Review Article

Effect of zero tillage on soil properties, weed dynamics and performance of chickpea under rice – chickpea cropping system: A review

Abstract

Farming is a critical segment in many countries of the world. Zero tillage systems are sustainable farming practices that involve sowing seeds without disturbing the soil through tillage. Instead of ploughing, this system leave the previous year's crop residues on the soil surface and plant directly into the undisturbed soil. This approach helps to maintain the soil structure, reduce soil erosion, increase water retention, and improve soil health. This sustainable farming practices has several benefits for farmers, including improved soil health, reduced soil erosion, increased crop yields, and environmental sustainability. This system helps to reduce soil erosion by minimizing soil disturbance, which prevents soil particles from being exposed to the wind and water. Also helps to retain soil moisture, which reduces the need for irrigation, and improves soil structure, which enhances soil fertility. Zero-tillage systems can have reduced labor and fuel costs associated with conventional tillage practices. Systems require less fuel and labor compared to conventional tillage practices, which can save farmers money and reduce their carbon footprint. This is because these systems improve soil fertility by increasing soil organic matter, which enhances soil nutrient availability. Moreover, zero tillage systems can increase water retention in the soil, which can improve crop growth and yield. By reducing soil erosion, conserving soil moisture, and improving soil health, these systems help to promote environmental sustainability. Also reduce greenhouse gas emissions by reducing fuel usage and sequester carbon in the soil through the accumulation of crop residues. Therefore, farmers should adopt zero-tillage systems to enhance their productivity, reduce costs, and promote environmental sustainability.

Key words: Zero tillage, soil properties, weed dynamics, rice – chickpea system, benefits

Introduction

Chickpea (*Cicer arietinum* L.) is grown in the winter season in sequence with different crops like rice, maize, soybean, sorghum and pearlmillet in the states of Madhya Pradesh, Maharashtra, Rajasthan, Andhra Pradesh, Tamil Nadu, Karnataka, Uttar Pradesh and Gujarat **(Adarsh*et al.*, 2019).**Rice- chickpea cropping system (RCCS) predominantly cultivated in northern part of the country next to rice-wheat cropping system **(Arya *et al.*, 2005).** Beside wheat, the introduction of chickpea in rice based cropping system is a feasible option to ensure sustainable food production and maintain environmental integrity. It can fix N up to 140 kg ha^{-1} in a growing period **(Poonia and Pithia, 2013)** and helps in eradicating obnoxious weeds like wild oat (*Avena fatua*) and canary grass (*Phalaris minor*) **(Ali and Basu, 1992).**Chickpea, sown during rabi season after harvesting of the rice, it considers as a most valuable and drought tolerant crop**(Gangwarand Singh *et al.*, 2010)**. Present agriculture has globally been facing major challenges including soil erosion which drastically lowers the crop yield. Chickpea can increase the productivity both in terms of N saving from fertilizer sources and build up soil fertility through biological source of N **(Banjara *et al.*, 2017).** In rice-chickpea cropping system (RCCS), the sowing of chickpea often delayed until last November or early December either due to late harvesting of rice or more time required to seedbed preparation for chickpea seeding. Late sowing put negative effects on germination, seedling establishment, reproductive stage due the less soil moisture and low temperature. Conventional tillage (CT) affect the sustainable resources through its influence on soil properties, crop growth and the use of excessive and un-necessary tillage operations is often harmful to soil **(Nazeer*et al.*,2012).** Conservation agriculture (CA) techniques involve zero tillage which reduces risk of late sowing of chickpea. Zero tillage seeding of chickpea helps in timely sowing, because it facilitates direct sowing in previous unprepared crop field. ZT also reduce the negative environmental effects of agriculture such as soil erosion and degradation of physical properties of soil leading to decrease crop productivity **(Monneveux*et al.*, 2006).**

Chickpeas work perfectly into a lot of different cropping schemes. The main cropping sequences that are followed in India's various climatic circumstances include pearl millet/sorghum-chickpea, rice/maize-chickpea, and cotton-chickpea **(AICRP-Sorghum, 2017).** One of the main agricultural systems in the Bundelkhand region is fodder sorghum–chickpea **(Singh and Praharaj, 2020).** Similarly, Andhra Pradesh and Karnataka follow the rice-chickpea, maize/sorghum-chickpea, and pearl millet-chickpea systems. These cereal-legume cropping systems aid in interrupting monocropping sequences, conserving nitrogen, halting soil erosion, and enhancing soil health.This review assesses the impact of zero tillage on performance of chickpea as well as impact on weed dynamics within the context of rice-chickpea cropping systems.

1.What is zero tillage

Zero tillage has emerged as a promising approach in sustainable agriculture, offering benefits such as improved soil health and reduced erosion. One of the conservation tillage techniques is zero-tillage systems, where soil disturbance is limited to sowing activities. It keeps crop leftovers on the soil surface, which raises the amount of soil organic carbon and enhances soil quality and health. In comparison to conventional tillage, zero tillage systems typically needed less maintenance and provided higher economic returns (**Smart and Bradford, 1999**). Zero tillage reduces cost by 3.8 % to 13.7 % and frees up at least 8 days for the growth of succeeding crops. Zero tillage farming is an option for low-income farmers (**Quddus *et al.*, 2020)**

Zero tillage globally advocated to it benefits. Zero tillage in rice-based system will not only enable the earlier planting of chickpea, also reduce the land preparation cost, avert the water logging by just utilizing the residual moisture, but also it will let the weeds stay dormant below the soil for their lack of exposure to light.

2. Effect of zero tillage

Mishra *et al.*(2012) reported that zero tillage in chickpea had significant impact on crop growth and yield parameters such as plantpopulation, number of branches, height of plants, number of pods per plant etc. When compared with conventional tillage. This may have been due to improved moisture conditions near the soil surface or greater seed-soil contact in ZT systems **(Miller*et al*., 2002).**Tillage systems affect soil disturbance, weed management, and weed seed production, a change in tillage systems will influence the species composition and vertical distribution of weed seeds in agricultural soils**(Bhular *et al.*, 1995).**

According to **Hemmat *et al.* (2004),** the grain production of chickpea at the Dryland Agricultural Research Station in Iran was higher under the minimum tillage-sweep ploughing, reduced tillage-tandem disk, and zero tillage techniques, respectively, than under the conventional tillage-mould board method.

2.1 Effect on growth and yield attributes of chickpea

In a field experiment **(Quddus*et al*., 2020)**observed significant variation in growth and yield attributes of chickpea due to different tillage practices except 100-seed weight. They obtained tallest plant (48.9 cm and 50.1 cm) underzero tillage (T_1) treatment as compared to the rest of treatments, they stated that tallest plant under zero tillage condition observed might be due toavailability of optimum soil moisture in soil for available nutrients to plant uptake. Performance of zero tillage and minimum tillage both achieved well and produced taller plant, maximum number of branches per plant, the highest number of pods per plant. The highest number of pods plant^{-1} was realized in zero tillage which is related with more branching**(Banjara *et al.*, 2017).** The climatic condition of zero tillage plots might be favoured to growth and development of chickpea plant. They stated that zero tillage system successfully adopts the weather conditions in the growing season. In an experiment carried out in ICARDA, Syria, tillage, residue, and weed control techniques had a significant impact on the growth and yield performance of chickpea. Compared to conventional tillage, zero-till seeded chickpea had a 26.3% greater grain yield **(Piggin *et al.*, 2015).**

3. Effect of Zero Tillage on Soil Properties:

Zero tillage have impact on physical, chemical and biological properties of the soil **(Bhatt,2017)**. No-till in the context of CA can also lead to improvements in soil quality by improving soil structure and enhancing soil biological activity, nutrient cycling, soil water holding capacity, water infiltration and water use efficiency **(Hobbs *et al.*, 2008**).

3.1Soil Physical Properties:

3.1.1Effect on bulk density- Bulk density significantly influenced ($P \leq 0.05$) by the different tillage practice. Under zero tillage and minimum tillage practices lower value of bulk density (1.36 and 1.39) observed by several researchers**(Lal *et al.*, 1989; Karlen*et al.*, 1994; Green *et al*., 2005;Jat*et al.*,2006).** Under conventional tillage the bulk density was 1.39Mgm^{-3}. They explain that this increase was the result of natural reconsolidation of soil particles because of subsequent irrigation and summer drying. The gradual increase the disturbances in the soil by increased number of tillage and intercultural operations resulting more compaction of soil that leads to increased bulk density. The increase in bulk density under tilled soils may be due to increase in non-capillary porosity and low soil mass per unit volume. Owing to the progressive increase in bulk density after tillage, the difference between the tilled and no tilled treatments becomes smaller and smaller with the time since tillage progresses. The no tillage system maintained a significantly greater amount of residue on the soil surface increase soil organic carbon and biotic activity, thereby decreasing bulk density, particularly near the soil surface.

3.1.2.Effect on water stable aggregate (WSA): Reduced tillage practices showing the higher WSA compare with the intensive tillage and more intercultural operations. The highest WSA was recorded in Zero tillage (59.32%) followed by under minimum tillage (59.22%). In an experiment**, Hula *et al.* 2010**, observed worsened soil structure under conventional tillage in comparison to reduced tillage.It might be due to that soil tillage, based on ploughing can result in faster deterioration of soil structure compared to shallower tillage which less disturbing the soil. According to various authors**(Daraghmeh*et al.*,2009); (Boguzas*et al.*,2010),**site adaptable tillage, in comparison to conventional methods, increases the amount of water stable aggregates and improves (soil) structure due to a combination of greater amounts of organic matter, reduced bulk weight of soil, and a greater share of larger aggregates. Enhanced in physical parameters of soil resulting in increased porosity and water stable aggregate hence more available water content.

3.1.3. Effect on soil aggregation: Soil aggregation is an important physical property and is affected by divergent tillage methods. According to **(Mannering *et al.*, 1975)**and**(Edwards *et al.*, 1988),** soil aggregation decreased in CT plots as tillage break down the aggregates. Aggregation was highest in the 0-0.05 m layer of ZT plots. Long term adoption of the ZT will certainly improve the aggregate stability of the topsoil **Douglas and Goss, (1982**).**(Lal *et al*., 1989)** reported that aggregate size tended to be around 22% higher under ZT treatments in comparison to that of tilled plots.Soil under ZT have better aggregates, aggregate stability, increased porosity which further improved rhizosphere environment for the better plant growth while intensive tillage led to decline in soil organic matter through accelerated oxidation of the organic matter (**Ghuman and Sur, 2001); (Francis** and **Knight, 1993); (Martino** and**Shaykewich, 1994); (Ghosh *et al*., (2010).** Zero tillage canimproved macro-aggregation (>0.25 mm) and mean weight diameter which further improved carbon sequestration potential of the soil**(Franzluebbers**and **Arshad, 1996; McConkey*et al.*, 2003).**Most studies coined that aggregation improved with the adoption of the ZT, ZT must be adopted for about 5-8 years**(Bhatt, 2015;Bhatt and Kukal, 2015e).**

4. Effect on soil chemical properties

Tillage operations and soil disturbance generally cause an increase in soil aeration, residue decomposition; Organic N mineralization and availability of N for plant use **(Dinnes*et al.*, 2002).(Moussa-Machraoui*et al*., 2010**) observed that some of the chemical parameters of soil were significantly modified under no tillage when compared to conventional tillage system. The nutrient (N, P, K, P_2O_5 and K_2O) contents were more under no tillage than conventional tillage.

4.1. Effect on EC: Lower electrical conductivity of soil under the ZT system compared with CT pertains to the enhanced water movement in the soil and improved soil aggregate development.Inconsistent effect of zero tillage on soil electrical conductivity (EC) is observed and reported by**(Singh and Singh, 2014)**and**(Chatterjee and Lal, 2009).(Patni *et al.*,1998**) alsoreported decrease in soil EC under NT which might bedue to more downward movement of salts along withwater infiltration into deeper layers.

4.2. Effect on soil pH: Long term adoption of the ZT resulting in acidification of the surface soil which further affects the supply and distribution of other nutrients within the rhizosphere. Under ZT, a significant lowering of pH observed at the upper soil 0-7.5 cm on silt loam soil

(Dick *et al*., 1986 and Tarkalson *et al*.,2006)).Soil acidity with ZT observed due to decomposition of organic residues at the surface with subsequent leaching of resultant organic acids into mineral soil **(Blevins *et al*.,1977).** While**Rahman *et al*.,2008** observed nosignificant differences in soil pH among no tillage and conventional tillage practices.

4.3. Effect on soil organic matter: Both quality and quantity of the organic matter (OM) in a particular soil is indicators of its quality as it affects almost all the physico-chemical properties. Generally, OM content of upper soil under ZT is higher, than for tilled soil. The OM quantity will generally improve with conservation tillage, but remain fairly constant, or perhaps decreasefurther, with intensive tillage **(Frye *et al*., 1985)**. Improvement in soil OM status in the upper 0.2 m to 0.4 m soil depth under ZT reported by**Freitas *et al*., 1999**and**Six *et al*., 2002.**The surface soil beneath the canopy had higher OM content in both tillage systems, particularly under no tillage. Contents of SOC was slightly greater under no tillage than under conventional tillage. No tillage canincrease soil C stock by an average of 4-7 per cent. The enhancement of SOC and SOM contents in the soil under no tillage is often accompanied by the enhancement of the cation exchange capacity **(Moussa-Machraoui*et al*.,2010).** The SOC was significantly higher when stubble was left on surface. Under conservation tillage the organic carbon increased by 11 per cent **(Bricchi*et al*., 2004)** and 14-17 per cent**(Hazarika *et al*., 2009**), while a reverse trend was observed in the lower depths.

5. Effect on biological properties of soil

5.1. Soil microbial populations: ZT conditions increased micro and macro soil organisms resulted larger number of worm channels and to their continuityattributed the higher infiltration rate of soil **(Hopp and Slater,1961).** Earthworm channelsincreased conveyed, which increase soil porosity, and provide for rapid water entry into a soil**(Doran *et al*., 1980)**. In comparison to that of conventional tilled plots, observed greater earthworm activity (up to five times), 35 and 57 per cent higher aerobic counts and facultative anaerobic counts under ZT conditions. The population of denitrifying bacteria was almost half in tilled plots in compared to than that of the ZT plots.

5.2. Soil respiration: CO_2 flux as impacted by agricultural management practice need to be delineated **(Reicosky *et al*., 1997).** Tillage opens the soil, thus improves the soil respiration and increased the emission of the CO_2**(Reicosky and Archer *et al*., 2007).** Nowadays, a rapid increase of CO_2 in environment is one of the main issues because of reported global warming consequences **(Wood *et al*., 1990).** However, soil management practices need to be refined to reduce soil respiration and organic matter decomposition without decreasing crop yield, ZT might be suitable answer. But scientists are of different opinions as some reported similar soil CO_2 emission rates from ZT and CT **(Elder and Lal, 2008),** while**(Oorts*et al.*2007)** observed large CO_2 emissions under zero tillage in comparison to the CT. Thus, a bridgebetween the two tillage systems might be an answer.

6. Effect on nodulation and root growth:

A long-term chickpea experiment showed that, in comparison to a conventional tillage system, the quantity and dry weight of root nodules/plant under a zero tillage system were 33.3 and 21.1% greater, respectively **(Lopez-Bellido *et al.*, 2011).**According to a study conducted in Spain, during conventional tillage (0.34 mm/cm^2), chickpea root length in the 0-15 cm layer was 38 and 27% larger than under zero tillage (0.18 mm/cm^2) **(Munoz-Romero *et al.*, 2012).**

The study carried out in Jabalpur revealed that ZTs chickpea produced after transplanted rice had a considerably greater nodule dry weight (71.8 mg/plant) than both ZTs direct-seeded rice (55.2 g/plant) and direct-seeded rice (59.2 mg/plant) **(Mishra *et al.*, 2012).**

7. Effect on crop production economics and energy efficiency:

The data on economics of rabi chickpea crop emphasized that conventional tillage requires higher cost of cultivation (16799.40 ha-^{1}) as compared to minimum (16790.70ha-^{1}) and zero tillage (16277.50 ha-^{1}) **(Ahmad *et al.*,2019).** While they realized maximum gross return (Rs. 60599.78 ha-^{1}) and net returns (Rs.43800.38 ha-^{1}) under conventional tillage. The higher returns under above conventional tillage might be due to higher seed yield coupled with lower cost of weed management treatments. Similar findings were also reported by **(Singh *et al*., 1991; Porwal,2000** and**Patel *et al*., 2006.**

Mishra*et al.*(2012)reported that total cost of cultivation in TPR-CT chickpea system (₹ 31410/ha) was higher than other systems due to higher costs involved in field preparation and transplanting operations in rice. The highest net returns (₹33,600/ ha) and benefit: cost ratio (2.33) was accrued with ZT-DSR, ZT- chickpea cropping system and the lowest with DSR-CT chickpea system (₹ 20 222/ha and 1.67). The PBR-CT chickpea system required maximum energy (₹ 20 867 MJ/ha) closely followed by TPR-CT chickpea (20,594 MJ/ha) due to higher energy required for puddling in rice and tillage operations in chickpea. The energy productivity (yield per unit energy consumed) was maximum (0.401 kg/MJ) in ZTDSR-ZT chickpea, followed by TPR-CT chickpea (0.327 kg/MJ). The output energy was maximum in TPR-CT chickpea (99 049 MJ/ha), followed by ZT DSR-ZT chickpea (96 344 MJ/ha) due to higher system productivity. The energy output:input ratio (5.90) was the highest in ZT-DSR-ZT- chickpea, followed by TPR-CT-chickpea (4.81). The lowest energy productivity (0.253 kg/MJ), output energy (72 765 MJ/ha) and output: input ratio (3.71) was observed from DSR-CT chickpea system.

According to **Roy and Singh (2012),** on the sandy loam soils of Ludhiana, Punjab, the net monetary returns of chickpea were higher under ZT with Pantnagar seed drill (₹2650/ha) and ZT with paddy stubbles (₹2100/ha) than under reduced tillage-RT (₹1950/ha). Similar view also reported by **(Kumari *et al.*, 2019)**by conducting an experiment on chickpea at Bhagalpur**.**

8. **Effect of zero tillage on weed dynamics in chickpea:**

Weed is also another serious problem in rice based cropping system. Infestation of weeds suppresses the crop especially during initial growth period. Weeds canreduce the chickpea yield by the tune of 10-50% loss of crop yield depends upon the intensity of weed flora and management practices **(Yaduraju and Mishra., 2002).** A significant obstacle to achieving potential chickpea yield is weeds. The weed species infesting the chickpea fields vary from one location to another depending on the agro-climatic conditions, prevailing cropping systems, tillage practices and weed management strategies adopted.

The experimental field of chickpea was dominated with broad-leaved weeds (95.4%), viz. Clover (*Medicagohispida*Gaertn) (50 %), common vetch (*Viciasativa* L.) (22.6 %), common lambsquarters (*Chenopodium album* L.) (7.3 %), and others including field bindweed (*Convolvulus arvensis* L.), *V. hirsuta* L., sweet clover (*Melilitusindica* All.) and *M. alba* L. (15.5 %). The grassy weeds, vizlittleseed canary grass (*Phalaris minor* Retz.) (3.1%) and wild oats (*Avenasterilis*)(1.5%) were of minor importance.**(Mishra *et al.*, 2011)** stated that Zero till chickpea significantly increased the population of *V. sativa* but reduced the problem of *C. album* as compared to conventional tillage. The population of *M. hispida*, *A. luduviciana*, *P. minor* and total weeds did not vary significantly due to change in tillage systems. Under zero tillage significantly reduced dry matter of *M. hispida* and *C. album*was observed by 20.3 and 58% as compared to conventional tillage, however, the dry matter of *A. luduviciana* and *V. sativa* increased.

In a study at Kanpur, **(Kumar *et al.*, 2022)** observed that, post–rainy seasons zero tillage with and without residues attributed higher weed diversity indices (Shannon and Simpson) compared with conventional tillage in seedbank. Importantly, CT–ZT + R with R–C–Mb (interaction) reduced 24% total viable seed density at 0–15 cm depth than CT–CT with R–W. Zero tillage in post-rainy seasons after puddled transplanted rice and intensive pulse based cropping (rice-chickpea-mungbean) can minimize viable weed seeds in soil vis–a–vis above–

ground weed density over time than conventional tillage and rice-wheat system. The reduced weed density could reduce soil fertility degradation, enhance crop/system productivity, restore soil health and provides opportunity for sustainable cropping intensification in rice ecologies of the Indo-Gangetic plains.

In a study conducted at IGFRI, Jhansi, zero tillage in the chickpea cropping sequence considerably reduced the weed density by 14.5-19.5% when compared to reduced and conventional tillage conditions **(Dixit *et al.*, 2015).**

Conclusion

Based on the research work carried by various workers as reviewed, it may be concluded that:

1. Zero tillage significantly reduces weed density and biomass, mitigating weed competition and enhancing chickpea growth and development.
2. Weed dynamics under zero tillage exhibit a favorable trend, facilitating improved resource utilization by chickpea crops and reducing the need for intensive weed management.
3. Chickpea yields demonstrate marked improvement under zero tillage, attributed to decreased weed interference and enhanced soil health.
4. The adoption of zero tillage offers a sustainable approach to weed management, promoting soil conservation and minimizing environmental impact.
5. Integrating zero tillage into rice-chickpea cropping systems holds promise for optimizing agricultural productivity while fostering long-term sustainability.

By reviewing the research work done by several workersit may be concluded that the efficacy and benefits of zero till chickpea in enhancing chickpea productivity and efficient weed management under rice-chickpea cropping systems, thereby offering a pathway towards sustainable agricultural practices and improved farm profitability.

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