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The Need for New Directions on Conservation Agriculture towards Weed Management: Review

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This work was carried with collaboration of all authors. Author OAW designed study outline. Author RUN collected review and other all authors helped in refining this article. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Agriculture conservation practices such as minimal soil disturbance, permanent soil covering by crop residues or cover crops, and crop rotations leads to higher farm productivity. Although conservation agriculture has been adopted in India since its inception, it has now been successfully used in Indo Gangetic Plains irrigated rice-wheat cropping systems and has recently been made known in parts of central India. In conservation agricultural system, cover crops play an important role in weed control, but their adoption level is still limited Changes in tillage practices, planting schemes, and other management techniques can change the soil environment and trigger a significant change in weed flora In intense tillage operations early season weed control could be obtained by turning the soil, which disrupts the germination of weed seeds and the growth of seedlings through burial. In addition, soil-administered herbicides that do not need to be manifested

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can have less persistence and efficacy in the presence of plant residues that can hinder and bind the chemical before it reaches the soil surface. Selective herbicide compounds that are effective on weed species and not on a specific crop, conferring non-selective herbicide tolerance on a crop may be enormously effectual for potent weed control.

Keywords: Advances; conservation agriculture; herbicide; management; weed.

1. INTRODUCTION

Conventional farming' methods has resulted in multiple issues relating to sustainability as compared to traditional methods. Conventional crop production technology has imparted: (i) intensive tillage to prepare fine seed and root beds for sowing to ensure proper germination; Early vigor, improved moisture conservation, control of weeds and other pests, mixing of fertilizers and organic manures, (ii) mono-cropping systems, (iii) removal or burning of all crop residues has results in bare soil, continuous soil profile nutrient and moisture mining, (iv) indiscriminate pesticide use of chemicals, use of chemical fertilizers due to declining input-use performance, production and environmental factors, contamination from groundwater, lakes, rivers and oceans and (v) energy-intensive agricultural systems. Prices, and also showed that agricultural production is an important means to stimulate economic growth and reduce poverty. But, post-Green Revolution input intensive conventional agriculture production systems have led to several global concerns, such as: (i) declining factor productivity, (ii) declining ground water table, (iii) development of salinity hazards, (iv) deterioration in soil fertility, (v) deterioration in soil physical environment, (vi) biotic interferences and declining biodiversity, (vii) reduced availability of protective foods, (viii) air and ground water pollution, and (ix) stagnating farm incomes. To resolve this, conservation agriculture is a system designed to ensure agricultural sustainability by enhancing the agroecosystem's biological functions with less mechanical activities and the effective use of chemical inputs [1]. Agriculture conservation is an agricultural management activity which includes less soil disturbance, residue retention for soil cover and crop rotation in its simplest form [2]. Conservation agriculture practices are designed to reinforce agricultural sustainability by introducing sustainable management practices that mitigate environmental degradation and save energy while preserving high yield productive systems, and also improve the agro-ecosystem's biological functions with less mechanical practices and effective use of external inputs. Globally, advances in crop management technologies focused on agricultural conservation have been shown to be more vigilant in accessing the problems around them [3]. Conserving agriculture has many benefits in terms of saving energy, fuel and time up to 40% relative to conventional agricultural practices [2], In contrast, it is also effective in improving soil biological activity as a result of crop residue and lack of soil disturbance in conservation farming. Conservation agriculture is also promoted as an alternative to traditional cropping practices for increasing crop yields and soil resource conservation. In addition to these advantages, the implementation of conservation agriculture cannot be widespread due to the looming threat posed by weeds, which are considered to be the main biological constraints in yield realization. Because of tillage scarcity, weeds grow and luxuriate in Agriculture Conservation if appropriate weed control steps are not taken.

1.1 Principles of Conservation Agriculture

I. Minimum soil disturbance: Method of least mechanical soil disturbance which is indispensable in maintaining minerals within the soil, preventing erosion, and stopping water loss occurring within the soil.

II. Crop residues retention: Managing the top soil to generate indefinite organic soil cover for growth of organisms within the soil structure.

iii. Diversified Crop rotation: The habit of crop rotation with more than two crop species.

2. CHALLENGES OF WEED MANAGEMENT IN CONSERVATION AGRICULTURE

Though conservation agriculture is gaining recognition for its positive impact on soil conservation, many farmers globally still don't know it. A big concern of among those familiar with the idea lies onweed management. While some of the challenges in the literature advocate for minimal or no-tillage systems over the long term. Agricultural production systems may not be defensible for well-managed conservation, they should be considered and planned, particularly for the first years, before the soil seed bank assembly has been predominantly depleted during tillage years. Although accessing weed control is a challenge, scientific studies have testament to the fact that minimal and no-tillage invoke weed population shifts particularly with regard to perennial weeds, creating a time-honored weed problem [4]. The same applies to annual weeds like Kochia (*Kochia scoparia* (L.) Schrad.) in tillage-based systems, and Russian thistles (Salsolaiberica Sennen & Pau) that are regulated but sometimes overgrow in minimum and non-tillage systems [5]. Small-seeded weeds that need light to break dormancy in broad-brush would likely become the primary weed species in minimal and no-tillage systems, even in the first years of conservation agriculture adoption. Operational weed management is thus considered a fault-finding problem, and in minimum and no-tillage based systems and conservation agriculture [6]. Progress with support of minimal and no-tillage, as circulated in various publications , is to allocate the use of herbicides to combat weeds, turn down inseparable loss of yield and cover with a shortage of labor in most countries [7]. In addition, in many cases, herbicides are rationalized in minimum and no-tillage as an alternative for primary tillage, terminated in tillage based systems, for pre-plant weed control [8]. Some authors indicate that herbicides have reduced dependence on traditional Tillage methods for weed control which have resulted in the introduction of minimal and no-tillage practices [9]. Burn-down herbicides are frequently used even when cover crops are cultivated for mulching and weed control Used before planting, to burn vegetation.

The herbicide-based no-till is controversial for many reasons. As a substitute for primary tillage, the herbicides used commonly for weed control consist of 2, 4-D, dicamba, diflufenzopyr, fluometuron, glyphosate, glufosinate and paraquat. Alternatives for some of the herbicides on this list which include slightly (Class III) or moderately (Class II) hazardous herbicides that can affect human health and the environment are still to be recognized. In reality, the challenge to use herbicides for the management of weeds in minimal and no-tillage and CA is further complicated by the mechanical. Introduction of herbicides into the soil cannot be accomplished with no -tillage or ridge- till systems, which restrict Options for herbicides only post-emergence. As a result of the use of herbicides, there is minimum resistance of some weed species and no-tillage systems and cases of multiple-resistance of the same weed have been identified Species containing multiple herbicides were also recorded [10]. Cut leaf evenings, for example Primrose (Oenothera laciniate Hill) has become glyphosate and paraquat resistant [11]. Alternatives to herbicides should therefore be encouraged to facilitate the adoption of CA in a farming environment where herbicide resistance has developed. commercial release of glyphosate-resistant crops has improved weed control and in some regions Nevertheless, a negative consequence of implementing minimal and no-tillage is the numerous implementations of Herbicide is now common in the absence of other methods for weed control (including those before the emergence of crops and additional in-season treatments to suppress weeds that grow after crop planting). The enormous selection pressure caused by the use of a single herbicide quickly progressed to the Glyphosate-resistant weeds [12]. CA systems, with an emphasis on crop rotations and associations should reduce the pressure on weeds, but farmers are faced with a challenge who engage in CA in an environment where glyphosate resistance has occurred, as this will reduce the applicability of the herbicide.

3. ADVANCES IN CONTROLLING WEEDS

3.1 Mulching with High Residue Cereal Cover Cropping

After the development of herbicide-resistant crops, the constant introduction of herbicide-resistant weed species was devastating for conservation tillage systems where suitability depends on this technology [13]. Cover crops that grow rapidly can hinder weeds' growth. Cover crops may hinder development of weeds through various mechanisms. among the mechanism of weed suppression of weeds include limiting resources required for weed development such as light, water and nutrients. They may also release alllochemicals into the soil that may be harmful to immediately competing weed species, especially for weeds of small seed [14].

Fig. 1. Cotton (*Gossypium hirsutum* L.) planted into a soil cover of black oat (*Avena strigosa* Schreb.)

Table 1. Weed control for year 1 in cotton, peanut, and soybean by percent control for four cover crop options and three herbicide inputs (by intensity) [15-17]

Cotton	**Peanut**			**Soybean**					
Herbicide input system	**Herbicide input system**			**Herbicide input system**					
Cover crop	High	Low	None	High	low	none	high	low	None
----Weed control (%)--- ----Weed control (%)-----Weed control (%)---									
Fallow	94	86	13	91	88	24	92	85	29
Black oat	95	91	35	93	94	70	95	95	86
Rye	94	89	26	94	93	61	95	91	83
Wheat	94	87	14	94	93	43	95	91	61

Table 2. Crop yield for year 1 as affected by three herbicide inputs and four cover crop options. No yield could be collected for cotton without herbicide input [15-17]

Cotton				**Peanut**			**Soybean**		
Herbicide input system				**Herbicide input system**			**Herbicide input system**		
cover crops	High	Low	None	High	Low	none	High	Low	None
	---Seed cotton (kg/ha)-			**---peanut (kg/ha) ---**			**---soybean (kg/ha) ---**		
Fallow	3660	3010	0	4280	4100	2030	4031	4031	1344
Black oat	3840	3630	0	4760	4740	3190	6719	7391	6047
Rye	3980	3350	0	4690	4850	3460	6047	6791	6047
Wheat	3970	3120	0	4670	4420	2500	6719	6719	4703

Results in table show that high-residue cover crop systems can be effectively exploit in conservation systems with increased yield potential and possible reductions in herbicide inputs for requisite weed control. Reduced herbicide dependence, without yield decrease, can acceptable help in reduced herbicide-resistance development and assist conservation tillage practices well into the future.

3.1.1 Seed predation in ecological weed management

The accumulation of surface seeds under no-tillage would increase their susceptibility to insect, rodent, and bird predation [18]. It can be an actionable path for environmentally sustainable weed control [19]. Less fractious (or zero) soil tillage combined with higher plant populations and heterogeneity was found to accommodate predation of weed seed, particularly by arthropods. An admiring example is the use of cover crops that have been a constant leader in bucking up insect-predating weed seeds [20].

3.1.2 Seed decay

Weed seed decay is a weed seed bank diminishing technique and is mentioned by [20]. Still an ill-understood process that involves, for example, innovation in soil conditions that cause fungal weed seed infections. A strategy for managing the notoriously deadly cereal crop weed-blackgrass (Alopecurusmyosuroides Huds.)-with no-tillage practices is a fine example [21].

3.1.3 Harvest weed seed control

The process of harvest weed control involves chaff carts, narrow-windrow burning, weed seed milling and bale-direct systems [22]. Weed seed milling (e.g., with Harrington Seed Destructor [23].

3.1.4 Weed header

It is primarily to prevent weeds from producing and shedding seeds which become prevalent in a crop. A weed header can be used to behead them to remove weed flowers which grow overhead crop height [24].

3.1.5 Photo-control

In conservation agriculture, photo-control of weeds is ongoing during the night to limit the germination of light-sensitive weed seeds [25]. This may be purposeful depending on what weed flora is present, regardless of whether or not this approach will be a worthwhile one. Seed germination experiments may be performed with and without light to determine the presence of organisms that are sensitive to light.

3.1.6 Mulching

Mulching allocates soil cover during the planting season or when the crop is not present. The mulch's primary purpose is to prevent / reduce light from entering the soil surface to smother germination of weeds. Under Conservation, the use of organic mulch (live / green mulch or crop / plant residue) is favoured, while there is non-living mulch order to work effectively, mulch requires a thick abundance to competently cover the soil surface. By using crop residues, it is necessary to ensure that the residue is applied continuously to the surface of the soil to complete the cover. Residue allotment can be performed automatically or manually during harvest. Also, depending on the amount of residue and biomass used for mulching, this may be a labor-intensive operation.

Fig. 2. A weed header (weed surfer) in action surmount weed seed heads come through above an organic organic beetroot (*Beta vulgaris* L.) crop (Photo: S Briggs). beetroot (*Beta vulgaris* L.) crop (Photo: S Briggs)

3.1.7 Timeliness of seeding operations

In dry climates seasonable seeding of crops is important to ensure the well-planned use of soil moisture and growing season. Seeding timing can be altered to improve crop productivity, depending on the form of weeds present. Once again, it is important to have a clear understanding of the form of weed and its life cycle, as they do have a particular germination state and timing [26].

3.1.8 Push-pull

Establishing the push-pull method for African cereal systems [20]. Applies for the management of stem-borer maize (*Busseolafusca lepidoptera*: Noctuidae) and parasitic witch weed (Striga). The means the process functions is as follows; maize is interspersed with desmodium silver leaf (*Desmodium uncinatum* (Jacq.) DC) and Napier grass (*Pennisetum purpureum*) forage crop Schumach (1827). is planted around the field border. Desmodium gives rise to volatile chemicals that drive back the adult stem-borer moths by signalling the region is already infested. The moths are 'pushed' to the Napier grass where, besides, the larvae do not thrive, desmodium serves as a 'false host' for witch weed that braces its germination without parasitisation. In this way a desmodium cover crop can, through suicidal germination, nearly eliminate Striga in a pair of seasons.

3.1.9 Competitive genotypes

Faster growing varieties can have an advantage over slow ripening varieties within a species. Genotypes with dwarf features, or a broader index of the leaf area, may also have an advantage. Such steps may be taken into account when choosing the variety to be planted, depending on the types of weeds present in the area. Allelopathic crop cultivars may also be tested.

3.1.10 Intercropping

Intercrops help to effectively predict weed efficiency and reduce weed growth, and can therefore be used as an effective weed control strategy in CA. For examples, Alfalfa+barley, Alfalfa+oats, Pigeonpea+urdbean / mungbean / cowpea / sorghum, Rice+Azollapinnata, Sorghum+cowpea / mungbean / peanut / soybean, Chickpea+mustard, etc.are some fortunate weed suppressing intercropping systems. The intercropping of short-duration fast-growing, and early-maturing legume crops with long-duration and wide-spaced crops contributes to rapid ground cover, with higher total weed capacity to suppress than sole crop. This technique increases weed control by increasing competition in the shades and crops. Within a field, intercrops, including cover crops, increase the ecological diversity. We very sometimes compete greater with weeds for light, water and nutrients.

3.1.11 Allelopathy

Crop allelopathy is used as a competitive tool in under conservation agriculture against weeds. Different crops are capable of significantly suppressing weeds such as alfalfa, barley, black mustard, buckwheat, corn, sorghum, sunflower and wheat; either by absorption of allochemical compounds from living parts of plants or by decomposing residues. demand for sustainable agricultural systems has forced increased cover crop work to better use these covers for effective weed control, so understanding the role of weed clampdown allelopathy within various cover crops is required [27,28]. Allelopathic pressure on weeds is usually higher when using grasses or crucifers as cover crops than when using legumes. The use of allelopathic features from crops or cultivars with significant weed discretion qualities along with specific weed control strategies can play an important role in developing sustainable agricultural conservation systems.

For illustration purposes, the articulate inhibitory effects of sunflower residues assimilate the total amount and biomass of weeds growing in a wheat field into field soil [32]. Mulching of allopathic plant residues, introduction of definite allopathic crops in crop rotation or as an intercrop or as a cover crop may be practiced for weed control in conservation agriculture. (Table 3). Such allopathic integrated strategies have the ability to serve as natural weed control agents with widespread effectiveness depending on the environmental and directorial aspects [33]. In Conservation Agriculture, allelopathy thus offers a viable alternative for weed control.

3.2 Laser Land Leveller

Laser land levelling results in uniform soil moisture in the field which allows for steady crop establishment and development leading to a reduced infestation of weeds. Depletion in the wheat weed population was reported in promptly leveling fields, as opposed to traditionally leveling fields [34].

3.2.1 Happy seeder

'Happy Seeder' technology — an improvement of the no-till seed drill and originally developed for direct drilling of wheat into a combine harvester of 34-1 rice residues (typically 5–9 t hectares of anchored and loose straw) in northwestern India — is a new novel passage that combines stubble mulching and seed-cum-fertilizer drilling. In front of the sowing tynes, which grab nearly bare soil, the stubble is cut and picked and thrown down behind the seed drill as surface mulch. The mulch also assists in moisture conservation and weed control by contributing to the value of direct drilling and preserving organic matter.

3.2.2 Cover crop rolling

Cover crop rolling is an advanced no-till technique. It presumes flattening a crop covered by high biomass to create a uniform mulch mat. Rolling is practical for weed eradication before seed is planted in high-biomass cover crop stands. For uniform mulch thickness uniform stands are essential. This method improves the amount of organic matter that is deposited back in the soil by a cover crop under the proper climatic conditions. Even the mulch developed has a positive impact as weed control and improves the keeping of moisture in drier and more arid climates and protects soil from rainfall and erosion.

3.2.3 Thermal weed control

Thermal weed control involves the use of fire, burning, hot water, steam and freezing [35], which provide rapid weed control without leaving chemical residues in the soil and water, selective to the weeds, do not damage the soil as in cultivation methods [36], but its efficacy depends on temperature, exposure period and energy input [35]. Thermal weed control methods kill above ground plant parts, they may regenerate and repeated treatments may be required.

Table 3. Weed control through allelopathic mulches, crop residues incorporation, cover crops and intercropping

Allelopathic source	Application mode	Crop	Weed species	Weed dry matter reduction (%)	Yield increase (%)	Reference
Sorghum	Soil incorporation	Wheat	Littleseed canary grass, Lamb's quarter	48–56	16-17	[29]
	Surface mulch	Cotton	Desert horse purslane, Field bind weed, Bermudagrass	5-97	69-119	[30]
	Allelopathic extract	Cotton	Desert horse purslane Littleseed canary grass, Indian Fumitory, Lamb's quarter, Toothed dock, Nutsedge	29	45	[30]
		Wheat		35–49	11-20	[29]
Sunflower + Rice + Brassica	Soil incorporation	Maize	Desert horse purslane	60	41	[31]
	Allelopathic extract	Wheat	Littleseed canary grass, Wild oat	2-16	2-6	[30]

Fig. 3. Laser land leveller with front loader

Fig. 4. Happy seeder

3.2.4 Flame weeding

Flame weeding uses the heat produced for destroying weeds from one or more propane burners. Intense heat sears the weeds' leaves, causing expansion of the cell sap, destroying cell walls [37]. This causes wilting of leaves and prevents water from moving from the roots to the leaves. The plant withers and dies in a small period of time [38].

3.2.5 Slashing

Normally this is done as a pre planting operation. Any plants growing in the field are chopped just before making pits or planting in furrows. In-row slicing, a technique common to farmers in some countries, is favoured for conservation agricultural, because it does not damage the soil. In order to avoid seed development, weeds should be chopped even after harvest and during the dry season [39].

Fig. 5. cover crop rolling

Fig. 6. Flaming weed control using propane gas

3.2.6 Perennial weeds and conservation tillage

Conservation tillage (CT) systems have seen changes in weed populations from annuals to perennials [40,41]. Perennial weeds in reduced- or no-tillage systems are known to flourish [42]. Most perennial weeds are capable of reproduction from various structural organs other than seeds. For example, two common weed species in California, nutsedge and johnsongrass (*Sorghum halepense*), typically reproduce from underground plant storage structures: tubers (or nutlets) and rhizomes, respectively. Conservation tillage may persuade these perennial reproductive structures by not burying them to depths that are unfavorable to emergence or by failing to uproot and kill them, in contrast to conventional tillage. Most perennial weeds exist in patches, however, mapping and periodically targeting these perennial weed patches with herbicide applications or mechanical control (pulling, etc.) may be an effective management technique in CT systems [43]. Found that the most successful purple and yellow nutsedge control in cotton was achieved through a combination of glyphosate in a Roundup Ready method involving mulching of seed beds and rising two or three times using sweep-type cultivators. Similarly [44]. In CT blackeye beans (Fig. 5), it was found that cultivation was important for effective field bindweed control (*Convolvulus arvensis* L.) This whole means that some level of cultivation might be required in some cropping systems in California for the management of "difficult-to-control" perennial weed.

3.3 Herbicide Use

Burndown herbicides Weeds present when planting crops in a CT system would probably need to be managed with a non-selective burndown herbicide such as glyphosate, paraquat, or glufosinate. Usually, selective herbicides are not used for burning in CT systems, as the target before the emergence of crops is complete vegetation control, and selective herbicides cannot control all of the weeds present. For example, common chickweed (*Stellaria media*), shepherdspurse (*Capsella bursa-pastoris*), London rocket (*Sisymbrium irio*), filaree (*Erodium spp.*), mustards (*Brassica spp.*), and fiddlenecks (*Amsinckia spp.*) are common annual weeds present in CT systems on fallow beds and early cotton stands, and these need to be controlled with non-selective postemergence herbicides [45]. The non-selective herbicide burndown can be applied before or after crop planting but before crop emergence [46]. Since the residual activity of these herbicides is lacking, applications should be planned as close to crop planting or emergence as the label would permit to mitigate further weed emergence before crop emergence. Occasionally a burndown herbicide is a tank mixed with a residual herbicide; the burndown herbicide is intended to suppress the weeds that have emerged and the residual herbicide so as to prevent weeds from emerging or growing. Usually these burndown herbicides are tanks mixed with carfentrazone (Shark) or oxyfluorfen (Goal) to control weeds on the broadleaf. Growers using CT may see this application of burndown herbicide as an increase in production costs, given that in a traditional

Fig. 7. Thermal weed control using hot water treatment

Fig. 8. Successful elimination of field bindweed and other weeds in CT black eye bean with cultivation in a CT system. Before cultivation (left) and after cultivation (right). Photos by D. Cordova

method, tillage would have managed these emerged weeds. We can, however, overlook cost savings for fuel, labor and energy which are realized when a grower practices CT.

3.3.1 Preemergence herbicides

In conventional tillage systems, crop residues are usually not present when the herbicide is applied for preemergence. However, in CT systems, residues may be present when applying herbicides and may decrease the efficacy of the herbicide as the residues intercept the herbicides, reducing the amount of herbicide that can reach and kill germinating weed seeds [46]. While most pre-emergence herbicides may be applied to the surface and then incorporated by rainwater or sprinkler irrigation into the soil, incorporation in CT systems should not be a problem. The increased organic matter on the surface of the soil can bind some of the herbicide, so that a grower can need to raise the application levels in order to gain adequate control Cover crops left on the surface present a different preemergence herbicide situation. Cover crop mulches are rarely even; thick mulch and bare ground are commonly seen in the same field. Researchers have observed that the mulch may block herbicide from reaching underlying weeds in areas with a thick mulch but may by itself be sufficient to control weeds; Whereas the herbicide can reach weeds and provide effective control in areas of the same field where the mulch is thin or non-existent [47]. A planter implement also moves mulch and crop residue away from the seed line, creating a relatively clean zone where it is most needed for good herbicide action.

3.3.2 Postemergence herbicides

Post emergence herbicides work equally well in CT and conventional tillage systems, while residues on the soil surface may interfere with successful herbicide contact with emerging seedlings in a CT system. [46] suggest that growers wait till the weeds develop and then manage them with herbicides after weed emergence is less uniform in CT than in conventional systems. However, a grower should not wait too long to apply treatment; weeds that appear along with the crop may result in greater yield losses than those that occur later in the growing season. Similarly, crop emergence and development in CT systems may be less uniform than in conventional tillage systems, particularly for plantings made during cool periods of the year and in fields with a lot of surface residue. Growers should expect this difference in the timing of weed emergence in spring and summer plantings to be much smaller. CT adoption has increased as a result of the production of HTCs that allow the application of post-emergence herbicides during the growing season with a relatively low risk of crop injury Nonetheless, if post-emergence herbicides are to be applied aerially, farmers should not wait as long as the crop canopy can be closed, as the crops could then absorb the herbicide applied aerially, minimizing the interaction between the herbicide and the weeds under the crop canopy. Correct identification of the optimal time frame for post-emergence herbicide application is crucial in CT.

Table 4. A number of selective post-emergence herbicides, some of which are low dose and high potential molecules, are now available to effectively manage weeds in major field crops like rice, wheat, soybean etc. under conservation agriculture [48]

Herbicide	Dose (g ha -1)	Time of application	Remarks
a. Rice			
Pendimethalin	1000–250	6-7 DAS/DAT	Annual grasses and some broad-leaved weeds. Ensure sufficient moisture at the time of application
Pyrazosulfuron	25–30	20–25 DAS/DAT	Annual grasses and some broad-leaved weeds
Azimsulfuron	35	20 DAS/DAT	Annual grasses and some broad-leaved weeds
Bispyribac-sodium	25	15–25 DAS/DAT	Annual grasses and some broad-leaved weeds
Chlorimuron+metsu lfuron	4	15–20 DAS/DAT	Annual broad-leaved weeds and sedges
2,4-D	500–750	20–25 DAS/DAT	Annual broad-leaved weeds and sedges
Fenoxaprop-p-ethyl	60–70	30–35 DAS/DAT	Annual grasses especially Echinochloa spp.
Fenoxaprop-pethyl+2, 4-D	60–70 + 500	20–25 DAS/DAT	Annual grasses and broad-leaved weeds
Fenoxaprop-pethyl+Almix	60–70 + 20	20–25 DAS/DAT	Annual grasses,broad-leaved weeds and sedges
Bensulfuron+pretilachlor	10000	0–3 DAS/DAT	Annual grasses and broad-leaved weeds
b. Wheat			
Pendimethalin	1000– 1250	0–3 DAS	Annual grasses and some broad-leaved weeds. Ensure sufficient moisture at the time of application.
Clodinafop propargyl	60	25–30 DAS	Annual grasses especially wild oat
2,4-D	500–750	20–25 DAS	Annual broad-leaved weeds and sedges
Metribuzin	175–200	30–35 DAS	Annual grasses and broad-leaved weeds
Herbicide	**Dose (g ha -1)**	**Time of application**	**Remarks**
Sufosulfuron	25	25–30 DAS	Annual broad-leaved weeds and grasses
Sufosulfuron +metsulfuron	25 + 2	25–30 DAS	Annual grasses, broad-leaved weeds and sedges
Mesosulfuron+ idosulfuron	12 + 24	20–25 DAS	Annual grasses, broad-leaved weeds and sedges
Isoproturon +metsulfuron	1000 + 4	20–25 DAS	Annual grasses and broad-leaved weeds
c. Soybean			
Metribuzin	35–525	0–3 DAS	Annual grasses and broad-leaved weeds
Chlorimuron ethyl	6–9	15–20 DAS	Annual grasses, broad-leaved weeds and sedges

4. 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. However, emergence of unique weed challenges in CA requires that its inbuilt weed management component (cover crop, crop residue mulching and crop rotation Allelopathy etc.). Further development and testing of alternative weed management practices that can be utilized along with herbicide applications must be chase in order for conservation practices to remain successful. Considering the diversity of weed problems, no single method of weed control, could provide the desired level of weed control efficiency under CA. Therefore, a combination of different weed management strategies should be evaluated for widening the weed control spectrum and efficacy for sustainable crop production.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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