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# Weed management in conservation agriculture: A brief review

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**Abstract**
Weed is a rogue plant which hamper the growth of main crop. The composition of weed flora depends upon the type of agroecosystem. The weed flora in rainfed system differs from irrigated system. Likewise annual crops will have different weed pattern than the perennial cropping system. In low intensity tillage or no tillage associated with conservation agriculture weeds are the major biological constraints towards the large scale adoption of it, and are considered to be one of the most important aspects in crop production under conservation agriculture as it does not allow the traditional means of weed management by ploughing to prepare the field for sowing. Conservation systems are necessary to preserve agricultural productivity and meet future food demand either domestic or global. In this context adequate weed control is vital to make these systems successful. Herbicide use has been a valuable asset when adopting conservation practices. However, prudent use of chemical weed control is essential to fulfill the goals of conservation agriculture by having reducing detrimental environmental impact as well as reducing herbicide resistance development in weeds.

**Keywords:** Weed, Management, Conservation agriculture

## Introduction
Adoption of green revolution technologies during 1960s led to increased productivity and elimination of acute food grain shortage in India. The transformation of 'traditional animal-based subsistence farming' to 'intensive chemical- and tractor-based conventional agriculture' have led to multiplicity of issues associated with sustainability of these production practices. This was also accompanied by the other so called modern methods of cultivation, which included maximum tilling of land, virtually clean cultivation with complete removal of crop residues and other biomass from the field, fixed crop rotations mostly involving cereals, and oilseed crops. It is realized that soils are getting impoverished due to imbalanced use of fertilizers, discontinuation of traditional practices like mulching, intercropping and inclusion of legumes in cropping systems. Further, the use of organic manures, compost and growing of green manure crops has also decreased considerably due to various reasons. Similarly, water resources are under great stress due to their indiscriminate exploitation and also getting polluted due to carious human interferences. Burning of fossil fuels, crop residues, excessive tillage including puddling for rice cultivation are leading to emission of greenhouse gases, which are responsible for climate change and global warming. Further, there is now a growing realization that the productivity levels are stagnating and the incomes of the farmers are reducing due to the rising cost of the conservation agriculture is a modern concept and an advanced agronomic tool of growing crops from year to year without disturbing the soil, avoiding frequent tillage which used to be done primarily for seed bed preparation and weed control. It is a crop management system being promoted due to its potential to conserve, improve and make efficient use of resources like soil, water and nutrients besides energy savings and environmental benefits. "Conservation agriculture is a resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment." (FAO, 2007) [9]. Aspects of conservation that we normally deal are the management of soil, water, crop diversity, animals, storage of produce (seed, fertilizer, etc.), and maintenance of tools, implements, machinery, etc. The important key principles of conservation agriculture (CA) are.

i. Tillage: practice of minimum mechanical soil disturbance which is essential to maintaining minerals within the soil, stopping erosion, and preventing water loss from occurring within the soil.
ii. Crop residues/ Mulch: Managing the top soil to create a permanent organic soil cover for growth of organisms within the soil structure.
iii. Crop rotation: The practice of crop rotation with more than two crop species.

i. Economics: Secure farm level economic viability and stability. To achieve this will involve the development of innovation systems focused on the needs of farmers and will include multiple agents who will use their comparative advantages to adapt the principles of CA to the farmers' various biophysical and socioeconomic conditions. Crop diversification could also be proved as remunerative.
ii. Environment protection: The CA has a role to conserve the environment in terms of climate resilient agriculture and emission of green house gases (GHG).

Amongst these principles, crop rotation can be used best as a "disease control" against other preferred crops (Hobbs, 2007) [14]. This process will not allow pests such as insects and weeds to be set into a rotation with specific crops. Rotational crops will act as a natural insecticide and herbicide against specific crops. Not allowing insects or weeds to establish a pattern within fields will help to eliminate problems with yield reduction and infestations within fields (FAO 2007) [9]. Similarly, crop diversification is also emerging as new avenue for making conservation agriculture economically viable. Moreover, due to conservation of tillage operation in the conservation agriculture the study on weeds dynamics pertaining to crop survival gains importance. In this way weed management has become an integral part of not only the crop husbandry but also conservation agriculture. Here attempt has been made to signify the role of weed management in making conservation agriculture more successful and profitable.

Day by day burgeoning population is increasing the pressure on agricultural system for more food demand. The agriculture system has many challenges like the shrinking agricultural area, labour availability, plateau in crop productivity, soil degradation, input availability and several other challenges. At the same time enough food is to be produced to feed the population with minimal environmental degradation. According to FAO (2010) [10], conservation agriculture is a system designed to achieve agricultural sustainability by improving the biological functions of the agroecosystem with limited mechanical practices and judicious use of chemical inputs. Losses caused due to weeds are more than made by any other pests like insect, diseases, rodents etc.

Although ploughing helps in weed management effectively by uprooting and burial, yet it is considered to be most energy-consuming, among all field operations. Compared to conventional agriculture, farmers can save up to 40% of time, labour and fuels in conservation agriculture besides reducing soil erosion, increasing soil moisture conservation, lowering surface run-off of herbicides and fertilizers, and improving profits. In low intensity tillage or no tillage associated with conservation agriculture weeds are the major biological constraints towards the large scale adoption of it, and are considered to be one of the most important aspects in crop production under conservation agriculture as it does not allow the traditional means of weed management by ploughing to prepare the field for sowing. Therefore use of herbicide is gaining importance to control weeds. Moreover, less tillage in conservation agriculture increase the difficulty in managing the weeds. This also leads to enrich weed seed bank due to greater survival of weeds when the farmers adopt the conservation agriculture. In this context herbicides application can effectively control weeds by saving time, labour and money. The most of the herbicides do not/ or cause little adverse impact on environment hazard as they are easily degradable and less persistent in soil. Thus, it meets out the objectives of conservation agriculture to restore and conserve natural resources like soil, water and environment. Here attempt has been made to highlight importance of weed management in conservation agriculture.

**Key Principles of Conservation Agriculture**

Farmers are now interested in sustainable crop production systems to adopt and adapt improved crop management practices, a step toward conservation agriculture (CA), which may be considered the ultimate solution. In general, CA focuses on the complete agricultural system involving major changes in farm cropping. Appropriate CA technologies encompass innovative crop production systems that combine the following basic tenets (Lumpkin and Sayre, 2009) [15]:

- Significant reductions in tillage
- Zero till or controlled till seeding for all crops in a cropping system if feasible.
- Rational retention of adequate levels of crop residues on the soil surface
- Surface retention of sufficient crop residues to protect the soil from water runoff and erosion; improve water infiltration and reduce evaporation to improve water productivity; increase soil organic matter and biological activity; and enhance long-term sustainability.
- Use of sensible crop rotations
- Employ economically viable, diversified crop rotations to help moderate possible weed, disease, and pest problems; enhance soil biodiversity; take advantage of biological nitrogen fixation and soil enhancing properties of different crops; reduce labor peaks; and provide farmers with new risk management opportunities.
- Farmer conviction of the potential for near-term improved economic benefits and livelihoods from sustainable CA systems
- Secure farm level economic viability and stability. To achieve this will involve the development of innovation systems focused on the needs of farmers and will include multiple agents who will use their comparative advantages to adapt the principles of CA to the farmers' various biophysical and socioeconomic conditions.
- Environment Protection
- The time has come to implement climate resilient agriculture. The niche of the agricultural system should be either no/less polluting or reduction in emission of green house gases (GHGs).

**What is weed?**

Weed is a rogue plant which hamper the growth of main crop. It competes with crop for nutrients, space, moisture, sunlight etc. Its impact depends on type of weed flora, weed infestation, growth pattern, cropping history, measures of weed control, level of inputs etc.

**Weed flora in field**

The composition of weed flora depends upon the type of agroecosystem. The weed flora in rainfed system differs from irrigated system. Likewise annual crops will have different weed pattern than the perennial cropping system. Altogether dominance of weed flora solely depend on type of crop, soil type, input level, microclimate, cropping system (monocrop/diversified crop) etc. The predominant weed observed in the field crops are either narrow leaf or broad leaf; either annual or perennial. However some are mentioned as follows:

Monocot: Cyperus rotundus, Cyperus esculentus, Cyperus ira, Cynodon dactylon, Parthenium hysterophorus, Saccharum

spontaneum, Dactylonium aegyptium, Digitaria sanguinalis, Echinochloa colonum etc.
Dicot: Parthenium hysterophorus, Digera arvensis, Euphorbia hirta, Euphorbia spp., Convolvulus arvensis, Trianrhema portulacastrum, Commelina benghalensis, Heliotropium eichwaldi, Lantana Camera, Melilotus alba.
Crop specific weed flora are: Rice: Echinochloa colonum, Echinichloa crassipes; Maize: Straiga; Wheat: Phalaris minor, Avena fatua, Avena ludoviciana,

**Weed Management in Conservation Agriculture**
Farmers plough the soil to control weeds. Tillage is easy to control weeds in the field crops. Weed control without tillage is more complicated and requires much more knowledge. A lot of farmers find controlling weeds to be very difficult in the first seasons of conversion from conventional agriculture to conservation agriculture (CA). Stopping soil tillage has an important effect on weed dynamics. When the soil is ploughed, weed seeds are buried, some of them deeply, and then returned to the surface in the following season. The "seed bank" in the soil is difficult to empty if the soil is continually tilled. Good weed control in CA for a few seasons will deplete the weed seed bank in the soil. If weeds did not allow to set seeds then weed problems will decline rapidly. There are several measures that can be taken to control the weeds:

a) Manual weed control
b) Stopping the weeds from setting seed
c) Effective crop rotations that suppress the weeds
d) Green manure cover crops to smother the weeds
e) Crop residues to help smother the weeds and build up biological activity
f) The use of herbicides

The best practice is to use as many of these options together as possible – in most cases using a combination of weed control strategies will markedly reduce weed populations within three years.
Manual weed control: Many small and marginal farmers rely on manual weed control. It is a very effective weed control method when carried out properly, but must be done when weeds are small (less than 10 cm) and these should be remove either with the sickle or intercultural operations by hoe. In CA, care should be taken to move the soil as little as possible. Manual weed control is time consuming and labour intensive, but does not require extensive knowledge nor is it risky.
Stopping the weeds from setting seed**:** The year-round weed control is needed to deplete the weeds from soil. Most farmers do not worry about weeds at the end of the season or during the winter because they do not affect the crop yield in the current year. However, these weeds set seed and lead to heavy weed infestation in the following season. Late season and winter weeding are vital to successful weed control in CA.
Crop rotation and green manure cover crops: Crop rotation to be followed must have one of the crops having smothering effect. It helps in hampering the weed growth by suppressing weeds. Some crops grow more vigorously than others. They cover the soil quickly and tend to smother the weeds. Including these crops (e.g. pigeonpea, soybean, cowpeas) in the rotation together with the other weed control methods will reduce weed populations and control annual weed easily.
Some green manure cover crops are very vigorous and can effectively reduce weed populations when planted as intercrops or sole crops in a rotation. Good weed control can be expected from velvet beans (Mucuna pruriens), lablab (Lablab purpureus) and sunnhemp (Crotalaria juncea). Velvet beans and lablab, if sown as intercrops, need to be seeded at about three (lablab) to six weeks (velvet bean) after the maize crop so that they do not compete too much and reduce maize yield.
Crop residues: Crop residues helps in covering the soil and conserve the moisture. The smothering effect of residues reduces the weed density and total population. The greater amount of residues prevents weeds to grow through the mulch. However, the residues also make hand weeding more difficult. Crop residues on the soil surface increase biological activity and insects and fungi attack weed seeds and reduce their viability.
Chemical weed control: Chemical weed control is quick and effective, but herbicides have to be applied properly. The person applying the chemical needs should have specialized knowledge of herbicide products, the weeds they control and the crops they are used for, their toxicity and how to handle them, the conditions under which they work best. Similarly activity of herbicide under which they do not work, application methods and rates, types of equipment and its calibration, types of nozzles, use of protective clothing etc. However, the herbicides needs initial capital and readily available at the onset of season.

**Role of herbicide in conservation agriculture**
Three core elements of conservation agriculture make possible the objectives of this system including minimal tillage operations, permanent vegetative residue for soil cover, and rotation of primary crops (FAO, 2010) [10]. Thus, conservation tillage seeks to reduce tillage practices and increase residual soil covering, which may not be permanently maintained, to achieve similar goals as conservation agriculture (Hobbs, 2007) [14]. There is shift from conventional tillage practices to conservation practices. Under such situation soil disturbance has to be less turned prior to planting compared to traditional tillage operations. One of the ways to control weeds is to use selective herbicides. Thus, post-emergence spray of such herbicides will help to manage weeds. The weed seed bank gets enriched under CA due to less tillage operations. Therefore, conservation systems have been characterized by greater weed densities than conventionally tilled agricultural production (Cardina *et al*., 2002; Sosnoskie *et al*., 2006) [4, 24]. The farmers have increasingly relied on herbicide control options to obtain satisfactory crop yields. However, the initial availability of effective formulations was limited for conservation tillage. With a tillage reduction in tillage, the farmer lose weed control offered from seed burial as well as the option to incorporate soil applied pre-emergent herbicides. Pre-emergence herbicides found less effective in controlling weeds because incorporation of these herbicides can have reduce persistence and efficacy in the presence of plant residue that may intercept and bind the chemical before it reaches the soil the soil surface (Potter *et al*., 2008) [17]. Therefore, farmer adopting conservation practices primarily dependent upon post-emergent chemical applications. Efficacy of such herbicides gets hampered due to shifts in weed population dynamics due to altered distribution of weed seed within the soil (Buhler, 1997) [3]; perennial weed species also thrive in reduced tillage settings and can be difficult to control with available post-emergent herbicide options (Swanton *et al*., 1993).
Precautions about herbicides: Herbicides kill plants- crops are also plants! The user needs to understand how to control weeds and not hurt the crop, people or the environment. There are many herbicides with different characteristics- the user

has to apply the right herbicide at the right dose and time and using the right method. Some herbicides control all plants and must be applied before the crop emerges. Others only control some plants and so can be applied when the crop is growing. Herbicides for one crop can kill other crops - a herbicide to control weeds in maize may kill cotton. Some herbicides must be applied before the weeds germinate, and others will only control weeds that have already germinated. Herbicides differ in their toxicity to humans and animals - some are very toxic. Before you use herbicides, make sure you read and understand all instructions on the label.

**Weed Management Strategies in CA**

Introduction of transgenic herbicide tolerant crops in the United States made the reduced tillage a viable option. The availability of such crops with resistance to a non-selective herbicide like glyphosate has provide the means for effective post-emergent herbicide control of a broad spectrum of weed species while reducing labour demands and repeated herbicide applications. For the development of a transgenic crop, particularly an herbicide-tolerant crop to be pursued, several factors must be investigated including: spectrum of weed control provided by the herbicide, safety risks to humans and the environment, yield performance of genetically modified crop, and economic value of the crop (Devine, 2005) [5].

Herbicide tolerant crops

Since identifying selective herbicide compounds that are active on weed species and not on a particular crop can be a difficult process, conferring herbicide tolerance of a non-selective herbicide to a crop can be tremendously valuable for effective weed control (Mazur and Falco, 1989). Glufosinate and glyphosate are non-selective herbicides and have been the focus for herbicide tolerant crops (Devine, 2005) [5]. The broad spectrum herbicide, glyphosate (Nphosphonomethyl) glycine), works through the inhibition of 5-enolpyruvilshikimate-3- phosphate synthase (EPSPS). The EPSPS is an enzyme required for the production of aromatic amino acids which are necessary for subsequent production of plant hormones and structural components (Sconbruunn *et al*., 2001; Dill, 2005) [22, 6]. The means of for conferring glyphosate resistance to crops is achieved through the insertion of a resistant transgene, referred to as CP4- EPSPS. It allows the plant's shikimate pathway to continue to function in the presence of glyphosate applications (Funke *et al*., 2006) [11]. Thus, a glyphosate-tolerant soybean was adopted in United States, Argentina, and Brazil (Dill, 2005) [6]. Similarly, glufosinate (LPhosphinothricin), a non-selective herbicide, acts as an inhibitor of glutamine synthase which impedes the production of amino acids and inhibits photosynthesis ((Droge-Laser *et al*., 1994; Ross and Lembi, 1999) [8, 21]. Glufocinate-tolerant plant varieties are produdced in canola (Brassica napus L.) through encoding for phosphinothricin acetyltransferase (PAT) proteins which detoxify glufosinate through N-acetylation (Droge *et al*., 1992; Herouet *et al*., 2005) [7, 13]. This crop was firstly introduced in Canada in 1995 with relative success. But could not further proliferate as certain weeds limit its efficacy due to lack of translocation of gluphosinate (Duke, 2005). The adoption- of glyphosate tolerant crops was especially suited to conservation system since glyphosate can effectively control many perennial species that appear when tillage practices are reduced (Ross and Lembi, 1999) [21]. However, as it was regular and overdependence on this herbicide lead to resistance in multiple weed species.

**Introduction of herbicide resistance crops**

The studies were conducted to find out resistance mechanism in crop for some of the herbicides. The Roundup Ready Soybean has been identified as the Glyphosate resistant cultivar of soybean. Glyphosate is a non-selective herbicide which controls wide range of weeds. Therefore, such varieties will help control broad spectrum of monocot and dicot weeds. Even perennial weeds can also be eradicated to some extent. It could solve the problem of labour scarcity also.

**High residue cereal cover cropping**

The continued appearance of herbicide-resistant weed species following the introduction of herbicide-resistant crops has been detrimental to conservation tillage systems where feasibility relies on this technology. Options for weed control must reduce selection pressure for herbicide resistance as well as provide season long weed suppression in order to be viable components of a new weed control strategy. Alternatives to repeated use of a single herbicide include: crop rotation, improved management practices, alternative herbicide chemistries, and use of high-residue cover crop systems (Price *et al*., 2009) [19]. Ideal alternative growing practices would incorporate several of these strategies to protect against resistance development, however, the use of a particular practice, high residue cover cropping, is proving to be an exceptional weed control technique in conservation systems. Cover crops can reduce weed numbers physically and chemically while actively growing or after termination. Prior to termination, cover crops can compete with weed species for necessary resources such as light, water, and nutrients. They can also release allelochemicals into the soil which may be detrimental to nearby competing weed species with particularly for small-seeded weeds (Price *et al*., 2008) [20].

**Constraints**

**Herbicide resistant weeds**

The repeated exposure of weeds to one herbicide could lead to the possibility of herbicide resistant weed biotypes (Appleby, 2005) [1]. Herbicide resistance in weed can be of two types (i) target site resistance where modification to the active site for an herbicide limits its toxicity and (ii) non target site resistance where herbicide movement to the active site is limited in some fashion (Powles and Yu, 2010) [18]. For example resistance mechanisms for glyphosate resistance comprised of both classification of resistance, including target site modifications, gene amplification as well as reduced herbicide translocation (Gaines *et al*., 2010) [12], The first case of herbicide resistance was formally documented in triazine resistant common groundsel (Senecio vulgaris L.). Heap (2010) reported about 346 herbicide resistant weed biotypes worldwide. Similarly, exposure to glyphosate has greatly increased selection pressure for resistant weed biotypes. Around 18 different weed species are resistance to glyphosate since 1996. In India resistant to Isoproturon in weed biotypes has been reported in wheat growing area.

**Conclusion**

Conservation systems are necessary to preserve agricultural productivity and meet future food demand either domestic or global. In this context adequate weed control is vital to make these systems successful. Herbicide use has been a valuable asset when adopting conservation practices. However, prudent use of chemical weed control is essential to fulfill the goals of conservation agriculture by having reducing detrimental environmental impact as well as reducing herbicide resistance

development in weeds. Thus in conservation agriculture weed could be controlled through integrated weed management practices.

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