Environment and Ecology 41 (4A): 2452—2459, October—December 2023
Article DOI: https://doi.org/10.60151/envec/ZQQJ1938
ISSN 0970-0420

A Review on Live Mulch for Better Agriculture

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Received 16 May 2023, Accepted 17 August 2023, Published on 31 October 2023

ABSTRACT

Living mulch is an eco-friendly practice of growing fast growing leguminous crops in the interrow spaces of a crop with an objective of weed suppression, thereby reducing the use of herbicides for sustainable agriculture. It reduces the negative impacts of intensive agriculture such as land degradation and is a practical way to boost agroecosystem biodiversity. Other benefits include increase in organic carbon content and available nutrient content, improvement in water holding capacity, reduction in soil erosion and pest and diseases. The selection of live mulch species is an important factor with respect to the main crop for reducing the crop- live mulch competition. It suppresses the weeds by shading, competes for light and below ground resources and allelopathy.

Keywords Competitiveness, Live mulch, Soil health, Weed suppression.

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INTRODUCTION

Agricultural production needs to increase 60% by 2050 to feed the growing global population. Over the years improvement in crop yields have noticed, but not much pronounced. At the same time, there is much pressure on farmers to enhance crop yields to ensure food security. The most urgent issues related to intensive agriculture are the land degradation and an overreliance on herbicides (Mortensen *et al.* 2012). It is challenging to address these issues in a way that is compatible with the infrastructure that already exists and the demand for higher yields (Foley *et al.* 2011). There are no possible 'silver bullet' fixes to attain sustainability. Live mulches are one among the eco-friendly agricultural practices for the sustainable crop production.

Live mulch

Living mulches are crops grown along with the main crop which can suppress the growth of weeds through fast growing nature without causing reduction in crop yield (Bhaskar *et al.* 2021). Live mulches have a greater suppressive effect on all weeds than crop residues used as mulch. Oyeogbe *et al.* (2017) opined that live mulches are effective in suppressing the weeds and improving the soil fertility through biological N fixation. It suppresses the weeds mainly by shading, competes for light and below ground resources and allelopathy (Petit *et al.* 2018). In direct seeded rice, *Sesbania rostrata* as live mulch resulted in a notable reduction in weed density and dry weight compared to control (Singh and Kumar 2020). Unlike other cover crops, live mulches can be advantageous throughout the entire growing season. Living mulches are a practical way to boost agroecosystem biodiversity and energy efficiency because they don't necessitate a total redesign of the cropping system (MacLaren *et al*. 2020, Petit *et al.* 2018). Live mulches help to prevent the degradation of land by reducing soil erosion and leaching, and by improving the health of soil (Hartwig and Ammon 2002). In addition, it provides strong weed suppression and also allow for a reduction in herbicide use (Hartwig and Ammon 2002, Teasdale *et al*. 1998, Verret *et al.* 2017). Live mulches can be included in non-chemical weed management and organic programs.

Live mulch species

The species selected as live mulch should establish more rapidly than weeds and its peak period of growth coincides with emergence of weed and should not coincide with the crop emergence. It should have higher competitive ability against weeds with short growth habit. It should be manageable and shouldn't hinder the main crop canopy. Ideally, the live mulches and main crop species should be of different families so that pest incidence can be minimized by maintaining the functional diversity.

Common living mulches : Plants commonly used as living mulches are cowpea, sesbania, sunhemp, horse gram, buck-wheat, alfalfa, sorghum Sudan grass.

Benefits of growing living mulch

The common benefits of growing living mulches are increase in organic carbon content, increase in nutrient content, improvement in water holding capacity, weed suppression, reduction in soil erosion, pest and diseases.

Effect of live mulch on weed control

Mechanisms of weed suppression

Live mulch deals with various types of weeds grow underneath the main crops. Live mulches compete with the weed plants for nutrients and their survival resulting the weed plants to starve and die. Shading or light interception is one of the effectual ways to control weed germination because most of the weed seeds will not germinate unless and until the required light is met (Batlla and Benech-Arnold 2014). In rice + cowpea cropping system (5:1), rapid growing cowpea suppressed the weed population by blocking the light from reaching the ground (Singh and Singh 2017). Live mulches control weed growth by lowering the intensity of light that reaches the soil's surface, as well as the ratio of red to far-red light.

Like shading, water use is another potential weed control mechanism. Actively growing live mulches can cut down the moisture access to weeds. Shallow-rooted weeds are more affected by the changes in water availability than deeper-rooted crops. Live mulches can limit the water availability to maize, although the water availability by different seasons and the effects on crop yield differ across studies (Bartel *et al.* 2020). Studies in wheat and asparagus revealed that living mulches don't necessarily result in yield reduction under restricting soil moisture (Brainard *et al.* 2012). An ideal live mulch system would control the weeds by various mechanisms without necessarily restricting the availability of resources to the primary crop.

Allelopathy and direct competition together have very effective control on weeds. According to Rueda-Ayala *et al.* (2015), competitive and allelopathic interactions reduced the weed biomass when different grasses or legumes were under-sown in pots of barley and wheat. Additionally having competitive and allelopathic effects, live mulches frequently alter the arthropod populations (Hooks and Johnson 2003). Positive and negative effects of these alterations remained to be determined, but one effect that already evident was rise in the density of seed predators when compared to plain ground and residue mulch (Blubaugh and Kaplan 2016).

An ideal living mulch system would control weeds using a variety of strategies while not significantly reducing the resources available to the primary crop. Understanding the effects of living mulches at various below- and above-ground heights and interpreting those effects in the context of weed and main crop biology are necessary for developing such systems. The competition for N in living mulch systems has frequently been the focus of experimental research. A useful step forward might be to put more emphasis on non-competitive weed-suppression strategies and competition for other resources. In maize- wheat cropping system under different weed management practices shown that cowpea live mulch in maize resulted in the highest system productivity. The results clearly showed that maize + cowpea treatment resulted in lower weed index due to the smothering effect of cowpea live mulch on weed growth. Therefore, it is suggested that maize can be intercropped with short lived legume like cowpea which lowers the weed density with little to no effect on maize yield (Singh *et al.* 2015).

Indicators of living mulch competitiveness

Living mulch biomass, live mulch cover and height are the indicators of living mulch competitiveness. Weed control frequently rises with cover crop residue biomass in non-living mulch systems (Osipitan *et al.* 2018). Research on living mulches indicated a conflict between the biomass of living mulch and that of weeds (Tarrant *et al.* 2020). The ratio of living mulch to main crop biomass can be used as a measure of weed control effectiveness to demonstrate the link between weed management and the possibility of competition with main crops (Lorin *et al.* 2015). Coverage of live mulch is a significant factor of weed control, like biomass. In a young, uncompetitive, or suppressed stand, coverage of live mulch is the best indicator of weed control (Bartel *et al.* 2017). Combined cover of live mulch and the main crop is the most precise indicator of weeds' access to its resources (Uchino *et al.* 2009). According to Pouryousef *et al.* (2015), increased density of live mulch may produce earlier season cover and subsequently enhance weed control. Generally, small live mulches are less likely to affect main crop yields than tall live mulches. The main crop yield was significantly influenced by the height of the living mulch, whereas weed control is strongly correlated with the biomass and growth rate of the living mulch (Den Hollander *et al.* 2007, Leoni *et al.* 2020). This was because relative heights frequently predict the results of crop-mulch competition. The competitive effects of short plants have thus been the focus of living mulch breeding plans (Moore *et al.* 2019).

With live mulch, it was relatively simple to keep weeds under control, but more challenging to do so without allowing too much competition between the mulch and the crops. Living mulches don't necessarily have to be more harmful than an equivalent mass or density of weeds to reduce the crop yields. Elevated total non-crop (including weed and live mulch) biomass is generally responsible for yield losses. Although live mulches are chosen and managed to minimize competition against the main crop, they may have a less negative impact on the main crop than weed biomass. According to Chase and Mbuya (2008) compared to the weedy control, the total biomass of *Brassica oleracea* L., the non-broccoli plant, was larger in living mulch treatments, but the yield of broccoli was comparable. In a one - year trial of broccoli grown with common purslane, a higher broccoli yield was obtained from the live mulch treatment than the chemical treatment (Ellis *et al.* 2000). With the growth of the living mulch, the competitive effects on other species become more pronounced. Height of live mulch is especially important to main crop yield, whereas living mulch biomass and cover generally have a negative correlation with weed biomass.

Living mulch management

Living mulch system management is a difficult subject. Weeds can also be eliminated and living mulches can be stifled using chemical or mechanical methods. Both weed management and main crop yield are improved by effective management programs. Life cycle and planting season of live mulches have an impact on weed control and competition with the primary crop. Annual live mulches work well with a range of crop rotations and management strategies. They can effectively suppress weed growth if they establish quickly. Although planting annual living mulches earlier can help in weed control, it also raises the possibility of yield losses (Brainard and Bellinder 2004). In contrast, lately planted living mulches typically have minimum impact on weeds and major crops. When other weed control techniques have been used at the early weeks of growing season, planting live mulches later may be the best (Montemurro *et al*. 2017). For instance, Brainard and Bellinder (2004) discovered that when live mulch of winter rye planted with broccoli transplanting, provided some weed management but decreased the yield of broccoli. When the rye was planted at 10 or 20 days after transplanting (DAT) with one or two cultivations (either at 10 or 10 and 20 DAT), both the weed control and broccoli yield were increased. Drilling of live mulch later can reduce weed density by the disturbance when it is placed between crop rows (Gerhards 2018). Therefore, late planting of annual live mulches was found better for weed suppression.

Weed species and communities

It has been shown in numerous studies that different weed species may respond differently to living mulches. Compared to grassy weeds, broad leaved weeds are more controlled by the living mulches. Leoni *et al.* (2020) stated that legume live mulches help to supress both broad leaf and grassy weeds in the first year, but they were not enough to reduce the grass weed pressure that increased in the second year of vegetable production. Although there are few management options for grass weeds, living mulches can also help to control them. Grass weeds can be controlled more successfully by the selection of live mulch and herbicide combinations specifically for the purpose (Nurse *et al.* 2018). Live mulches that lower weed seed production may aid in preventing significant weed issues in upcoming growing seasons. A significant benefit of live mulches over any crop residue mulch is their capacity to decrease the production of weed seeds. Living mulches have a big impact on the diversity and makeup of weed communities. According to research by Barilli *et al.* (2017), winter wheat with lucerne live mulch reduced the biomass of weeds under conditions of reduced till but it enhanced the diversity of weed community (in terms of evenness, richness, and the Shannon diversity index).

The diversity of beneficial arthropods also tends to increase with the increase in weed diversity. Hiltbrunner *et al.* (2007) discovered that weed density and species richness were generally higher in the control treatment than in the live mulch treatments while testing the effects of different live mulches for winter wheat. Broad leaved or annual weeds are more likely to be suppressed by living mulches than perennial grass weeds, but these overarching trends do not account for all species-level variation. Strongly suppressed weed species produce fewer seeds. In living mulch systems, weed communities consequently change in favor of species that are less impacted.

Effect of live mulch on soil health

Live mulch helped to maintain soil moisture, reduce soil erosion and to improve the soil physico-chemical properties. Among all the soil nutrient parameters, soil organic matter plays a vital part in the soil productivity.

Reducing soil erosion

Live mulches are extremely important for preventing soil erosion. It reduces the ability of moving water to carry soil by slowing its motion and aids in stabilizing the soil particles in the live mulch root system. Live mulches also increase the water holding capacity by improving pore structure, and preventing large amounts of water from moving across the soil surface. The fibrous root systems of crop species, such as oats and rye, show a greater potential to reduce soil erosion compared to thick roots, such as fodder radish and white mustard (De Baets *et al.* 2011). The coverage on the soil will roughly determine how much soil erosion is reduced as a result of live mulch.

Conserving soil moisture

In order to reduce the amount of rain that falls on the soil surface, live mulch serves as a barrier between the soil surface and precipitation. As a result, increased water infiltration recharges soil moisture storage instead of draining off. Additionally, it aids in lowering soil surface evaporation, preserving moisture from irrigation and rainfall, increasing the water holding capacity at field capacity by 10% to 11% and increasing plant available water by 21% to 22% (Sharma *et al.* 2018). Changes in soil moisture by live mulches can either increase or decrease the crop yields. While cover crops improve water infiltration, they also evaporate water from the soil and cause fields to become drier, which could possibly reduce yields. Therefore, an adverse effect can be avoided by promptly terminating a live mulch.

Improving soil structure

In comparison to conventionally managed (fallow) soil, live mulches increase soil aggregation and maintain higher organic carbon pools by increasing root activity and carbon inputs. By altering soil structure, aggregate stability, and macropores with crop residues of live mulch that were retained in the soil, soil hydraulic conductivity and infiltration were improved. Hydraulic conductivity in the zero-till stubble-retained system was eight times higher than in the treatments where the stubble was burned off (Naresh *et al.* 2013). Surface crusting can be reduced or eliminated, infiltration can be increased, surface runoff and soil loss can be reduced, and crop yields can be increased by using tillage techniques that leave the live mulch residues on the soil surface. When residues are left on the soil, the infiltration rate is significantly higher than when the soil is left bare (Ranaivoson *et al.* 2017).

Soil carbon sequestration

The amount of soil organic carbon (SOC) may rise with the use of live mulches. SOC depletion in agricultural soils is up to 30 to 40% higher than that of natural vegetative cover (Poeplau and Don 2015). Due to the variation in plant carbon inputs and rates of mineralization, crop management techniques can have an impact on SOC sequestration in both conventional tillage and no-till soils. The process of transferring atmospheric carbon dioxide (CO_2) into SOC and soil inorganic carbon (SIC) pools by the production of plant biomass is known as soil carbon sequestration under live mulch (Lal 2004).

Soil nutrients

Soil organic matter (SOM), one of the measures of soil nutrients, is crucial for soil productivity. Fresh organic matter, such as remnants, litter and root exudates from legume live mulch has showed that there was an acceleration in the SOM decomposition and its content (Duchene *et al.* 2017). In comparison to no live mulch, oat and rye reduce nitrate leaching by 26% and 48%, respectively, under live mulch (Kaspar *et al.* 2012). Besides other nutrients, nitrate is not firmly attracted to soil particles. Any nitrogen that is in solution will be washed away with the onset of heavy winter rains. Therefore, nitrate losses from soil can be substantial when it left bare during the winter. This results in environmental pollution because nitrates can cause human health problems and also leads to the growth of algal blooms in waterbodies. It is well known that keeping a crop cover throughout the winter is one among the best ways to stop nitrate leaching. Excess nitrate in the soil can be "sopped up" by using green manures as live mulch. In comparison to a sole crop of rice applied with 5 t ha^{-1} of FYM and 100% of the recommended dose of nitrogen, the concurrent growth of sesbania and its incorporation at 30 DAS was successful in increasing the succeeding rice yield and soil fertility status (Anitha *et al.* 2012).

Soil biological properties

Due to their involvement in nutrient cycling through the breakdown of organic matter and nutrient storage, soil micro-organisms are essential for maintaining soil quality. For the growth of soil microorganisms, live mulches offer very favorable environmental conditions (moisture, temperature and carbon availability). According to Zhong *et al.* (2018) the continued cultivation of *Arachis pintoi* and *Chamaecrista rotundifolia* mulch significantly changed soil's chemical properties by raising the concentrations of total nitrogen, alkaline hydrolysis nitrogen, SOC, total soil carbon, and organic matter. The amounts of total nitrogen, $NH4^+$ -N, and NO_3 -N varied between treatments as well. Additionally, mulching with *C. rotundifolia* and *A. pintoi* significantly changed the richness and diversity of soil bacteria. In comparison to the control (no mulch), the continued use of legume mulch in *C. rotundifolia* and *A. pintoi* systems significantly enhanced SOM content in 0–20 cm soil depth. The intercropped legume mulches were said to increase the N content of the soil/plant system through nitrogen fixation (Duchene *et al.* 2017).

Legumes may increase SOM input and lower the C:N ratio because of higher root exudation and litter quality (Schutter and Dick 2002). The structure and makeup of soil's bacterial community were remarkably altered by the long-term application of *A.*

pintoi and *C. rotundifolia* mulch (Zhong *et al.* 2018). Proteobacteria, that dominated in all soil samples, were more prevalent after mulching.

The cowpea's canopy cover lessens the amount of direct sunlight that reaches the soil's surface, which has an impact on soil temperature. Difference in the soil temperature among cowpea live mulch (CPLM) plots may be due to timing of CPLM planting in relation to the development of cowpea canopy (Rahman *et al.* 2022). The findings of earlier research (Yin *et al.* 2016, Chang *et al.* 2020) confirmed that mulched fields reduce temperature of the soil more than non-mulched fields. According to Gitari *et al.* (2019), the cowpea canopy cover lessens the effect of rainfall on the soil surface, increases biomass, and as it decomposes, forms bio-pore channels that helps to bring down the soil compaction. Living mulch systems have been linked to decreased soil bulk density (Sharma *et al.* 2010, Gitari *et al.* 2019). The effect of planting time on cowpea canopy and biomass production could be the reason for variation in soil bulk density among the CPLM. Soil moisture is impacted by reduced evaporation from the soil due to the coverage of cowpea canopy on the soil surface.

Living mulch enhanced physical and chemical properties of soil. Increased SOM input led to an increase in the population of soil bacteria and a change in the makeup of the soil bacterial community. The secretion of specific enzymes has an impact on the growth of the microbial population (Singh *et al.* 2007). An improved soil would result from the elevated enzyme activities, which would hasten the organic matter degradation and the mineralization of soil nutrients and nutritional status. Additionally, an increase in soil nutrients would encourage the microbial growth and alter the soil microbial community.

Future prospects

An effective cropping system would include a live mulch to reduce soil erosion and water runoff. Living mulch also generates an allelochemical that inhibits the germination of weed seeds and may even control weeds that have already established without affecting the growth and yield of main crop. With allelopathic qualities, the live mulch wouldn't be competitive. Gene transfer with known allelopathic traits from an organism may be used to achieve this. Compared to directly introducing a weed controlling gene into crop, this would be probably more successful and popular with the general public. Early in the growing period, even an enhanced allelopathic crop like maize would not be able to effectively control weeds between the rows of corn due to the excessive spacing between them. It will be important to look forward for living mulches that can be managed to make them compatible for each crop like herbicide do.

CONCLUSION

Live mulches brought many benefits to the crop production. It potentially conserves the soil moisture, reduces the evaporation losses and suppress the weed. The other benefits are improvement in soil health, nutrient availability, soil microbial activity, moisture availability and temperature regulation. But the harmful effect is the risk of competition against crop. However, it can be reduced by the choice of suitable varieties of live mulch.

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