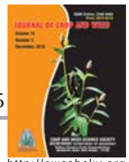
Journal of Crop and Weed, 16(1): 09-19 (2020)
ISSN- O : 2349 9400 ; P : 0974 6315



http://cwssbckv.org
www.cropandweed.com

Weed management in conservation agriculture, its issues and adoption : a review

J. K. SONI, [1]V. K. CHOUDHARY, [1]P. K. SINGH AND [2]S. HOTA

ICAR-RC NEH Region, Mizoram Centre, Kolasib-796081, Mizoram, India
[1]ICAR-Directorate of Weed Research, Jabalpur-482004, Madhya Pradesh, India
[2]ICAR-NBSS & LUP, Regional Centre, Jorhat-785004, Assam, India

Received : 23.04.2020 ; Revised : 18.06.2020 ; Accepted : 21.06.2020

DOI : 10.22271/09746315.2020.v16.i1.1267

ABSTRACT

Conventional agriculture is tillage driven system that increases the cost of crop production, accelerates soil erosion and contributes towards climate change.These difficulties in conventional agriculture demands shift in agriculture system,and conservation agriculture (CA)become the best feasible option. CA is becoming popular as it brings sustainability of the production system without compromising crop and soil productivity. CA is based on three pillars viz., minimal mechanical tillage, permanent residue cover on the soil and crop diversification. However, adoption of CA, influences the weed population differently over conventional agriculture as tillage manipulates the weed habitat. Thus, weed management in CA possesses a great challenge for farmers. This mainly due to minimum soil disturbance resulting in most of the weed seeds remain over the top layer of soil and crop diversification brings change in weed composition. Thus shift in weed flora becomes more problematic for farmers to control it effectively under CA. In zero tillage, perennial weeds become more problematic. However, when crop residue is uniformly spread with appropriate quantity, it may suppress weed seed germination and provide a competitive advantage for crop over the weed and also help in moisture retention, lowering the soil temperature and increase in soil organic matter (SOM). Generally, the use of herbicides brings effective weed control. However, crop residue incorporation followed by the application of post-emergence herbicide is found more effective than pre-emergence herbicide.Thus under CA, herbicide efficacy depends on the time of application, formulation and quantity of application. Moreover, integrated weed management (IWM) is the best way to manage weeds effectively in an eco-friendly and cost-effective manner under CA. IWM approaches comprise crop establishment, crop rotations, use of cover crops and crop residues as mulch with a combination of pre- and post-emergence herbicides could be integrated to develop sustainable and operative weed management strategies under CA systems. However, there are some problems in the adoption of CA that are the mindset of farmers towards tillage, timely availability of improved implements, the initial purchasing power of farmers and technical knowledge.

Keywords: Conservation agriculture, herbicide, integrated weed management, tillage, weed shift

Agriculture (crop and livestock production) is a worldwide stirring activity that relates unswervingly and vigorously to the present and future condition of environments, economies, and societies. It provides the basic, social and economic needs of individuals(Smit and Smithers, 1993). Exponentially increase in global population and continuously increase in global food, feed, fibre, bio-energy demand, creates hunger and poverty problem. To tackle this issue, the demand for intensive agriculture, increase in agricultural productivity, and associated total and individual factor productivities are focused (Kassam *et al.*, 2015).This brings faulty production system, which may threaten the sustainability of the agro-ecosystem by groundwater over exploitation, development of herbicide resistance of weeds, chemical contamination in food, soil, water and air, development of sub-soil hardpan, deterioration of soil health, multi-nutrient deficiency and high cost of cultivation(Day *et al*., 2016). Hence, there is a need to enhance the sustainability in production systems. Further, it is necessary to circumventthe degradation of agricultural land and ecosystem, and the rehabilitation of degraded and waste agricultural land. In this view, conservation agriculture (CA) is one of the best options.FAO defines CA as an approach to managing agro-ecosystems for improved and sustained productivity, increased profits and food security with preserving and enhancing the resource base and the environment simultaneously. This includes three principles *viz.*, continuous minimum mechanical soil disturbance (*i.e.* zero and/or no-tillage, broadcasting of crop seeds, line sowing, band placement of seed, set bed planting), permanent soil organic cover (with crop residue and/or cover crops such as mulch crop with at least 30 per cent soil surface) and crop diversification (with crop rotation, mixed cropping and intercropping of crop) (FAO, 2014).

History and status of conservation agriculture

Tillage is the physical manipulation of soil. It is intended to loosen the soil, preparation of seedbed to bring good and uniform seed germination, manage

Email : jeetendra.soni@icar.gov.in

weeds, help in good crop growth through mineralization, incorporation of crop residues and soil amendments (Hobbs *et al.,* 2008). In a fragile ecosystem, tillage was first questioned in the 1930s, when a huge area of the mid-west United States was devastated by the dustbowls. That brought the new concepts of soil-crop cover and termed as conservation tillage. Principles of CA were illustrated first timein their book by Edward Faulkner in “Ploughman’s Folly” (Faulkner, 1945) and Masanobu Fukuoka in “One Straw Revolution” (Fukuoka, 1975). Thereafter, in early 1970s increase in fuel price ledto shifting of farmers towards CA. In this way, farmersarenow adopting CA for mitigating drought-induced soil erosion and energy-saving(Farooq and Siddique,2015).The estimated area under conservation agriculture by FAOwas about 157 million ha in 2013 worldwide, with 35.6 million ha in the USA ranks first and India having 1.5 million ha. In some areas of Indo-Gangetic plains zero or/and no-till farming, laser-assisted precision land levelling, direct drilling into the residues, direct-seeded rice (*0ryza sativa* L.), raised-bed planting are being practised in nearly 5 million ha that includes India, Pakistan, Nepal and Bangladesh (Kassam *et al*., 2015; Jat *et al*., 2016). It is estimated that the area under CA is increasing slowly but continuously year after year. But the major problem under CA is weeds, the shift in weed flora and its management.

Conservation agriculture and weeds

Weed management is an essential part of the agriculture production system and CA requires special attention for its management. Based on habitat, weeds act differently. Tillage provides different habitat for weeds by manipulating and changing the microclimate of soil and play an important role in weed management (Bajwa, 2014; Choudhary, 2015). Weed management in CA depends upon good agronomical practices, use of herbicide and tillage level (Lafond *et al*., 2009). In the CA system, during initial years higher the weed influx (Shahzad *et al*., 2016),small-seeded weeds get favoured for germination and growth as most of the seedsremain on the surface whereas, dormant seeds buried in soil remains dormant due to minimum soil disturbance against in the conventional system (Chauhan *et al.,* 2006). It leads to shifting of weeds underthe CA system. Many small-seeded annual and biennials weeds germinate under no and/or zero-till system with no or minimal soil cover whereas, perennial weeds get dominated and proliferated in the first year where few plants get a chance to germinate (Curran *et al.*, 1996).

Furthermore, in CA perennial weeds tend to dominate over annual broadleaf and grasses. This indicates that in CA there is the shift in weed flora from docileweeds to obnoxious perennial weeds such as bermudagrass (*Cynodondactylon* L.) and mexican clover (*Richardia scabra* L.) (Mashingaidze *et al*., 2012; Shahzad *et al*., 2016).

Conservation agriculture and shift in weed flora

The shift in weed flora takes place from the transformation of conventional to conservation tillage system (Singh *et al*., 2017). It depends on the frequency and intensity of tillage that disturbs the soil surface (Baker *et al.*, 2018). Under zero tillage (ZT) system, gramineous weeds are favoured more over the other weed species and spread more easily that mimic pasture or roadside surroundings (Nichols *et al*., 2015). Annual grasses increase gradually whereas annual dicotyledonous weeds population decreases (Tuesca *et al*., 2001).In contrary to this, Mekonnen and Markos (2016) found that the family of broadleaf weeds were to be the most abundant under CA system. Long-term field experiment and farmer surveys viewed change in the weed continuum in ZT wheat with lesser soil disturbance and found that broad-leaved weeds density get increased (Ramesh, 2015). Also, weed dynamics is associated with cropping system and other management practices along with CA (Ball and Miller, 1993; Swanton *et al*., 1993). Crop residues under CA influences weed composition. Small-seeded weed species are inhibited more than large-seeded one. A relatively large-seeded, light-insensitive weed, velvetleaf *(Abutilon theophrasti*) was less affected than the small-seeded redroot pigweed *(Amaranthus retroflexus* L.), and common lambsquarters (*Chenopodium album* L.). In general, small-seeded annual weed species that require light for germination affected more by crop residue (Teasdale, 1996). In CA, weeds species tolerant to shade, wet condition and low temperature can flourish more than the other weed species and have the capacity to troublesome in reduced tillage (Martin *et al*., 2002).Owen (2008) reported that CA with the application of herbicide having a single mode of action hastens in weed population shifts.

Weed control measures under conservation agriculture

In CA, weed interference is more subjective compared to the conventional system (Singh *et al*., 2015). Under crop residue, weed density was reduced by nearly 50 to 75% (Mohler and Teasdale, 1993). Conservation practices *viz*., crop residues, crop rotation, herbicide use, integrated weed management (IWM) well fitted for weed management are elaborated below:

Crop residues

Under CA, crop residues comprise organic material like live/green mulch or crop/plant residue and sometimes non-living materials such as plastic sheets used in various cropping systems (Slims *et al*., 2018). Crop residues, its quantity and allelopathic property effect the weed seed germination and emergence (Chauhan *et al*., 2006; Singh *et al*., 2017; Vivek *et al*., 2019). After the harvest of crop, crop residues are distributed mechanically or manually. In CA, mulch of cover crop on the soil surface suppresses weed seed germination by decreasing the light transmission and their allelopathic effect (Chauhan *et al*., 2012; Choudhary and Kumar, 2014; Slims *et al.*, 2018). Delayed weed emergence provides crop to take competitive advantage over weeds which have less impact on crop yield loss (Chauhan and Johnson, 2010).Ranaivoson *et al*. (2017) reported that incorporation of crop residue of 1 t ha^{-1} or more helps in reduction of weed emergence and its biomass by 50% compared to conventional system, however, maximum effect was observed under 4 t ha^{-1} or above. Application of rice straw at 4 t ha^{-1} could effectively manage weeds under direct wet seeded rice method (Devasinghe *et al*., 2011). Apart from the amount of crop residue, types of residue also influence the weed dynamics. Radicetti *et al.* (2013) observed that weed suppression ability of oat residues was higher than rapeseed and hairy vetch residues.The emergence of weed reduces by increasing the crop residue when spreads uniformly over the soil surface (Ranaivoson *et al.*, 2018; Choudhary and Kumar, 2019). Crop residue helps in moisture retention, lowering the soil temperature and increases the soil organic matter content that helps in germination of some weeds too *e.g*., *Avenafatua* (Young and Cousens, 1999; Choudhary *et al*., 2015). In general, crop residue reduced the germination of most of the weed species. In wheat crop, ZT with crop residue along with early sowing results in suppression of *Phalaris minor* and other weeds (Bhullar *et al.*, 2016; Singh *et al*., 2017). Singh *et al*. (2013) reported that in Punjab, happy seeder sown crop leads to an average reduction of weed population over the rotavator and farmer's practice was 26.5 and 47.7%, respectively. To achieve long-term weed control there is a need for integratingthe use of herbicide.Also,to decide the quantity of crop residue that will not hamper the germination of the crop.

Crop rotation

Continuous monocropping under similar management practices favours the dominance of specific weed species (Jena and Meena, 2017). Under crop rotation, diversity of weeds increases as compared to monocropping. Higher weed diversity prevents the dominance of any particular weed flora (Demjanova, 2004). Rotation of crops altersselection pressures that prevent one weed species to remain dominant in a particular regime (Choudhary, 2016). It alters selection pressures *via* three mechanisms *viz.*altering management *e.g.*, agronomical means (Choudhary *et al*., 2016), different patterns of resource competition, and allelopathy (Nichols *et al*., 2015). Crop rotation brings diversification of crop and breaks the cycle of dominating weed flora under monoculture (Martin *et al*., 2002; Rahman, 2017). Every crop has unique architecture and requires variable management techniques that generate different microclimate. The type of crop canopy filters the incoming solar radiation that can inhibit the germination of most weed species (Silvertown, 1980). Mimic weeds can successfully be eradicated by rotation (Derksen *et al*., 2002). Crop rotations with a different duration such as winter wheat-maize and winter wheat-sugar beet brought a reduction in the weed seed bank (Koocheki *et al*., 2009). Crop used in rotation must have quick growing ability that helps in suppressing weed growth *e.g.*, cowpea, soybean *etc*., (Vishwakarma *et al*., 2017). Phophi *et al*. (2017) reported that the use of cowpea and lablab in CA for effective weed suppression due to its high smothering effect. Sowing of soybean and sunflower under no-tillage with desiccated rye mulch resulted in 90% reduction in weed biomass of *Chenopodium album*, *Amaranthusretroflexus* and *Ambrosia artemisiifolia*as compared to tillage and no rye mulch (Gnanavel, 2015). It was reported thatrice-wheat-greengram sequence showed lowerweed population compared to rice-wheat, rice-chickpea and rice-pea sequence (Singh *et al*., 2012).Therefore, regardless of tillage, crop rotation is an effective practice to use for weed management.

Herbicide use

Chemical used for controlling weeds called herbicide. It is the one of effective and economical way under CA system for managing weeds (Muoni *et al*., 2013). Minimum or ZT system under CA has obligated farmers to be more dependent on herbicides for effective weed control (Eslami, 2014). Its efficacy under CA system depends on the suitability of herbicide, application time (either pre- or post-emergence) and the amount of crop residue on the soil surface (Vargas and Wright, 2005). Under CA, post-emergence herbicides are more effective as crop residue on soil surface dilutes the effect of pre-emergence herbicide. Post-emergence herbicide applied after the weed emergence and its efficacy is not influenced by tillage practices under both conventional and CA (Bajwa, 2014). The study shows that under CA, crop residue can intercept nearly 15-80% of applied herbicide that results in its reduced efficiency (Buhler, 1995; Rao and Chauhan, 2015). Application of atrazine in wheat stubble shows that only 40% of applied herbicide reaches the ground (Ghadiri *et al*., 1984). Herbicidal efficacy also depended on its formulation under CA. For example, pre-emergence herbicides with granular formulation are more effective than the liquid one (Bhullar *et al.*, 2016). It is assumed that granular molecules reach the soil surface more effectively than liquid formulated herbicide (Johnson *et al*., 1989). Therefore, herbicide performance in CA systems should be undertaken carefully; such assuitable herbicide type, application time, and formulation. Since the timing of weed emergence is inconsistent in CA than in the conventional system and suggested that farmers should wait for application of post-emergence herbicide until the weed get emerged (Chauhan *et al*., 2012).

Non-selective herbicide and conservation agriculture

In CA, during the planning of crops, non-selective herbicides are required to control the existing weeds. Some of the non-selective herbicides are glyphosate, paraquat and glufosinate (Chauhan *et al*., 2012).That should apply either before or after planting but before the crop emergence (Hartzler and Owen, 1997).But the unremitting application of the same herbicide such as glyphosate year after year may result in weed flora shifts or may hasten the development of glyphosate resistance in weeds. Therefore herbicides rotation with different modes of action may reduce the selection pressure that can avoid or delay the development of resistance (Bhullar *et al*., 2016).

Selective herbicide and conservation agriculture

CA poses more challenge for the efficacy of pre-emergence herbicide than the post-emergence. Hence, a higher rate of pre-emergence herbicide is requiredfor effective weed control (Locke *et al.*, 2002). However, satisfactory weed control was observed when supplementing with post-emergence herbicides such as glyphosate along with the pre-emergence herbicide (Vanlieshout and Loux, 2000). For effective weed control in Direct Seeded Rice (DSR), pre-emergence (pendimethalin or pretilachlor or oxadiargyl with safner) followed by post-emergence (bispyribac or bispyribac based tank mixture including bispyribac+ pyrazosulfuron/2,4-D / azimsulfuron / fenoxaprop or halosulfuron with saftner or fenoxaprop based tank mixture including fenoxaprop + ethoxysulfuron) herbicide application have provided efficient weed control in DSR (Malik *et al*., 2018). Singh *et al*. (2017) reported that application of metsulfuron + clodinafop (4 + 60 g ha^{-1}) in wheat under ZT with crop residues (R) of preceding soybean under ZT+R-ZT+R-ZT+R and ZT-ZT+R-ZT+R system has resulted in lower weed density and biomass resulted with higher weed control efficiency. Under ZT, atrazine 750 g ha^{-1} (as pre-emergence) followed by (*fb)*one hand weeding was effective in controlling weeds in maize crop (Khedwal *et al*., 2017).

To combat the ill effect of herbicide with effective and profitable weed management, integrated weed management strategy is required.

Integrated weed management (IWM)

IWM is a multidimensional approach that helps in bringing the weed population below the threshold level. It offers a combination of different weed management practices *viz*., good agronomical practices, in-time field operation and withholding of crop residue that improve weed control efficiency. Weeds can be effectively controlled by planting of the weed-competitive cultivar in narrow rows with high seeding rates and use of residue as mulch and an effective post-emergence herbicide may manage weeds effectively in CA systems (Jena and Meena, 2017). The combined use of higher seed rate (150 kg ha^{-1}) narrow row spacing (15 cm), and 25% lower dose of clodinafop reduced *P. minor* density than the normal spacing (22.5cm), normal seed rate (125 kg ha^{-1}) and field dose of clodinafop (Bhullar and Walia, 2004). IWM helps inboosting agricultural productivity and keeping apprehension on environmental safety.

Conservation agriculture and soil physical and chemical properties

CA has a significant effect on these soilphysical and chemical properties. Under CA, it improved due to a decrease in the impact of soil degradation *viz*., crusting of soil, organic matter depletion, soil compactness and deterioration of soil structure (Dalal and Bridge, 1996). Crop residues present on the soil surface improve soil tilth and conserve moisture (Locke and Bryson, 1997; Choudhary *et al*., 2013). Size of soil aggregate increases under both wet and dry condition due to increase in soil organic matter content that helps in the binding of soil particle (Lichter *et al*., 2008; Govaerts *et al*., 2009). Soil bulk density decreases due to an increase in the number of soil aggregates (Shaver, 2010). The direct impact of raindrops on the soil surface may create the soil crust by sealing the soil pores through splashed soil particles. This might be due to negligible crop residue in the conventional system of cultivation. Whereas, under CA crop residue over the soil surface avoid the soil crust formation and increasing the infiltration rate (Benyamini and Unger, 1984). The conventional system of cultivation reduces the numberof macro and micropores and increases the bulk density whereas, vice-versa true in CA (Indoria *et al*., 2017). Relative lower temperature with little fluctuation in soil temperature in CA as compared to a conventional system, this might be due to least tillage operation and retention of crop residue on it (Kosterna, 2014). Dahiya *et al*. (2007) reported that due to mulching, average soil temperature reduced by 0.74^{0}C, 0.66^{0}C, 0.58^{0}C at 0.05, 0.15, and 0.30 m soil depth, respectively. Residue cover over the bare soil reduced run off and erosion of soil particle (Mailapalli *et al*., 2013). The 30% of soil surafce cover with residue is expected to reduce the erosion by 80% (Jat *et al*., 2014).

Soil organic matter content is the prime indicator of soil property. Verhulst *et al*.(2012)reported that under ZT soil organic matter content increases on the surface of the soil as compared to conventional tillage. Low available nitrogen was reported under ZT with cereal residues which might be because of immobilization due to greater availability of residue on the soil surface. However, legume residues with a low C/N may result in N mineralization (Turmel *et al*., 2015). Higher extractable phosphorus and potassium compared tothe tilled soil was observed under ZT due to less messing with soil (Zibilske *et al*., 2002). Availability of micronutrients (Zn, Fe, Mn and Cu) remain higher under ZT with retention of crop residue compared to conventional tillage. The retention of crop residue significantly increases the cation exchange capacity in 0-5cm of soil and soil turn to more acidic at the surface (Govaerts *et al*., 2007).

Conservation agriculture for crop yield and economics

CA may advance the crop yield through recuperating soil productivity by conserving resources *viz*., soil, water and sequestering soil organic carbon in farmland (Zheng *et al*., 2014).The real effect of CA on crop yield may depend on specific CA practices, micro and macro-climate and cropping systems (Hobbs *et al*., 2008). But in the short term, ZT generally resulted in lower yields than with conventional tillage (CT) (Brouder and Macpherson, 2014). Sommer *et al*. (2012) observed that the improvement in wheat yield under ZT with residue retention in comparison with C.T. Kutu (2012) reported that under ZT highest maize grain yield under supplementary irrigation and dryland conditions was 2805 and 2776 kg ha^{-1}, respectively. ICARDA (2018) demonstrated that under CA, reduction in the cost of crop production and improvement in yield occur simultaneously. Nearly US$ 120 ha^{-1} net return can be generated by farmers under CA with good crop management and 12% higher yield and low cost of production (about US$ 40 ha^{-1} saving). Jat *et al*.(2015) reported that wheat data collected from 100 randomly selected farmers shows that wheat yield in CA was 6 and 13% higher in 2013-14 and 2014-15, respectively, incomparison to conventional cultivation. Also, less yield loss was observed. Bayala *et al*. (2012) revealed that increases in the yield in low to medium productive soil for sorghum, maize and millet under CA practices. Sharma and Jat (2014) observed higher system productivity(15.8 t ha^{-1}) in CT with transplanted rice (TPR) *fb* ZT in wheat *fb* ZT in greengram with previous crop residues retention than complete ZT + previous crop residues in rice *fb* wheat *fb* greengram (14.8 t ha^{-1}) and CT in TPR *fb* CT in wheat cropping system (13.0 t ha^{-1}). However, energy use was more (73832 MJ ha^{-1}) in CT in both TPR and wheat than CT inTPR *fb* ZT in wheat *fb* ZT in greengram (56543 MJ ha^{-1}) and ZT + previous crop residues in rice *fb* wheat *fb* greengram cropping system (51582 MJ ha^{-1}).

Edralin *et al*. (2017) conducted a study in 10 farmer's fields to estimate the effect of CA and CT on the yield of vegetables and found significantly higher yield than the CT. Marahatta (2014) observed that through the adoption of ZT-wheat, reduced tilled-wheat and dry DSR farmers can save the production cost by 32, 34 and 34% as well as an increased benefit-cost ratio by 52, 29 and 54%, respectively. Several studies show that saving of nearly 2000-3000 Rs ha^{-1} takes place in wheat crop under CA (Choudhary *et al*., 2016). In degraded agricultural land, an increase of 1 ton of soil carbon pool may enhance crop yield by 0.5 to 1 kg ha^{-1} for cowpeas, 10 to 20 kg ha^{-1} for maize, and 20 to 40 kg ha^{-1} for wheat (Lal, 2004). Thus, the above research finding clearly indicates that CA may enhance yield and net return and reduced the cost of cultivation.

Conservation agriculture and climate change

Agriculture is vulnerable to climate change that is associated with a rise in temperature, an increase in atmospheric CO_2 concentration and rainfall variability that leads to a decline in crop yield (Mall *et al*., 2017; Kumar *et al*., 2017).The rise in temperature leads to an increase in oxidation of the soil organic carbon and brings down the soil organic content. Runoff and wind erosion may accelerate due to an extreme weather event. These changes bring poor soil fertility, loss of soil microbial population and water stress (FAO, 2011). Faulty agricultural practices areassociated with GHGs emission in the atmosphere result in climate change that consequence in low agricultural production (Six *et al*., 2004).Thus, promoting agricultural practices that alleviate climate changeby reducing GHGs emissions is essential(Bisht *et al*., 2016).

CA agricultural practices make the agricultural system more resilient to climate change (FAO, 2012). This may be due to the application of soil management practices that help increase in soil organic carbon, reduced soil disturbance and reduces the use of fuel consumption that helps to reduce GHG emission (Choudhary *et al.*, 2012; Choudhary *et al.*, 2016). Organic agriculture (OA) is one of the best management practices in CA. Worldwide adoption of OA has the potential to sequester up to the equivalent of 32% of all current anthropological GHG emissions (FAO, 2009). Lal (2004) reported that if 1,500 million ha land under CT is converted into CA practices, it will be able to fix 0.6-1.2 gigatons of carbon/year.

Conservation agriculture and problems in adoption

CA benefited the farmers to gain more returns with a reduced amount of labour, irrigation and other external inputs, maintain soil health and its productivity and sustain the agro-ecosystem.About 8-10% of farmers across the world go after CA (Dhar *et al*., 2017). Regardless of the seperceptiblere compenses, expansion of CA is relatively slow. The transformation from conventional agriculture practice to CA practice seems to require considerable farm management skills and availability of equipment and implements suitable for CA; that may require minimum levels of capital to encourage its spread out. Limited availability of crop residues for CA practices and farm animals feeding, crop residue burning and overcoming the mindset of farmers regarding tillage are barriers for adopting CA (Bhan and Behra, 2014). Heavy incidence of weed without tillage practices and limited accessibility to buy expensive herbicides has been observed for small and marginal farmers (Meena *et al.*, 2016).

This review indicates that conventional agriculture leads to indiscriminative use of limited natural resources, declining crop productivity, deprived soil health and the high production cost that pose a threat for food security and sustainability. CA isthe best alternative over conventional agriculture. That brings all possible solution towards achieving higher crop productivity with sustainability, conserving natural resources, eco-friendly and more climate-resilient agriculture system. Minimum tillage in the combination of residue retention enhances soil organic carbon in the top layer of soil surface. Residue retention or inclusion of cover crops on the soil surface improves soil moisture retention, temperature moderation and weed control. ZT reduced the CO_2 emission and enhances the SOC in soil. Crop diversification may break the cycle of dominating weed flora under monoculture. Weed infestations were found to be the major threat under CA and shift in weed flora were observed. Depending upon the type of crops, ZT could increase or decrease certain weed species. Use of herbicide, mulching and cover crops helps in managing weeds in CA system. However, IWM is the best way to bring down the weed population below the threshold level. Besides the huge advantages of CA, there are also many constraints for its adoption *viz*., the attitude of people towards tillage, availability of suitable implements and lack of knowledge.Therefore, the paradigm shift from tillage intensive conventional agriculture to CA systems require technical know-how, technological support and policy framework that will help to enhance system productivity, improve environmental quality, bring sustainability and spread rapidly across the globe.

ACKNOWLEDGEMENT

The authors extend sincere gratitude towards ICAR-Directorate of Weed Research, Jabalpur for providing all Institutional support. We also thank Director, ICAR RC for NEH Region, Umiam for financial and institutional support.

REFERENCES

Adhikary and Bajwa, A.A. 2014. Sustainable weed management in conservation agriculture.*Crop Prot.*, **65**:105-113. DOI: 10.1016/j.cropro.2014.07.014.

Baker, C., Madakadze, I.C., Swanepoel, C.M. and Mavunganidze, Z. 2018. Weed species composition and density under conservation agriculture with varying fertiliser rate. *S. Afr J. Pl. Soil*, **35**:5, 329-336, DOI: 10.1080/ 02571862. 2018.1431814.

Ball, D.A. and Miller, S.D. 1993. Cropping history, tillage, and herbicide effects on weed flora composition in irrigated corn. *Agron. J.*, **85**: 817-21. DOI: 10. 2134/ agronj 1993.00021962008500040007x.

Bayala, J., Sileshi, G.W., Coe, R., Kalinganire, A., Tchoundjeu, Z., Sinclair, F. and Garrity, D. 2012. *J. Arid Environ*.,**78**:13-25. DOI:10.1016/ j.jaridenv.2011.10.011.

Benyamini, Y. and Unger, P.W. 1984. Crust development under stimulated rainfall on four Soils. In Agronomy Abstracts, American Society of Agronomy (ASA), Madison, WI, pp. 243.

Bhan, S.and Behera, U.K. 2014. Conservation agriculture in India – Problems, prospects and policy issues. *Int. Soil Water Conserv. Res.*, **2**(4):1-12. DOI: 10.1016/S2095-6339(15)30053-8.

Bhullar, M.S. and Walia, U.S. 2004.Effect of seed rate and row spacing on the efficacy of clodinafop for combating isoproturon resistant *Phalaris minor* Retz.in wheat. *Pl. Prot. Q.***19**:143-46.

Bhullar, M.S., Pandey, M., Kumar, S. and Gill, G. 2016. Weed management in conservation agriculture in India. *Ind. J. Weed Sci.*, **48**(1):1–12. DOI: 10.5958/ 0974-8164.2016.00001.0.

Bisht, J.K., Meena, V.S., Mishra, P.K. and Pattanayak, A. 2016.Conservation Agriculture: An Approach to Combat Climate Change in Indian Himalaya. *Springer* Singapore. DOI: 10.1007/ 978-981-10-2558-7_17.

Brouder, S.M. and Macpherson, H.G. 2014. The impact of conservation agriculture on smallholder agricultural yields: A scoping review of the evidence. *Agric. Ecosyst. Environ.*,**187**: 11–32. DOI :10. 1016/ j. agee. 2013. 08. 010.

Buhler, D.D. 1995. Influence of tillage systems on weed population dynamics and management in corn and soybean in the central USA. *Crop Sci.,* **35**: 1247-1258. DOI: 10.2135/ cropsci1995.0011183X003500050001x.

Chauhan, B.S. and Johnson, D.E. 2010.The role of seed ecology in improving weed management strategies in the tropics.*Adv. Agron*.,**105**: 221-262. DOI: 10.1016/S0065-2113(10)05006-6.

Chauhan, B.S., Gill, G. and Preston, C. 2006. Tillage system effects on weed ecology, herbicide activity and persistence: a review. *Aust. J. Exp. Agric.,* **46**:1557-1570. DOI: 10.1071/EA05291.

Chauhan, B.S., Gill, G.S. and Preston, C. 2006. Seedling recruitment pattern and depth of recruitment of 10 weed species in minimum tillage and no-till seeding systems. *Weed Sci.,* **54**: 658–668. DOI: 10.1614/ WS-05-135R.1.

Chauhan, B.S., Singh, R.G. and Mahajan, G. 2012. Ecology and management of weeds under conservation agriculture: A review. *Crop Prot.,* **38**: 57-65. DOI: 10. 1016 /j. cropro.2012.03.010.

Choudhary, M., Bisht, J., Meena, V., Mishra, P. and Pattanayak, A. 2016. Conservation agriculture and climate change: an overview. Conservation Agriculture.*Springer*, Singapore.DOI:https:// doi.org/10.1007/978-981-10-2558-7_1.

Choudhary, V.K. 2015.Tillage and mulch effects on productivity and water use of pea and soil carbon stocks.*Arch. Agron. Soil Sci.,* **61**(7): 1013-1027. DOI:10.1080/03650340.2014.977785.

Choudhary, V.K. 2016.Response of land configuration and mulches on maize-frenchbean-toria cropping system.*Agron. J.,* **108**(5): 2147-2157. DOI: 10.2134/agronj2016.02.0088.

Choudhary, V.K. and Kumar, P.S. 2014. Influence of mulching on productivity, root growth and weed dynamics of maize (*Zea mays*)-based cropping systems. *Ind J.Agron.*,**59** (3): 364-370.

Choudhary, V.K., and Kumar, P.S. 2019. Weed prevalence, nutrient wash, water productivity and yield output of turmeric (*Curcuma longa* L.) under different land configuration and mulches. *J. Clean. Prod.*,**210**: 793-803. http://doi.org/10.1016/ j.jclepro.2018.11.071.

Choudhary, V.K., Dixit, A. and Bhagawati, R. 2016. Scaling-up of toria (*Brassica campestris*) productivity using diverse agro-techniques in eastern Himalayan region.*Ind. J.Agric. Sci.,* **86**(1): 37-41.

Choudhary, V.K., Dixit, A., Bhagawati, R., Vishwakarma, A.K. and Brajendra. 2015. Influence of locally available mulches on soil moisture content, root behaviour, weed dynamics and productivity of pea (*Pisum sativum* L.). *Progressive Res. - Int. J.,* **10** (Special Issue): 1372-1375.

Choudhary, V.K., Kumar, P.S. and Bhagawati, R. 2013.Response of tillage and *in situ* moisture conservation on alteration of soil and morpho-physiological differences in maize under Eastern Himalayan Region of India.*Soil Till. Res.*,**134**: 41-48. DOI: 10.1016/j.still.2013.07.004.

Choudhary, V.K., Kumar, P.S., Kanwat, M. and Bhagawati, R. 2012.Improvement of jhum with crop model and carbon sequestration techniques to mitigate climate change in Eastern Himalayan Region, *Ind.J. of Agric. Sci*., **4**(4): 181-189.

Curran, W.S., Lingenfelter, D.D. and Garling, L. 1996. Weed management in conservation tillage. In: conservation tillage fact sheet series. Penn State College of Agric. Sci., Univ. Park, PA.

Dahiya, R., Ingwersen, J. and Streck, T. 2007. The effects of mulching and tillage on the water and temperature regimes of a loess soil: Experimental findings and modelling. *Soil Till. Res*., **96**: 52–63. DOI: 10.1016/ j.still.2007.02.004.

Dalal, R.C. and Bridge, B.J. 1996.Aggregation and organic matter storage in sub-humid and semi-arid soils. In Advances in Soil Science (eds Carter, M. R. and Stewart, B. A.), CRC Lewis Publishers, Boca Raton, FL, *pp*. 263–307.

Day, A., Dwivedi, B.S., Bhattacharya, R., Datta, S.P., Meena, M.C., Das, T.K. and Singh, V.K. 2016. Conservation agriculture in a rice-wheat cropping system on alluvial soil of North-Western Indo-Gangetic Plains: Effect on soil carbon and nitrogen pool. *J. Ind. Soc. Soil Sci.,* **64**(3):246-254. DOI: 10.5958/0974-0228.2016.00034.7.

Demjanova, E. 2004. Effects of crop rotation and tillage systems on weed populations, density and diversity in maize (*Zea mays* L.). *Acta Fytotech.Zootech.*,**7**: 61–63.

Derksen, D.A., Anderson, R.L., Blackshaw, R.E. and Maxwell, B. 2002. Weed dynamics and management strategies for cropping systems in the northern Great Plains. *Agron. J.,* **94**:174–185. DOI: 10.2134/ agronj2002.1740.

Devasinghe, D., Premarathne, K., Sangakkara, U. 2011.Weed management by rice straw mulching in direct seeded lowland rice (*Oryza sativa* L.). *Trop. Agric. Res.*, **22**(3): 263-272.DOI: 10.4038/ tar.v22i3.3699.

Dhar, A.R., Islam, M.M, and Ahmed, J.U. 2017. Adoption of Conservation Agriculture in Bangladesh: Problems and Prospects. *World J. Agric. Res*., **5**(5): 265-72.

Edralin, D.A., Sigua, G.C., Reyes, M.R., Mulvaney, M.J. and Andrews, S.S. 2017. Conservation agriculture improves yield and reduces weeding activity in sandy soils of Cambodia. *Agron. Sustain. Dev*., **37**: 52. DOI:10.1007/s13593-017-0461-7.

Eslami, S.V. 2014. Weed management in conservation agriculture systems. *Recent Adv. Weed Manag.*,87-124. DOI: 10.1007/978-1-4939-1019-9_5.

FAO. 2009. Food Security and Agricultural Mitigation in Developing Countries: Options for Capturing Synergies. [www.fao.org] Assessed on: Feb 25, 2016.

FAO. 2011. Climatic risk analysis in conservation agriculture in varied biophysical and socioeconomic settings of southern Africa. Food and Agriculture Organisation of the United Nations, Rome.

FAO. 2012. Conservation agriculture for climate change mitigation highlights from the learning event, September 2012.

FAO. 2014. CA adoption worldwide, FAO-CA website (http://www.fao.org/ag/ca/6c.html)

Farooq, M. and Siddique, K.H.M. 2015.Conservation agriculture.Springer Cham Heidelberg New York Dordrecht London.pp 6.

Faulkner, E.H. 1945. Ploughman’s Folly. Michael Joseph, London. pp142.

Fukuoka, M. 1975. One-Straw Revolution, Rodale Press. English translation of shizennohowaraippeon no kakumei, Hakujusha Co., Tokyo. pp.138.

Ghadiri, H., Shea, P.J. and Wicks, G.A. 1984. Interception and retention of atrazine by wheat (*Triticumaestivum*) stubble. *Weed Sci.*, **32**: 24-27. DOI: 10.1017/ S0043174500 058458.

GnanavelI, 2015. Eco-friendly weed control options for sustainable agriculture. *Sci. Int.* **3**(2): 37-47. DOI: 10.3923/sciintl.2015.37.47.

Govaerts, B., Mezzalama, M., Unno, Y., Sayre, K. D., Luna-Guido, M., Vanherck, K., Dendooven, L. and Deckers, J. 2007. Influence of tillage, residue management, and crop rotation on soil microbial biomass and catabolic diversity. *Appl. Soil Ecol.*, **37**:18–30. DOI:10.1016/j.apsoil.2007.03.006.

Govaerts, B., Sayre, K.D., Goudeseune, B., De Corte, P., Lichter, K., Dendooven, L. and Deckers, J. 2009. Conservation agriculture as a sustainable option for the central Mexican highlands.*Soil till. Res.*,**103**: 222–230. DOI: 10.1016/j.still.2008.05.018.

Hartzler, R.G. and Owen, M.D. 1997. Weed management in conservation tillage system. Iowa State University, Ames. Available online: www.extension.edu/ Publications/PM1176. pdf.

Hobbs, P.R., Sayre, K. and Gupta, R. 2008. The role of conservation agriculture in sustainable agriculture Philos. *Philosophical transactions of the Royal Society of London. Series B*, **363**:543-55. https:// doi.org/10.1098/rstb.2007.2169.

ICARDA. 2018. Conservation agriculture: higher yield, lower cost. https://www.icarda.org /conservation - agriculture/conservation-agriculture-higheryield lower-cost.

Indoria, A.K, Rao, C.S., Sharma, K.L. and Reddy, K.S. 2017.Conservation agriculture – a panacea to improve soil physical health.*Curr. Sci.*, **112**:52 -61. DOI: 10. 18520/ cs/v112/i01/52-61.

Jat, M.L., Jat, H.S., Jat, R.K., Tetarwal, J.P., Jat, S.L., Parihar, C.M. and Sidhu, H.S. 2016. Conservation agriculture-based sustainable intensification of cereal based systems for enhancing pulse production and attaining higher recourse-use efficiency in India. *Ind. J. Agron.*, **61** (4th IAC Special issue):S182-S198.

Jat, R.A., Sahrawat, K.L. and Kassam, A.H. 2014. Conservation agriculture: global prospects and challenges. Publisher: CABI International, Wallingford, Oxfordshire, UK. pp 1-25. ISBN-13: 978 1 78064 259 8.

JatH, S., Rai, M., Baliyan, S. and Agarwal, T. 2015. Minimizing yield losses via conservation agriculture. CIMMYT NEWS. https:// www.cimmyt.org/minimizing-yield-losses-via-conservation-agriculture/#.

Jena, T. and Meena, B.L. 2017. Weed Management Options in Conservation Agriculture. *Int. J. Curr. Microbiol. App. Sci.*, **6**(12):1232-44. DOI: 10.20546/ijcmas.2017.612.139.

Johnson, M.D., Wyse, D.L. and Lueschen, W.E. 1989. The influence of herbicide formulation on weed control in four tillage systems.*Weed Sci.*, **37**: 239-49. https:// doi.org/ 10.1017/S004317450007185X.

Kassam, A., Friedrich, T., Derpsch, R. and Kienzle, J. 2015.Overview of the worldwide spread of conservation agriculture. *Field Actions Sci. Rep.*,**8**:1-11.

Khedwal, R.S.,Yadav, D.B., Hooda, V.S., Dahiya, S. and Singh, M. 2017. Zero-till sowing and residue mulching in rainy season maize: effect on weeds, crop productivity and profitability. *Ind. J. Weed Sci.*, **49**(2):198-200. DOI: 10.5958/0974-8164.2017.00051.X.

Koocheki, A., Nassiri, M., Alimoradi, L. and Ghorbani, R. 2009. Effect of cropping systems and crop rotations on weeds. *Agron. Sustain. Dev.*, **29**: 401-08. DOI: 10.1051/agro/2008061.

Kosterna, E. 2014. The effect of covering and mulching on the temperature and moisture of soil and broccoli yield. *Acta Agrophysica* **21**(2):165-78.

Kumar, V., Sharma, A., Soni, J. K., and Pawar, N. 2017. Physiological response of C3, C4 and CAM plants in changeable climate. *Pharm. Innov. J.*, **6**(9): 70-79.

Kutu, F.R, 2012. Effect of conservation agriculture management practices on maize productivity and selected soil quality indices under South Africa dryland conditions. *Afr. J. Agric. Res.*, **7**(26):3839-3846. DOI: 10.5897/AJAR11.1227.

Lafond, G.P., Conkey, Mc.B.G. and Stumborg, M. 2009. Conservation tillage models for small scale farming: linking the Canadian experience to the small farms of inner Mongolia Autonomous Region in China. *Soil till. Res.*, **104**:150-55. https://doi.org/10.1016/j.still.2008.08.014.

Lal, R. 2004. Soil carbon sequestration impacts on global climate change and food security. *Sci*. **304**(5677): 623-627. DOI: 10.1126/science.1097396.

Lichter, K., Govaerts, B., Six, J., Sayre, K.D., Deckers, J. and Dendooven, L. 2008. Aggregation and C and N contents of soil organic matter fractions in a permanent raised-bed planting system in the highlands of Central Mexico. *Pl. Soil* **305**: 237-52. DOI: 10.1007/s11104-008-9557-9.

Locke, M.A. and Bryson, C.T. 1997. Herbicide-soil interactions in reduced tillage and plant residue management systems. *Weed Sci.*, **45**(2):307-20. https:// doi.org/ 10.1017/ S0043174500092882.

Locke, M.A., Reddy, K.N. and Zablotowicz, R.M. 2002. Weed management in conservation crop production systems. *Weed Biol. Manag.*, **2**: 123-32. https://doi.org/10.1046/j.1445-6664.2002.00061.x.

Mailapalli, D.R., Burger, M., Horwath, W.R. and Wallender, W.W. 2013. Crop residue biomass effects on agricultural runoff. *Appl. Environ. Soil Sci.*, **2013**:1-8. http://dx.doi.org/10.1155/2013/805206.

Malik, R.K., Kumar, V. and McDonald, A. 2018. Conservation agriculture-based resource-conserving practices and weed management in the rice-wheat cropping systems of the Indo-Gangetic Plains. *Ind. J. Weed Sci.*, **50**(3):218-22. DOI: 0.5958/0974-8164.2018.00051.5.

Mall, R.K., Gupta, A. and Sonkar, G. 2017.Effect of climate change on agricultural crops.*Curr. Develop. Biotech.Bioengin.*,**23**:46. https://doi.org/10.1016/b978-0-444-63661-4.00002-5.

Marahatta, S. 2014. Evaluation of conservation agriculture practices on rice-wheat system in inner terai of Nepal. *Int. J. Curr. Microbiol. App. Sci.* **,** **3**(11): 313-319.

Martin, A.L., Reddy, K.N. and Zablotowicz, R.M. 2002. Weed management in conservation crop production systems. *Weed Biol. Manag.*, **2**:123-32. DOI: 10.1046/j.1445-6664.2002.00061.x.

Mashingaidze, N., Madakadze, C., Twomlow, S., Nyamangara, J. and Hove, L. 2012. Crop yield and weed growth under conservation agriculture in semi-arid Zimbabwe. *Soil till. Res.*, **124**:102-10. http://dx.doi.org/10.1016/j.still.2012.05.008.

Meena, B.P., Shirale, A.O., Dotaniya, M.L., Jha, P., Meena, A.L., Biswas, A.K. and Patra, A.K. 2016. Conservation agriculture: A new paradigm for improving input use efficiency and crop productivity. In conservation agriculture: An approach to combat climate change in Indian Himalaya; Bisht, J.K., Meena, V.S., Mishra, P.K., Pattanayak A, Eds.; *Springer*: Singapore, 2016; pp. 39–69. https://doi.org/10.1007/978-981-10-2558-7_2.

Mekonnen, B. and Markos, D. 2016. Weed population dynamics in four year conservation (CA) and conventional (CN) agriculture plots in southern maize belt of Ethiopia. *J. Bio. Agric. Healthcare* **6**(9):1-9.

Mohler, C.L. and Teasdale, J.R. 1993. Responseof weed emergence to rate of *Viciavillosa* Roth and *Secalecereale* L, residue.*Weed Res.*, **33**: 487-99 https://doi.org/10.1111/j.1365-3180. 1993.tb01965.x.

Muoni, T., Rusinamhodzi, L. and Thierfelder, C. 2013. Weed control in conservation agriculture systems of Zimbabwe: identifying economical best strategies. *Crop Prot.*, **53**: 23-28. DOI: 10.1016/j.cropro.2013.06.002.

Nichols, Verhulst, N., Cox, R. and Govaerts, B. 2015. Weed dynamics and conservation agriculture principles: A review. *Field Crops Res.*, **183**: 56–68 https://doi.org/10.1016/j.fcr.2015.07.012.

Owen, M.D.K. 2008. Weed species shifts in glyphosate-resistant crops. *Pest Manag. Sci.*, **64**(4): 377-87. DOI: 10.1002/ps.1539.

Phophi, M.M., Mafongoya, P.L., Odindo, A.O. and Magwaza, L.S. 2017. Screening Cover Crops for Weed Suppression in Conservation Agriculture. *Sustain. Agr. Res.*, **6**(4): 124-31. DOI:10.5539/sar.v6n4p124.

Radicetti, E., Mancinelli, R. and Campiglia, E. 2013. Impact of managing cover crop residues on the floristic composition and species diversity of the weed community of pepper crop (*Capsicum annuum* L.).*Crop Prot.*, **44**:109-19.

Rahman, M.M. 2017. Weed management in conservation agriculture. *Adv. Plants Agric. Res.*, **7**(3):302-03. DOI: 10.15406/apar.2017.07.00257.

Ramesh, K. 2015. Weed problems, ecology, and management options in conservation agriculture: issues and perspectives. *Adv. Agron.*, 251-303.DOI: 10.1016/bs.agron.2014.12.003.

Ranaivoson, L., Naudin, K., Ripoche, A., Affholder, F., Rabeharisoa, L. and Corbeels, M. 2017. Agro-ecological functions of crop residues under conservation agriculture-A review. *Agron. Sustain. Dev.*, **37**: 26. DOI:https://doi.org/10.1007/s13593-017-0432-z.

Ranaivosona, L., Naudinb, K., Ripocheb, A., Rabeharisoa, L. and Corbeels, M. 2018. Is mulching an efficient way to control weeds? Effects of type and amount of crop residue in rainfed rice based cropping systems in Madagascar. *Field Crops Res.*, **217**: 20-31. DOI: 10.1016/j.fcr.2017.11.027.

Rao, A.N. and Chauhan, B.S. 2015. Weeds and weed management in India - A Review. In: Weed science in the Asian Pacific region. Indian Society of Weed Science, Hyderabad, pp. 87-118. ISBN 9788193197806. http://oar.icrisat.org/id/eprint/9093.

Shahzad, M., Farooq, M. and Hussain, M. 2016. Weed spectrum in different wheat-based cropping systems under conservation and conventional tillage practices in Punjab, Pakistan. *Soil Till. Res.*, **163**: 71–79. https:// doi.org/ 10.1016/ j.still.2016 .05.012.

Sharma, D.K. and Jat, H.S. 2014. Sustainable intensification of cereal based cropping system in north-west India. (In) National Symposium on Agricultural Diversification for Sustainable Livelihood and Environmental Security 18-20 November 2015, Ludhiyan, Punjab pp 8-10.

Shaver, T. 2010.Crop residue and soil physical properties. Proceedings of the 22nd Annual central plains irrigation conference, Kearney, NE, Available from CPIA, 760 N. Thompson, Colby, Kansas, 24–25.

Silvertown, J. 1980. Leaf-canopy-induced seed dormancy in a grassland flora. *New Phytol.*, **85**: 109-18. https://doi.org/10.1111/j.1469-8137.1980.tb04452.x.

Sims, B., Corsi, S., Gbehounou, G., Kienzle, J., Taguchi, M.I. and Friedrich, T. 2018. Sustainable weed management for conservation agriculture: options for smallholder farmers. *Agric.*, **8**(0): 1-20. DOI:10.3390/agriculture8080000.

Singh, A., Kang, J.S., Kaur, M. and Goel, A. 2013. Root parameters, weeds, economics and productivity of wheat (*Triticumaestivum*) as affected by methods of planting in-situ paddy straw. *Int. J. Curr. Microbiol. App. Sci.*, **2**(10): 396-405.

Singh, A., Kaur, R., Kang, J.S. and Singh, G. 2012. Weed dynamics in rice-wheat cropping system. *Global J.Bio. Agric. Health Sci.*, **1**(1):7-16.

Singh, P., Kewat, M.L., Sharma, A.R. and Sapre, N. 2017. Tillage and weed management effect on productivity of wheat under soybean-wheat-greengram cropping system in conservation agriculture.*Ind. J. Weed Sci.*, **49**(3): 226-30. DOI: 10.5958/0974-8164.2017.00060.0.

Singh, P. K., Sondhia, S., Dubey, R.P., Sushilkumar, Kumar, B., Gharde, Y. and Choudhary, V.K. 2017. Adoption and impact assessment of weed management technologies in wheat and greengram under conservation agriculture system in central India. *Ind. J. Weed Sci.*,**49**(1): 23-28.

Singh, V.P., Barman, K., Singh, R. and Sharma, A. 2015. Weed Management in Conservation Agriculture Systems. In M. Farooq, & Siddique K. H. M (Eds.), Conservation Agriculture (pp. 39-77). Switzerland: Springer International Publishing. DOI: 10.9790/2380-1008010108.

Singh, V.P., Barman, K.K., Singh, P.K., Singh, R. and Dixit, A. 2017.Managing weeds in rice (*Oryza sativa*) – wheat (*Triticumaestivum*)-greengram (*Vignaradiata*) system under conservation agriculture in black cotton soils.*Ind. J. Agric. Sci.*,**87**(6): 739-45.

Six, J., Ogle, S.M., Conant, R.T., Mosier, A.R. and Paustian, K. 2004. The potential to mitigate global warming with no-tillage management is only realized when practised in the long term. *Global Change Bio.*, **10**(2):155-60. DOI: 10.1111/j.1529-8817. 2003. 00730.x.

Smit, B. and Smithers, J. 1993. Sustainable agriculture: interpretations, analyses and prospects. *Can. J. Reg. Sci.*, **XVI**: 3, 499-524.

Sommer, R., Piggin, C., Haddad, A., Hajdibo, A., Hayek, P. and Khalil, Y. 2012. Simulating the effects of zero tillage and crop residue retention on water relations and yield of wheat under rainfed semiarid Mediterranean conditions. *Field Crops Res.*, **132**: 40-52.

Swanton, C.J., Clements, D.R. and Derksen, D.A. 1993. Weed succession under conservation tillage: a hierarchical framework for research and management. *Weed Tech.*, **7**: 286-97. DOI: 10.1017/S0890037X00027615.

Teasdale, J.R. 1996. Contribution of cover crops to weed management in sustainable agricultural systems.*J. Prod. Agric.*, **9**: 475-79. https://doi.org/10.2134/jpa1996.0475.

Tuesca, D., Puricelli, E. and Papa, J. 2001. A long-term study of weed flora shifts indifferent tillage systems. *Weed Res.*, **41**: 369-82. https://doi.org/10.1046/j.1365-3180.2001.00245.x.

Turmel, M.S., Speratti, A., Baudron, F., Verhulst, N. and Govaerts, B. 2015. Crop residue management and soil health: A systems analysis. *Agric. Sys.*,**134**(C): 6-16. DOI: 10.1016/j.agsy.2014.05.009.

Vanlieshout, L.A. and Loux, M.M. 2000. Interactions of glyphosate with residual herbicides in no-till soybean (*Glycine max*) production.*Weed Tech.*, **14**: 480-87. https://doi.org/10.1614/0890-037X(2000)014[0480:IOGWRH]2.0.CO;2.

Vargas, R.N. and Wright, S.D. 2005. UC IPM Pest Management Guidelines: Cotton. State wide IPM Program. Division of Agriculture and Natural Resources, University of California Publication 3444, Oakland.

Verhulst, N., François, I. and Govaerts, B. 2012.Conservation agriculture, improving soil quality for sustainable production systems? International Maize and Wheat Improvement Center. pp 1-16.

Vishwakarma, A.K., Wanjari, R.H., Brajendra, and Gopal, R. 2017. Weed management in conservation agriculture: A brief review. *J. Pharmacognosy Phytochem.*, **SP1**: 502-06.

Vivek, Naresh, R.K., Tomar, S.K., Kumar, S., Mahajan, N.C. and Shivani. 2019. Weed and water management strategies on the adaptive capacity of rice-wheat system to alleviate weed and moisture stresses in conservation agriculture: A review. *Int. J. Chem. Stud.*, **7**(1): 1319-34.

Young, K.R. and Cousens, R.D. 1999. Factors affecting the germination and emergence of wild radish (*Raphanusraphanistrum*) and their effect on management options. In: Bishop, A.C., *et al.* (Eds.), *Proceedings of 12th Australian Weeds Conference*. Tasmanian Weed Society, Tasmania, Hobart, pp 179-182.

Zheng, C., Jiang, Y., Chen, C., Sun, Y., Feng, J., Deng, A., Song, Z. and Zhang, W. 2014. The impacts of conservation agriculture on crop yield in China depend on specific practices, crops and cropping regions. *Crop J.*, 1-12. https://doi.org/10.1016/j.cj.2014.06.006.

Zibilske, L.M., Bradford. J.M. and Smart, J.R. 2002. Conservation tillage induced changes in organic carbon, total nitrogen and available phosphorus in a semi-arid alkaline subtropical soil. *Soil Till. Res.*, **66**:153-63. DOI: 10.1016/S0167-1987(02)00023-5.