the nutrient paper mulching promoted flower bud differentiation enhanced yield and improved fruit quality in tomato as compared to the plastic mulch or no mulching. Uppal et al. (2001)observed that mulched

tubers of potato contained about 46 per cent less reducing sugars compared to normal crop. Nagalakshmi et al. (2002) obtained the maximum number of fruits per plant (97.67),length of fresh fruit (6.93 cm), circumference of fruit (3.57 cm) and yield of chilli (8.60 t ha^{-1}) with the application of black LLDPE mulch compared to organic mulch and no mulch. chawla (2006)obtained highest number of flowers per plant(53.45), average flower weight (47.21 g/ 10flowers), maximum flower diameter (5.47 cm) and highest flower yield (11.66 t ha-1) in marigold cv.Double mix with application of black LLDPE mulch compared to white LLDPE mulch, organic mulch and no mulch. Shashidhar et al. (2009) reported that the total leaf yield of mulberry was found maximum in paddy straw mulched plots (15.20 tha-1) as compared to control plots (11.78 t ha^{-1}).

NEGATIVE IMPACTS OF MULCHING

There are also some negative impacts of mulching such as more labor requirement, higher transportation charge, removal and disposal problems etc. The plastic film has intimate contact with soil which creates fragment and contaminants to soil (Steinmetz et al. 2016). Many types of organic mulching such as grass and straw contain seeds that may allow to grow weeds and release acid to soil (Chalker-Scott 2007; Patil Shirish et al. 2013). Moreover, organic mulch material especially newspaper is affected by wind. Constant moisture content, higher temperature, and better aeration of the soil tend to favor higher microbial biomass in the soil thus ensure more complete nitrification under mulched soil (Huang et al. 2008). Soils are heavily contaminated with the films which are disposed by farmers through on-site land filling and burning (Gonzalez-dugo et al. 2014). The plastic film fragments are discarded and buried in the arable layer which retards crop growth.

CONCLUSION

Mulching has become a common water conservation technique in modern agricultural production in arid and semi-arid areas. The mulch content protects the soil surface from direct sunlight, reducing evaporation and altering soil temperature. Water utilization within the soil root zone is a vital phenomenon for increasing water quality and conserving water supplies by mulching. Mulching is also responsible for the beautification of farmlands in addition to being a water-saving technique. Mulch material selection is primarily determined by availability, environment, durability, and cost-effectiveness.It must also be environmentally viable in order to be used indefinitely. As a result, it is concluded that various mulching materials can be used to conserve water in agriculture, resulting in increased crop yield in rain-fed agriculture.

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