Mulching and Nutrients Use Efficiencies in Plant

Mukkram Ali Tahir, Noor-us-Saba, Amir Aziz, and Adeel Ahmad

Abstract Rapid urbanization and industrialization have resulted in an increased global temperature over the year. Consequently, the agro-ecological system disturbing worldwide. Therefore, new agricultural practices that are eco-friendly are needed. Mulching could potentially serve the purpose by conserving moisture, reducing weed growth, reducing soil evaporation, improving microbial activities and controlling soil temperature. Additionally, mulches could provide environmental and economical advantages to agriculture and landscape and enhance the nutrient status in soil. This review chapter focuses on multiple significant impacts of mulches on nutrient use efficiencies in the plant. Secondly, discuss problems regarding nutrients use efficiencies and loss of nutrient from soil system and also discussed strategies to improving nutrient use efficiencies. This discussion leads to improve the nutrients use efficiencies in the plant by mulching.

1 Background

The Agricultural and food industry made huge progress in the last five decades throughout the world (Alexandratos, 1999). In the coming fifty years it is estimated that the population will increase continuously and consequently the demand for soil, water and nutrients will also increase to fulfil the food requirements of people (Godfray et al., 2010; Tilman et al., 2001). Therefore, it is a need of the hour to boost the productivity of agricultural goods. Mulching is an important practice used in agriculture for increased productivity and nitrogen-containing fertilizers have also been used (Qin et al., 2015; Tilman et al., 2002; Wang et al., 2016). It is also necessary to minimize the environmental risks caused by modern agriculture. That's why it is

M. A. Tahir · Noor-us-Saba · A. Aziz (✉)
Department of Soil and Environmental Sciences, College of Agriculture, University of Sargodha, Sargodha, Pakistan
e-mail: amieazizuos@gmail.com

A. Ahmad
Institute of Soil and Environmental Science, University of Agriculture Faisalabad, Faisalabad, Pakistan

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essential to discuss the impacts of nitrogen fertilizers as well as mulching on the soil along with the requirement of the plants. Presently mulching is used for the cultivation of many crops namely maize, rice, wheat, potatoes, barley, sunflowers, groundnuts, hairy vetch, coffee, okra, turmeric, green grams, rosemary, mint, fruit and vegetable trees (Alliaume et al., 2017; Li et al., 2001; Liuet al., 2014a, 2014b; Nzeyimana et al., 2017; Qin et al., 2014; Singh, 2013).

In general, nitrogen fertilizer and mulch application show the best performance in terms of agricultural production (Fan et al., 2005; Liu et al., 2014a, 2014b; Mo et al., 2017; Rahman et al., 2005; Wang et al., 2015). Application of N fertilizers plays a vital role in improved crop yield but excessive use is imparted negative effects on soil health (Han et al., 2015; Xu et al., 2012). Therefore, it is necessary to consider the impacts of N fertilizers on the crop, soil and the environment. The main sources of nitrogen are both organic and inorganic namely crop stubbles, farmyard manure, compost, biological fixation, urea, ammonium bicarbonate, ammonium nitrate, ammonium hydroxide and ammonium sulfate respectively (Agehara & Warncke, 2005; Crews & Peoples, 2004; Das & Adhya, 2014). The available forms of N are NO_{3^-} and NH_{4^+} in dry soil and flooded soils respectively (Krapp, 2015; Xu et al., 2012).

2 Importance of Nutrition for Plants

The nutrient requirement of plant is similar as for animals. The nutrients are important for seed germination, plant growth, and insect pest resistance and reproduction. For plant, health nutrients are required in variable concentrations (Sainju et al., 2008). In plants nutrients play different roles like these are the building blocks of cells, it modifies the osmotic as well as turgor pressure, metabolic reactions and enzymatic activities. These all functions must be performed smoothly to improve the plant yield (Zhao et al., 2016). The nutrients that are essential for plants are seventeen in number. Among these nutrients that are required in higher quantities are called macronutrients (N, P, K, S, Mg, and Ca. However, those required in lower quantity are called micronutrients like Fe, Mn, B, Mo, Cu, Zn, Cl, Co. It is not possible to recognize the knowledge of plant nutrition. This is because plants have many species and all species are variable from each other. If the nutrients are not available according to the need of the plants this may lead to nutrient deficiency. On the other hand, if these nutrients are present in excess of plant need this may lead to nutrient toxicity. Moreover, there is the possibility that excess of one nutrient may suppress the other nutrient like excess of ammonium ion may suppress the uptake of potassium ion (Norman & Hunter, 2008). The concentration of nitrogen in the atmosphere is 78% and this atmospheric nitrogen is now changing to available form through nitrogen fixation. But plants mostly meet their nitrogen requirement from the soil. The nitrogen present in the soil is in most plant-available form. Though the nitrogen in the atmosphere is in higher concentration its utilization demands a lot of energy to change it into a plant-available form. The plants that fix atmospheric

nitrogen are mostly beans, gram, alfalfa etc. However, rice, wheat, cotton and other commercial crops uptake nitrogen from soil (Wang et al., 2017).

3 Problems Regarding Plant Nutrition

In developing countries, the loss of soil fertility is now becoming serious environmental degradation and affect the crop yield to a higher extent. The main causes of fertility losses are nutrient diminution and nutrient depletion. This may affect food production and consequently the lives of many people. Due to fertility loss water holding capacity of oil is affected and results in drought condition (Bodner et al., 2007). Soil fertility is an important factor for farmers and the whole ecosystem. The main purpose of a farmer is to sustain the fertility of his soil. This purpose can only be achieved by improving soil structure, proper airing, appropriate soil moisture, suitable pH and favourable nutrient concentrations. To manage such a vast system is very difficult. The soil fertility can be enhanced or decreased depending upon the cropping pattern, number of animals rearing on the farm and management practices. It is concluded that if we want to sustain soil fertility, a balance should be maintained between nutrient removed and replaced in each crop rotation (Souri & Hatamian, 2019).

4 Losses of Macronutrients

The deficiency of nitrogen causes slow growth, chlorosis and stunted growth. Plants having nitrogen-deficient accumulate anthocyanin pigments and result in the appearance of the purple stem, underside of leaves and petioles (Norman & Hunter, 2008). Deficiency of phosphorus shows the same symptoms as nitrogen deficiency characterized by more reddish or green colouration due to lack of chlorophyll in leaves. The plant leaves become denatured and show sign of death if the plant faces a high deficiency of phosphorus and leaves of the plant appear purple due to anthocyanin accumulation. According to Russel, deficiency of phosphorus fifer from deficiency of nitrogen and it is very difficult to diagnose the phosphorus deficiency. The deficiency of potassium causes necrosis or interveinal chlorosis. This deficiency leads to wilting, pathogens, brown spotting, and chlorosis and plant damage from heat and frost. Potassium deficiency affects older tissues and then progress toward growing points. Acute deficiency of potassium affects growing points, reduce growth in diameter and height, and reduced the needle length (Heiberg & White, 1950). Calcium deficiency affects the newly developed cell in the root system. Biological and root functions disrupt even short term disruption in calcium supply. Leaf curling is common symptoms of calcium deficiency that moves toward the centre of the leaf. Sometimes leaves have a blackened appearance. Leaves tips mat appear cracking and burned by the deficiency of calcium if they face sudden humidity increase. Calcium deficiency mostly arises

in tissues causing blossom end rot (watermelons), tomatoes and peppers, bitter pits in apple and empty peanut (White & Broadley, 2003).

5 Losses of Micronutrients

Molybdenum (Mo) deficiency usually occurs in older growth. Iron (Fe), Copper (Cu) and Manganese (Mn) affect new growth, causing yellow or green veins. Zinc (Zn) can affect new or old leaves and Boron (B) seems on terminal buds. Due to reduced internodal expansion, plant leaves on top of each other in zinc deficiency. For industrial crop cultivation, the most widely deficient plant nutrient is zinc, followed by boron. The deficiency of boron affecting pollen fertility and seed yields are common in laterite soils. For cell wall strengthening and proper forming, boron is essential. Due to boron deficiency, short thick cells produced stunted roots and fruiting bodies. Boron deficiency results in stunted growth and death of the terminal growing points. The deficiency of boron can be fined by analysis of plant material. Boron deficiency in strawberries will produce lumpy fruit and apricots will drop their fruit or not fruit depending on boron deficient level. Foliar application of boron is immediate but must be repeated and broadcast supplements of boron are very effective and long term (Heiberg & White, 1950).

6 Strategies for Improving Nutrient Use Efficiencies

6.1 Crop Variety/Species

With the help of plant breeding and genesis, we can increase the nutrient use efficiency by selecting those species/genotype of plant that is more efficient to the uptake of plant nutrients from the soil system. Generally, genotype closely linked with extensive and efficient root system or effective associations with mycorrhizal fungi in order to access the volume of soil (Ramaekers et al., 2010).

6.2 Rate and Time of Fertilizer Application

With the help of the right time and right rate application of fertilizer, we can enhance nutrient use efficiency. The best time of application of fertilizer (P) is at sowing time. In sandy soil, fertilizer can be applied in the split application. The rate of application of fertilizer is very important to nutrient use efficiency. Adding fertilizer to a soil system that already has a sufficient amount of plant is wasteful and lead to nutrient

losses to water bodies. Soil testing is the only way to find the correct rate of fertilizer requirement along with other agronomic considerations (Roberts, 2007).

7 Mulching and Its Importance in Plant Nutrition

Mulching is important in plant nutrition, it is because:

- Mulch prevents the compaction of the soil.
- It also reduces lawnmower damage.
- It also keeps weeds out to help to prevent root compaction.
- It also retains water that helps to moist the roots.
- It also provides a buffer from cold and heat temperature.

Soil moisture conditions may improve by the use of mulch on the top surface of the soil. Mulch also increases the yield of crop by improving soil physical conditions. As compared to um-mulched soil, different types of mulch material increase the soil moisture and ultimately decreased the evaporation rate from the surface of the soil (Maged, 2006). Mineral mulch is more effective to impervious water vapour and expected to conserve the moisture of soil as compared to organic mulch (Lei et al., 2004). Tillage and mulching used in combination also increased soil water conservation. Mulched soil, almost 0–60 cm soil layer contains more moisture content as compare to un-mulch soil (Ramakrishna et al., 2006). By the use of mulch, the greatest reduction in soil moisture content showed in soil; 92% soil moisture content at 10 cm soil, 83% soil moisture content at 5 cm soil and 52% soil moisture content at 2 cm soil (Diaz et al., 2005). Some researchers also experimented in the laboratory to check the effect of gravel mulch on evaporation (Mellouli et al., 2000). By this research, soil surface covering with gravels and coarse sand can reduce 10–20% evaporation as compared to un-mulched soil. Soil surface area available for evaporation decreases by the use of gravel mulch material. In many crops, mulching increased productivity by conserving the soil moisture (Huang et al., 2005; Rahman et al., 2005; Zhang et al., 2005). While mulching material also controlling the growth of weeds (Erenstein, 2002). In wheat crop, uptake of water is increased by using mulch combined with an irrigation system (Li et al., 2004). Mulch decreases capillary diffusion during the first stage of evaporation and water moves mostly vapour phase from the soil surface to mulch surface (Li, 2003). On the other hand, mulch also reduces the evaporation of water from the soil by shading the surface of the soil from the sun (Shading is most effective when soil is wet during the first stage of evaporation). Different type of mulch also affects soil temperature. Furthermore, researchers found that the mulch influenced the temperature of soil (Kar & Singh, 2004).

7.1 Decline of Weeds

In nursery and field conditions, mulching is an important tool for controlling the population of weeds. However, the weeds reduction phenomenon is not fully understood till now. But weeds the population reduces 92% as compared to non-mulched soil. Mulch act as a barrier and cannot light pass, resulting in reduced the small seed of weed germination after the spread of mulch on the surface of the soil. Researchers also found that almost fifteen different types of mulches were used and results that there were no significant differences between all types of mulch but a huge difference exists for weeds reduction when compare with non-mulched soil (Kader et al., 2019). Mulches act as a physical barrier to the emergence of weeds. However, weeds seed quickly come out of the surface of the soil when decomposed the organic mulches (Ahmad et al., 2015, 2020). Some mulches create an environment that is very beneficial for microbes (Chalker-Scott, 2007).

In different mulch materials, by using organic and inorganic mulch materials at adequate soil depth are used widely for the reduction of weed control and these materials help to prevent the soil from compaction. On the other hand, inorganic mulch materials (gravel and stone mulch) avoid weed species colonization when used at 4 cm depth of soil. Organic mulches control the colonization of weed in different ways. Compost (organic mulch) does not control the weeds because compost is full of nutrients and fertile the soil (Maclean et al., 2003). A thick layer of mulch material reduces the seed germination otherwise, a thin layer of mulch material enhance the germination of weed seed (Rokich et al., 2002). Sawdust thick layer will be helpful for the exchange of gas and water (Stenn, 2005). Mulching also reduces the penetration of light that helps to stop the photosynthesis process in weeds and ultimately weeds cannot use nutrients from the soil. So mulching is the best strategy to save the pant nutrients to the uptake of weeds (Ahmad et al., 2015, 2020).

7.2 Soil Moisture Conservation

Some factors (abiotic) are responsible for the loss of plant nutrients and soil moisture and convert it into barren land. These factors including harsh climate conditions, high winds, temperature level elevation and competing plantation. It has seemed that up to 25% water loss due to the presence of weeds by the process of evapotranspiration. On the other hand, straw mulch decreases the evaporation rate by 35% (Harris, 1992). A few advantages of mulching have been shown in Fig. 1.

Organic and inorganic mulches have conserved the water of soil as compared to synthetic and barren soil (Lakatos et al., 2000). Generally, plant residues, livestock wastes and different types of stone gravels are used to retain soil moisture (Siipilehto, 2001). The irrigation requirement of pants can be reduced and sometimes the need for irrigation can be finished by the use of mulches (Kader et al., 2019; Iqbal et al., 2019). Surface runoff of water also reduces by used straw mulch up to 43%. Supplemental

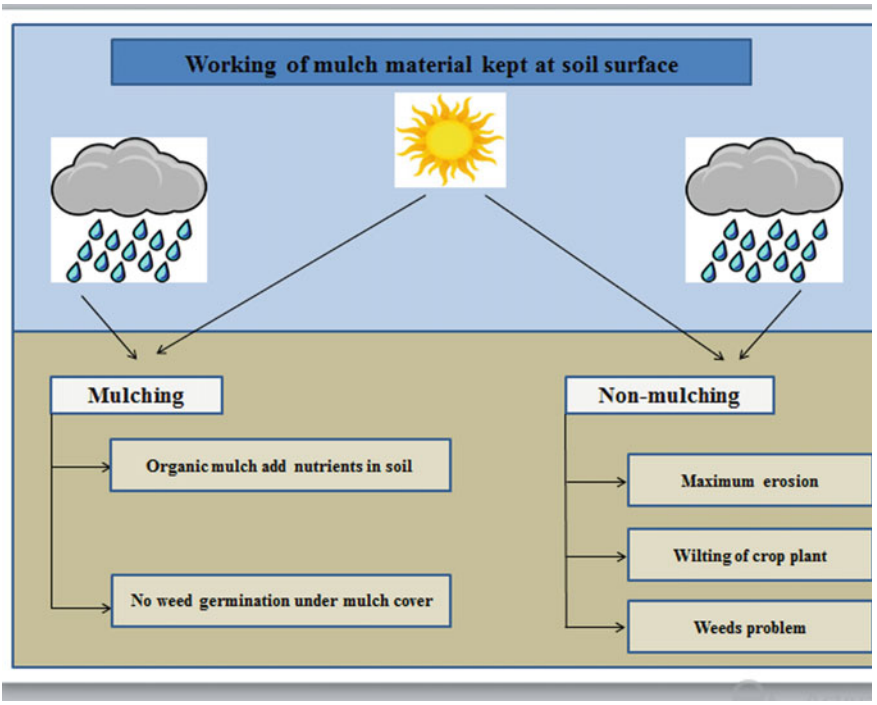

Fig. 1 Working of mulch material kept at the soil surface

irrigation is also reduced by the use of mulches. It is because water runoff decreases and water retention ability increases (Smith, 2000).

8 Role of Mulching to Reduce Nutrient Losses

8.1 Minimizing Soil Compaction and Erosion

Soil can be protected from water and wind erosion with the help of mulching material and also reduce the soil compaction which can negatively affect the plant roots and consequently decrease plant growth. Some legumes and grasses are used as living mulch. Grass growing (Living mulch) on slopes reduces the erosion of soil by aggregating the soil particles and makes a complex unit (Tanavud et al., 2001). Mulch material increases the rate of infiltration and also maintain the slope stabilization n hilly areas (Chalker-Scott, 2007). We can solve the compaction problem by the addition of organic mulch (Fig. 2). The researcher suggested that before the development of soil compaction, mulching should be performed. There will be no improvement in the soil after the compaction of soil by mulching (Oliveira & Merwin, 2001).

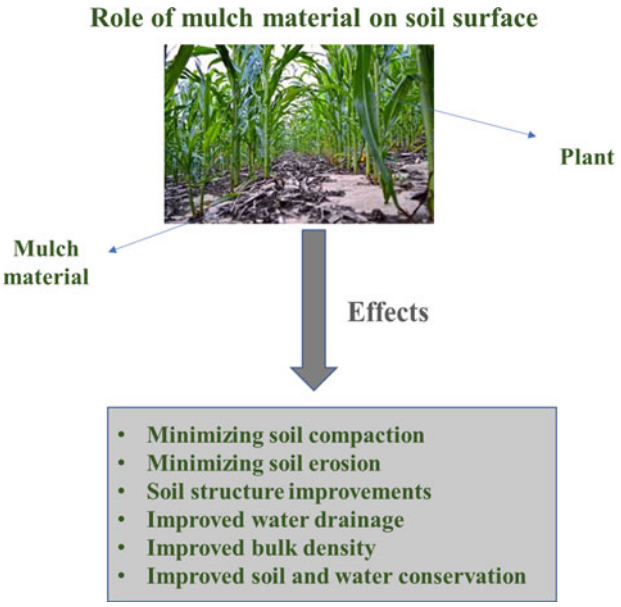

Fig. 2 Role of mulch material on soil surface

8.2 Soil Temperature Regulation

Soil surface covers by mulch and it's helpful to maintain the temperature of soil that is beneficial for the growth of the crop. Researchers found that soil remains cool during a very hot climate by the application of mulch (Kader et al., 2019; Long et al. 2001) while on chilling days soil remain warm/normal (Kader et al., 2019). High temperature adversely affects the nutrients and water uptake and also affects the newly growing roots. Newly plant roots are not able to uptake plant nutrients and adequate amount of water at high-temperature condition (Chalker-Scott, 2007). Therefore, soil temperature regulation is a very important factor for the growth of the plant. However, mulch decreases the 10 °C temperature in a dry and hot climate as compared to barren soil. To control the soil temperature, course mulch is more favourable as compared to fine ones. Different type of mulches is used to control the soil temperature. Some mulch (living mulches) increase the soil temperature due to solar radiation absorption as compared to barren soil (Montague & Kjelgren, 2004). Moreover, Researchers observed that organic and living mulch materials perform better in maintaining soil temperature as compared to other types of mulches. Living mulch decreases the soil temperature through increase evapotranspiration due to its cooling effect by evaporation effect (Montague & Kjelgren, 2004).

9 Influence of Mulching on Nutrient Use Efficiencies

For mulch selection, it is very important to know that how soil will be explored by the application of mulching. By organic mulches applications, we achieved more root density and development as compared to synthetic mulch, living mulch and un-mulch soil (Fausett & Rom, 2001). Some synthetic mulch material (film and sheet) perform as barriers to air and water which enhance root growth. Organic mulch performs best as compared to other mulches, it is because organic mulch provides water and nutrients to newly grown plant roots. If the root of plants successfully grows, then increase the survival of transplanted seedling under nursery and field conditions (Ansari et al., 2001). In early study, some researchers perform experiments and the outcomes of the study are the mulched crop performed better as compared to the control treatment. Turf mulch used as a competitive cover crop and also reduced plant growth rate as compared to un-mulched soil (Cahill et al., 2005).

10 Conclusion and Further Directions

It is clear from the above discussion that mulching has a strong influence on nutrients use efficiencies in the plant. The application of mulch not only conserves soil moisture, reduces soil evaporation, influences soil microorganisms, control soil structure and temperature but also improves soil moisture retention which is of great concern to any crop. It is necessary to understand the effect of various mulching material on crop yield, soil environment and nutrient use efficiency. Plastic mulching materials are more efficient than organic mulches. However, organic mulching materials are environmentally friendly, inexpensive and beneficial to soil microorganisms. Furthermore, mulching mitigates disease, insects and weeds and can further improve nutrients use efficiencies. In the future attention could be focused to accelerate crop production by further improving nutrients use efficiencies by using organic and inorganic mulches in combination, as organic mulches will enhance the organic matter of soil in addition to the improvements made by inorganic mulches.

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