

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 tillage and fuel costs associated with conventional tillage practices. Systems require less fuel and tillage 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 enhances crop growth and yield by improving soil structure and moisture retention, while also reducing weed competition. 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 pearl millet 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 its 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 better impact on crop growth and yield parameters such as plant population, 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 positively 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

Research by **Quddus et al., (2020)** showed variation in growth and yield attributes of chickpea due to different tillage (zero, single, two, three and four times tillage) practices except 100-seed weight. They obtained tallest plant (48.9 cm and 50.1 cm) under zero tillage treatment as compared to the single, two, three and four times tillage treatments, they stated that tallest plant under zero tillage condition observed might be due to availability 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).

3.1 Soil Physical Properties:

3.1.1 Effect on bulk density- Bulk density significantly influenced ($P \leq 0.05$) by the different tillage practice (Alam *et al.*, 2014). Under zero tillage and minimum tillage practices lower value of bulk density (1.36 and 1.39) observed by (Lal *et al.*, 1989 and Green *et al.*, 2005). Under conventional tillage the bulk density was 1.39Mgm^{-3} . They explain that this bulk density increase was the result of the 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 (Kumar *et al.*, 2018). 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%). It is shown in the work of Hula *et al.*, (2010), worsened soil structure under conventional tillage in comparison to reduced tillage. According to various authors (Daraghmech *et al.*, 2009); (Boguzas *et al.*, 2010), zero 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 “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 can improve 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, P₂O₅ and K₂O) 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. Anomalous 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) also reported decrease in soil EC under NT which might be due to more downward movement of salts along with water infiltration into deeper layers (Kahlon and Singh, 2014).

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 as compared to CT, 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 no significant differences in soil pH among no tillage and conventional tillage practices.

4.3. Effect on soil organic matter: Organic matter (OM) content and quality in a particular soil act as indicators of its quality, and they affect 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 decrease further, 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 were slightly greater under no tillage than under conventional tillage. 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 percent (**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: As compared to conventional tillage (CT), zero tillage (ZT) conditions were observed to be better for both micro and macro soil organisms. Greater number of worm channels and to their continuity, which was better in no-tilled soil than in plowed soil attributed the higher infiltration rate of loess soil in Germany (**Ehlers 1979**). (**Hopp and Slater, 1961**) reported that earthworm channels, which increase soil porosity, are highly stable and provide for rapid water entry into a soil. In comparison to that of conventional tilled plots, (**Lal, 1976**) reported greater earthworm activity (up to five times) in ZT plots. **Doran (1980)** reported 35 and 57 per cent higher aerobic counts and facultative anaerobic counts under ZT conditions.

5.2. Soil respiration: CO₂ 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 CO₂ (Reicosky and Archer *et al.*, 2007). Nowadays, a rapid increase of CO₂ 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 CO₂ emission rates from ZT and CT (Elder and Lal, 2008), while (Oorts *et al.*, 2007) observed large CO₂ emissions under zero tillage in comparison to the CT. Thus, a bridge between 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/cm²), chickpea root length in the 0-15 cm layer was 38 and 27% larger than under zero tillage (0.18 mm/cm²) (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 (Rs.16799.40 per ha) as compared to minimum (16790.70 per ha) and zero tillage (Rs.16277.50 per ha) (Ahmad *et al.*, 2019). The conventional tillage method yielded the highest gross return and net return among the tillage management techniques, with a B:C ratio of 2.62 for (60599.78 per ha) gross return and (43800.38 per ha) net return, respectively. The minimum and zero tillage methods were determined to be the least effectively. 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 Transplanted Rice-Conventional Tillage chickpea system (TPR-CT chickpea) (₹ 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 Zero tillage – Direct Seeded Rice (ZT-DSR), ZT- chickpea cropping system and the lowest with DSR-CT chickpea system (₹ 20 222/ha and 1.67). The Puddled broadcast rice- conventional tillage (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 ZT-DSR-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 serious problem in rice based cropping system. Infestation of weeds suppresses the crop especially during initial growth period. Weeds can reduce 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 site of experiment of chickpea was dominated with broad-leaved weeds (95.4%), viz. Clover (*Medicago hispida* Gaertn) (50 %), common vetch (*Vicia sativa* L.) (22.6 %), common lambsquarters (*Chenopodium album* L.) (7.3 %), and others including field bindweed (*Convolvulus arvensis* L.), *V. hirsuta* L., sweet clover (*Melilitus indica* All.) and *M. alba* L. (15.5 %). The grassy weeds, viz littleseed canary grass (*Phalaris minor* Retz.) (3.1%)

and wild oats (*Avena sterilis*) (1.5%) were of minor importance (Mishra *et al.*, 2011). (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. ludoviciana*, *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. ludoviciana* 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, Conventional tillage –Zero tillage + Residue mulch (CT–ZT + R) with rice-chickpea-mungbean (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 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 favourable 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 workers it 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.

Based on the review of literature on the effect of zero tillage on soil properties, weed dynamics, and chickpea performance in the rice-chickpea cropping system, the following points for future research could be identified:

1. **Soil Health Monitoring:** Conduct longitudinal studies to monitor changes in soil health indicators over time under zero tillage, including soil organic matter content, soil structure, microbial activity, and nutrient availability.
2. **Weed Species Composition:** Investigate the shifts in weed species composition and abundance under zero tillage compared to conventional tillage, particularly focusing on the emergence patterns, competitive abilities, and herbicide resistance of dominant weed species.
3. **Integrated Weed Management Strategies:** Develop and evaluate integrated weed management strategies tailored specifically to zero tillage systems in the rice-chickpea cropping system, incorporating cultural, mechanical, biological, and chemical control methods.
4. **Chickpea Genotype Selection:** Assess the performance of different chickpea genotypes under zero tillage conditions, considering traits such as early vigor, root architecture, disease resistance, and yield stability.
5. **Nutrient Cycling Dynamics:** Investigate the effects of zero tillage on nutrient cycling processes, including nutrient mineralization, immobilization, and leaching, to optimize nutrient management practices and improve chickpea productivity while minimizing environmental impacts.
6. **Water Use Efficiency:** Evaluate the water use efficiency of chickpea under zero tillage compared to conventional tillage systems, considering factors such as soil moisture retention, evapotranspiration rates, and irrigation requirements.
7. **Economic Viability:** Conduct economic assessments to determine the cost-effectiveness and profitability of adopting zero tillage practices in the rice-chickpea

cropping system, considering both short-term input costs and long-term benefits such as soil conservation and yield stability.

8. **Climate Change Resilience:** Investigate the role of zero tillage in enhancing the resilience of rice-chickpea cropping systems to climate change impacts, including drought stress, extreme weather events, and temperature fluctuations.
9. **Farmer Knowledge Exchange:** Facilitate knowledge exchange and farmer-to-farmer learning networks to disseminate information about the benefits and challenges of zero tillage adoption in the rice-chickpea cropping system and promote its uptake among farming communities.

References -

Adarsh, S., Giffy, T. and Jacob, J. (2019). Role of pulses in cropping systems: A review. *Agricultural Reviews* 40(3): 185–191.

AICRP-Sorghum. (2017). Sorghum agronomy. Indian Institute of Millets Research, Hyderabad.

Amgain, L. P., Sharma, A. R., Das, T. K., & Behera, U. K. (2013). Effect of residue management on productivity and economics of pearl millet (*Pennisetum glaucum*)-based cropping system under zero-till condition. *Indian Journal of Agronomy*, 58(3), 298–302.

Dixit, A. K., Kumar, S., Rai, A. K., & Kumar, T. K. (2015). System productivity, profitability, nutrient uptake and soil health under tillage, nutrient and weed management in rainfed chickpea (*Cicer arietinum*)–fodder sorghum (*Sorghum bicolor*) cropping system. *Indian Journal of Agronomy*, 60(2), 205–211.

Hemmat, A., & Eskandari, I. (2004). Tillage system effects upon productivity of a dryland winter wheat–chickpea rotation in the northwest region of Iran. *Soil and Tillage Research*, 78(1), 69–81.

Kumar, B. R., and Angadi, S. S. (2016). Effect of tillage, mulching and weed management practices on the performance and economics of chickpea. *Legume Research-An International Journal*, 39(5), 786–791.

Kumari, S., Kumar, S., Chaurasiya, A., Dutta, S. K., Pradhan, A., & Behera, S. K. (2019). Conservation agriculture based tillage options for rabi crops cultivation in eastern India: Effects on Productivity and Profitability. *International Journal of Current Microbiology and Applied Sciences*, 8(7), 1678–1689.

Mishra, J. S., Singh, V. P., Chandra, B., & Subrahmanyam, D. (2012). Crop establishment, tillage and weed management techniques on weed dynamics and productivity of rice (*Oryza*

sativa)-chickpea (*Cicer arietinum*) cropping system. *Indian Journal of Agricultural Sciences*, 82(1), 15–20.

Piggin, C., Haddad, A., Khalil, Y., Loss, S., & Pala, M. (2015). Effects of tillage and time of sowing on bread wheat, chickpea, barley and lentil grown in rotation in rainfed systems in Syria. *Field Crops Research*, 173, 57–67.

Rathod, P. S., Patil, D. H., & Dodamani, B. M. (2017). Integrated weed management in chickpea (*Cicer arietinum* L.) under rainfed conditions of Karnataka, India. *Legume Research-An International Journal*, 40(3), 580–585.

Roy, R., & Singh, A. (2012). Crop establishment techniques for improving soil properties and productivity of chickpea (*Cicer arietinum* L.). *Journal of Food Legumes*, 25(3), 237–239.

Singh, D., Pazhanisamy, S., Kumar, S., Kumar, A., & Reddy, S. L. (2020). Bio-efficacy of different herbicides in broad spectrum weed management for chickpea. *International Journal of Current Microbiology and Applied Sciences*, 9(3), 2313–2317.

Singh, N. P., & Praharaj C. S. (2020). Scenario of pulses production in India, Abstracts of international conference on pulses as the climate smart crops: challenges and opportunities, Bhopal, India, 3–9.

Munoz-Romero, V., López-Bellido, L., & López-Bellido, R. J. (2012). The effects of the tillage system on chickpea root growth. *Field Crops Research*, 128, 76–81.

Ahmad, A., Chowdhury, T., & Kumar, A. (2019). Effect of Tillage and Weed Control Techniques on Energy Dynamics and Profitability of Chickpea (*Cicer arietinum* L.)-Rice Cropping Sequence in Irrigated Ecosystem of CG Plains. *Curr. J. App. Sci. and Tec*, 38(6), 1-8.

Ali M. (1992). Genotypic compatibility and spatial arrangement in chickpea (*Cicer arietinum* L.) and Indian mustard (*Brassica juncea*) in intercropping in north-eastern plains. *Indian Journal of Agricultural Sciences* 62(4) :249-53.

Arya, R.L., Kumar, L., Singh, K.K. and Kushwaha, B.L., (2005). Effect of fertilizers and tillage management in rice (*Oryza sativa*)–chickpea (*Cicer arietinum*) cropping system under varying irrigation schedules. *Indian Journal of Agronomy*, 50(4), pp.256-259.

López-Bellido, L., Benítez-Vega, J., García, P., Redondo, R. and López-Bellido, R.J., 2011. Tillage system effect on nitrogen rhizodeposited by faba bean and chickpea. *Field crops research*, 120(1), pp.189-195.

Banjara, T. R., Pali, G. P., Tigga, B. K., Kumar, S., & Shori, A. (2017). Effect of Different Tillage Practices on Growth, Yield and Economics of Chickpea (*Cicer arietinum* L.) under Rainfed Condition of Chhattisgarh. *International Journal of Current Microbiology and Applied Sciences*, 6(2), 1464-1470. <https://doi.org/10.20546/ijcmas.2017.602.164>.

- Barley, K. P. (1961). The abundance of earthworms in agricultural land and their possible significance in agriculture. *Advances in agronomy*, 13, 249-268.
- Bhatt, R and S.S. Kukal. (2015e). Soil physical environment as affected by double ZT in rice wheat cropping system of North-West India. *Asian J. Soil Sci.* 10 (1): 166-172.
- Bhatt, R. (2015). Soil water dynamics and water productivity of rice-wheat system under different establishment methods. Dissertation submitted to the Punjab Agricultural University, Ludhiana.
- Bhatt, R. (2017). Zero tillage impacts on soil environment and properties. *Journal of Environmental and Agricultural Sciences*, 10, 01-19.
- Bhuler, D.D. (1995). Influence of tillage systems on weed population dynamics and management in corn and soybean production in central USA. *Crop science*.133 (35):1247-1257.
- Blevins, R. L., Thomas, G. W., & Cornelius, P. L. (1977). Influence of No-tillage and Nitrogen Fertilization on Certain Soil Properties after 5 Years of Continuous Corn 1. *Agronomy journal*, 69(3), 383-386.
- Blevins, R.L., G.W. Thomas and P.L. Cornelius (1977). Influence of no-tillage and nitrogen fertilization on certain soil properties after five years of continuous corn. *Agron. J.* 69:383-386.
- Boguzas, Vaclovas, Ausra Marcinkeviciene, and Rita Pupaliene(2010). "Weed response to soil tillage, catch crops and farmyard manure in sustainable and organic agriculture." 43-50.
- Bricchi E, Formia F, Esposito G, Riberi L, Aquino H (2004). The effect of topography, tillage and stubble grazing on soil structure and organic carbon levels. *Span. J. Agric. Res.* 2: 409-18.
- Bricchi, E., Formia, F., Espósito, G., Riberi, L., & Aquino, H. (2004). The effect of topography, tillage and stubble grazing on soil structure and organic carbon levels. *Spanish Journal of agricultural research*, 2(3), 409-418.
- Chatterjee, A and Lal, R. (2009). On farm assessment of tillage impact on soil carbon and associated soil quality parameters. *Soil Till. Res.* 104: 270-77.
- Chatterjee, A., & Lal, R. (2009). On farm assessment of tillage impact on soil carbon and associated soil quality parameters. *Soil and Tillage Research*, 104(2), 270-277.
- Daraghmeh, O. A., Jensen, J. R., & Petersen, C. T. (2009). Soil structure stability under conventional and reduced tillage in a sandy loam. *Geoderma*, 150(1-2), 64-71.
- Dick, W. A., Van Doren Jr, D. M., Triplett Jr, G. B., & Henry, J. E. (1986). Influence of long-term tillage and rotation combinations on crop yields and selected soil parameters

- Dick, W.A., D.M. Van Doren, G.B. Triplett and J.E Henry (1986). Influence of long term tillage and rotation combinations on crop yields and selected soil parameters. II. Results obtained for a TypicFragiudalf soil. *OhilAgric Res Dev Cent* 1181: 1-34.
- Dinnes, D. L., Karlen, D. L., Jaynes, D. B., Kaspar, T. C., Hatfield, J. L., Colvin, T. S., &Cambardella, C. A. (2002). Nitrogen management strategies to reduce nitrate leaching in tile drained Midwestern soils. *Agronomy journal*, 94(1), 153-171.
- Doran, J. W. (1980). Soil microbial and biochemical changes associated with reduced tillage. *Soil Science Society of America Journal*, 44(4), 765-771.
- Edwards, J. H., Thurlow, D. L., & Eason, J. T. (1988). Influence of tillage and crop rotation on yields of corn, soybean, and wheat. *Agronomy Journal*, 80(1), 76-80.
- Edwards, J.H., D.L. Thurlow and J.T. Eason. (1988). Influence of tillage and crop rotation on yield of corn, soybean, and wheat. *Agron. J.* 80: 76-80.
- Elder, J. W., & Lal, R. (2008). Tillage effects on gaseous emissions from an intensively farmed organic soil in North Central Ohio. *Soil and Tillage Research*, 98(1), 45-55.
- FAO. (2012). Advancement and impact of conservation agriculture/no-till technology adoption in Kazakhstan. FAO Information Note. Retrieved from [http://www.fao.org/ag/ca/doc/Importance_Zero_Tillage_Northern Kazakhstan.pdf](http://www.fao.org/ag/ca/doc/Importance_Zero_Tillage_Northern_Kazakhstan.pdf)
- Francis, G. S., & Knight, T. L. (1993). Long-term effects of conventional and no-tillage on selected soil properties and crop yields in Canterbury, New Zealand. *Soil and Tillage Research*, 26(3), 193-210.
- Franzluebbers, A.J and M.A. Arshad. (1996b). Soil organic matter pools with conventional and ZT in a cold, semiarid climate. *Soil till. Res.* 39: 1–11.
- Freitas, P.L., P. Blancaneaux, E. Gavinelli, M.C. Larré-larrouy and C. Feller. (1999). Nature and level of organic stock in clayey Oxisols under different land use and management systems. *PesqAgro pec Bras.* 35:157-170.
- Frye, W. W., Smith, W. G., & Williams, R. J. (1985). Economics of winter cover crops as a source of nitrogen for no-till corn. *Journal of Soil and Water Conservation*, 40(2), 246-249.
- Frye, W.W., O.L. Burnett and G.J. Buntley. (1985). Restoration of crop productivity on eroded or degraded soils. In *Soil Erosion and Crop Productivity*, eds. R.F. Follet and B.A. Stewart. Madison, WI: *American Society of Agronomy Journal*. Pp: 335- 356.
- Ghosh, P.K., A. Das, R. Saha, E. Kharkrang, A.K. Tripathi, G.C. Munda and S.C. Ngachan. (2010). Conservation agriculture towards achieving food security in North East India. *Curr. Sci.* 99(7): 915-921.
- Gangwar, K.S. and Singh, H.R., (2010). Effect of rice (*Oryza sativa*) crop establishment technique on succeeding crops. *Indian Journal of Agricultural Sciences*, 80(1), pp.24-28.

- Ghuman, B.S and H.S. Sur. (2001). Tillage and residue management effects on soil properties and yields Eastern Gangetic Plains of South Asia: Yield trends and economic profitability. *Field Crops Res.* 164: 199-210.
- Green, V. S., Cavigelli, M. A., Dao, T. H., & Flanagan, D. C. (2005). Soil physical properties and aggregate-associated C, N, and P distributions in organic and conventional cropping systems. *Soil Science*, 170(10), 822-831.
- Hazarika S, Parkinson R, Bol R, Dixon L, Russel P, Donovan S, Allen D (2009). Effect of tillage system and straw management on organic matter dynamics. *Agron. Sust. Dev.* 29: 525-33.
- Hobbs, P. R., Sayre, K., & Gupta, R. (2008). The role of conservation agriculture in sustainable agriculture. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 363(1491), 543-555.
- Jat, M. L., R. K. Gupta, O. Erenstein, and R. Ortiz. (2006). Diversifying the intensive cereal cropping systems of the Indo - Ganges through horticulture. *Chronica Horticulturae* 46 (3), 27–31.
- Karlen D.L., Wollenhaupt N.C., Erbach D.C., Berry E.C., Swan J.B., Eash N.S., Jordahl J.L. (1994). Long-term effects on soil quality. *Soil and Tillage Research*, 32: 313–327.
- Kumar Narendra, Nath C.P., Hazra K.K., Praharaj, C.S. Singh S.S., and Singh N.P. (2022). Long-term impact of zero-till residue management in post-rainy seasons after puddled rice and cropping intensification on weed seedbank, above-ground weed flora and crop productivity. *Ecological Engineering* 176:106540.
- Lal, R. *et al.* (1989). Conservation tillage for sustainable agriculture: tropics vs. temperate environments. *Advances in Agronomy*, 42, 85–197.
- Mannering, J.V., R. Griffith and B. Richey. (1975). Tillage for moisture conservation. Ameri. Soc. of Agriculture and Engineering. *St Joseph MI, Paper No. 75-2523.*
- Martino, D. L., and Shaykewich, C. F. (1994). Root penetration profiles of wheat and barley as affected by soil penetration resistance in field conditions. *Canadian Journal of Soil Science*, 74(2), 193-200.
- McConkey, B.G., B.C. Liang. A. Campbell, D. Curtin, A. Moulin, S.A. Brandt and G.P. Lafond. (2003). Crop rotation and tillage impact on carbon sequestration in Canadian prairie soils. *Soil Till. Res.* 74:81–90.
- Miller, P., McKay, K., Jenks, B., Riesselman, J., Neill, K., Buschena, D. and Bussan, A. J. (2002). Growing chickpea in the northern Great Plains. MontGuide fact sheet #200204/Agriculture, Montana St Univ Ext Serv, Bozeman, MT, USA [Online] Available: <http://www.montana.edu/wwwpb/pubs/mt200204.html> [2005 Dec. 15]

- Mishra, J.S. and Singh, V.P., (2011). Effect of tillage and weed control on weed dynamics, crop productivity and energy-use efficiency in rice (*Oryzasativa*)-based cropping systems in Vertisols. *Indian Journal of Agricultural Sciences*, 81(2), p.129.
- Mishra, J.S., Singh, V.P., Bhanu, C. and Subrahmanyam, D., (2012). Crop establishment, tillage and weed management techniques on weed dynamics and productivity of rice (*Oryzasativa*)—Chickpea (*Cicer arietinum*) cropping system. *Indian Journal of Agricultural Sciences*, 82(1), p.15.
- Moussa-Machraoui SB, Errouissi F, Ben-Hammouda M, ouira S (2010). Comparative effects of conventional and no-tillage management on some soil properties under Mediterranean semi-arid conditions in north-western Tunisia. *Soil Till Res* 106: 247-53.
- Oorts, K., Merckx, R., Gréhan, E., Labreuche, J., & Nicolardot, B. (2007). Determinants of annual fluxes of CO₂ and N₂O in long-term no-tillage and conventional tillage systems in northern France. *Soil and Tillage Research*, 95(1-2), 133-148.
- Patni, N. K., Masse, L., & Jui, P. Y. (1998). *Groundwater quality under conventional and no tillage: I. Nitrate, electrical conductivity, and pH* (Vol. 27, No. 4, pp. 869-877). *American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America*.
- Poonia, T. C., and M. S. Pithia (2013). "Pre-and post-emergence herbicides for weed management in chickpea." 223-225.
- Quddus, M. A., Naser, H. M., Siddiky, M. A., Ali, M. R., Mondol, A. T. M. A. I., Islam, M. A., & Gazipur, B. (2020). Impact of zero tillage and tillage practice in chickpea production. *Journal of Agricultural Science*, 12(4), 106-118.
- Rahman MH, Okubo A, Sugiyama S, Mayland HF (2008). Physical, chemical and microbiological properties of an Andisol as related to land use and tillage practice. *Soil Till*.
- Reicosky, D. C., & Archer, D. W. (2007). Mouldboard plow tillage depth and short-term carbon dioxide release. *Soil and Tillage Research*, 94(1), 109-121.
- Lal, R. 1976. Soil erosion problem on Alfisol in western Nigeria and their control. IITA monograph no. 1 Nigeria 184 pp.
- Reicosky, D. C., Dugas, W. A., & Torbert, H. A. (1997). Tillage-induced soil carbon dioxide loss from different cropping systems. *Soil and Tillage Research*, 41(1-2), 105-118. Res. 101:10-19.
- Six, J., Conant, R. T., Paul, E. A., & Paustian, K. (2002). Stabilization mechanisms of soil organic matter: implications for C-saturation of soils. *Plant and soil*, 241, 155-176.
- Smart, J.R and Bradford, J.M. (1999) Conservation tillage corn production for a semi-arid, subtropical environment. *Agronomy Journal*. 91:116-21

Tarkalson D.D., Gary W.H. and Kassman K. G. (2006). Long-term effects of tillage on soil chemical properties and grain yields of a dryland winter wheat-sorghum/ corn-fallow rotation in the great plains. *Agron. J.* 98: 26-33.

Wood, D. M. (1990). *Soil behaviour and critical state soil mechanics*. Cambridge university press.

Yaduraju N T and Mishra J S. (2002). Weeds management in chickpea: Challenges and Opportunities. *Agricultural Situation in India*, pp 423–30. October (2002).

Singh, A., Phogat, V.K., Dahiya, R. and Batra, S.D., (2014). Impact of long-term zero till wheat on soil physical properties and wheat productivity under rice–wheat cropping system. *Soil and Tillage Research*, 140, pp.98-105.

Monneveux, P., Quill rou, E., S nchez, C. and Lopez-Cesati, J., (2006). Effect of zero tillage and residues conservation on continuous maize cropping in a subtropical environment (Mexico). *Plant and Soil*, 279, pp.95-105.

Ehlers, W. 1979. Influence of tillage on hydraulic properties of loessial soils in western Germany. In “*Soil Tillage and Crop Production*” (R. Lar. ed.), Proc. Ser. No. 2: 33-45. Int. Inst. Trop. Agric., Ibadan, Nigeria.

Nazeer, S., Malik, A.U., Nazir, G. and Ahmad, J. 2012. Effectiveness of tillage systems and farm manure levels on rice productivity.

Kumar, J., De, N., Pradhan, A., Sharma, P. and Charry, G. R. 2018. Effect of Tillage on Nutrient Dynamics and Physical Condition of Soil under Rainfed Rice Chick Pea Based Cropping System of Bastar, Chhattisgarh. *International Journal of Current Microbiology and Applied Sciences* 7 (12).

Alam, M.K., Islam, M.M., Salahin, N. and Hasanuzzaman, M., 2014. Effect of tillage practices on soil properties and crop productivity in wheat-mungbean-rice cropping system under subtropical climatic conditions. *The scientific world journal*.

Kahlon, M.S. and Singh, G. 2014. Effect of tillage practices on soil physico-chemical characteristics and wheat straw yield. *International Journal of Agricultural Sciences*. Vol. 4 (10), pp. 289-293.

Boko CSA, Bagan GC, Zimonse E, Kouazounde N. Effects of the Speed of Mechanical Tillage on the Structure of Ferralitic Soil. *J. Exp. Agric. Int.* [Internet]. 2023 Feb. 18 [cited 2024 May 22];45(2):25-37. Available from: <https://journaljeai.com/index.php/JEAI/article/view/2102>

Muindi EM, Mrema J, Semu E, Mtakwa P, Gachene C. Soil Chemical Properties as Affected by Tillage Method, Phosphorus and Lime Application. *Int. J. Plant Soil Sci.* [Internet]. 2023 Jun. 24 [cited 2024 May 22];35(16):213-21. Available from: <https://journalijpss.com/index.php/IJPSS/article/view/3147>

Meena JR, Behera UK, Chakraborty D, Sharma AR. Tillage and residue management effect on soil properties, crop performance and energy relations in greengram (*Vigna radiata* L.) under maize-based cropping systems. *International Soil and Water Conservation Research*. 2015 Dec 1;3(4):261-72.

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