Living Mulches for Sustainable Pest Management

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Abstract The need for non-chemical insect pest management is the demand of present-day lifestyle emphasized by the demand for organic food production and environmental degradation caused by synthetic insect control measures. Mulches are a well-known environmental diversification technique that has been used in agriculture for decades. They have become commonplace in cultivating a wide range of crops worldwide, gaining significance in organic systems as a sustainable management strategy for controlling weeds and pests and providing other ecological benefits. Mulches can also improve the soil's structure, porosity, and fertility, making it more suppressive and difficult for insect pests to survive. Mulches come in various shapes and compositions, including organic, non-organic, alive, synthetic, dead, biodegradable, and non-biodegradable mulches. In this chapter, we discussed the potential for using live mulches in biological pest management. Moreover, we discussed the

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K. Akhtar et al. (eds.), *Mulching in Agroecosystems*,
https://doi.org/10.1007/978-981-19-6410-7_8

problems caused by living mulches, such as insect pest infestation, weed infestation, disease transmission, and bird infestations.

Keywords Integrated pest management · Insect pest control · Mulches · Agriculture

1 Introduction

The important component of the sustainable ecosystems is biodiversity (Pimentel, 1961), The management of insects depends on crop modification. The non-host plant supported the susceptibility of plants, and therefore host plant density is decline, while enhance the occurrence of natural enemies (Andow, 1991). Sans and Altieri (2005), and Jones and Sieving (2006) reported that weed control, plant pest and diseases could significantly impacted by living mulch and intercropping. Further, in the north part of USA a case study reported that significant lower cucumber beetle were noted on the leaves if Zucchini plants in the interplanted plots compared with fallow plots. The report of Schmidt et al. (2007) revealed the higher rate of natural enemies with a decrease in Aphis glycine's in a soybean field under alfalfa living mulch conditions. While Frank and Liburd (2005) reported that compared with mulch treated plots, living mulch plots have less adult whiteflies and aphids.

Mulches are known for their numerous benefits, for instance, improving grain yield and consistency, enhancing soil quality, soil water retention, and weed suppression (Jabran & Chauhan, 2018; Nawaz et al., 2017). Mulches can also play a vital role in managing insect pests and disease pathogens (Brown & Tworkoski, 2004; Farooq et al., 2011). In traditional and organic farming, common mulches are often observed to combat insect pests and disease pathogens (Quintanilla-Tornel et al., 2016). There are sufficient evidence and proof that mulches effectively manage target insects without chemical applications (Brown & Tworkoski, 2004). Because the misapplication and/or degradation (after initial applications) of chemical insecticides causes long term sublethal effects (Desneux et al., 2007; Ullah et al., 2019b, 2019c), hormesis effects (Cutler et al., 2022; Ullah et al., 2019a, b; 2020c) and facilitate resistance development in insects (Ullah et al., 2020a, 2020b). Organic agricultural operations utilize pest-control tactics that eliminate or minimize the use of high-risk synthetic pesticides and benefit from IPM programs (Nottingham et al., 2016). The core object of these approaches is to diminish pests' impact, interrupt the progress of insecticide resistance, reduce the threats to human health, and eliminate air emissions (Pedigo & Rice, 2009).

Mulches are a well-known environmental diversification technique that alters the soil habitats of arthropods and other organisms, affecting crop yields and other variables. Mulches come in a variety of shapes and compositions, including organic, non-organic, alive, synthetic, dead, biodegradable, and non-biodegradable mulches. Insect species and crop loss are partially decreased owing to increased natural enemy

behavior (Schmidt et al., 2004; Thomson & Hoffmann, 2007). Pests and their associated damage are increased due to the pest's increased micro-environment, interfering with natural enemy operation. Mulching is the technique of covering the soil surface with mulch to reduce moisture loss, weed development, and insect pests and disease pathogens (Mulvaney et al., 2011). It is also considered one of the most efficient means of providing shelter for predatory insects (Brown & Tworkoski, 2004; Gill & McSorley, 2010; Johnson et al., 2004). Furthermore, pine bark mulch (*Panax quinquefolius* L.) has been observed due to an increase in the control of weeds and diseases in ginseng (Reeleder et al., 2004). Mulches can significantly promote plants ability to tolerate the attack by insect pests and help them preserve the temperature and soil moisture, which is vital for plant strength (Johnson et al., 2004). Against certain plant species, mulch residues may have allelopathic efficiency. Weston et al. (1989) observed that sorghum (*Sorghum bicolor* (L.) Moench) has the efficiency to control weeds and also has allelopathic potential. Adler and Chase (2007) reported that Allelopathic residues of cowpea (*Vigna unguiculata* (L.) Walp) impaired the weed species, including *Amaranthus lividus* L. (livid amaranth) and *Amaranthus hydridus* L (smooth amaranth). It is necessary to produce chemical mulches from cotton, seed residues, hay, pine needles, shredded bark, or other readily available plant materials (Campiglia et al., 2010). Cultural management strategies, which include mulches and cover crops, are non-chemical approaches to controlling various pest species. Wheat (*Triticum aestivum* L) is a winter cover crop that reduces the number of insects, including Aphid (Aphididae), thrips (Thysanoptera), and plant bugs (Miridae), and leafhoppers (Cicadellidae) (Tremelling et al., 2002). In contrast to broccoli (*Brassica oleracea* L. var. botrytis) monoculture, living mulches increased the abundance of spiders and decreased the number of lepidopteran eggs and larvae (Hooks & Johnson, 2004).

To combat invasive soybean aphid outbreaks, *Aphis glycines* Matsumura (Hemiptera: Aphididae), alfalfa living mulch (*Medicago sativa* L.) has tremendously enlarged the aphidophagous insect predator community (Schmidt et al., 2007). Alfalfa mulches and kura clover (*Trifolium ambiguum* M. Bieb) are ingested by European maize borer (*Ostrinia nubilalis* Hubner) and predator organisms (Prasifka et al., 2006). Sweet potato (*Ipomoea batatas* (L.) Lam.) gained an increased population of fire ants, rove beetles, and carabid beetles using pitfall traps in parcels loaded with killed crop cover (Jackson & Harrison, 2008). Numerous factors, including sampling dates and soil cover sort, including plastic mulch and straw mulch (Minarro & Dapena, 2003), relied on the dominance of several carabid species in an apple (*Malus domestica* Borkh.) orchard. Natural enemy predation on beet armyworm pupae, *Spodoptera exigua* (Hubner), was 33% greater in killed cover grain mulch than conventional production plots (Pullaro et al., 2006). Sunshine hemp mulch (*Crotalaria juncea* L.) protects the seed with a reduced incidence of lower cornstalk borer (*Elasmopalpus lignosellus* Z.) in bush beans (*Phaseolus vulgaris* L.) (Gill et al., 2010). Mulches can be used to control airborne insect pests by affecting their capacity to find food or hosts (Brown & Tworkoski, 2004; Gill et al., 2010; Hooks & Johnson, 2004; Prasifka et al., 2006; Pullaro et al., 2006; Reeleder et al., 2004; Schmidt et al., 2007; Tremelling et al., 2002).

2 Uses of Living Mulches in Biological Pest Management

The occurrence and dominance of predators in mulching environments proved to be effective against insect pest control (Flint, 2018; Vincent et al., 2003). The predator population was enhanced under the mulching residues (Quintanilla-Tornel et al., 2016). Schmidt et al. (2007) discovered that 45% of natural enemies were increased in soybean field under alfalfa living mulch condition, while took longer for *Aphis glycines* to establish resulting in lower peak populations (Schmidt et al., 2007). Natural enemies will slow the spread of *A. glycines*, and an increase in the aphidophagous predator, plenty vulnerable the spread of *A. glycines*, avoiding economic populations from developing. Living mulch showed an unintended effect on *A. glycines* population development, reducing the inherent growth rate of aphids and offering a bottom-up suppression of the aphid (Fig. 1).

Compared with no mulch plot, the increase in predator abundance and intake of corn borer were in noted in corn and soybean plots under alfalfa and kura clover mulches (Prasifka et al., 2006) (Fig. 2).

An indirect adverse impact is caused by wheat straw mulch on the Colorado potato beetle (*Leptinotarsa decemlineata*) (Brust, 1994). After the mulch application, a substantial concentration of rodents may occur within 15–20 days fed on the Colorado potato beetle eggs, 1st, and 2nd instars. Several major predators were *Coleomegilla maculate*, *Chrysoperla carnea* and *Perillus bioculatus* (Brust, 1994). In the bush bean (*Phaseolus vulgaris* L.), sunshine hemp straw (*Crotalaria juncea* L.) mulch was used to control the disease of lesser cornstalk borer (*Elasmopalpus lignosellus*) (Gill et al., 2010). By manuring mulch in the apple orchard, the number of predators increased, and the population of spotted tentiform leafminer (*Phyllonorycter blancardella*) and woolly apple aphid (*Eriosoma lanigerum*) was controlled (Brown & Tworkoski, 2004). In agricultural production, plastic mulch gained its demand specifically to overcome the farming of high-value crops. Insect pests, including aphids, thrips, and whiteflies, can be suppressed using plastic mulch due to their smell, color, or surface (Diaz & Fereres, 2007; Vincent et al., 2003). Colored plastic mulch has its light reflectance pattern to suppress the insect pest population (Vincent et al., 2003).

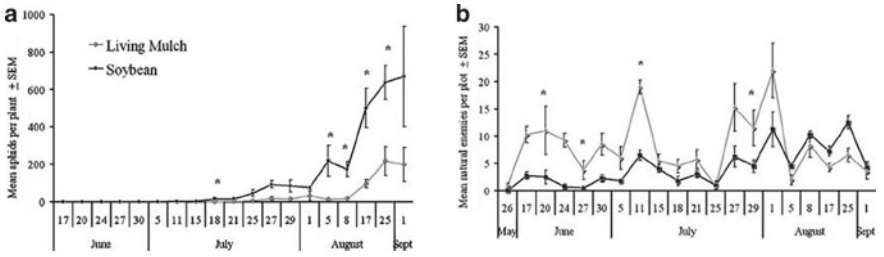

Fig. 1 Mean natural *A. glycines* infestation in soybean-growing alone or alfalfa living mulch (A) and mean natural enemies in soybean with living mulch and alone (B). *Two treatments significant changes (df = 1,3, $P \leq 0.05$). Reproduced from Schmidt et al. (2007)

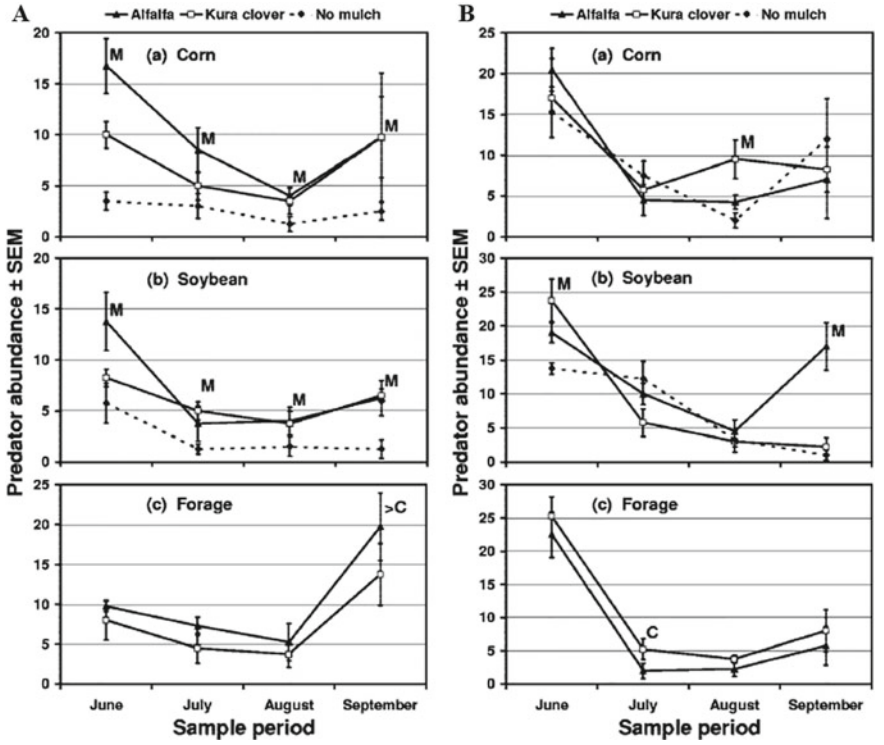

Fig. 2 During June to September 2004 (**a**) and 2005 (**b**) the predator abundance in different crops

Silver mist and black plastic mulch usage in squash will keep the aphid population away from it and boost the marketable squash yield (Summers et al., 1995).

3 Living Mulching Problems

3.1 Insect Pest Infestation

There is inconsistency in the usage of sustainable mulching practices. Certain researchers have noticed that organic kinds of mulches also attract rodents, but in contrast, several researchers also observed that such organic mulches are being used as pest repellent (Anderson et al., 2002). For several pests, such as clothing moths, cockroaches, and repelling types of ants, carpet beetles, and termites with certain varieties of Thuja are utilized as a natural repellent (Chalker-Scott, 2007). Sometimes it is considered that woody types of mulching are attractions for the termites. An experiment that was performed using organic (grass) and inorganic (gravel) mulches (Long et al., 2001) disclosed termite activity at a higher rate under gravel mulch as compared

to woody mulch. The organic mulches used for controlling termites cause a higher mortality rate than other mulches. Duryea et al. (1999) showed that mulches with more significant nitrogen and phosphorus content cause higher mortality in termites. Therefore, in places where termites are the primary pests, organic mulches with less nutritional content could be used (Martin & Poultney, 1992). Landscape fabrics and black plastic mulch can minimize different pests (Duncan et al., 1992). By nature, numerous mulch products can repel organisms by their distinct odors, spines, or unique texture characteristics (Chaudhary et al., 2003; Szwedo & Maszczyk, 2000). Thick mulches may also attract pests such as rats trying to find protection (Siipilehto, 2001).

3.2 Weed Infestation

Composts or residues that are practically used as mulches are assumed to bear different weed species' seeds if such mulches are not sufficiently decomposed (Chalker-Scott, 2007). Research has shown that weed destruction is closely connected with mulch depth (McDonald et al., 1996). Compared to those mulches applied at shallow depths, organic mulches used at a higher depth have increased potential to minimize weed infestation (Horowitz & Thomas, 1994).

3.3 Disease Transmission

Pathogens are present in the mulch materials of diseased plants from where they can spread to healthy plants. As a result, mulch products should be thoroughly composted before being used (Hoitink & Krause, 1999). Temperature treatment is very important to kill all useful and detrimental organisms present in mulch products. To stop pathogens, we should focus on commercially available mulches that are sterile (Chalker-Scott, 2007). Honey locust canker, commonly used as mulch, contains toxic pathogens (Koski & Jacobi, 2004). Different studies have shown conflicting findings, claiming that using diseased mulch as contaminated maple trees does not result in disease transmission (Dochinger, 1956). According to a six-year investigation, no pathogen transmission was identified when canker infected mulches were put to robust plants. Infected Austrian pine foliage was used as mulch for the same species and was the only proof of tip blight transmission (Jacobs, 2005). The Austrian pine tip blight pathogen did not affect other crop plants and may be susceptible to the pathogen (Chalker-Scott, 2007). Epidemiology, rather than the pathogenic source, may cause the disease (Chalker-Scott, 2007). Pathogens can also be transmitted by soil. In healthy soils, pathogens or microorganisms are still present. These pathogens become active when soil conditions are low or anaerobic, causing significant losses to vigorous crop plants (Foreman et al., 2002). The use of uncomposted mulch materials will result in pathogen transmission (Koski & Jacobi, 2004).

3.4 Bird Infestations

Pesticide and herbicide use has been shown to have both beneficial and harmful effects on agricultural bird species diversity, reproduction, and food resources such as insects and weeds (Geiger et al., 2010). According to theory (Tscharntke et al., 2012), the spatial heterogeneity will reduce the destruction of bird habitats caused by the use of foils on crops. Depending on the species studied, most of the factors studied (crop diversity, forest and human settlement cover, cabbage crop cover) had different (positive or negative) effects, so they are of limited practical use in bird conservation landscape planning. Grassland patches scattered around an intensively cultivated landscape with controlled crops are critical for farmland biodiversity (Batary et al., 2007). Grassland cover in the landscape presents an ideal breeding and foraging environment for birds (Concepcion et al., 2012). Grassland, which is intensively mowed or grazed by cows, is ideal for ground-feeding birds because, in these conditions, the prey becomes easier (Morris & Thompson, 1998). In habitats with small fields, there were more bird species. This was also valid for experts in farmland. More species live in agricultural habitats with smaller fields (Herzon & O'Hara, 2007). Fields in Poland are separated by narrow grass strips, increasing the density of potentially useful microhabitats for birds (Concepcion et al., 2012).

4 Conclusion

The need for non-chemical insect pest management is the demand of present-day lifestyle emphasized by the demand for organic food production and environmental degradation caused by synthetic insect control measures. With this idea, the potential for using various types of live mulches to manage insect pests has been assessed in this chapter. Resultantly, increased predator and parasitoids activity or populations will aid in the consumption of more insect pests. Similarly, inter-cropping, dense vegetation, and border copings patterns alter the spectrum of the incident light, which negatively affects insect pest activity via changes in temperatures and humidity of their habitats. This provides a means of repelling or deflecting many insect pests, particularly in high-value crops. Organic mulches are likely to improve biocontrol agent activity or increase the concentration and activity of certain enzymes that can suppress the pest population (by hardening the cell wall consumed by insects). Mulches can also have a beneficial effect on soil structure, porosity, and fertility, making it more suppressive and difficult to survive for insect pests.

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