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Organic Weed Management: A Step Forward Towards Sustainability

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ABSTRACT

Organic farming faces significant weed control challenges. So even though organic farming benefits the environment and preserves species variety, it may also result in an increase in weed infestations that deters farmers from switching from conventional farming to organic farming (Albrecht, 2005). Organic farming is a method of food production that relies on locally available renewable resources, preserves biodiversity, soil fertility, and productivity, and largely forgoes the use of synthetic fertilizers and chemicals while still producing high-quality, chemical-free food for both people and livestock. Weeds are one of the main obstacles in organic farming because they can adjust to a variety of climatic conditions, grow quickly, produce more seeds than crops, and lower yields (Rose *et al*., 2018). In organic farming, weed control strategies include mulching, manual weeding, tillage techniques, plant population, bioherbicides, and intercropping. The most effective strategy for restraining weed infestations below the level that would be economically detrimental is integrated weed control. In no area is it possible to completely prevent and eradicate weeds, but organic farming makes it possible and cheap to reduce their infestation and spread (Barberi, 2002). To control weeds below the economic threshold level, various agronomic practices that are ethically sound from an economic, ecological, and toxicological perspective are combined into integrated weed management. Maintaining weed control is the primary goal of weed management in an organic farming system.

Key words: *Organic farming, Conventional farming, Weed management, Intercropping; Economic threshold level; Agronomic practices.*

Introduction

Adopting organic agricultural practices is necessary to save the ecosystems and natural resources from the harmful effects of conventional agriculture (Albrecht, 2005). Conventional agricultural practices have a negative impact on the environment because they deplete soil microorganisms, increase insect resistance to pesticides, pollute groundwater with heavy metals, and contaminate food with pesticides. Consistently following conventional or Intensive (monoculture) agricultural practices reduces soil productivity, increasing the need for the usage of synthetic chemicals to get high results, as well as the expense of cultivation. Moreover, continuous use of herbicides not only pollutes the environment but also develops the horizontal resistance of weeds to several modes of actions of herbicides is seen in several weed species (Shaner, 2014). According to USDA, Organic farming is a production system that largely excludes the use of synthetic chemicals like fertilizers, pesticides, growth hormones, and livestock feed additives. This system mainly depends upon the on-farm resources which convert outputs

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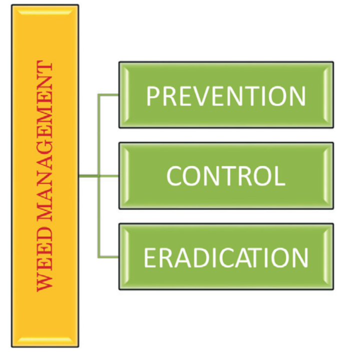
(farmyard manure) into inputs (nutrient source), crop rotation, green manuring, biofertilizers, off-farm organic waste, intercropping, and mechanical cultivation methods. Organic farming is a holistic system that improves soil health, and earthworms, maintains biodiversity and agro-ecosystem, and maintains resource ability for future generations. Farmers claim that the largest obstacle to converting from conventional to organic farming is the lack of effective weed management. It's widely accepted that weeds pose the biggest threat to the growth of organic crops. Despite this, there hasn't been much research done on weed management-related issues in organic agriculture. Moreover, prevention is widely used in the treatment of weed management (Barberi, 2002). Weeds are often considered a major threat to organic crop production (Penfold and miyan, 1995). Weeds can lower agricultural yields by competing with crops for resources like sunlight, water, nutrients, and space. They serve as a host for some plant viruses, insects, and pathogens. Some weed species can lower the quality of the harvested crop(Jabran *et al*., 2018). In terms of total potential loss, weeds accounted for 34%, whereas insects and phytopathogens accounted for losses of 18% and 16% respectively (Oerke, 2006). The main objective of a weed management strategy in an organic farming system is to lower weed competition with crops and to reduce weeds below the economic threshold level. In many instances, not all weeds will be totally removed. Weed management should reduce competition from present and future weeds in crop fields. Because of the advancement of technologies and the use of numerous tactics, weed management in organic farming now results in more productive crops and weed control measures that are economically viable. The crop's main goal is to outcompete the weeds by limiting the availability of resources. Weed control can be effective if the farmer can give the crop a competitive ability using organically feasible strategies. Complete zero level of weed control may not be possible but weeds are significantly reduced in organic farming systems by adopting an integrated weed management system (Scavo *et al*., 2020).

Fundamentals of weed management

All steps taken to prevent weeds from entering a region, growing there, and spreading throughout it are considered part of weed prevention. Preventive steps such as refraining from using crop seeds contaminated with weed seeds, refraining from feeding weed-contaminated feed to animals, cleaning the farm equipment before entry into the main field, and, especially in organic farming, refraining from adding weeds to the manure pits. When a weed is eradicated, all of its living components, including its roots and tubers, are pulled up from the earth. Hand weeding and manual hoeing are included. However, in heavily weeded-out areas, it is both expensive and uneconomical. Although it is virtually impossible to completely eradicate weeds from agricultural areas, doing so would be unethical in terms of protecting biodiversity. Thus, a more mediated and moderate approach towards weed management; by controlling the weed population below the ETL levels can provide the crop a competitive advantage over the weeds with respect to the resource use using various physical, cultural, and chemical methods.



Weed Control Measures

Physical/mechanical method

With the physical or mechanical method of weed control, weeds are controlled using a combination of manual labor, tractor power, and machinery that is powered by human labor. These techniques harm the ecology and soil as little as possible. Fields were successfully kept weed-free as Agri-farming got more and more industrialized using mechanical weed control techniques and tools. Integrated weed management techniques can be created by combining them with other weed-controlling strategies. In addition to secondary tillage operations and seedbed preparation, in-situ conservation of weeds deeply buried in the soil also plays a crucial part in weed management. Integrated weed management techniques can be created by combining them with other weed-controlling strategies. This tactic is usually chosen when there are small infestations, and a significant number of volunteers are ready to help. Tools including hoes, sickles, digging forks, chainsaws, and chaining are frequently used for manual weeding. Organic farms, vegetable and fruit gardens, and crops put in rows all benefit greatly from mechanical weed management approaches. These techniques are effective at controlling weeds even when other techniques are not; in some cases, they may even be successful where other techniques have failed to do so.

Tillage: Tillage is a key crop production practice that involves mechanically working the soil using tools and equipment to provide a healthy seedbed for germination, transplanting, and subsequent plant growth. Tillage activities alter the soil's bulk density and strength, which improves soil aeration and fosters a conducive environment for plant life. Techniques for tillage Crop plants develop and improve when weeds are controlled, a good seedbed is provided, crop stubbles and weed plants are incorporated into the soil, the top layer of soil is loosened, and the physiochemical qualities of the soil are improved. Tillage is a general phrase that encompasses zero tillage, conservation tillage, etc. Tillage can reduce the weed density by up to 71% (Weber *et al*., 2017).

Zero-tillage: In conventional tillage, subsurface buried weed seeds are deposited on the surface layer of soil which causes competition with crop plants and has a negative effect on yield. In a zero-tillage system, there is no disturbance to the soil and no exposure of weed seeds to favorable conditions which causes a secondary dormancy. Zero tillage can considerably decrease the total weed density as compared to conventional tillage techniques. (Mann, 2004) confirmed that an average decrease of 32% in weed density in wheat was observed in zero tillage compared to a decrease of 26% in weed density under conventional tillage in a span of three years. Adopting long-term zero tillage in wheat has less soil disturbance it leads to less or low weed emergence and reduces weed density especially *Phalaris minor* compared to conventional tillage (Singh *et al*., 2010).

Conservation tillage: It is a type of tillage that keeps at least 30% of plant leftovers on the soil's surface. The most effective areas between rows for weed control with conservation tillage and cereal ryegrass (*Secale cereal* L.) as a cover crop mulch were those where the cover crop was left untouched by planting. Increased rye biomass may improve control even though the amount of cover crop biomass completely prevented weed emergence. The organic flue-cured tobacco (*Nicotiana tabacum* L.) yielded by conservation tillage with cover crop residue was lower than that of conventional tillage treatments (Machanoff *et al*., 2022). Sahoo *et al*., (2021) confirmed that conservation tillage and organic weed control techniques improve soil qualities such as organic matter content, water holding capacity, cation exchange capacity, and bulk density.

Hand weeding: The removal and collection of weeds from crop fields is done by hand or using manual power. It is a part of integrated weed management, which uses a variety of weed-control strategies, including cultural, mechanical, biological, and chemical ones. Since hand weeding is environmentally beneficial and labor is easily accessible at reasonable wages, it benefits farmers with limited resources. Hand-weeding techniques that attempt to reduce the soil weed seed bank are being considered to prevent dense above-ground weed communities and reduce weed management expenses (Gopinath *et al*., 2009). Hand weeding increases production and has positive financial results.

Inter-row tillage: The process of employing tillage tools like tractor-drawn cultivators, small rotavators, and power tillers to control weeds in the interrow space of a crop with wider spacing. Cono-weeders are used in organic farming to control weeds in lowland areas where thin-row cereal crops, like rice, are grown. Weeds can be controlled after inter-row cultivation without the use of herbicides. The timing of inter-row cultivation is crucial for effective weed management. Further steps must be taken to minimize weeds because it does not manage weeds that are growing between the rows of a crop. All these operations must be carried out carefully to prevent harm to the growing tubers and roots. (Singh *et al*., 2014) confirmed that the highest weeding efficiency was obtained in two passes of the rotary tiller (93.20%), followed by a single pass of the rotary tiller (88.01%), power tiller (87.97%), and cultivator (83.22%).

Soil solarization: Soil solarization uses a thin, transparent polythene sheet to heat the soil and so kill bacteria, fungi, and other unwanted pests. The dirt is covered with transparent or dark polyethylene plastic during the summer, moistened underneath the plastic, and left in place for at least six weeks

(Albrecht, 2010). The death of weed seeds and early plants caused by heat, moisture, and direct contact with the plastic causes burning. Research has demonstrated that solarizing with transparent or black plastic from July through October effectively suppresses weeds without reducing crop yield (Ravishankar *et al*., 2017). Thinner films effectively transmit heat despite being more flexible and lasting less time than thicker ones. The film should adhere to the soil's surface as closely as possible to prevent air gaps and wind damage. Transparent plastic does not effectively suppress weeds as much as black plastic does. Yet when used for soil solarization, it performs best. It raises the warmth of the soil and kills seeds. Weed density can be minimized by one-handed weeding after planting the crop and soil solarization with a 25˜ polythene mulch during the summer (Chavan *et al*., 2021).

Cultural Methods: These techniques are the most efficient strategies for enhancing or improving crop competitiveness and establishment, which could dominate weeds in terms of access to light, nutrients, space, and weed establishment. Cultural techniques like crop rotation, sowing time, crop geometry, seed rate, fertilizer application method, management of irrigation schedule and amount, intercropping, and organic mulch all these procedures hinder the growth and emergence of weeds. In recent years, modifying the row layout and seeding rate of crops has become more significant for controlling weeds.

Crop rotation: It is the practice of cultivating various crops on a specific plot of land for a set period to increase soil fertility, microbial diversity, and weed suppression in crop fields while disrupting crop weed associations and weed population dynamics that may arise from using crops with various life cycles and sowing times (Anderson, 2010). Crop rotation technologies are an obligation to be considered before any other methods for controlling the growth of weeds in crops. Comparing long-term crop rotation versus short-term crop rotation, weed development in any crop can be considerably reduced.

Seed rate: High seed rates or higher planting density have been proven to be successful strategies for boosting crop competitiveness against weeds and promoting quick canopy closure, which helps to effectively inhibit weed emergence and growth (Gibson *et al*., 2002).

Intercropping: It is a way of growing two distinct kinds of crops in a certain row pattern on a given piece of land at a specific period, primarily cereal + legume crops. It can limit or even stop the growth of weeds in the spaces between broader rows of a crop. Much fewer weeds were grown when maize and cowpeas were intercropped and weed control effectiveness increased (Sannagoudar *et al*., 2021).

Cover crop: Plants known as "cover crops" are raised to reduce soil erosion and increase the productivity and health of the soil. They are sown in between cycles of ordinary crops to give several advantages, including lowering soil erosion, raising soil fertility, controlling weeds, and supplying habitat for beneficial insects. In both growing seasons, the two-way combinations of barley, buckwheat, and chickpeas were more effective at controlling weeds than the three-way combination. Consequently, it seems that the weeds can be impacted by the kind of cover crop chosen, planting rate ratios, and perhaps other management practices (Ghahremani *et al*., 2021). According to (Mirsky *et al*., 2013) crops with higher biomass production competently reduced weed growth when compared to crops with lower levels. For soil erosion control and to compete with weeds for nutrients, water, and light, annual or short-term perennial cover crops can be employed in place of a fallow period.

Live mulching: By using the live mulching technique, living plants are placed between the rows of the primary crop to cover the soil's surface. This mulching technique helps to increase soil fertility, lessen soil erosion, and stop the growth of weeds. Since live mulch can compete with plants for nutrients, light, and moisture in this growth technique, yields may be reduced (Liebman *et al*., 1993). Even if the weeds are being controlled and there is competition from broccoli, the crop's qualitative and quantitative qualities measured before and after the addition of the live mulch did not reveal any discernible negative effects. When compared to traditional tillage, utilizing Trifolium mulch produced the least amount of weed infestation. Living mulch also improved weed control without lowering broccoli output or quality (Fracchiolla *et al*., 2020).

False-seed bed: The false seed-bed approach is preparing a standard seedbed (early) and allowing the weeds to germinate by providing irrigation to the field and controlling the weeds before planting or sowing the actual crop by shallow cultivation up to

5cm soil depth with spike harrow or blade harrow farm machinery. This method was widely used in ancient days and is now again gaining interest in organic farming for reducing the weed density and weed competition with the main crop without using any herbicides and providing a weed-free environment in the field for better crop stand and improving the crop canopy efficiently (Travlos *et al*., 2020).

Biofertilizers: Biofertilizers are microbial formulations that improve soil nutrient uptake, fix atmospheric nitrogen, and solubilize nutrients to increase soil fertility. They also promote plant growth. Due to a lack of light and a warm climate, biofertilizers can also prevent weeds from emerging in lowland rice environments. Azolla is a form of biofertilizer that works symbiotically with cyanobacteria to fix atmospheric nitrogen. Low-lying rice fields are injected with it. When there is enough water, Azolla grows more quickly and develops a mat-like structure that blocks sunlight and weed seed emergence. In rice fields, Azolla can also be integrated into the soil using a cono-weeder (Rathod *et al*., 2019).

Organic mulch: Natural substances like paddy straw, grass clippings, compost, sawdust, and other agricultural wastes that decompose quickly make up organic mulches. (Rathod *et al*., 2019) concluded that applying rice bran at a rate of 2 t/ha three days after transplanting, followed by one-handed weeding, decreased weed dry weight and density and boosted crop production. The effectiveness of weed management can directly relate to the mulch layer thickness (10 cm), as the mulch layer acts as a physical barrier for the germination of weed seeds. The regrowth of perennial weeds was more in plots with straw and grass mulches, rather than peat and sawdust mulch. However, organic mulches such as sawdust, straw, and peat inhibited the growth of annual weeds and perennial weeds. It is crucial that mulches are free of weed seed contamination. Biodegradable or photodegradable plastic mulches are those that break down after being exposed to sunlight for 30 to 60 days (they degrade when they encounter soil microbes). Degradable materials can stay in the pitch after the growing season, and some can even be added to the soil to speed up the process. Reusable materials, such as black polypropylene mulch, can be used in nurseries and with some high-value crops to manage weeds over time (Ravishankar *et al*., 2017).

Stubble or summer tillage: Early shallow stubble tillage is essential in organic farming after grain crops have been harvested to get rid of weeds. Stubble tillage is a good way to efficiently control perennial weeds. The desiccation of perennial weed tubers and rhizomes, which prevents them from developing a canopy, should be done during the dry summer months. Hence, not considering how it impacts annual weeds, it should be done soon after harvest in organic farming. Although they can prevent sporadic plant regeneration, repeated tillage operations throughout the summer may aid in even greater weed suppression. For cutting the soil across its entire working width, a cultivator or rotavator with wing blades works best. By incorporating this technique, organic farmers may be able to reduce weed diversity and density in specific crop-weed combinations. The crop is more productive during the summer because there is less competition for the same nutrient pool between weeds and crops.

Crop geometry: Weed infestation in agriculture fields can be reduced by the spacing between individual plants and between plant rows. The ability of a crop to compete with weeds for nutrients and light can be increased by lowering or narrowing the space between its rows. According to (Mahajan *et al*., 2011) the DSR's paired row planting pattern (15-30-15cm row spacing) has a substantial effect on weeds in comparison to conventional row planting (23cm row spacing). The distance between individual plants and between plant rows can help crop fields with weed infestation. A crop's ability to compete with weeds for light and nutrients can be increased by lowering or narrowing the space between its rows. When compared to conventional row planting, the DSR's paired row planting design (15-30-15cm row spacing) significantly reduced the number of weeds (23cm row spacing). Paired row planting significantly aids in weed suppression by maintaining the rice plant's dominating position over weeds by altering the canopy structure. By putting a crop canopy over the soil and space between the rows, crop geometry changes can affect how quickly weeds germinate and grow vegetatively (Arce *et al*., 2009).

Biological Methods: Biological weed control is the practice of preventing weed populations from establishing and expanding past a point at which they are no longer economically viable. While the pathogenic fungus in mycoherbicides is "inoculated" by dosing the pathogens onto target weeds, the application methods for conventional and bioherbicides are similar. Bioherbicides are now thought to be a crucial part of organic farming's weed management strategy. To lessen the harm that weeds create, a method known as biological control is used. By way of their natural enemies, insects can control their populations of potential pests. The microorganisms used in bioherbicides, which are used to suppress weeds, include pathogens and phytotoxins that are obtained from plant extracts.

Insect bioagents: Insect predators applied to weeds have been shown in a few studies to reduce weed growth and infestation by eating the plant's leaves and other vegetative elements. The following are some instances of helpful insects for weed control: *Crocidosema lantana* for *Lantana camara*, *Zygogramma bicolorata* for controlling *Parthenium hysterophorus*, *Bactra verutana* for *Cyperus rotundus* and *Dactylopius indica* for controlling *Opuntia ficus indica.* Chrysolina beetle is a beneficial insect it reduces the population of *Hypericum perforatum* and *Cactoblastis cactorum* for controlling *Opuntia spp* (Appleby, 2005).

Mycoherbicides: Species of *Colletotrichum*, *Alternaria*, *Rhizoctonia*, *Phomopsis*, *Ascochyta, Phytopthora, Fusarium spp.,* are the major genera developed as mycoherbicides. Some fungal spores for controlling weeds such as *Colletotrichum coccodes* for velvetleaf, *Fusarium oxysporum* f.sp. *orthoceras* for *Orobanche* spp., *Phoma chenopodicola* for *Chenopodium album* (Robert *et al*., 2022). Other mycoherbicides that manage weeds are Collego for managing joint vetch grass in rice fields and Devine for managing strangle vine in various citrus species. Since it is less expensive to employ than synthetic herbicides, the usage of a fungal phytotoxic metabolite may eventually replace them. We are convinced that fungal metabolites-based herbicides will eventually replace chemical herbicides due to their environmental safety and ability to increase agricultural yield (Singh *et al*., 2019).

Plant based Bioherbicides: In addition to being used medicinally, plant extracts may also replace synthetic herbicides in organic farming to control weeds sustainably. A distinct secondary metabolite known as allelochemicals, including alcohols, fatty acids, phenolics, flavonoids, and steroids that prevent the growth and development of nearby plants, are present in bioherbicides made from plant extract. A specific inhibitor against weed development is present in several plant extracts, and this agent has no negative effects on crops. Canary grass, lambs-quarter, and bindweed are among the weed species that are Phyto-toxic to sorghum extract, a water-soluble phytotoxic extract (Khamare *et al*., 2022). The radicle length, seedling growth and germination of *Avena fatua* was found to be significantly inhibited by the leaf, stem, and root preparations of *Brassica nigra* (Turk and Tawaha, 2003). Essential oils are organic, volatile substances with phytotoxic potential that are obtained from various plant parts or the entire plant and are involved in chlorosis, poor plant development, a decrease in chlorophyll content and cellular respiration, and leaf necrosis (Hasan *et al*., 2021). A biological process known as allelopathy occurs when one organism releases biochemicals into the atmosphere that prevent the growth and development of other organisms. *Sorghum bicolor* releases an allelochemical called *sorgoleone* that controls *Phalaris minor, Cyperus rotundus*, and *Anagallis retroflexus* from growing.

Conclusion

Effective weed control is the main barrier to profitable organic farming. It would be advisable to combine a variety of strategies rather than using just one to manage weeds from organic sources because doing so might be challenging in organic farming. To efficiently control weeds, integrated weed management combines several cultural, mechanical, and biological strategies (IWM). IWM works to preserve wildlife, improve the environment, reduce soil pollution, and promote biodiversity. The weather, climatic conditions, and the quantity and diversity of soil weeds are essential components for the development of efficient weed management systems. Herbicide resistance in weeds can be slowed down by using a variety of weed control techniques. Using several control strategies less often, weed management costs are decreased, and sustained crop production is enabled *via* integrated weed management. For weeds to be controlled below the economic threshold level, it is crucial to choose cultural, mechanical, and biological treatments carefully and to eradicate them throughout the crop-weed competition phase. For weed control in organic farming to be effective, it is required to integrate various weed control measures.

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