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16. Weed Management Under Conservation Agriculture: Identifying Strategies for Smallholder Farmers

Bhumika Arora

Department of Botany,
Akal University,
Bathinda, Punjab, India.

Babita, Gajanand Modi

School of Basic and Applied Science,
RNB Global University,
Bikaner, Rajasthan, India.

Nivedan Bhardwaj

Department of Zoology,
Chaudhary Devi Lal University,
Sirsa, Haryana, India.

Abstract:

Sustainable crop production is necessary for both environmental and global food security. Due to its sustainable practices, including scheduled crop rotations, permanent soil cover, and integrated weed management, conservation agriculture (CA) is becoming more and more popular all over the world. Additionally, CA can promote soil water retention and lessen erosion, which will improve water quality and decrease runoff. Adopting CA methods can also support biodiversity and improve soil carbon sequestration, aiding in the fight against climate change.

The use of more herbicides has been associated with weed control in conservation agriculture in other nations, but problems with chemical access, herbicide resistance, and environmental consequences, there is the need for more effective weed elimination methods that may be used by smallholder farmers. Climate, soil type, and the availability of resources were taken into account while evaluating the regional applicability of these weed management tactics. The analysis also took into account the unique difficulties encountered by rainfed smallholder farmers, such as their limited access to inputs and shortages of labour.

There are still several solutions lacking in this chapter which are necessary for smallholder farmers. This combination expected to reduce weed competition while also being financially sensible and long-lasting. To ensure correct use and continuous success of these strategies, it is also necessary to offer farmers support and training.

Keywords:

Conservation agriculture, smallholder farmer, control strategies, weed, sustainable.

16.1 Introduction:

Over the upcoming years, a confluence of challenges, increasing migration and population growth, labour shortages, decreased food scarcity, climate change, and agricultural output, will affect agriculture, especially smallholder agriculture in emerging nations. In terms of putting into practice sustainable farming methods. This entails using practices that improve soil health and minimize chemical inputs, such as crop rotation, conservation tillage, and organic farming techniques. In order to increase knowledge of the value of sustainable agriculture and inspire farmers to adopt such techniques for long-term food security, it is also important to participate in research and education. Crop production is a crucial part of agriculture, which ensures the global food supply. The first and most important agronomic element that results in optimal crop production is effective soil management. The term "conventional tillage," has been described as a system that includes primary deep cultivation and secondary agriculture operations, is firmly connected with modern agriculture (Holland, 2004). Agriculture's use of tillage dates back thousands of years, when it was primarily used to benefit animals and productive areas near rivers. (Hillel, 1992). Tillage is the process of modifying the soil to improve the aggregates for the development and also for suitable well-prepared seed bed before planting. It serves a variety of purposes and promote appropriate emergence of seeds due to optimal positioning that provides sufficient nutrition, light, and water (Reicosky and Allmaras, 2003). Further, through tillage, additionally the soil gets modified with a number of substances.. Moreover, it helps to prevent and treat diseases and pests that propagate from soil (Owens, 2001) and play crucial role in conventional agriculture.

Several scenarios available in which farmers have benefited from the employment of this technology, including (i) decreased manufacturing costs (Malik et al., 2005); (ii) improved soil quality, or soil physical, chemical, and biological conditions (Kaschuk et al., 2010); (iii) higher carbon sequestration and the accumulation of soil organic matter (Saharawat et al., 2012); (iv) a decrease in the occurrence of weeds (Malik et al., 2005); (v) enhanced the nutrient and water utilization efficiency (Kaschuk et al., 2010). The management of weeds has been established as an essential CA component and calls for specific treatment. Moreover, weeds serve as a heaven for insects and other pests that spread disease, which lowers crop quality and raises the possibility of crop failure. The various natural and artificial habitats that tillage offers to weeds are both varied and diverse. From ancient times, tillage has been utilized as an efficient tool and plays a significant part in weed management. Tillage techniques are still quite successful, and numerous modern agriculturalists and weeders have rendered mechanical weed control easier. (Wallace and Bellinder, 1992). According to FAO (2002), Low mechanical soil disturbance, continuing organic soil cover, and species diversification through rotation of crops and integrating are the three tenets of CA. CA offers recommendations for crop-growing that is environmentally friendly manner rather than a rigid set of standards, and these recommendations can be adjusted to match particular local conditions and requirements. These recommendations enable farmers to modify CA techniques in accordance with local factors, like the variety of soil, rainfall patterns, and the resources that are obtainable (Wall, 2007). Furthermore, CA urges biodiversity and aids in the preservation of natural resources like water and nutrients. Additionally, it can help to mitigate climate change by lowering the release of greenhouse gases by retaining carbon in the soil. (Thierfelder et al, 2015).

CA needs sustained efforts to manage weed infestations at first, but after a particular threshold level is maintained, it becomes simpler to do so. To effectively control weeds, integrated measures must be considered and optimized. It is critical to investigate the environmental, natural, and social components of herbicides. Also, a methodical strategy is required to maximize various management alternatives depending on the Agro-ecosystem's ecological and geographical aspects. That helps in the identification of new routes for long-term control and site-specific weed management. Future work in this area must be targeted on providing all-encompassing answers while keeping an eye on the disparities.

16.2 Weed Control in Sustainable Farming: A Challenge:

Although CA is becoming more well-known for its beneficial impact on soil conservation, many farmers around the world are still unaware of it. For those who are familiar with the idea, managing weeds presents a significant problem. In the long run, literature on minimal or zero-tillage crop production systems may not apply to well-managed CA systems. It is critical to plan for these challenges, especially in the early years, until the soil seed bank is depleted. Minimal and no-tillage encourages the growth of perennial weeds, which leads to for a long time weed problems. (Thierfelder et al., 2018). Moreover, Even in the early years of CA implementation, small-seeded weeds that require light to emerge from dormancy would probably take over as the leading species of weeds in limited and no-tillage systems. As a result, successful weed control is regarded as a significant issue that determines the success of systems based on minimum and zero cultivation as well as CA (Giller et al., 2009). According to various publications, Herbicides serve for suppressing weeds, reduce innate output loss, and deal with manpower shortages in majority countries has been credited with the success of the implementation of a minimum and minimal cultivation system (Nakamoto et al., 2006). In fact, herbicides are usually seen as a replacement for the main type of tillage performed in tillage-based systems for pre-planting control of weeds in minimum and no-tillage systems (Scopel et al., 2013). The use of burn-down herbicides to eradicate the vegetation prior to planting is common, even if cover crops are grown for plowing and control of weeds. Herbicides such as fluometuron, glyphosate, and paraquat are frequently utilized for controlling weeds as an alternative to main tillage. Several of the herbicides on the following list, such as those that are slightly or moderately toxic and may be detrimental to human health and the natural world, are still unidentified. Indeed, the difficulty in applying herbicides for weed control within minimum and zero-tillage systems in California is made more difficult by the fact that minimal cultivation or ridge-till platforms cannot physically incorporate herbicides into the soil, hindering herbicide options to only post-emergence usages. Herbicide use has resulted in various weed species developing resistance in affluent and minimal cultivation systems, as well as documented instances of the same weed species developing multiple resistance to different herbicides (Binimelis et al., 2009). For instance, cutleaf evening primose (*Oenothera laciniate* Hill) has developed resistance to glyphosate and paraquat (Anderson, 2005). Thus, it is important to offer alternatives to herbicides in order to encourage the use of CA in agriculture where herbicide resistance has already developed. The commercialization of glyphosate-resistant crops has made it easier the removal of weeds and, in certain regions, led to the widespread use of minimum and minimal cultivation farming; however, the drawback is that numerous application of the weed killer are now common in spite of other weed management techniques (including those sprayed prior to crop emergence as well as in-season therapies for controlling weeds that might grow after crop planting). The usage of a single herbicide resulted in such a strong selection pressure that glyphosate-resistant weeds appeared very quickly (Johnson et al., 2009). However, there is a conundrum for farmers that employ CA in a climate where glyphosate resistance has arisen, decreasing the use of herbicides. Weed pressure will be minimized in CA systems because of their focus on crop rotation. Clearly, the pressure of weeds, plant resilience, or intrinsic production losses might discourage farmers from accepting conservation tactics such as seeding directly unless the control of weeds is handled sustainably in CA, especially in the initial stages. Degradation of soil and erosion, in reality, threaten biodiversity, agricultural sustainability, and long-term global security of food. (Montgomery and Dirt, 2007). CA seems to be a suitable strategy to prevent Erosion and deterioration of soil and to enhance soil health (Conservation Agriculture, 2018).

16.3 Weed Management Strategies:

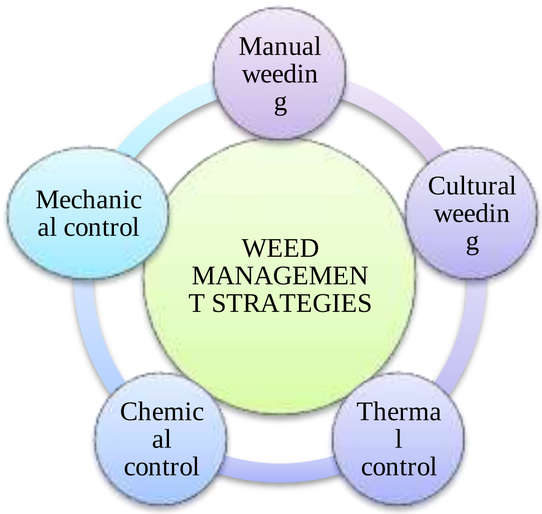

Figure 16.1: Various Strategies for Weed Management

16.3.1 Manual Weeding:

The most popular weed control methods used by smallholder farmers are manual and mechanical (sometimes including animal traction) (Gianessi et al. 2009). For smallholder farmers, hand cultivating or hand hauling is a common controlling instrument for mechanical weed control (Mashingaidze et al., 2012). Because to increased weed pressure in the early years of CA adoption, manpower requirements for mechanical control of weed in CA platform may rise (Nyamangara et al., 2014). Depending on the weed management approach employed, these labor requirements often vary greatly. Farmers that use hand hoes for controlling weeds must use the implement to shallowly wipe the soil surface rather than a digging action, which may take more time. For smallholder farmers adopting CA technology, is a major obstacle due to lack of labor to control weed populations (Giller et al., 2009). Avoiding weeding can have a significant adverse effect on yields of crops due to weeds competing with the main crop for nutrients, light, and water. By timely weeding fields, farmers with a sufficient labor supply can increase the advantages of manual or automated weed management (Vogel, 1994). As an instance, high-intensity weeding was carried out four times during the growing season in a semi-arid region of Zimbabwe: a week prior planting, one week after planting, five weeks after planting, and shortly prior harvest. The results showed that the early season weed densities of the moldboard-plow and minimal tillage systems were comparable (Mashingaidze et al., 2012). Weeding at a high intensity is difficult for farmers with limited resources and manpower, though. The higher labor requirements for weeding disproportionately affect women and children (Giller et al., 2009). Furthermore, compared to traditional tillage systems, higher weed densities are occasionally observed in CA systems even when high-intensity weeding tactics are used, and emphasizing the necessity for alternate weed management methods (Mashingaidze et al., 2012).

16.3.2 Mechanical Control via Animal Traction:

Where draft animals are available, appropriate mechanical cultivators for weed management are frequently used in place of conventional tillage (Riches et al., 1997). While cultivators are not as efficient compared to conventional tillage techniques for determining weed-free planting beds, they are able minimize weed pressure. Smallholder farmers might profit from animal-drawn cultivators like soil rippers, which are equipment fixed on a frame that has multiple tines. They are capable of mechanically disturbing small and emerging weeds, which can be an efficient method of mechanical weed management (Mafongoya et al., 2016). Mechanical cultivators have the disadvantage that they are ineffective and impracticable when there are significant amounts of plant leftovers present (Erenstein, 2003). As a result, they are only appropriate when there is little residue cover, which is frequently the case of semi-arid regions(Mazvimavi et al., 2010). Smallholder farmers may be given access to mechanical cultivators by Cooperatives, agricultural agencies, and vendors of services. Small-scale cultivators would not be able to make the necessary large-scale investments without this strategy. Also, it would shorten the time that farmers in a community would have to wait to use weeding tools (Najafi and Torabi Dastgerduei, 2015). As weed populations are increasing, the timing of seedbed preparation is critical for decreasing crop-weed conflict are heavily influenced by the timing of crop planting (Mhlanga et al., 2016). Given the fact that a lot of small-scale farmers have farms of fewer than five acres, restricted shared ownership or service provision of low-powered or draught-powered devices that disturbs the soil as little as feasible may be the most practical way to offer farmers with access to automated planting and weed management technologies. (Baudron et al., 2015). Government and non-profit organizations (NGOs)-led initiatives might boost access to small-scale machinery by improving regional industry.

As an example, FAO fieldwork in Tanzania and Kenya sought to create relationships with markets and a local manufacturing sector for other CA products, like the hand jab planter (Sims et al., 2012).

16.3.3 Chemical Control:

The accessibility of chemical weed management techniques has been primarily credited for the CA system's achievement (Swenson and Moore, 2009). However, evaluating the potential long-term consequences of based entirely on herbicides is essential as excessive reliance may result in the development greater resistant to herbicides in weed populations. In addition, with integrated weed management strategies that include chemical, mechanical, and cultural control techniques may minimize the harmful effects of herbicide use while maintaining effective control of weeds. (Gianessi et al., 2009). The major issues of the next part are the use of herbicides and seed coatings for weed control, as well as how they could be used effectively without harming local agro ecosystems.

A Herbicides:

For CA systems to be successful throughout the Americas and Australia, herbicide application has been essential (Llewellyn et al., 2012). Herbicide usage should be governed by an integrated weed management strategy, which includes optimal application rates and timing for herbicide applications (Norsworthy et al., 2012). With training, extension agents and researchers must address barriers to herbicide application and access, including as geographic accessibility, and safe chemical handling. The authors also noted that paraquat or glyphosate alone were less successful than interaction and permanent herbicide arrangements, such as atrazine, against annual grasses and broadleaf plants. Yet only some crops can employ residual herbicides, therefore their usage must be carefully studied. When creating an herbicide treatment program, factors including Weed density, the most prevalent species, and producer expertise would all need to be considered. Moreover some studies suggest utilizing cover crops to help in herbicide application (Chauhan et al. 2012). The cover crop is killed and used as cover when a non-selective herbicide like glyphosate is used, lowering weed growth and germination.Also, governments could promote the production of generic forms of non-patented herbicides such as glyphosate, which might improve access and possibly result in cheaper prices (Little, 2010). To be effective, herbicide quality and safety would need to be guaranteed through the setup of testing infrastructure and the implementation of quality standards. Many application techniques, such as weed wipers, can increase the effectiveness of an herbicide.

B Seed Coating:

Herbicide use may be facilitated by the adoption of herbicide-resistant seeds, but smallholder farmers must first have access to this technology (Kanampiu et al., 2003). Additionally, the subsequent growing seasons revealed no lingering impacts on maize seeds that were not herbicide-resistant. Hence, seed coatings seem to be a more focused and efficient strategy to attack some parasitic weed species, Although research into the effects of seed coverings on other important weed and used for farming species would be advantageous. Maize resistant to imazapyr was created via traditional breeding techniques, as opposed to genetic editing, which makes this strategy farmers and governments are going to consider it more appropriate that are unwilling or unable to use crops that have been modified. In short, chemically controlling weeds is an important tool for many farmers using CA, but smallholders' access to seed coating and pesticide technologies needs to be extended. Nonetheless, herbicides can effectively reduce weeds, particularly those that are resistant to manual or mechanical methods of weed control (e.g., couch grass). To minimize inappropriate application that could harm crops, lessen herbicide resistance, and prevent adverse environmental effects, farmers must be instructed in their safe usage (Mtambanengwe et al., 2015). Despite knowing that they are inefficient against non-parasitic weeds, herbicide seed coatings can help manage parasitic weed species like Striga spp.

16.3.4 Cultural Control:

Cropping systems are used in cultural weed management to lessen weed pressure. In many cases, cultural management techniques cost less than chemical techniques and benefit the soil more by incorporating biological material and nitrogen that has been organically fixed (Norsworthy et al., 2012). Crop rotations, enhanced crop rivalry by means of the use of growing and the fertilization process schedules, residue from agriculture preservation for controlling emerging invasive plants, intercropping strategies to increase crop productivity, and their harvest weed seed control for minimizing species-specific weed pressures will be addressed in the following chapter. For smallholder farmers who lack access to herbicides or do not generate enough biomass to retain Crop waste as a weed-control agent, crop competition is an affordable weed management technique (Mhlanga et al., 2016). When population growth is feasible, crop competition can be increased. Planting and fertilization schedules can also help smallholder farmers in using management techniques when crop and weed varieties are most actively competing (Kumar et al., 2013). Research on the impact of fertilization on crop competitiveness are conflicting, and the outcome is heavily influenced by The agricultural product and the most prevalent weed species (Walker and Buchanan, 1982). It was discovered that earlier planting and N-fertilizer application at the winter wheat stem elongation stage reduced In comparison to N-fertilizer application at the tillering stage, *Veronica hederifolia L.* biomass has risen while crop biomass yield was improved. (Liebman and Davis, 2000). A study on weed interference with hybrid maize, on the other hand, observed that less N fertilization led in higher crop yields of maize with fewer weed interference. (Tollenaar et al., 1994). As a result, additional investigation and observation of weed population patterns in relation to planting and fertilization date adjustments are required prior to making recommendations to landowners.

A. Crop Rotations:

The competition of weeds with crops can be decreased and weed development made harder by maintaining live soil cover via rotations of crops (Blackshaw et al., 2008). In addition to biological nitrogen fixation, Rotating cover crops with leguminous plants promotes food diversity (for both people and animals) (Govaerts et al., 2009). Crop rotation gazes like it's extremely advantageous in areas that are semi-arid, while the literature shows that its effectiveness as a weed control approach fluctuates. The limited growing season in semi-arid areas (often from November to April) makes it difficult to implement certain rotation of crops strategies (Mupangwa et al., 2016), therefore, crops might be rotated annually. Yet, if farmers see the changes to their soils, the advantages of rotation of crop as a device for

control and soil improvement might exceed anticipated hazards from implementing a rotating system. Crops must be rotated annually because the short growing season in semi-arid regions (typically from November to April) makes it challenging to use various crop rotation schemes. Yet, if farmers see the changes to their soils, the advantages of rotation of crop as a tool for control of weed and Sand enhancement could be greater than the risks associated with putting a rotating system into place (Thierfelder and Wall, 2010). Many research have been done to investigate the impact of these agricultural methods on weed populations, which involve intercropping, as rotation of crops, and residue from crops preservation. The dearth of research in the regions emphasizes the significance of this field even more, since it will aid farmers in more effectively implementing these tactics in their particular environments.

16.4 Conclusion:

Controlling weeds is one of the most important obstacles to successful crop production, especially in CA system applications. Successful implementation of CA in smallholder agricultural systems is improbable without efficient weed management and control techniques. Weed management in massive agricultural systems is not suitable for small-scale farmers due to a lack of financial resources, knowledge of, and accessibility to herbicides. While control of weeds is an important obstacle in the beginning stages of CA conversion, which is managed by small-scale producers. The scope and breadth of their implementation, as well as the selection of weed control methods used, are dictated by the farming circumstances of the farmers to whom all of the options have to be tailored. Weed pressure typically decreases when the first weed-related difficulties of converting to CA are under control, making it simpler for smallholder farmers to continue. Farmers still need to stick to CA guidelines and procedures throughout the years in order to successfully eradicate weeds. Farmers must modify their long-standing practices and how they handle their land in order to adopt CA, otherwise, the benefits will not be realized. Therefore, it is important to assist farmers in implementing effective weed control techniques, such as preventing weeds from establishing seed, preserving crop residue cover, and routinely adopting rotations or intercropping with crop species that are competitive. Farmers will be able to benefit from CA if they can find appropriate weed control techniques and boost their adoption, which may increase their long-term resilience to various stresses.

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