SUNSHINE AGRICULTURE
e-Newsletter

ISSN (E): 2583 – 0821

Sun. Agri.:e- Newsletter, (2025) *5*(11), 60-63

Article ID: 477

Sustainable Weed Management through Cover Crops and Mulching

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Open Access

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Available online at
www.sunshineagriculture.vitalbiotech.org

Article History
Received: 2. 11.2025
Revised: 6. 11.2025
Accepted: 11. 11.2025

INTRODUCTION

Weeds are one of the most serious threats to agricultural productivity due to their competition for growth resources with crops, such as nutrients, water, light, and physical space. Competition from weeds not only causes reduction in crop yields but also depreciates the quality of the harvested produce. Traditional methods of weed management have been characterized by the frequent application of chemical herbicides and intensive tillage, resulting in various environmental and agronomic problems linked to the deterioration of soil structure, loss of beneficial soil organisms, decline in soil fertility, and development of herbicide-resistant weed biotypes. Lately, in view of these issues, sustainable methods for managing weeds have taken center stage, focusing on ecological principles of suppressing weed populations while improving soil health and resilience of the system at the same time. Of the methods, cover cropping and mulching are among the most effective, non-polluting, and economically viable practices that reduce weed pressure and improve soil quality in annual and perennial cropping systems.

2. Cover Crops for Weed Suppression

Cover crops are non-commercial species grown primarily to improve soil health, reduce erosion, enrich biodiversity, and suppress weeds. When properly integrated into crop rotations, these crops offer a natural protective vegetation cover, reducing weed emergence, improving soil fertility, and suppressing the weed seedbank. Their competitive ability against weeds, modification of the soil microenvironment, and enhancement of general soil biological activity make them a critical component of sustainable weed management.

2.1 Mechanisms of Weed Suppression by Cover Crops

a. Physical Suppression (Mulch Effect)

When cover crops are terminated, a large amount of their residue remains on the soil surface, serving as a type of natural mulch. This mulch limits the amount of sunlight reaching the soil, creating a dark environment that is not conducive to weed seed germination.

It also provides some physical impedance whereby a majority of weed species are not able to emerge through the soil. It further moderates soil temperature and moisture, smoothing out extreme fluctuations that generally stimulate weed growth. This mulching effect can offer long-lasting weed suppression, especially in cases involving high-biomass cover crops.

b. Allelopathy

Some cover crops produce allelochemicals, natural biochemical compounds that reduce weed seed germination, inhibit root development, and suppress seedling growth. For example, rye (Secale cereale) synthesizes benzoxazinoid compounds, while sorghum–Sudan grass produces sorgoleone; both are strong inhibitors of many problem weeds. Similarly, various mustard species of Brassica spp. synthesize glucosinolates, which have broad-spectrum weed suppression activity. These allelochemicals act like natural herbicides and play a very important role in the early-season reduction of weed pressure.

c. Competition

With their rapid growth, cover crops outcompete weeds for space, sunlight, soil nutrients, and water. The rapid formation of their canopies shades the soil surface, and their deep root systems exploit available moisture and nutrients more effectively than many weed species. This competitive advantage helps suppress weed establishment throughout the growth cycle.

2.2 Common cover crops for weed management

Leguminous Cover Crops

Cowpea, berseem clover, mungbean, and sunn hemp are some of those legume species that, through symbiosis with rhizobia bacteria, fix atmospheric nitrogen while simultaneously suppressing weeds. These crops can produce enough biomass to form nutrient-rich mulch, which enhances the fertility of the soil and inhibits weed germination.

Cereal Cover Crops

Cereal cover crops are in demand because of their rapid growth and high biomass production. They produce dense canopies, as well as thick residues after termination, which serve to be highly effective in suppressing weeds. Also, a strong mulch layer decomposes slowly, which leads to extended weed control.

Brassica Cover Crops

Mustard and radish species provide not only excellent ground cover but also release allelopathic compounds that help suppress a wide range of weeds. Their biofumigation effect is particularly good for controlling stubborn and hard-to-manage weed species.

Mixed Cover Crop Systems

Mixtures of legumes and cereals (e.g., mungbean + barley or cowpea + rye) increase biomass production, improve nutrient cycling, and enhance weed suppression. Mixed systems help achieve both high mulch output and balanced soil nutrient enrichment.

2.3 Advantages of Cover Crops

Cover crops have many agronomic and environmental benefits. They reduce reliance on chemical herbicides due to natural weed suppression by their residues. They enhance soil fertility through the addition of organic matter and fixation of nitrogen, thus improving soil biological activity. They prevent soil erosion, reduce nutrient leaching, and provide a habitat for beneficial insects and microorganisms. They also break disease and pest cycles due to the disruption of weed–pathogen hosts. Additionally, they improve structure, increase water-holding capacity, and promote long-term soil resilience.

3. Mulching for Sustainable Weed Control

Mulching is the application of organic or inorganic materials on the soil surface that reduces weed growth, preserves the moisture content of the soil, and produces a favorable microenvironment for the roots. It has been widely adopted in horticultural crops and increasingly in field crops because it is simple, effective, and provides multiple agronomic benefits.

3.1 Types of Mulches

A. Organic Mulches

Organic mulching materials include crop residues like paddy straw, wheat straw, sugarcane trash, green waste compost, sawdust, wood chips, dry leaves, and grass clippings. Over time, these materials decompose and add organic matter to the soil when applied as mulches, thus improving nutrient cycling, enhancing soil structure, and promoting microbial activity.

B. Inorganic Mulches

Inorganic mulches primarily include plastic mulch films (black, silver-black, white, or biodegradable), gravel, and stones. Plastic mulches represent one of the most commonly used mulching materials in horticultural crops as they are very effective in controlling weeds and preserving soil moisture. They can prevent weed emergence by acting as a physical barrier, modify the soil temperature, and increase yield and quality of crops.

3.2 Mechanisms of Weed Suppression by Mulching

Mulches effectively prevent light from reaching weed seeds, and consequently, photosynthesis is also restricted, which inhibits the germination process. The physical obstruction due to mulches

reduces weed seedling emergence; small-seeded species are more sensitive. Mulching prevents soil crusting, which facilitates weed seedling establishment. Organic residues such as eucalyptus leaves and sorghum mulch release allelopathic compounds that inhibit weed growth. Mulches modify soil temperature and moisture, making it less conducive to weed seed germination, allowing crops to compete better.

3.3 Advantages of Mulching

Mulching provides a very efficient non-chemical method of weed suppression and thus is suitable for organic and sustainable farming systems. Mulching saves soil moisture through the reduction of evaporation, which is very important in dryland and semi-arid agriculture. Mulches improve soil temperature, which favors early-season crops and promotes rapid plant growth. They enhance root development, promote better nutrient-use efficiency, and protect soil from erosion and nutrient runoff. Mulching can enhance the quality of produce, especially fruits such as strawberries and tomatoes, by preventing direct contact with the soil. Organic mulches help soil microbial activity, build up soil organic carbon, and thereby contribute toward long-term soil health.

4. Integrated approach: cover crops + mulching

Integrating cover crops with mulching offers a comprehensive and highly effective strategy for sustainable weed management. The combination enhances soil health, provides extended weed suppression, and reduces the need for synthetic herbicides.

4.1 How They Complement Each Other

Cover crops produce a lot of biomass that can be terminated and used as organic mulch. The mulch layer then protects the soil from erosion, conserves moisture, and prolongs the longevity of the cover crop residues. Less use of herbicides enhances beneficial soil microbes, promoting ecological balance.

4.2 Examples

Practical examples include using rye as a winter cover crop, followed by no-till planting in spring where the rye residue acts as a mulch. Sunn hemp can be rolled down before planting vegetables, providing improvement of soil fertility and weed suppression. Mustard residues applied to soil act as bio-mulch with strong weed-suppressive and biofumigation properties.

5. Adoption Challenges

Despite advantages, several barriers exist to widespread adoption of cover crops and mulches. Most farmers have limited knowledge on how to select appropriate species and their management and long-term benefits. Initial costs of buying seeds or mulch materials could be limiting to the small-scale farmer. For large-scale farms, specialized machinery may be required for terminating cover crops and managing the resultant heavy residues. Thick mulch layers may provide microhabitats that attract pests or rodents. In addition, different mulch materials differently affect soil moisture dynamics, hence the need for modification in irrigation practices.

6. Future Prospects

Further research and development of technologies in the future will facilitate the adoption of sustainable weed management methods. Biodegradable and plant-based mulches can replace traditional plastic mulches, thereby reducing environmental pollution. Plant breeders may develop newer varieties of cover crops with strong allelopathic potential and higher biomass production. Integration with precision agriculture tools such as drones and remote sensors will help in improving the timing and management of cover crops. Advances in mechanization will enable cover crop termination and residue management efficiently even on large farms. Supportive policies, incentives, and farmer educational programs will also facilitate eco-friendly weed management systems.

7. CONCLUSION

Sustainable management of weeds, considering cover cropping and mulching, is an effective alternative to both chemical and mechanical methods of weed management. These practices reduce not only weed pressure but also improve soil fertility, enhance biodiversity, conserve moisture, and promote ecosystem resilience. Cover crops and mulches can be integrated into reducing dependence on herbicides, lowering the cost of production, and promoting agricultural sustainability in the long term. These methods hence make great contributions to climate-smart agriculture and ensure sustainable food production for generations to come.

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